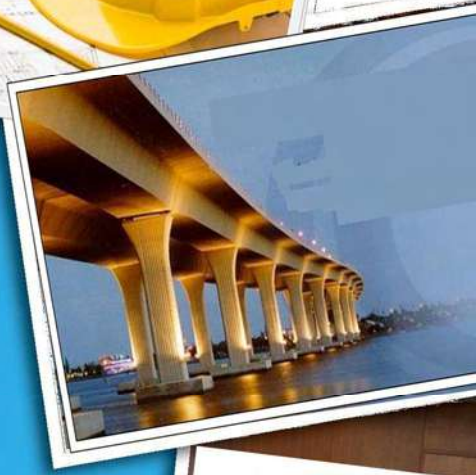


KERALA
PWD

QUALITY CONTROL MANUAL

JULY 2015

GOVERNMENT OF KERALA

KERALA PUBLIC WORKS DEPARTMENT

QUALITY CONTROL MANUAL

(*Copy for website publication*)

JULY 2015

ISSUED BY THE AUTHORITY OF THE GOVERNMENT OF KERALA

PUBLIC WORKS DEPARTMENT

Government Secretariat

Thiruvananthapuram

Official website: www.keralapwd.gov.in

Rights of publication and translation reserved.

PREFACE

Kerala Public Works Department plays a major role in the infrastructure development of our State. It undertakes the construction and maintenance of National Highways, State Highways, Major District Roads, bridges, culverts and majority of Government buildings. Government felt the need to put more emphasis on Quality Assurance and Quality Control in the projects undertaken by PWD. To achieve this, a paradigm shift in the contract conditions related to quality control was considered by Government.

With the above intention, the Government introduced a new three tier system of quality control through the revised PWD Manual 2012, for works executed by PWD. Subsequently, Quality Control laboratories were established in all the 14 districts with necessary equipment and staff. Quality Control test results in accordance with relevant codes/standards have been made mandatory for passing bills. The Technical Committee constituted by the Government for the rectification of anomalies in the revised PWD Manual 2012 took the initiative for preparing a separate Quality Control Manual for the Department. The Working Group constituted for the purpose prepared the draft of the QC Manual in consultation with the experts in this field. Opinions received from Engineers and Contractors were also incorporated before finalizing the draft.

The Manual has been compiled following standards prescribed by the statutory organisations including the Bureau of Indian Standards, the Indian Roads Congress etc. Every officer of PWD, entrusted with the execution of Public Works, is expected to be conversant with the contents of this Manual and to follow the guidelines strictly in the discharge of his/her duties. It is also expected that relevant provisions of this Manual, when made part of the contract conditions, will help in enhancing the quality standards of public works.

I express my appreciations and thanks to all the Engineers who were directly or indirectly associated with the compilation of this Manual.

Any errors, omissions or variations from the standards prescribed by the codes or new updates may be brought to the notice of Government for issue of correction and amendment wherever necessary.

Sd/-

A P M Mohammed Hanish IAS

Secretary to Government, PWD

ACKNOWLEDGEMENT

Government have introduced a three tier quality monitoring system in Kerala Public Works Department vide clause 2401 and 2406 of the revised PWD Manual 2012 published as per GO (P) N0. 13/2012/PWD dated 1-2-2012. Subsequently for achieving the desired level of quality in public works envisaged by the revised PWD Manual, a Quality Control wing was set up in the department with effect from 1-10-2013 as per G.O (Ms) No. 79/PWD/2013 dated 28-09-2013. Testing laboratories were established in all districts with necessary equipment and staff.

Government vide G.O (Rt) No. 1784/2012/PWD dated 20-10-2012 formed a Technical Committee for rectifying the anomalies and discrepancies in the revised PWD Manual. Under the initiative of the Technical Committee, a working group was formed in the Department to prepare a separate QC Control Manual for PWD.

The working group did a commendable job in the task of compiling this Manual. Workshops were held for engineers of the Department and Government Contractors and acceptable suggestions received in these workshops have been incorporated in the final draft.

The following officers/experts of the department were instrumental in the preparation of the first edition of PWD Quality Control Manual. Their work was initially coordinated by Er. K. Sundaran, former Chief Engineer (Design & Administration) and subsequently by Er. M. Pennamma, Chief Engineer, Buildings, who is also Convener of the Technical Committee for rectification of anomalies in the revised PWD Manual 2012.

(i) Er. P.K. Rajeev, Superintending Engineer (Rtd) & Former Special Officer, PWD Manual Revision.
(ii) Er. T. Santhosh Kumar, Director, I&QC (Rtd).
(iii) Er. V.G. Hari, Director, I&QC.
(iv) Er. S. Saju, Joint Director, Highways Design.
(v) Er. P. Indu, Asst. Exe. Engineer, GIS & RMMS Cell.
(vi) Er. G.S. Indu, Assistant Engineer, National Highways.

The Department place on record appreciation for the dedicated effort taken by the above engineers for the preparation of this first edition of the Quality Control Manual.

The Department also appreciates the assistance rendered by Er. T.A. Shali, V.S. Maneesha, Er. S. Syam, Er. P.R. Sushama (Assistant Executive Engineers), Er.G. Arathy, Er. P. Ayyappan, Er. P.B. Biju, Er. S. Satheesh kumar, Er. Leksmi Subash (Assistant Engineers) and Sri. Saji. K. Zackariah (Draftsman) in compiling this Manual. Engineers of the Department, their associations and associations of Government Contractors who provided valuable suggestions also deserve appreciation.

It is expected that this first edition of the PWD Quality Control Manual will prove to be a useful and valuable document for officers of the Department for proper implementation of the Quality Control System in Public Works Department.

Sd/-
P. K. Satheesan
Chief Engineer, Administration

Thiruvananthapuram
July, 2015

CONTENTS

Title			Page No.
PREFACE			i
ACKNOWLEDGEMENT			ii
CONTENTS			iii
ABBREVIATIONS			xxii
INTRODUCTION			**1**
PART A - BUILDINGS			
SECTION 100: QUALITY CONTROL IN BUILDING CONSTRUCTION			**11**
101	GENERAL		11
102	TECHNICAL SPECIFICATIONS AND STANDARDS		11
	102.1	CPWD specifications	11
	102.2	National Building Code of India	11
	102.3	Handbooks published by the Bureau of Indian Standards	11
	102.4	Indian Standard Codes	12
	102.5	American Society for Testing of Materials (ASTM)	12
103	OVERVIEW OF CONTENTS		12
SECTION 200: SITE CLEARANCE AND EARTHWORK			**14**
201	GENERAL		14
202	SITE CLEARANCE		14
203	SETTING OUT		14
204	EARTHWORK EXCAVATION		15
	204.1	Requirements/workmanship	15
	204.2	Protections	17
	204.3	Excavation in soil	17
	204.4	Excavation in ordinary/hard rock	18
	204.5	Blasting	18
	204.6	Excavation methods	18
	204.7	Excavation in under water	19
	204.8	Planking and strutting	20
205	EARTH FILLING		21
	205.1	Fill materials	21
	205.2	Fill/Backfill	21
206	ANTI-TERMITE TREATMENT		22
207	QUALITY CONTROL		23
208	REFERENCES		23
SECTION 300: BUILDING FOUNDATIONS			**24**
301	GENERAL		24
302	SHALLOW FOUNDATION		24
	302.1	Materials	24
	302.2	Requirements	24
	302.3	Workmanship	27
303	DEEP FOUNDATIONS		27
	303.1	Pile foundation	27
304	TOLERANCES		31
305	TESTING OF PILES		32

Title			Page No.
	305.1	Initial load test	32
	305.2	Routine load tests	33
306	QUALITY CONTROL TESTS		33
307	REFERENCES		33
SECTION 400: MASONRY			**34**
401	GENERAL		34
402	MASONRY MORTARS		34
	402.1	Materials	34
	402.2	Requirements	35
	402.3	Stacking and storage	37
	402.4	Curing	37
	402.5	Quality tests for masonry mortar	37
403	BRICK MASONRY		38
	403.1	General	38
	403.2	Types of bricks	39
	403.3	Classification	39
	403.4	Physical requirements	39
	403.5	Construction	39
	403.6	Sampling and testing	40
	403.7	Quality control tests	42
404	CONCRETE BLOCK MASONRY		43
	404.1	General	43
	404.2	Dimensions and tolerances	44
	404.3	Classification of concrete blocks	44
	404.4	Physical requirements	45
	404.5	Marking	45
	404.6	Quality tests for cement blocks	45
405	STONE MASONRY		46
	405.1	General	46
	405.2	Requirements	46
	405.3	Workmanship	47
	405.4	Simple field tests	48
	405.5	Quality control tests	48
406	LATERITE MASONRY		49
	406.1	General	50
	406.2	Requirements	49
	406.3	Workmanship	50
	406.4	Sampling and testing	50
407	REFERENCES		51
SECTION 500: SCAFFOLDINGS			**53**
501	GENERAL		53
502	DIFFERENT SYSTEMS		53
503	TIMBER/BAMBOO SCAFFOLDING		53
	503.1	Single scaffolding	53
	503.2	Double scaffolding	54
	503.3	Requirements	54
504	STEEL SCAFFOLDING		54
	504.1	Independent scaffold	55
	504.2	Putlog scaffold	55
	504.3	Individual component type scaffold	55
	504.4	Unit frame type scaffold	55
	504.5	Materials	55

Title			Page No.
505	REQUIREMENTS		55
506	STEEL FITTINGS		56
	506.1	Steel sections, bars and rivets	56
	506.2	Bolts and nuts	56
	506.3	Finish	56
507	DISMANTLING OF METAL SCAFFOLDS		56
508	REFERENCES		56
SECTION 600: CONCRETE CONSTRUCTION			**57**
601	GENERAL		57
602	CEMENT		57
	602.1	Cement identification	57
	602.2.	Requirements	57
	602.3.	Sampling and testing	59
	602.4.	References	59
603	AGGREGATES		60
	603.1	Requirements	60
	603.2	Sampling and testing	61
	603.3	References	61
604	WATER		62
	604.1	Requirements	62
	604.2	Supply and storage	62
	604.3	Sampling and testing	62
	604.4	References	63
605	ADMIXTURES		63
	605.1	General	63
	605.2	Type of admixtures	63
	605.3	Requirements	64
	605.4	References	65
606	REINFORCING STEEL		65
	606.1	General	65
	606.2	Requirements	65
	606.3	Storage and handling	66
	606.4	Placing of reinforcement	67
	606.5	Welded joints or mechanical connections	67
	606.6	Tolerances	68
	606.7	Inspection, sampling and testing	68
	606.8	Acceptance criteria	69
	606.9	References	71
607	CONCRETE		71
	607.1	Requirements	71
	607.2	Workmanship	72
	607.3	Field checks to be effected during concrete work	83
	607.4	Sampling and testing	83
	607.5	Inspection and testing of structures	85
	607.6.	References	85
608	FORMWORK		86
	608.1	Requirements/workmanship	86
	608.2	Tolerances	89
	608.3	References	89
SECTION 700: DOORS AND WINDOWS			**90**
701	GENERAL		90
702	TIMBER		90

Title			Page No.
	702.1	Moisture content	90
	702.2	Seasoning of timber	91
	702.3	Quality tests	91
703	FRAMES FOR DOOR, WINDOW AND VENTILATOR		91
704	SHUTTERS – PANELLED, GLAZED OR PANELLED AND GLAZED		91
705	FLUSH DOOR SHUTTERS		92
	705.1	Quality tests for flush doors	92
706	STEEL DOORS AND WINDOWS		93
	706.1	Materials	93
	706.2	Sampling and criteria for conformity	93
707	PRESSED STEEL DOORS AND WINDOWS.		94
708	PRE-COATED GALVANISED STEEL DOORS AND WINDOWS		94
	708.1	Openable window systems	95
	708.2	Openable door systems	95
	708.3	Sliding window systems	95
709	PVC/UPVC DOORS		96
	709.1	Quality control tests	96
710	ALUMINIUM DOORS AND WINDOWS		97
	710.1	Fittings for aluminium doors and windows	98
711	FIBRE GLASS REINFORCED PLASTIC (FRP) DOORS		98
712	SOLID PVC FOAM PROFILE DOORS		98
713	LAMINATED VENEER LUMBER (LVL)		99
714	UPVC DOOR FRAME		99
715	DOOR/WINDOW FITTINGS		99
	715.1	Butt hinges	99
	715.2	Parliament hinges	99
	715.3	Spring hinges	99
	715.4	Door handles (Doors and windows)	99
	715.5	Floor door stopper	99
	715.6	Door closers	99
	715.7	Mortice locks	100
716	REFERENCES		100
SECTION 800: FINISHING			**103**
801	GENERAL		103
802	CEMENT PLASTER		103
	802.1	Cement plaster with a flushing coat of cement	103
	802.2	Plastering on top of walls for bearing of slabs	103
	802.3	Rough cast plaster	104
	802.4	Plain bands of cement mortar	104
	802.5	Moulded bands of cement mortar	104
	802.6	Cement water proofing compound	104
803	POINTING ON BRICK WORK, TILE WORK AND STONE WORK		105
804	WHITE WASHING		105
805	COLOUR WASHING		105
806	DRY DISTEMPERING		106
	806.1	Oil emulsion (Oil bound) washable distempering	106
807	CEMENT PRIMER COAT		106
808	CEMENT PAINT		107
809	PAINTING ON EXTERIOR WALL		107
810	PAINTING PRIMING COAT ON WOOD, IRON OR PLASTERED SURFACES		107
811	PAINTING SYNTHETIC ENAMEL PAINT OVER G S SHEETS		108
812	PAINTING RAIN WATER/SOIL/WASTE/VENT PIPES AND FITTINGS OF CAST IRON		108

Title			Page No.
813	PAINTING WITH WOOD PRESERVATIVE		108
814	COAL TARRING		108
815	WALL PAINTING WITH PLASTIC EMULSION PAINT		108
816	PAINTING WITH SYNTHETIC ENAMEL PAINT		109
817	PAINTING WITH ALUMINIUM PAINT		110
818	PAINTING WITH ANTI-CORROSIVE BITUMASTIC PAINT		110
819	VARNISHING		110
820	FRENCH POLISHING		110
821	BEES WAXING OR POLISHING WITH READY MADE WAX POLISH		110
822	REMOVING OLD PAINT		110
823	REFERENCES		111
SECTION 900: PANELLING AND PARTITIONS			**113**
901	GENERAL		113
902	WOODEN PANELLING		113
	902.1	Requirements	113
	902.2	Quality control tests	113
903	PLYWOOD/PLYWOOD BOARDS		113
	903.1	Requirements	113
	903.2	Quality test	114
904	MARINE PLYWOOD		114
	904.1	Tests for marine plywood	114
905	VENEERED DECORATIVE PLYWOOD		115
	905.1	Tests for veneered decorative plywood	115
906	FIRE RETARDANT PLYWOOD		115
	906.1	Sampling for tests	116
	906.2	Tests for fire retardant plywood	116
907	PARTICLE BOARDS		116
	907.1	Tests for particle board	116
908	PRE-LAMINATED PARTICLE BOARDS		117
909	VENEERED PARTICLE BOARDS		118
910	NON-ASBESTOS FIBRE BOARDS		118
911	WIRE CLOTH (WIRE GAUZE)		118
912	COIR VENEER BOARD		119
	912.1	Quality control tests	119
913	DECORATIVE THERMOSETTING SYNTHETIC RESIN BONDED LAMINATED SHEETS		119
914	ALUMINIUM PARTITIONS		120
	914.1	Aluminium sections	120
	914.2	Aluminium sheet	121
	914.3	Float glass	121
	914.4	EPDM gaskets	121
	914.5	Sealant	122
	914.6	Reflective glass	122
915	ALUMINIUM COMPOSITE PANEL CLADDING		122
	915.1	Quality control tests	123
916	ALUMINIUM FABRICATION		124
917	REFERENCES		125
SECTION 1000: ROOFING AND CEILING			**126**
1001	ROOFING		126
	1001.1	Terminology	126
	1001.2	Galvanised steel sheet roofing	126
	1001.3	Non-asbestos high impact poly propylene reinforced cement corrugated sheet roofing	130

Title			Page No.
	1001.4	Non-asbestos high impact poly propylene reinforced cement semi-corrugated sheet roofing	133
	1001.5	Galvalume/zincalume and colour coated roofing sheets	137
	1001.6	Polycarbonate (pc) sheets	138
	1001.7	Plastic translucent sheets (glass fibre reinforeced)	139
	1001.8	Prepainted galvanised steel sheets	141
	1001.9	Aluminium roofing sheets	142
	1001.10	Sandwich polyurethane foam panels	143
	1001.11	Fibre-reinforced plastic sheets	144
	1001.12	Polyvinyl chloride roofing sheets	144
	1001.13	Unpalsticized polyvinyl chloride roofing sheets	145
	1001.14	Asphaltic roofing	146
1002	CEILING		147
	1002.1	Wooden ceiling	147
	1002.2	Ceiling with fibre insulating building boards	148
	1000.3	Particle board/multipurpose cement board ceiling	150
	1002.4	Plain/semi perforated particle board tiles ceiling	150
	1002.5	Gypsum board ceiling	151
	1002.6	PVC ceiling	151
	1002.7	Ttranslucent white acrylic plastic (PMMA) sheet ceiling	152
	1002.8	Plaster of paris (gypsum anhydrous) ceiling over wooden strips	152
	1002.9	Thermal insulation for roofing with cellular concrete	153
	1002.10	Thermal insulation for roofing with resin bonded fibre glass wool (bonded mineral wool)	154
	1002.11	Thermal insulation for roofing with expanded polystyrene	155
1003	REFERENCES		156
SECTION 1100: FLOORING			**159**
1101	GENERAL		159
1102	CEMENT CONCRETE FLOORING		159
	1102.1	Materials	159
	1102.2	Requirements	159
	1102.3	Workmanship	159
1103	CEMENT PLASTER IN RISERS OF STEPS, SKIRTING, DADO . .		160
	1103.1	Workmanship	160
1104	TERRAZO (MARBLE CHIPS) FLOORING LAID IN-SITU . . .		161
	1104.1	Materials	161
	1104.2	Requirements	161
	1104.3	Workmanship	161
1105	CRAZY MARBLE STONE FLOORING		162
1106	TERRAZZO TILE FLOORING		163
	1106.1	Materials	163
	1106.2	Workmanship	164
	1106.3	Tolerances	165
	1106.4	Sampling	165
1107	CHEQUERED TILE FLOORING		166
	1107.1	Requirements	166
	1107.2	Workmanship	166
1108	ACID OR ALKALI RESISTANT TILES		167
	1108.1	Requirements	167
	1108.2	Workmanship	167
	1108.3	Tolerances	167
	1108.4	Sampling and testing	167

Title			Page No.
1109	PRESSED CERAMIC TILE FLOORING		168
	1109.1	General	168
	1109.2	Requirements	168
	1109.3	Workmanship (Flooring)	168
	1109.4	Workmanship (Skirting and Dado)	169
	1109.5	Sampling and testing	169
1110	TILE FIXING WITH QUICK SET ADHESIVE (WATER BASED)		170
	1110.1	General	170
	1110.2	Materials	170
	1110.3	Workmanship	170
1111	VITRIFIED TILE FLOORING		170
	1111.1	Materials	170
	1111.2	Requirements	171
1112	MARBLE STONE FLOORING		171
	1112.1	Materials	171
	1112.2	Requirements	172
	1112.3	Workmanship	172
	1112.4	Tolerances	173
1113	KOTA STONE FLOORING		173
	1113.1	Materials	173
	1113.2	Requirements	174
	1113.3	Workmanship	174
	1113.4	Tolerances	174
1114	GRANITE FLOORING		174
	1114.1	Materials	174
	1114.2	Requirements	175
	1114.3	Workmanship	175
1115	WOODEN FLOORING		175
	1115.1	Materials	175
	1115.2	Requirements	175
	1115.3	Workmanship	176
1116	REFERENCES		176
SECTION 1200: STRUCTURAL STEEL WORK			**178**
1201	GENERAL		178
1202	REQUIREMENTS		178
1203	MATERIALS		179
	1203.1	Structural members	179
	1203.2	Structural fasteners	180
	1203.3	Non-structural member	182
	1203.4	Paint	184
1204	WORKMANSHIP		185
	1204.1	Fabrication	185
	1204.2	Shop erection	188
	1204.3	Packing	189
	1204.4	Transportation	189
	1204.5	Tolerances of field erection	189
	1204.6	Safety and security during erection	190
	1204.7	Grouting	190
	1204.8	Surface preparation and painting	190
1205	REFERENCES		192

Title			Page No.
SECTION 1300: DRAINAGE, SANITARY AND WATER SUPPLY			**196**
1301	REQUIREMENTS FOR DRAINAGE		196
1302	GLAZED STONEWARE PIPES AND FITTINGS		196
1303	CEMENT CONCRETE PIPES (LIGHT DUTY, NON-PRESSURE)		196
1304	CAST IRON PIPES AND SPECIALS		196
	1304.1	Gully grating	196
	1304.2	Manhole covers and frames	197
1305	PVC/UPVC PIPE		197
	1305.1	Requirements	197
	1305.2	Quality control tests	198
	1305.3	Sampling and criteria for conformity	198
	1305.4	Test certificate	198
1306	MANHOLES		198
1307	OPEN SURFACE DRAIN		199
1308	GULLY CHAMBER WITH GRATING		199
1309	BRICK MASONRY GULLY TRAP		200
1310	SEPTIC TANK		200
1311	SANITARY INSTALLATIONS		200
1312	APPLIANCES AND FITTINGS		200
	1312.1	Water closet	200
	1312.2	Flushing cisterns	201
	1312.3	Requirements of flushing cistern	203
	1312.4	Quality control tests for flushing cistern	203
	1312.5	Flush valve	204
	1312.6	Wash basins/sinks	204
	1312.7	Mirror	204
	1312.8	Floor trap or Nahani trap	204
	1312.9	Urinals	205
1313	FIXING AND JOINTING OF PIPES AND FITTINGS		205
	1313.1	Jointing	205
	1313.2	Testing	205
	1313.3	Painting	205
1314	WATER SUPPLY		205
	1314.1	Requirements	205
	1314.2	Components of water supply system	207
1315	PIPES AND SPECIALS		207
	1315.1	Centrifugally cast (Spun) iron pipes	207
	1315.2	Galvanised iron (GI) pipes	207
	1315.3	PVC/UPVC Pipes	208
	1315.4	Medium density polyethylene (PE) pipes	210
	1315.5	High density polyethylene (HDPE) pipes	210
	1315.6	Polypropylene random co-polymer (PP-R) pipes	212
	1315.7	Chlorinated polyvinyl chloride (CPVC) pipes	213
	1315.8	PE-AL-PE pipes	215
1316	PLUMBING FIXTURES		216
	1316.1	General requirements	216
	1316.2	Pillar taps	216
	1316.3	Shower rose	216
	1316.4	Bidet	216
	1316.5	Bath tubs, whirlpools (jacuzzi), sauna and steam baths	217

Title			Page No.
	1316.6	Valves	218
	1316.7	Surface box	222
	1316.8	Water meter (Domestic type)	222
1317	POLYETHYLENE WATER STORAGE TANKS		223
1318	TUBE WELLS WITH HAND PUMPS		223
1319	BORE WELL WITH SUBMERSIBLE PUMP		224
1320	REFERENCES		224

PART B - ROADS

SECTION 2000: QUALITY CONTROL IN ROAD CONSTRUCTION . .			**227**
2001	GENERAL		227
2002	TECHNICAL SPECIFICATIONS FOR ROAD CONSTRUCTION IN INDIA .		227
	2002.1	General	227
	2002.2	Bureau of Indian Standards (BIS)	227
	2002.3	Indian Roads Congress (IRC)	227
	2002.4	MoRTH Specifications	227
	2002.5	Central Public Works Department (CPWD)	227
	2002.6	British Standards (BS)	228
	2002.7	American Society for Testing and Materials (ASTM)	228
	2002.8	American Association of State Highway and Transportation Officials (AASHTO)	228
2003	INTERNATIONAL ORGANISATION FOR STANDARDS . . .		228
2004	HIGHWAY CLASSIFICATION		228
	2004.1	Non-urban roads	228
	2004.2	Urban roads	229
2005	ROAD CROSS SECTION		229
2006	CLASSIFICATION OF PAVEMENTS		230
2007	PAVEMENT COMPONENTS		230
	2007.1	Subgrade	231
	2007.2	Subbase	231
	2007.3	Base course	231
	2007.4	Wearing course	232
2008	OVERVIEW OF CONTENTS		232
SECTION 2100: EARTHWORK			**234**
2101	GENERAL		234
2102	CLASSIFICATION OF EXCAVATED MATERIALS . . .		234
2103	EXCAVATION FOR ROAD		235
	2103.1	General	235
	2103.2	Quality control	236
2104	EMBANKMENT CONSTRUCTION		236
	2104.1	General	236
	2104.2	Materials	237
	2104.3	Construction	238
	2104.4	Quality control	239
2105	ROCKFILL EMBANKMENT		240
	2105.1	General	240
	2105.2	Materials	241
	2105.3	Construction	241
2106	TURFING WITH SODS		241
	2106.1	General	241
	2106.2	Material	241

Title			Page No.
	2106.3	Construction	242
2107	TURFING BY SEEDING AND MULCHING		242
	2107.1	General	242
	2107.2	Material	242
	2107.3	Construction	243
2108	GROUND IMPRROVEMENT USING PVD WITH SURCHARGE . .		244
	2108.1	General	244
	2108.2	Materials	244
	2108.3	Construction	244
2109	RAMMED STONE COLUMNS FOR GROUND IMPROVEMENT . .		245
	2109.1	General	245
	2109.2	Materials	246
	2109.3	Construction	246
2110	REFERENCES		246
SECTION 2200: NON-BITUMINOUS BASE AND SUB BASE COURSES . . 247			
2201	GENERAL		247
2202	CONTROL OF ALIGNMENT, LEVEL AND SURFACE REGULARITY . .		247
	2202.1 Horizontal alignment		247
	2202.2 Surface levels		247
	2202.3 Surface regularity of pavement layers		248
2203	WATER BOUND MACADAM		248
	2203.1	Materials	248
	2203.2	Requirements	250
	2203.3	Construction	250
	2203.4	Quality control	251
2204	MECHANICALLY STABILIZED SOIL SUB BASE		252
	2204.1	Construction	252
	2204.2	Quality control	252
	2204.3	Rectification of surface irregularities	253
2205	LIME STABILIZED SOIL		253
	2205.1	Materials	253
	2205.2	Construction	253
	2205.3	Quality control	254
	2205.4	Rectification of surface irregularities	254
2206	CEMENT MODIFIED SOIL		255
	2206.1	Materials	255
	2206.2	Construction	255
	2206.3	Quality control	255
	2206.4	Rectification of surface irregularities	255
2207	GRANULAR SUBBASE		255
	2207.1	Materials	256
	2207.2	Construction	256
	2207.3	Quality control	256
	2207.4	Rectification of surface irregularities	256
2208	WET MIX MACADAM		257
	2208.1	Materials	257
	2208.2	Construction	257
	2208.3	Quality control	258
	2208.4	Rectification of surface irregularities	259
2209	CRUSHER-RUN MACADAM		259
	2209.1	Materials	259
	2209.2	Construction	259

Title			Page No.
	2209.3	Quality control	260
2210	DRY LEAN CEMENT CONCRETE SUBBASE		260
	2210.1	Materials	261
	2210.2	Proportions of material for DLC Mix	262
	2210.3	Preparation of subgrade	262
	2210.4	DLC mix preparation	262
	2210.5	Placing and compaction	263
	2210.6	Curing	264
	2210.7	Mix design	264
	2210.8	Quality control	265
2211	REFERENCES		266
SECTION 2300: BITUMINOUS BASE AND SURFACE COURSES . .			**268**
2301	GENERAL		268
2302	PRIME COAT AND TACK COAT		268
	2302.1	Prime coat over granular base	268
	2302.2	Tack coat	269
2303	BITUMINOUS MACADAM (BM)		270
	2303.1	Materials	270
	2303.2	Combined aggregate grading and binder content	271
	2303.3	Preparation of the surface	272
	2303.4	Construction procedure	272
	2303.5	Mix preparation	272
	2303.6	Spreading and rolling of the mix	272
	2303.7	Quality control	273
2304	DENSE BITUMINOUS MACADAM (DBM)		273
	2304.1	Materials	273
	2304.2	Combined aggregate grading and binder content	274
	2304.3	Mix design	275
	2304.4	Job mix formula	276
	2304.5	Approval of the job mix formula	276
	2304.6	Plant and field trials	276
	2304.7	Construction	277
	2304.8	Spreading and compaction	277
	2304.9	Quality control	277
2305	SAND BITUMEN MIX		278
	2305.1	Materials	278
	2305.2	Construction	279
	2305.3	Quality control	279
	2305.4	Rectification of surface irregularities	280
2306	SINGLE COAT SURFACE DRESSING		280
	2306.1	Construction	280
2307	TWO COAT SURFACE DRESSING		281
	2307.1	Quality control	281
	2307.2	Surface regularity	281
2308	SURFACE DRESSING WITH PRE-COATED AGGREGATE . . .		281
	2308.1	Construction	281
2309	OPEN-GRADED PREMIX SURFACING		282
	2309.1	Materials	282
	2309.2	Construction	282
	2309.3	Quality control	283
	2309.4	Rectification of surface irregularities	283
2310	CLOSE-GRADED PREMIX SURFACING/MIX SEAL SURFACING . .		284

Title			Page No.
	2310.1	Materials	284
	2310.2	Construction	284
2311	SEAL COAT		284
	2311.1	Materials	285
	2311.2	Construction	285
2312	SLURRY SEAL		285
	2312.1	Materials	286
	2312.2	Mix design	287
	2312.3	Construction	287
	2312.4	Quality control	289
2313	MICRO-SURFACING		289
	2313.1	Material	289
	2313.2	Mix requirements and design	290
	2313.3	Construction	291
	2313.4	Quality control	291
2314	BITUMINOUS CONCRETE (BC) SURFACING		291
	2314.1	Materials	291
	2314.2	Bituminous concrete mix requirement	292
	2314.3	Job mix formula	292
	2314.4	Plant and field trials	293
	2314.5	Construction	293
	2314.6	Spreading and compaction	294
	2314.7	Quality control	295
2315	STONE MATRIX ASPHALT		296
	2315.1	Materials	296
	2315.2	Aggregate grading	297
	2315.3	Mix requirements	297
	2315.4	Mix design	298
	2315.5	SMA mix production	298
	2315.6	Construction	298
	2315.7	Density and levels of the compacted layer	299
	2315.8	Quality control	299
2316	SEMI-DENSE BITUMINOUS CONCRETE		299
	2316.1	Materials	300
	2316.2	Mix requirements	301
	2316.3	Job mix formula	302
	2316.4	Plant and field trials	302
	2316.5	Construction	302
	2316.6	Spreading and compaction	303
	2316.7	Quality control	304
2317	REFERENCES		305
SECTION 2400: CEMENT CONCRETE PAVEMENT			**306**
2401	GENERAL		306
2402	MATERIALS		306
	2402.1	Joint materials	306
	2402.2	Storage of materials	306
2403	MIX DESIGN		307
2404	PREPARATION OF SUBBASE		307
2405	CONSTRUCTION JOINTS		307
2406	WEATHER		308
2407	FORMS		308
2408	MIXING AND PLACING OF CONCRETE		308
2409	CURING		308
2410	METHOD STATEMENT		308
2411	QUALITY CONTROL		309

Title			Page No.
	2411.1	Rectification of deficiencies	309
2412	REFERENCES		309
SECTION 2500: MAINTENANCE OF ROAD			**310**
2501	GENERAL		310
2502	DETERIORATION OF BITUMINOUS SURFACES		310
2503	CLASSIFICATION OF MAINTENANCE OF BITUMINOUS PAVEMENTS		310
2504	EVALUATING THE NEED FOR MAINTENANCE		310
2505	SURFACE DEFECTS AND THEIR RECTIFICATION		311
	2505.1	Fatty surface	311
	2505.2	Smooth surface	311
	2505.3	Streaking	311
	2505.4	Hungry or lean surface	312
2506	CRACKS ON THE PAVEMENT SURFACE		312
	2506.1	Hair-line cracks	312
	2506.2	Alligator cracks	312
	2506.3	Longitudinal cracks	312
	2506.4	Edge cracks	313
	2506.5	Block cracking	313
	2506.6	Reflection cracks	313
2507	TREATMENT OF CRACKS		313
	2507.1	Crack sealing	313
	2507.2	Crack filling	313
	2507.3	Crack prevention course	314
2508	LAYER DEFORMATION AND THEIR RECTIFICATION		314
	2508.1	General	314
	2508.2	Slippage	314
	2508.3	Rutting	314
	2508.4	Corrugations	314
	2508.5	Shoving	315
	2508.6	Shallow depressions	315
	2508.7	Potholes	315
	2508.8	Settlement and upheaval	316
	2508.9	Stripping	316
	2508.10	Loss of aggregates	317
	2508.11	Raveling	317
2509	RESTORATION OF RAIN CUT		317
2510	MAINTENANCE OF EARTHEN SHOULDER		318
2511	JOINT REPAIRS OF CONCRETE ROAD		318
2512	REFERENCES		319
SECTION 2600: GEOSYNTHETICS			**320**
2601	GENERAL		320
2602	TYPES OF GEOSYNTHETICS		320
2603	QUALITY OF GEOSYNTHETICS		321
2604	GEOTEXTILES FOR DRAINAGE, SEPARATION & EROSION CONTROL		321
2605	GEOGRIDS IN SUBBASE REINFORCEMENT		323
2606	GEOCOMPOSITE DRAINS		324
	2606.1	Fin drains	324
	2606.2	Prefabricated vertical drains (PVDs)/band drains 325	
2607	GEOCELL FOR SLOPE PROTECTION		325
2608	GEOSYNTHETIC MAT		326
	2608.1	Requirements	326
	2608.2	Installation	327
2609	NATURAL GEOTEXTILES		327
2610	PAVING FABRICS/GLASS GRIDS.		328

2611 REFERENCES 330

Title **Page No.**

SECTION 2700: ROAD DRAINAGE 331
2701 GENERAL 331
2702 NEED FOR A DRAINAGE SYSTEM 331
2703 TYPES OF ROAD DRAINAGE 331
2704 INVESTIGATIONS FOR ROAD DRAINAGE 331
2705 SURFACE DRAINS 332
2705.1 Road side drains 332
2705.2 Shoulder drains 333
2706 CATCH WATER DRAIN 334
2707 SUBSURFACE DRAINS 334
2707.1 Perforated pipe drains 334
2707.2 Aggregate drains 335
2707.3 Subsurface drains in other areas 335
2708 REFERENCES 336

SECTION 2800: TRAFFIC SIGNS AND ROAD MARKINGS . . . 337
2801 GENERAL 337
2802 CLASSIFICATION OF TRAFFIC SIGNS 337
2802.1 Mandatory/regulatory signs 337
2802.2 Cautionary/warning signs 337
2802.3 Informatory/guide signs 338
2803 MATRIALS FOR TRAFFIC SIGNS 338
2803.1 Concrete 338
2803.2 Reinforcing steel 338
2803.3 Bolts, nuts and washers 338
2803.4 Plates and supports 338
2803.5 Sign panels 338
2804 TRAFFIC SIGNS HAVING RETRO-REFLECTIVE SHEETING . . 338
2804.1 Classes of retro-reflective sheeting 338
2804.2 Class A Retro-reflective sheeting 339
2804.3 Class B High intensity grade sheeting 339
2804.4 Class C Micro-prismatic grade sheeting 340
2804.5 Other requirements of traffic signs having retro-reflective sheeting 340
2805 INSTALLATION OF TRAFFIC SIGNS 342
2806 OVERHEAD SIGNS 343
2806.1 General 343
2806.2 Materials 343
2806.3 Installation 343
2807 WARRANTY AND DURABILITY 344
2808 MAINTENANCE OF SIGNS 344
2809 ROAD MARKINGS 345
2810 MATERIALS FOR ROAD MARKING 345
2810.1 Ordinary road marking paint 345
2810.2 Thermoplastic material for road marking 345
2810.3 Reflectorising glass beads 346
2810.4 Reflectorised paint 346
2810.5 Cold applied reflective paint 348
2811 PROPERTIES OF FINISHED ROAD MARKINGS 349
2812 REFLECTIVE PAVEMENT MARKERS (ROAD STUDS) AND SOLAR POWERED ROAD MARKERS (SOLAR STUDS) 350
2812.1 Reflective pavement markers (Road studs) 350
2812.2 Solar powered road markers (Solar studs) 351
2812.3 Installation of pavement markers 351
2813 WARRANTY AND DURABILITY 351
2814 REFERENCES 352

Title			Page No.
SECTION 2900: MISCELLANEOUS			**353**
2901	USE OF PLASTIC WASTE IN HOT BITUMINOUS WEARING COURSE MIXES		353
	2901.1	Introduction	353
	2901.2	Types of waste plastics	353
	2901.3	Materials	354
	2901.4	Design requirements of waste plastic incorporated mixes	354
	2901.5	Construction	355
	2901.6	Quality control	356
2902	REFERENCES		356

PART C – BRIDGES AND CULVERTS

SECTION 3000: QUALITY CONTROL IN BRIDGE CONSTRUCTION			**357**
3001	GENERAL		357
3002	TECHNICAL SPECIFICATIONS AND STANDARDS/CODES		357
	3002.1	MoRTH specifications	357
	3002.2	Indian Roads Congress Codes/ Special publications	357
	3002.3	Indian Standard Codes	357
	3002.4	American Society for Testing and Materials (ASTM)	357
3003	CLASSIFICATION OF BRIDGES AND CULVERTS		357
3004	COMPONENTS OF BRIDGE		358
3005	OVERVIEW OF CONTENTS		358
SECTION 3100: SITE CLEARANCE AND EARTHWORK			**360**
3101	SITE CLEARANCE		360
3102	EARTHWORK		360
3103	ROCK EXCAVATION		360
3104	REFERENCES		360
SECTION 3200: MASONRY FOR BRIDGES & CULVERTS			**361**
3201	BRICK MASONRY		361
3202	STONE MASONRY		361
3203	TYPE OF MASONRY		361
3204	REFERENCES		361
SECTION 3300: CONCRETE WORK FOR BRIDGES & CULVERTS			**362**
3301	GENERAL		362
3302	MATERIALS		362
	3302.1	Cement	362
	3302.2	Aggregate	362
	3302.3	Water	363
	3302.4	Admixtures	363
	3302.5	Steel reinforcement	363
3303	REQUIREMENTS FOR CONCRETE		364
	3303.1	Grade of cement	364
	3303.2	Mix design	366
	3303.3	Proportioning	367
	3303.4	Design of formwork	369
3304	WORKMANSHIP		370
	3304.1	Formwork	370
	3304.2	Placing and fixing of steel reinforcements	371
	3304.3	Preparations required before placing concrete	373
	3304.4	Batching	373
	3304.5	Mixing	373

	3304.6	Transportation	373
Title			**Page No.**
	3304.7	Placing	373
	3304.8	Compaction	373
	3304.9	Curing	374
	3304.10	Removal of formwork	374
	3304.11	Ready mixed concrete	375
	3304.12	Mass concrete	376
3305	TOLERANCES		377
3306	SAMPLING AND TESTING		377
3307	ACCEPTANCE CRITERIA		379
3308	REFERENCES		380
SECTION 3400: PRESTRESSING			**381**
3401	GENERAL		381
3402	MATERIALS		381
	3402.1	Wires and strands	381
	3402.2	Sheaths and cores	383
	3402.3	Anchorages	384
	3402.4	Mechanical couplers	384
3403	WORKMANSHIP		384
	3403.1	Jacking equipment	384
	3403.2	Tensioning	384
	3403.3	Grouting	385
	3403.4	Grout mixer	386
	3403.5	Properties of grout	386
	3403.6	Post tensioning	387
3404	TOLERANCES		387
	3404.1	Permissible tolerances for structural unit	387
	3404.2	Tolerances for prestressing strands	388
3405	SAMPLING AND TESTING		388
3406	REFERENCES		388
SECTION 3500: STEEL WORK FOR BRIDGES			**389**
3501	GENERAL		389
3502	MATERIAL		389
3503	WORKMANSHIP		389
	3503.1	Storage of materials	389
	3503.2	Straightening, bending and pressing	390
	3503.3	Preparation of edges, ends and surfaces	390
	3503.4	Rivet and bolt holes	390
	3503.5	Bolted construction	390
	3503.6	Riveted construction	391
	3503.7	Welded construction	391
	3503.8	Welding of stud shear connectors	392
	3503.9	Shop assembly	392
	3503.10	Painting	393
3504	FABRICATION TOLERANCES		393
3505	INSPECTION		397
3506	TESTING		399
	3506.1	Non-Destructive testing of welds	399
	3506.2	Inspection of members and components	400
3507	REFERENCES		401
SECTION 3600: CULVERTS			**402**
3601	GENERAL		402
3602	PIPE CULVERTS		402
	3602.1	Requirements	402

3602.2 Workmanship 402

Title **Page No.**

3602.3 Tolerances 403
3602.4 Sampling and testing 404
3603 RCC SLAB CULVERTS – SOLID SLABS AND BOX CULVERTS . . 404
3603.1 General 404
3603.2 Requirements/workmanship 404
3603.3 Sampling and testing 405
3604 REFERENCES 405

SECTION 3700: FOUNDATIONS 406
3701 GENERAL 406
3702 OPEN FOUNDATION 406
3702.1 Workmanship 406
3702.2 Tolerances 407
3703 PILE FOUNDATION 408
3703.1 Requirements/workmanship 408
3703.2 Precast concrete piles 408
3703.3 Bored cast-in-situ concrete piles 408
3703.4 Pile cap 410
3703.5 Tolerances 410
3703.6. Testing of piles 411
3704 WELL FOUNDATION 412
3704.1 Sinking of well 412
3704.2 Cutting edge 413
3704.3 Well curb 413
3704.4 Well steining 413
3704.5 Well sinking 414
3704.6 Precautions during well sinking 415
3704.7 Tolerances 416
3705 SAMPLING AND TESTING 416
3706 REFERENCES 416

SECTION 3800: SUBSTRUCTURES 417
3801 GENERAL 417
3802 MATERIALS 417
3803 REQUIREMENTS/WORKMANSHIP 417
3803.1 Abutment and piers 417
3803.2 Abutment cap and pier cap 418
3803.3 Dirt wall, return/wing walls 418
3804 TOLERANCES 418
3805 SAMPLING AND TESTING 419
3806 REFERENCES 419

SECTION 3900: SUPERSTRUCTURES 420
3901 GENERAL 420
3902 MATERIAL 420
3903 REQUIREMENTS/WORKMANSHIP 420
3903.1 Cast-in-situ decks 420
3903.2 Pre-cast girders 424
3904 LOAD TEST ON SUPERSTRUCTURE 425
3905 REFERENCES 425

SECTION 4000: BEARINGS 426
4001 GENERAL 426
4002 ELASTOMERIC BEARINGS 426
4002.1 Materials 426
4002.2 Workmanship 428

	4002.3	Tolerances	429
Title			**Page No.**
	4002.4	Testing	430
	4002.5	Certification and marking	432
	4002.6	Maintenance	432
4003	POT/POT CUM PTFE BEARINGS		433
	4003.1	Materials	433
	4003.2	Workmanship	434
	4003.3	Inspection and testing	435
	4003.4	Maintenance	436
4004	REFERENCES		436
SECTION 4100: EXPANSION JOINTS			**437**
4101	GENERAL		437
4102	SINGLE STRIP/BOX SEAL JOINT		437
	4102.1	Components	437
	4102.2	Fabrication	438
	4102.3	Installation	439
4103	COMPRESSION SEAL JOINT		440
	4103.1	Components	440
4104	WORKMANSHIP		442
4105	SAMPLING AND TESTING		444
	4105.1	Routine tests	444
	4105.2	Acceptance tests	445
4106	REFERENCES		446
SECTION 4200: WEARING COAT AND APPURTENANCES			**447**
4201	GENERAL		447
4202	WEARING COAT		447
	4202.1	Bituminous wearing coat	447
	4202.2	Cement concrete wearing coat	447
	4202.3	Workmanship	447
4203	RAILING AND CRASH BARRIER		448
	4203.1	Metal railing/Crash barrier	448
	4203.2	Cast in-situ concrete railing/Crash barrier	449
	4203.3	Precast concrete railing/Crash barrier	449
4204	APPROACH SLAB		449
4205	DRAINAGE SPOUTS		449
4206	WEEP HOLES		450
4207	REFERENCES		450
SECTION 4300: RETAINING WALLS			**451**
4301	GENERAL		451
4302	SOLID RETAINING WALL		451
4303	RCC RETAINING WALL		451
4304	REINFORCED SOIL RETAINING WALL		452
	4304.1	Reinforcing elements	452
	4304.2	Sampling and testing	453
	4304.3	Earth fill	453
	4304.4	Facia material	454
	4304.5	Workmanship	456
	4304.6	Tolerances	457
4305	CONSTRUCTION OF RETAINING WALL IN HILLY TERRAIN		457
4306	REFERENCES		458
SECTION 4400: RIVER PROTECTION WORKS			**459**
4401	GENERAL		459
4402	GUIDE BUND		459

4403 APRON 460

Title **Page No.**

4404 PITCHING/REVETMENT ON SLOPES 460
4405 TOE PROTECTION 460
4406 RUBBLE STONE FLOORING 461
4407 CURTAIN WALL AND FLEXIBLE APRON 461
4408 QUALITY CONTROL 461
4409 REFERENCES 462
INDEX . . . . . .
APPENDIX . . . . . .

ABBREVIATIONS

AASHTO	American Association of Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BIS	Bureau of Indian Standards
BS	British Standards
°C	Degree Celsius
CBR	California Bearing Ratio
CI	Cast Iron
cm	Centimetre
cm^2	Square centimetre
CRCA	Cold Rolled Close Annealed
dB	deciBel
Dia	Diametre
DIN	German Standards
EN	European Standards
GI	Galvanised Iron
gm	Gram
GS	Galvanised Steel
HDPE	High Density Polyethylene
IRC	Indian Roads Congress
IS	Indian Standard
ISI	Indian Standards Institute
ISO	International Organisation for Standardization
IRHD	International Rubber Hardness Degree
J	Joule
K	Kelvin
kg	Kilogram
kgf	Kilogram force
kN	Kilo Newton
kPa	Kilo Pascal
l	Litre
m	Metre
m^2	Square metre
MDD	Maximum dry density
mg	Milligram
mic	Micron
ml	Millilitre
mm	Millimetre
Max	Maximum
Min	Minimum
MM	Masonry Mortar
MoRTH	Ministry of Road Transport & Highways
MPa	Mega Pascal
MS	Mild steel
MS-2	Asphalt Institute Manual Series No. 2
MW	Mega Watt

N	Newton
PCC	Plain Cement Concrete
PET	Polyethylene Terephthalate
PP	Polypropylene
PTFE	Polytetrafluoroethylene
PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Flouride
RCC	Reinforced Cement Concrete
rpm	Revolutions per minute
Sp.	Specific
Spec.	Specifications
UCS	Unconfined compressive strength
UPVC	Unplasticized Polyvinyl Chloride
VG	Viscosity grade
W	Watt
w/c ratio	Water to cement ratio
µ	Micron
µm	Micrometre

INTRODUCTION

1 GENERAL

The PWD Quality Control Manual is prepared to provide a base document to effect quality control in construction of projects undertaken by Kerala Public Works Department. This is intended to enable the engineers and supervisory staff to check the different activities of construction with reference to the quality aspects and ensure that standards envisaged are achieved.

2 QUALITY CONTROL (QC) AND QUALITY ASSURANCE (QA)

The terms "quality assurance" and "quality control" are often used interchangeably to refer to ways of ensuring the quality of a service or product. The terms, however, have different meanings.

Quality Assurance (QA) is the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled.

Examples of quality assurance include process checklists, project audits, and methodology statements and standards development.

Quality Control (QC) is the observation techniques and activities used to fulfill requirements for quality. Quality control is used to verify that the product delivered are of acceptable quality and that they are complete and correct. Examples of quality control activities include inspection, close review of the product and the testing process.

3 QUALITY ASSURANCE (QA)

a) QA aims to prevent defects with a focus on the process used to make the product. Hence it is a proactive quality process.
b) The goal of QA is to improve development and test processes so that defects do not arise when the product is being developed.
c) Statistical tools and techniques can be applied in QA also. When they are applied to processes (process inputs & operational parameters), they are called Statistical Process Control (SPC) and it becomes the part of QA.
d) Prevention of quality problems through planned and systematic activities including documentation is an integral part of QA.
e) QA involves establishing a good quality management system and the assessment of its adequacy, conformance audit of the operation system and the review of the system itself.

3.1 Key parameters of QA system

The quality assurance system should have the basic parameters listed below:

i) Site documents.
ii) Mandatory testing of materials and works.
iii) Field and regional testing laboratories.
iv) Manufacturer's test certificates.
v) Departmental inspection teams.
vi) Checklist for works.
vii) Evaluation of the completed works.

viii) Quality certification.
ix) Monthly reporting and review meetings.

4 QUALITY CONTROL

a) QC aims to identify defects in the finished product. Quality control, therefore, is a reactive process.
b) The goal of QC is to identify defects after a product is developed and before it is released.
c) When statistical tools and techniques are applied to finished products (process outputs), they are called as Statistical Quality Control (SQC) which is a part of QC.
d) The activities or techniques used to achieve and maintain the product quality, process and service comes under QC.
e) QC is exercised by finding and eliminating causes of quality problems through tools and equipment so that user requirements are satisfied.

5 ORGANISATIONAL SET UP FOR IMPLEMENTATION OF QUALITY SYTEM

Quality Control is an essential part of any production. QC is required in infrastructure development also. QC system was thus implemented in PWD in 2013 as per G. O (Rt) 469/2103/PWD dated 30-3-2013. Sanction for setting up 11 district QC laboratories with offices and two Regional laboratories with all amenities like building, testing equipment, vehicles, computers and software etc. were accorded. The Kerala Highway Research Institute (KHRI), Thiruvananthapuram was entrusted with the responsibility of Quality Control testing for Thiruvananthapuram district.

The QC activities of the District and Regional QC laboratories and the Kerala Highway Research Institute are monitored by the Director (I&QC) attached to the Office of the Chief Engineer (Design), Thiruvananthapuram, who is the head of the Quality Control Wing. Government circular no.10434/C3/2014/PWD dated 8.5.2014 directs that Director (I&QC) shall monitor the working of the Quality Control laboratories and implementation of second tier quality control in the Department. The Director (I&QC)

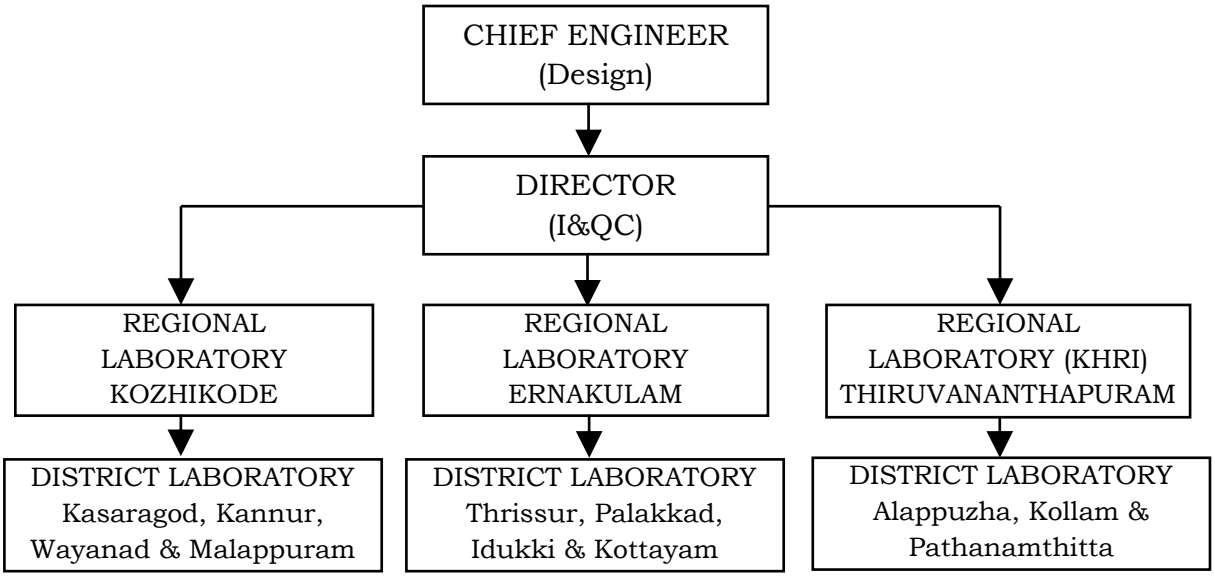


Fig. 1: Organisational set up Quality Control Wing in PWD

shall also conduct quarterly review of QC activities and submit recommendations to the Chief Engineer (Design).

Government circular stated above also directs that Superintending Engineers shall conduct quarterly review of implementation of the two tier QC system and forward reports to Government under intimation to the Chief Engineers and Director (I&QC). The Chief Engineer's Committee shall give timely instructions for effective implementation of the QC system in the department.

The Quality Control organizational set up established in PWD with effect from 1-10-2013 is as given in figure 1.

6 PWD QUALITY CONTROL MANUAL

The Quality Control Manual has been prepared in three parts as mentioned below:

Part A – Buildings

Part B – Roads

Part C – Bridges and Culverts

Standards prescribed by Bureau of Indian Standards (BIS) has been followed mainly for preparing the guidelines, suggesting quality control tests, frequency, standard values and tolerances in each case. Wherever Indian Standards are not published or are silent, standards fixed by American Society for Testing and Materials (ASTM), "Deutsches Institut für Normung" (DIN) meaning German Institute for Standardization and the British Standards (BS) have been followed.

Similarly for roads, mostly standards prescribed by the Indian Roads Congress (IRC) are followed. Where IRC standards are not published or is silent, standards suggested by ASTM and American Association of State Highway and Transportation Officials (AASHTO) are also followed.

Building works done in PWD are mainly based on Central Public Works Department (CPWD) specifications and road and bridge works, based on specifications approved by Ministry of Road Transport and Highways (MoRTH).

7 QUALITY CONTROL SYSTEM IN PWD

Quality control tests have been made mandatory for projects undertaken by state PWD from 1.9.2014. Clause 2401 and 2406 of Revised PWD Manual - 2012 stipulates that PWD shall follow a three tier quality control system for ensuring quality of projects executed. This includes technical audit after completion of construction. The system envisaged is as below:

7.1 First-tier QC testing

In first-tier QC testing, the Contractor has to carry out the required tests at his own cost during the course of a work. First tier quality control tests are mandatory for all projects including maintenance and repair works, estimated cost of which is above Rs.15 lakhs. As per Govt. circular No. 23631/G2/2013/PWD dated 1.11.2013, Contractors shall establish field laboratories at the site of a project, if the estimated project cost is above Rs 2 crores. If any test cannot be carried out with the facilities available in the Contractor's laboratory, it shall be got done in an approved laboratory by the Contractor at his own cost.

If the QC test is done in the field laboratory established at site, the test results shall be signed by the Overseer/Assistant Engineer, whoever is supervising the work. It shall also be signed by the Contractor. Copy of test results shall be forwarded by the Assistant Engineer to the Assistant Executive Engineer/Executive Engineer for review.

The same procedure shall be followed, in case of tests done in an approved laboratory also.

7.2 Second-tier QC testing

Second-tier QC checks/tests are to be done by the QC wing of PWD on a random basis. However, it is desirable that the QC wing does quality control tests for all major and important items of construction. The frequency of tests shall be as given in this Manual or as specified in the Contract. The QC wing is authorized to inspect all projects undertaken by PWD, including maintenance and repair works, irrespective of the estimated cost and conduct quality tests. Results of the tests so done shall also be recorded in the QC module in PRICE software. As far as possible, results shall be forwarded through e-mail to the Executive Engineer with copies to the Assistant Executive Engineer and Assistant Engineer within the minimum time required for carrying out the test.

7.3 Third-tier QC checking (Technical audit)

As per clause 2406 of the revised PWD Manual 2012, Technical audit shall be done by an external agency/expert empanelled for the purpose after the construction of a project is completed. This will form the third tier of QC system. Technical audit shall be done for projects, estimated cost of which is above Rs 5 crores. All tests carried out in the first-tier and second-tier QC testing shall be reviewed during technical audit. Technical Audit shall be completed within six months from the date of completion of construction. Non-destructive testing techniques shall be adopted if conventional testing techniques cannot be applied.

7.4 Third party testing

Third party testing is carried out by an independent laboratory other than that of the Contractor or the Department. This is required when the Contractor raise a dispute due to difference in the test results of first-tier and second-tier testing or certain specific tests cannot be carried out with the facilities available in the Contractor's or Department laboratories or existence of manipulated results are suspected.

The Executive Engineer shall decide whether a third part testing is required to settle the dispute. If so, he shall issue a written direction to carry out a test in another approved laboratory. The test shall be arranged to be done in the presence of the Assistant Executive Engineer/Assistant Engineer and the Contractor. The result obtained in this test shall be final and binding on both the Contractor and the Department. The expenses for third party testing shall be met by the Contractor.

During sampling for the first-tier and second-tier testing, sufficient number of additional samples shall prepared and kept under safe custody for third-party testing, if warranted. Third-party testing is expected to provide a nonbiased view and thus a better confidence in the test results.

With respect to the methodology of independent testing, the following aspects are important in order to achieve the right quality:

i) The laboratory must be able to choose and apply the test method that provides a technically correct answer to the problem.
ii) The testing must be performed efficiently, also in such a way that delivery times can be met and costs and charges minimized.
iii) The laboratory must be able to provide reliable results with accuracy appropriate to the needs.
iv) The testing laboratory must have the necessary expertise available to be able to assist in the evaluation of the test results and to provide other relevant

technical services of an advisory nature. The expertise may be in another organisational unit.

v) The reports and presentations of the results must be clear and complete, and the recipient must be able to understand and apply them correctly.

8 INTIMATION TO QUALITY CONTROL WING

Agreement Authority shall forward copy of contract documents to the concerned Assistant Executive Engineer, QC wing within 10 days of executing agreement. The Assistant Engineer in charge of the work shall intimate the date of carrying out of concrete and bituminous works or any item of work which requires sampling during the course of construction, well in advance to the Assistant Executive Engineer, QC wing. The Assistant Executive Engineer in charge of the work shall ensure that the date of commencement of each item of work is intimated in a timely manner to the concerned Assistant Executive Engineer of the QC wing for arranging second-tier QC testing.

9 SCOPE OF THIS MANUAL

The Manual does not attempt to suggest technical specifications, since these are stated in the contract documents. However, it will provide guidance on good engineering practices and quality control and its recommendations are not intended to be exhaustive. The QC Manual aims to ensure that the works are executed as per specifications.

All tests shall be done as per the guidelines in this Manual. If any quality test required to be performed is not covered in this Manual, the same shall be done in line with the stipulations/provisions of relevant code of practice published by BIS/IRC. If any difference is observed between the tests or quality control procedures given in this Manual and those stipulated in the contract documents and specifications, the later shall prevail. As per clause 2214 of revised PWD Manual 2012, quality control test results shall accompany the bill submitted for payment. It shall be the responsibility of the Assistant Engineer to ensure that bills for payment are not submitted without attaching the first-tier quality test results. Second-tier test results shall also be attached, if the QC wing has carried out any test for the items covered in the bill.

10 RESPONSIBILITY OF OFFICERS AND CONTRACTOR

10.1 Contractor

Primary responsibility for ensuring quality control in each item of work in a project shall vest with the Contractor. As the agency entrusted for carrying out a project, it shall be the Contractor's responsibility to supply materials conforming to standards and to carry out the works as per specifications so that the desired quality is achieved. The Contractor shall also carry out tests prescribed in this Manual for each item as per the frequency stipulated. It shall also be responsibility of the Contractor to carry out rectification works as directed by the Engineer, if test results do not comply with the requirement.

In order to fulfill the responsibilities in ensuring quality control, the Contractor shall employ qualified technical personnel at site, as agreed in the contract. The technical personnel so employed shall have thorough knowledge regarding all quality control aspects of the project including QC tests. The Contractor cannot evade from the responsibility of ensuring quality control in the items of work done on the plea that he

does not possess sufficient technical knowledge or that the works done are supervised by the departmental officers.

10.2 Overseer

It shall be the responsibility of the Overseer in charge to directly supervise all items of work and ensure that works done are as per the specifications and that quality standards are achieved. Overseer shall inspect all materials supplied then and there and ensure that the materials conform to standards. He shall not allow the Contractor to supply materials not conforming to specifications and standards. He shall ensure that only good quality work is done at site. Any instance of violation of his instructions during supply of materials or carrying out work shall be recorded in Workspot order book and reported to the Assistant Engineer in writing immediately. He shall not permit the Contractor to proceed with the work in case his instructions are not complied with.

10.3 Assistant Engineer

Assistant Engineer shall ensure that work is being carried out by the Contractor as per specification and standards. He shall visit the site of work frequently and issue instructions enabling adherence to specifications and strict quality control. If any defective work is noticed during inspection, the Contractor or his authorised representative at site shall be instructed to stop bad quality work and rectify the defects of the work done. The Assistant Engineer shall record details of such defective work noticed and instructions issued therein in the Workspot order book. The fact of having done rectification satisfactorily shall also be noted subsequently in the Workspot order book. Notice shall be issued under intimation to the Agreement Authority, in case of non-compliance of instructions issued at site. The Agreement Authority shall initiate action to terminate the contract and initiate penal action, if the desired level of quality is not exercised in the construction.

The Overseer and the Assistant Engineer shall ensure that the Contractor takes samples and carries out tests as per frequency suggested in this Manual for the first-tier QC testing. It shall be their responsibility to obtain the test results from the Contractor and to record them in the Quality Control Register kept in the Section office. Copies of test results shall be made available at site for verification by the inspecting officers. They shall also ensure that Contractor carries out all rectification works including dismantling and reconstruction in case of unacceptable works.

10.3 Assistant Executive Engineer

Assistant Executive Engineer shall monitor the entire quality control process and ensure that his subordinate officers are carrying out their duties promptly. In case of lapse on the part of any officer, he shall report to the Executive Engineer for initiating disciplinary action. He shall also report lapse, if any on the part of the Contractor to the Agreement Authority for penal action as per rules of registration and contract conditions.

11 DUTIES AND RESPONSIBILITIES OF OFFICERS IN THE QC WING

11.1 Overseer (QC wing)

The Overseer attached to the QC laboratories shall be responsible for collecting representative samples from the work site, labeling, and sealing, wherever necessary, and transporting the samples safely to the laboratory without any damage. On reaching the laboratory, the sample details shall be entered in the sample register with a unique number. This number shall be referred as sample number in all the

tests. The tests to be carried out on the sample received also shall be indicated in the sample register.

The Overseer is responsible to conduct the required tests as per the guidelines in the QC Laboratory Manual or relevant codes and instructions of the Assistant Engineer. The Overseer shall check and ensure that the laboratory equipment are kept clean by the support staff and are functioning properly. Any defects noted shall be reported to the Assistant Engineer.

The laboratory data and results shall be recorded in the required format by the Overseer, get it verified by the Assistant Engineer and approved by the Assistant Executive Engineer of the QC wing. The Overseer shall record the results in the register kept in the laboratory and affix signature in the register. The Overseer shall ensure that the test reports are forwarded to the officers executing the work. He shall also be responsible for making entries in the QC module in PRICE software.

The Overseer, on a daily basis, shall compile all the intimations forwarded by the Field Engineers regarding the commencement of the work or execution of an item of the work, bring them to the notice of the Assistant Engineer and Assistant Executive Engineer and abide by their instructions in the matter of field inspections/testing, collecting samples and laboratory testing.

11.2 Assistant Engineer (QC wing)

The Assistant Engineer of the QC laboratories shall be responsible for second-tier QC testing. He shall supervise the tests conducted by the Overseer, giving necessary instructions for proper conduct of the tests. He shall verify the test results recorded in the laboratory register, PRICE software and submit the test reports to the Assistant Executive Engineer (QC) for forwarding to the officers executing the project. He shall inspect the project sites, verify the field tests and arrange to take representative samples for laboratory testing. Any instances of violation in the QC procedures observed at site, shall be brought to the notice of the field officers immediately. A report of such instances shall be made to the Assistant Executive Engineer, QC wing. The Assistant Engineer shall prepare monthly progress report of QC activities in the desired format and submit to the Assistant Executive Engineer, QC on or before the 3rd working day of the succeeding month for submission to the Director (I&QC). The Assistant Engineer shall be responsible for arranging the repairs, regular maintenance, and calibration of the laboratory equipment.

11.3 Assistant Executive Engineer (QC wing)

Assistant Executive Engineer of the QC laboratories shall be responsible for implementing second-tier quality control tests in the projects executed by the department in the entire district of his jurisdiction. He shall inspect sites, monitor the quality control process and bring to the notice of field officers any shortfall in the quality of works carried out. He shall ensure that his subordinate officers will inspect the maximum number of project sites and carry out maximum number of quality tests in each project. He shall correspond with Field Engineers on issues related to quality control. He shall be responsible for approving the results of tests conducted in his laboratory and forwarding it to the Executive Engineer of the Regional Laboratory and the Field Engineers. He shall submit monthly reports on tests conducted to the Director (I&QC) with copy to Executive Engineer, QC wing within 10 days of the succeeding month. The Assistant Executive Engineer, QC wing shall prepare review notes for the quarterly review meeting by the Director (I&QC). The Assistant Executive Engineer shall monitor the timely repair, maintenance, and calibration of the

laboratory equipment. Assistant Executive Engineer shall initiate action for providing additional equipment and facilities to the laboratory so that the performance of the QC activities is not hindered due to any reason.

11.4 Executive Engineer, (QC wing)

Executive Engineer, QC wing/Joint Director, KHRI shall monitor and review the second-tier QC system in the entire region of his jurisdiction. He shall inspect sites and bring to the notice of field officers any shortfall in quality of works done or the quality control process being followed. He shall take up quality control issues in a project with the Agreement Authority or the concerned Chief Engineer, wherever required. He shall review the monthly report of QC activities in each district submitted by the Assistant Executive Engineer and recommend action on the non-compliance reports. He shall submit quarterly reports to the Director (I&QC) regarding the implementation of QC in his region within 15 days after each quarter. He shall attend the State level review meetings on Quality Control.

12 MANUFACTURER'S CERTIFICATE

The Contractor shall produce Manufacturer's certificate wherever required as per the guidelines in this Manual. The Contractor shall record the following statement in the Manufacturer's certificate before submission to the Assistant Engineer. "This Manufacturer's Certificate for the supply of ..... (Name of material with item number in Schedule) has been obtained by me from the manufacturer/dealer M/s ..... (Enter name and address of dealer/manufacturer) on ....., for the actual Material supplied at Site".

He shall sign below the statement with date and name seal. The Contractor shall be responsible for the genuineness of the certificate submitted by him.

13 PROCEDURE FOR TAKING SAMPLES AT SITE

Samples for all tests in the first-tier QC testing shall be taken in the presence of an officer not below the rank of the Overseer in charge. Photographs in which departmental officers and Contractor's representative are present may be taken during sampling of items and kept as a record. There shall be a separate module for Quality Control in the PRICE software for recording the photographs and test results. The photographs shall be uploaded on the very next day of sampling. After sampling, the Overseer in charge shall make entries regarding the samples taken in the QC register at the earliest. The entries in the QC register shall be duly checked and attested by the Assistant Engineer.

Samples taken shall be kept in sealed bags and these bags shall be opened only at the time of testing. The samples which require curing shall be kept for curing at the site itself. The responsibility for sealing the bags shall vest with the Assistant Engineer/Overseer. The responsibility for keeping the sealed samples under safe custody and curing shall vest with the Contractor. The Overseer shall ensure that the curing of the sample is done properly.

Samples for second-tier testing shall be taken from site by an officer not below the rank of an Overseer of the QC wing. If samples taken are kept at the site for curing, the same procedure detailed for first-tier testing shall be followed. An acknowledgement for receipt of the sample shall be obtained by the QC wing from the Contractor or his representative, to ensure that he will keep the sample under safe custody. Photographs of sampling shall be taken by the officer entrusted to take the

sample. The photograph shall be uploaded in the PRICE software by the Assistant Executive Engineer of the concerned QC laboratory on the very next day.

14 RECTIFICATION OF DEFECTIVE WORK

The Contractor is bound to carry out the rectification works at his own cost, if results obtained during quality control tests either in the first-tier or second-tier is do not comply with the requirement. He shall also carry out rectification works, if any pointed out during technical audit done after completion of work.

The Executive Engineer shall initiate action, if required based on the test results obtained from first-tier and second-tier testing and the technical audit. On receipt of the test reports, the Executive Engineer shall compare the results obtained in the tests with the values specified. If the result of any test falls outside the requirement, he shall issue notice to the Contractor forthwith, pointing out the nature and extend of defects and directing to rectify the defects by suitable methods. The Executive Engineer shall inspect site after rectification is completed and issue approval in writing if he is satisfied with the rectification work carried out.

If a Contractor does not comply with the direction to carry out rectification work, his contract shall be terminated at his risk and cost and penal action as per registration rules shall be initiated against him.

15 CHECKLISTS

There shall be a quality verification of the work at the time of submission of each bill by the Contractor. For this, checklists are to be filled up by the Overseer concerned during the execution. It shall be verified and attested by the Assistant Engineer and reviewed by the Assistant Executive Engineer before submission to the Executive Engineer along with the bill for payment. The entire monitoring process shall be done through PRICE software. Specimen checklists for quality assurance are given in Appendices of this Manual.

16 DEFINITIONS

Agreement Authority: The officer who has invited and received bids for the project and has executed agreement for execution.

Bid or Tender: The Contractor's priced offer to the Employer for the execution and completion of the project and the remedying of any defects therein in accordance with the provisions of Contract.

Contract: Signed document between the Agreement Authority and the selected bidder to execute, complete and maintain the project.

Contractor: Person or persons, firm or partnership or company or consortium of companies who have entered into contract for the execution of the work.

Drawings: Includes all drawings, calculations and technical information related to the project approved by the Engineer from time to time under the Contract.

Engineer: The equivalent nomenclature used in the revised PWD Manual/Standard Bidding Document as applicable.

Engineer's Representative: Any subordinate staff posted to assist the Engineer, in supervision, execution and to maintain documents.

Field Engineer: Engineers at Section and Sub Divisional offices who are directly in charge of execution of the project.

Materials: All supplies, including consumables used by the Contractor for incorporation in the works.

Site: The the places identified by the Engineer where the project is executed. It may also include any other place or places forming part of the site, mentioned in the Contract.

Specification: Instructions, provisions, conditions and detailed requirements contained in the tender documents which form part of the Contract and any modification or addition made or approved by the Agreement Authority.

Works: Includes materials and activities required by the Contractor to construct, install and hand over to the Engineer as defined in the Contract.

+++++++

Part - A
Buildings

SECTION 100 QUALITY CONTROL IN BUILDING CONSTRUCTION

101 GENERAL

Public Works Department is entrusted with the construction and maintenance of buildings owned by various departments of Kerala Government. Construction is undertaken by the department based on designs approved by the Competent Authority. During execution of a building project, it has to be ensured that the specifications are strictly adhered to and the standards prescribed by the relevant codes are achieved. The various Sections included under Part A of this Manual explain in detail the quality aspects of each item forthcoming in a building project and the tests to be carried out and the standards fixed for each item by the various codes. Quality of a work is the conformity to the standards and requirements and is one of the key parameters in the successful completion of any project.

102 TECHNICAL SPECIFICATIONS AND STANDARDS/CODES

102.1 CPWD Specifications

Central Public Works Department (CPWD) Specifications are followed for execution of building projects undertaken by Kerala Public Works Department. These specifications are based on codes published by the Bureau of Indian Standards (BIS).

102.2 National Building Code of India

The National Building Code of India (NBC) enforces unified building regulations throughout the country. It is a single document in which the information contained in various Indian Standards is compiled and can be immediately adopted or enacted for use by various departments. The provisions of the NBC are followed invariably in the building projects undertaken by Kerala Public Works Department.

102.3 Handbooks published by the Bureau of Indian Standards

Bureau of Indian Standards has published the following handbooks which unify the constructional practices being followed by various organisations engaged in construction of residential, commercial and industrial buildings and is mainly based on various Indian standards published in the respective areas of construction. The handbook provides information regarding methods of construction of any particular element of the building using different materials and methods. Some of the handbooks useful for reference are listed below:

i) SP 62 Handbook on building construction practices.
ii) SP 16 Design aids for reinforced concrete to IS: 456.
iii) SP 20 Handbook on masonry design and construction.
iv) SP 21 Summaries of Indian standards for building materials.
v) SP 22 Explanatory handbook on codes of earthquake engineering (IS: 1893 and IS: 4326).
vi) SP 23 Handbook on concrete mixes (Based on Indian standards).
vii) SP 24 Explanatory handbook on Indian standard code of practice for plain and reinforced concrete (IS: 456).
viii) SP 25 Handbook on causes and prevention of cracks in buildings.
ix) SP 32 Handbook on functional requirements of industrial buildings (Lighting and ventilation).

x) SP 33 Handbook on timber engineering.
xi) SP 34 Handbook on concrete reinforcement and detailing.
xii) SP 35 Handbook on water supply and drainage with special emphasis on plumbing.
xiii) SP 38 Handbook on typified designs for structures with steel roof trusses (With and without cranes).
xiv) SP 40 Handbook on structures with steel portal frames (Without cranes).
xv) SP 41 Handbook on functional requirements of buildings (Other than industrial buildings).
xvi) SP 43 Handbook on structures with reinforced concrete portal frames (Without cranes).
xvii) SP 47 Handbook on structures with steel lattice portal frames (Without cranes).

102.4 Indian Standard Codes

Codes published by the Bureau of Indian Standards prescribe specifications and standards for various items of building work. It also stipulates the tests to be done and methods of sampling.

102.5 American Society for Testing and Materials (ASTM)

ASTM/DIN Standards are suggested to be followed for certain items of work where BIS codes are not published or silent.

103 OVER VIEW OF CONTENTS

The quality control aspects and standards related to building work are detailed in Part A of this Quality Control Manual under 12 sections. The sections and the contents are mentioned below.

a) *Site clearance and earthwork*: The quality control aspects in site clearance and earthwork related to building works are detailed under this section. Requirements for fill material, blasting in hard rock, excavation under water, anti-termite treatment and quality control tests for compacted layers of filling are also detailed.
b) *Building foundations:* This section details the quality aspects in the construction of shallow and deep foundations. Precautions to be taken while placing shallow foundations on sloping ground and during installation of pile foundation are also explained.
c) *Masonry*: Masonry is one of the major items of construction in a building project. Quality requirements and quality control tests related to masonry mortars and ingredients, including simple field tests, are given in this section. Points to be given attention during construction of brick masonry, stone masonry, concrete block masonry and laterite masonry, sampling for tests, quality control tests for materials and requirements for each item as per BIS Codes are also explained under this section.
d) *Scaffoldings*: Scaffoldings are temporary structures erected during construction for supporting labour and materials for executing masonry, plastering and related works. This section covers the different systems of scaffolding, timber and steel scaffoldings and its requirements.
e) *Concrete*: Concrete is a major item in the construction of a building. This section covers the quality control aspects of concrete work including materials required such as cement, fine aggregate, coarse aggregate, water, admixtures,

reinforcing steel and formwork. Standards fixed by BIS for the various items, requirements of materials, quality control tests to be conducted, frequency of tests and tolerances are included. Measures to be adopted during stacking of materials, batching, mixing, transportation, placing and compaction of concrete are also presented.

f) *Doors and windows*: Quality control aspects of doors and windows made with timber, steel, aluminium, fibreglass reinforced plastic, UPVC and related fittings are included under this section.

g) *Finishing*: Finishing of a building includes works related to floor, wall and ceiling. Quality aspects of cement plastering, white washing, colour washing, distempering and painting with plastic emulsion and synthetic enamel are given under this section.

h) *Panelling and partitions*: Panelling and partitions are inevitable in the present day building construction. Requirements and tests prescribed for materials including ordinary and marine plywood, particle boards, aluminium sections, aluminium composite cladding and structural glazing are presented under this section.

i) *Roofing and ceiling*: Quality control aspects including specifications, laying and fixing, standards and tests for different types of roofing and ceiling materials are given under this section. Thermal insulation for roofing is also included in this section.

j) *Flooring*: Floor provides a horizontal surface to support the occupants of a building, furniture and equipment. Quality control aspects of cement concrete, terrazzo, marble, Kota stone, ceramic, vitrified and wooden tile flooring are detailed in this section.

k) *Structural steelwork*: This section provides guidelines regarding quality control measures for material procurement, fabrication, assembly, storage, transportation, erection and painting of bolted/welded structural steelwork.

l) *Drainage, sanitary and water supply*: Drainage, sanitary and water supply installations are important for the functioning of a building. Detailing on the quality control aspects of drainage, sanitary and water supply installations are presented separately in this section.

+++++++

SECTION 200 SITE CLEARANCE AND EARTHWORK

201 GENERAL

This section consists of quality control aspects in site clearance and earthwork for building and auxiliary structures in accordance with the details shown on the Drawings and conforming to the requirements of the Specifications or as directed by the Engineer.

a) The Contractor shall prepare and submit a report to the Engineer on the pre-construction condition of all structures that may be affected during construction after a detailed inspection of the site. The report may include photographs and videos if necessary, drawings and sketches with levels and dimensions fully illustrating the structure's condition. In particular, it shall note any existing damage or structural inadequacy. Deficiencies and damage are to be suitably marked on the structure in a way that it is not permanently defaced.

b) The construction of access roads, main sewers and drains shall preferably be completed before commencing the work of foundations.

202 SITE CLEARANCE

a) Before the earthwork is started, the area coming under cutting and filling shall be cleared of shrubs, vegetation, grass, brushwood, trees and saplings of girth up to 30 cm measured at a height of one metre above ground level and rubbish removed up to a distance of 50 metres outside the periphery of the area under clearance. The roots of trees and saplings shall be removed to a depth of 60 cm below ground level. The holes or hollows due to removal of old foundation shall be filled up with the earth, well consolidated to the required compaction and levelled.

b) The trees of girth above 30 cm measured at a height of one metre above ground shall be cut only after obtaining written permission of the Engineer. The roots of trees shall also be removed. Existing structures and services such as old buildings, culverts, fencing, water supply pipe lines, sewers, power cables, communication cables, drainage pipes etc. within or adjacent to the area if required to be diverted/removed, shall be diverted/dismantled as per directions of the Engineer.

c) If the site of a structure is such that surface water shall drain towards it, land may be dressed or drains laid out to divert the water away from the site.

203 SETTING OUT

a) Generally the site shall be levelled before the layout of foundations is set out.

b) Before setting out, the Contractor shall collect the relevant Drawings from the Engineer. The Contractor shall prepare the set out plan and submit the same to the Engineer for approval.

c) In case of sloping terrain, care shall be taken to ensure that the dimensions on plans are set out correctly in one or more horizontal planes.

d) The layout of foundation shall be set out with steel tapes. Angle shall be set out with theodolite or total station in the case of important and complex structures. In other cases these shall be set out by measurement of sides.
e) In rectangular or square setting out, diagonals shall be checked to ensure accuracy.
f) The setting out of walls shall be facilitated by permanent row of pillars, parallel to and at a suitable distance beyond the periphery of the building. The pillars shall be located at junctions of cross walls with the peripheral line of pillars.
g) The centre line of the cross walls shall be extended to and permanently erected on the plastered tops of the corresponding sets of pillars.
h) The datum line parallel to and at the known fixed distance from the centre lines of the external walls also shall be permanently marked on the corresponding rows of pillars to serve as a check on the accuracy of the work as it proceeds. The tops of these pillars shall be at the same level and preferably at the plinth or floor level. The pillars shall be of sizes not less than 25 cm wide and shall be bedded sufficiently deep into ground so that they are not disturbed.
i) A masonry pillar to serve as a bench mark shall be erected at a suitable point in the area, which shall be visible from all points. This bench mark shall be constructed and connected with the standard bench mark as approved by the Engineer.
j) The ground levels shall be taken at 5 m to 15 m intervals (as directed by the Engineer) in uniformly sloping ground and at closer intervals where local mounds, pits or undulations are met with. The ground levels shall be recorded in field books and plotted on plans. The plans shall be drawn to a scale of 5 m to 1 cm or any other suitable scale decided by the Engineer. North direction line and position of bench mark shall invariably be shown on the plans. These plans shall be signed by the Contractor and the Engineer before the earthwork is started.

204 EARTHWORK EXCAVATION

204.1 Requirements/Workmanship

a) When the excavation has been carried down to bottom level of foundation, the Contractor shall inform the Engineer or his representative that the excavation is ready for inspection and the Engineer shall, without reasonable delay, inspect the excavation.
b) The Contractor is to employ only plant which is suited to the soils to be handled. He should not at any time use plant which damages or reduces the natural strength of the soil either in its in-situ state or during handling and placing or in its final compacted state. Unsuitable or faulty plant shall be removed from the work site and borrow pits at the order of the Engineer.
c) Any loose, improperly compacted, soft or other unsuitable material which is encountered below or adjacent to structural foundation levels shall be completely removed, backfilled with a suitable material and compacted to 95% of the maximum dry density or as described in the specifications or as directed by the Engineer.
d) The following situations as shown in Fig. 200-1 shall be considered carefully to avoid failure of excavated trench or excavation:

i) When a trench is dug, the sides of the open excavation are exposed to air. The moisture content of the soil begins to change almost immediately and the strength of the walls gets reduced which may cause the collapse.

ii) The walls of trenches may subject to vibrations from vehicle traffic or construction operations such as moving of soil, compaction, pile driving and blasting, which can affect the strength of the trench.

iii) A surcharge like mobile equipment, excavated earth piled or other materials stored near the trench can put pressure on the walls which may affect the stability of a trench. The cuttings should be kept as far from the edge of the trench as is practical. One meter from the edge of the base of the pile of rubble is a minimum requirement. The distance shall be greater for deeper trenches.

iv) When the old trenches of utilities cross or go in parallel with the new trench, can affect the strength and stability of the new pit or trench. The soil around and between these ancient excavations is very unstable.

v) When the foundation of a building adjacent to the trench or excavation extends to the rupture zone of the trench or excavation, this may result in a collapse.

vi) Rain water, overflow from streams, storm drains and sewer systems can increase the infiltration rate and reduce the strength of the adjacent soil which may cause collapse. Trenches or excavations shall not be kept open for a long time to reduce the risk of such collapses.

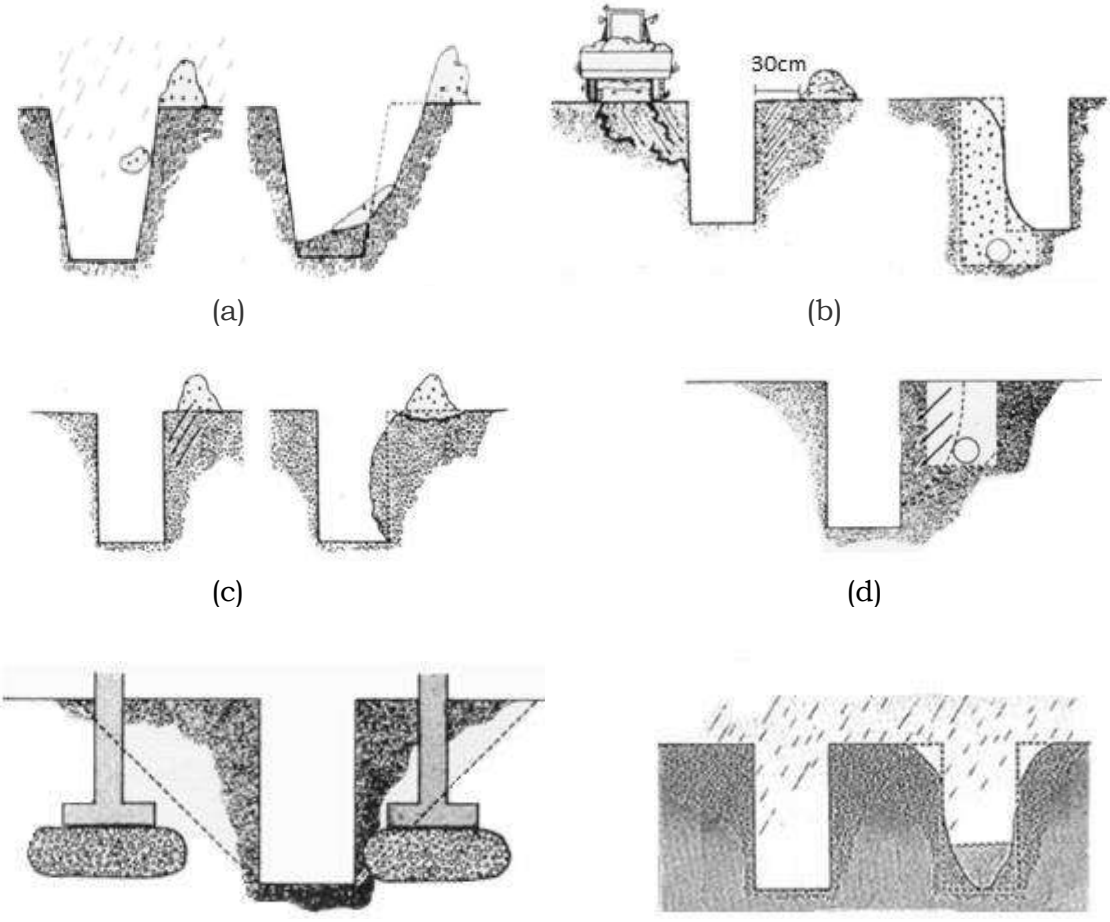


Fig. 200-1 Examples of excavation failures

204.2 Protections

a) The Contractor shall take adequate protective measures to see that the excavation operations do not damage the adjoining structures or dislocate the services. Water supply pipes, sluice valve chambers, sewerage pipes, manholes, drainage pipes and chambers, communication cables, power supply cables etc. met within the course of excavation shall be properly supported and adequately protected, so that these services remain functional. However, if any service is damaged during excavation, it shall be restored in reasonable time.

b) Excavation shall not be carried out below the foundation level of the adjacent buildings until underpinning, shoring etc. is done as per the directions of the Engineer.

c) Any damages done by the Contractor to any existing work shall be made good by him at his own cost. Existing drains pipes, culverts, over head wires, water supply lines and similar services encountered during the course of execution shall be protected against damage by the Contractor. The Contractor shall not store material or otherwise occupy any part of the site in manner likely to hinder the operations of such services.

204.3 Excavation in soil

a) During the excavation, the natural drainage of the area shall be maintained. Excavation shall be done from top to bottom. Undermining or undercutting shall not be done.

b) In firm soils, the sides of the trenches shall be kept vertical up to a depth of 2.0 m from the bottom. For greater depths, the excavation profiles shall be widened by allowing steps of 50 cm width on either side after every 2.0 m from the bottom. Alternatively, the excavation can be done so as to give slope of 1:4 (1horizontal to 4 vertical).

c) Where the soil is soft, loose or slushy, the width of steps shall be suitably increased or sides sloped or the soil shored up as directed by the Engineer. It shall be the responsibility of the Contractor to take complete instructions in writing from the Engineer regarding the stepping, sloping or shoring to be done for excavation deeper than 2.0 m.

d) The excavation shall be done true to levels, slope, shape and pattern indicated by the Engineer.

e) In case of excavation for foundation in trenches or over areas, the bed of excavation shall be to the correct level or slope and consolidated by watering and ramming. If the excavation for foundation is done to a depth greater than that shown in the Drawings or as required by the Engineer, the excess depth shall be made good by the Contractor at his own cost with the concrete of the mix used for levelling/bed concrete for foundations.

f) Soft/defective spots at the bed of the foundations shall be dug out and filled with concrete as directed by the Engineer.

g) While carrying out the excavation for drain work care shall be taken to cut the side and bottom to the required shape, slope and gradient. The surface shall then be properly dressed. If the excavation is done to a depth greater than that shown on the Drawing or as required by the Engineer, the excess depth shall be made good by the Contractor at his own cost with ordinary earth, properly watered and rammed.

204.4 Excavation in ordinary/hard rock

a) In ordinary rock, excavation shall be carried out by crowbars, pick axes or pneumatic drills and blasting operation shall not be generally adopted. Where blasting operations are not prohibited and it is practicable to resort to blasting for excavation in ordinary rock, the Contractor may do so with the permission of the Engineer in writing.

b) Where hard rock is met with and blasting operations are considered necessary, the Contractor shall obtain the approval of the Engineer in writing for resorting to the blasting operations. Blasting operations shall be done as specified and chiselling shall be done to obtain correct levels, slopes, shape and pattern of excavation as per the Drawings or as required by the Engineer.

c) Rock excavation consists of the excavation and satisfactory disposal of all unaltered and un-weathered firm and rigid igneous, metamorphic and sedimentary solid rock that in the opinion of the Engineer can only be excavated by the use of pneumatic hammers or other such similar apparatus.

d) Where blasting operations are prohibited or are not feasible, excavation in hard rock shall be done by chiselling.

204.5 Blasting

a) Blasting will not be permitted without prior approval from concerned authorities.

b) Blasting work shall be done under careful supervision and trained personnel shall be employed.

c) Blasting operations shall be carried out under the supervision of a responsible authorized agent of the Contractor, during specified hours as approved in writing by the Engineer.

d) All procedures and safety precautions for the use of explosives, drilling and loading of explosives before and after shot firing and disposal of explosives shall be taken by the Contractor as detailed in IS: 4081.

e) The maximum of eight boreholes shall be loaded and fired at one occasion. The charges shall be fired successively and not simultaneously. Immediately before firing, warning shall be given and the agent shall see that all persons have retired to a place of safety. The safety fuses of the charged holes shall be ignited in the presence of the agent, who shall see that all the fuses are properly ignited.

f) Careful count shall be kept by the agent and others of each blast as it explodes. In case all the charged boreholes have exploded, the agent shall inspect the site soon after the blast but in case of misfire the agent shall inspect the site after half an hour and mark red crosses (X) over the holes which have not exploded.

g) The Engineer shall also be informed by the Contractor of all cases of misfires, their causes and steps taken in that connection.

204.6 Excavation methods

a) The excavation shall be done manually or by mechanical means as directed by the Engineer after considering the feasibility, urgency of work, availability of labour/mechanical equipments and other factors involved.

b) Earthwork by mechanical means involves careful planning keeping in view site conditions i.e. type of soil, nature of excavation, distances through which excavated soil is to be transported and working space available for employing

these machines. The earthmoving equipment shall be selected accordingly.

c) The earthmoving equipment consists of equipment for excavating and transporting materials. Excavating equipments may be further classified as excavators and tractor based equipment.

204.7 Excavation in under water

a) At locations where the excavation extends below the groundwater table, a dewatering system is to be provided which will lower ambient groundwater levels. The resulting groundwater level shall be at a depth which is sufficiently below the excavation level so as to allow the safe and proper execution of the work. The resulting foundation level shall be stable, which is suitable for the execution of subsequent operations.

b) The Contractor is to design the dewatering methods and settling basins so that no critical amounts of soil, sand or silt are removed during dewatering operations.

c) Complete working drawings showing the type of dewatering and groundwater control system proposed shall be submitted to the Engineer for his review and approval. The Contractor shall indicate his proposed location(s) for the discharge of extracted groundwater. Guidelines to be followed shall be as per IS: 9758.

d) The dewatering system design shall also include the details of measures required to prevent damage due to settlement of roads, pavements, utilities, sewers, buildings and other structures outside the excavation but within the area affected by the dewatering.

e) All water that may accumulate in excavations during the progress of the work from springs, tidal or river seepage, broken water mains or drains (not due to the negligence of the Contractor), and seepage from subsoil aquifer shall be bailed, pumped out or otherwise removed.

f) The Contractor shall take adequate measures for bailing and/or pumping out water from excavations and construct diversion channels, bunds, sumps, cofferdams etc.

g) Pumping shall be done directly from the foundation trenches or from a sump outside the excavation in such a manner as to preclude the possibility of movement of water through any fresh concrete or masonry and washing away parts of concrete or mortar.

h) During laying of concrete or masonry and for a period of at least 24hours thereafter, pumping shall be done from a suitable sump separated from concrete or masonry by effective means.

i) Capacity and number of pumps, location at which the pumps are to be installed, pumping hours etc. shall be decided from time to time in consultation with the Engineer.

j) Pumping shall be done in such a way as not to cause damage to the work or adjoining property by subsidence etc. Disposal of water shall not cause inconvenience or nuisance in the area or cause damage to the property and structure nearby.

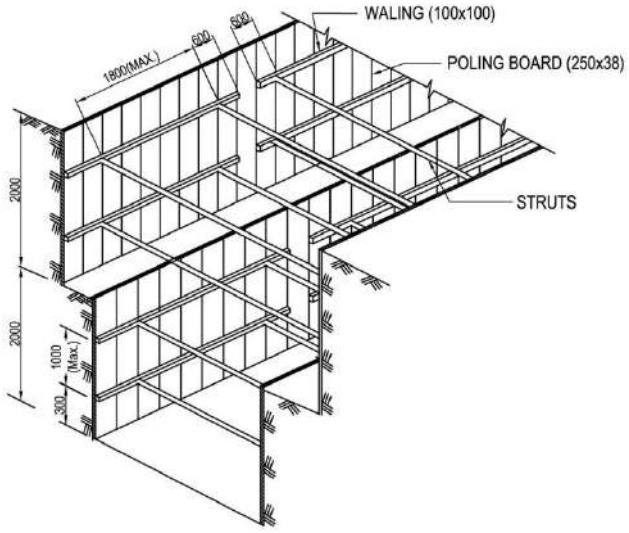
k) To prevent slipping of sides, planking and strutting may also be done with the approval of the Engineer.

204.8 Planking and strutting

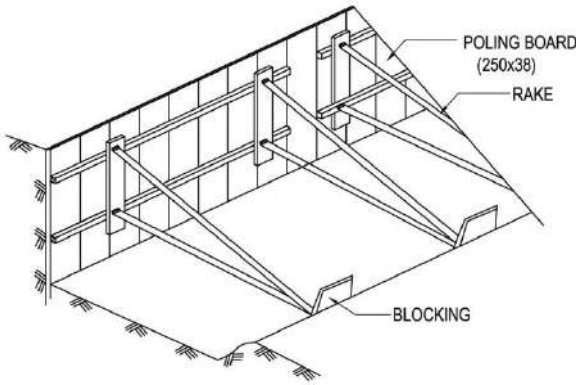
a) When the depth of trench in soft/loose soil exceeds 2 m, stepping, sloping and/or planking and strutting of sides shall be done. In case of loose and slushy soils, the depths at which these precautions are to be taken shall be determined by the Engineer according to the nature of soil.

b) Planking and strutting shall be 'close' or 'open' depending on the nature of soil and the depth of trench as shown in figure 200-2. The types of planking and strutting shall be determined by the Engineer.

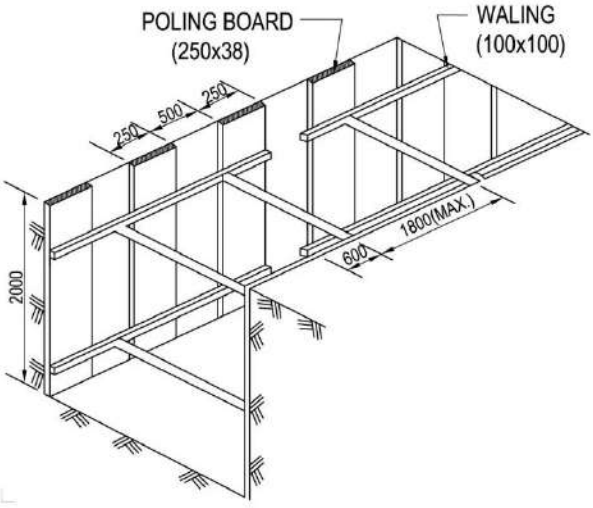
c) It shall be the responsibility of the Contractor to take all necessary steps to prevent the sides of trenches from collapse. Guidance shall be taken from IS: 3764 for designing the shoring and strutting arrangements and specifying the profile of excavation.



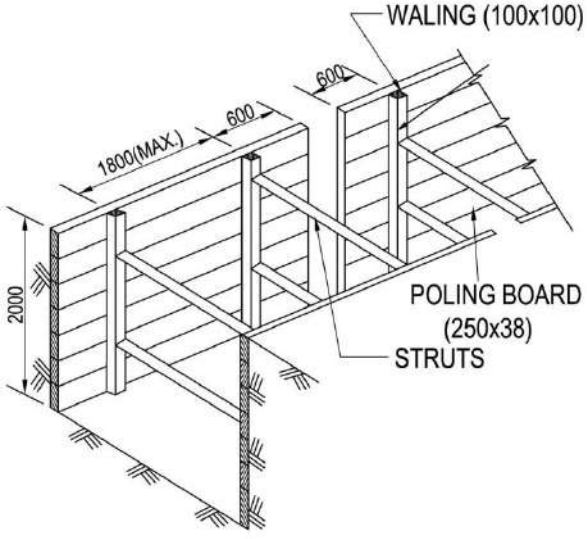
a) Close planking and strutting with vertical poling board



b) Planking and strutting for shallow-wide excavation



c) Open planking and strutting



d) Close planking and struting with longitudinal poling board

Fig. 200-2: Types of planking and strutting (dimensions are in mm).

205 EARTH FILLING

205.1 Fill materials

a) Suitable material for fill shall be approved soil with a liquid limit not exceeding 35% and a plasticity index not exceeding 10%. The material passing the 0.075 mm sieve shall not exceed 20% and the organic matter content shall not exceed 2% (As determined by relevant BIS).

b) Where excavated rock is to be used as fill material elsewhere on the site, the excavated rock shall meet the requirement of the specification for fill material.

c) The Contractor is responsible for mixing the excavated rock with suitable fill material imported and/or excavated from within the site should it be necessary in order to produce a suitable fill material that complies with the requirements of the Specification.

d) Unsuitable materials include the following:
   i) Organic material containing greater than 2% stumps and other perishable material.
   ii) Material susceptible to spontaneous combustion.
   iii) Soils of liquid limit exceeding 35% and/or plasticity index exceeding 10%.
   iv) Material containing more than 5% of water soluble salts by weight of dry soil (Individually, water soluble chloride exceeding 1% or water soluble sulphate exceeding 1.5%) or more than 10% of acid soluble salts (Individually, acid soluble chloride exceeding 2% or acid soluble sulphate exceeding 3.0%) as determined by relevant BIS.
   v) Any other material which the Engineer may deem to be unsuitable for earthworks.

e) All excavated material determined as suitable by the Engineer, is to be utilised as backfill.

205.2 Fill/Backfill

a) Backfilling of the trench shall be carried out only after the permanent works therein have been approved and after the removal of any building debris or deleterious material from the trench.

b) Selected excavated material will normally be used for backfilling in the manner described in the specifications or as directed by the Engineer. Where the excavated material is not considered suitable, selected material from an approved source is to be used.

c) The backfill will be brought to a suitable level above ground to provide for anticipated settlement and unless indicated otherwise, is to be sloped away from the structure.

d) The bottom of all excavations is to be probed and any poor bearing area shall be reported to the Engineer who will direct remedial work. Soft spots and other unsound materials are to be dealt with suitable measures as instructed by the Engineer.

e) Fill shall be compacted by a suitable plate type vibrator, pedestrian operated vibrator roller, small tandem roller or other approved compaction plant.

f) The material shall be placed in layers within the effective range of compaction of the plant provided that the maximum loose thickness of each layer does not exceed 200 mm.

g) The material is to be watered and mixed as necessary to ensure that prior to compaction the moisture content of the whole layer is ±3% of the optimum

moisture content. Compaction of each layer is to continue till 95% of the maximum dry density (MDD) has been achieved.

h) All fill material used in earthwork shall be compacted as stipulated in the specification using equipment approved by the Engineer for that purpose. If required by the Engineer, the Contractor shall carry out compaction trials on the material supplemented by laboratory testing to determine the correct equipment required to achieve the specified requirements.

i) Potable water shall be preferred for compaction of all fill material within the area of excavation.

j) All adjustment of moisture content shall be carried out in such a way that the specified moisture content remains uniform throughout compaction.

k) No completed fill layer shall be covered by the next layer until it has been inspected and approved by the Engineer.

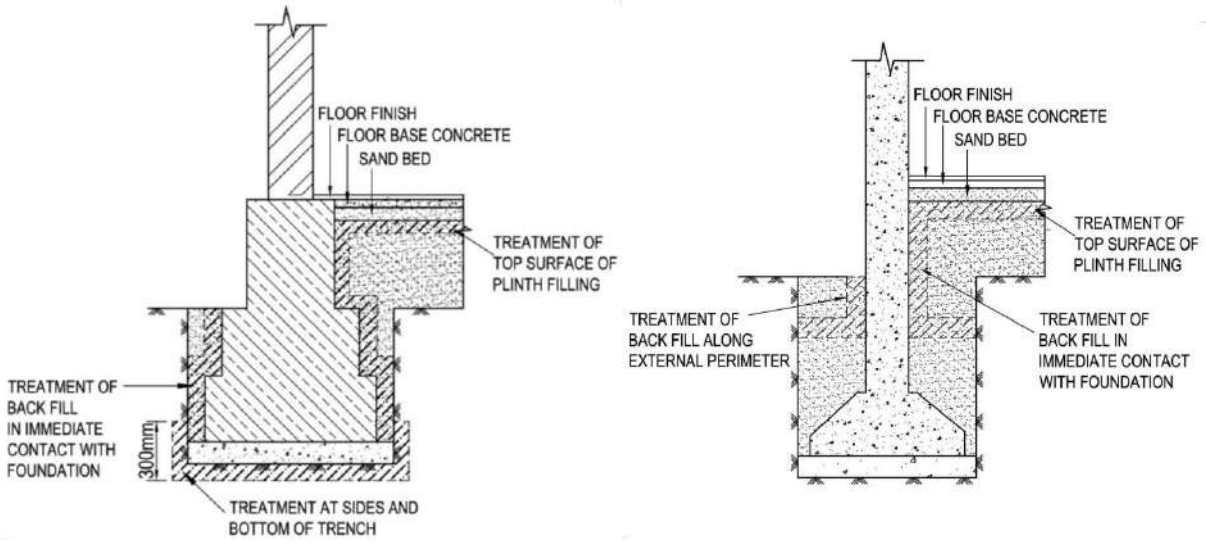
l) Where fill material is to be deposited in areas where the existing ground is sloping, the Contractor shall excavate benches so that fill material is deposited onto a horizontal surface. The levels of the benching terraces shall match the layers of the fill material that are deposited in the adjacent areas.

206 ANTI-TERMITE TREATMENT

a) Termites form nests or colonies underground in the soil near ground level in a stump or other suitable piece of timber in a conical or dome shaped mound. The termites find access to the superstructure of the building either through the timber buried in the ground or by means of mud shelter tubes constructed over unprotected foundations.

b) Termite control in existing as well as new building structures is very important as the damage likely to be caused by the termites to wooden members of building and other house hold article like furniture, clothing, stationery etc. is considerable.

c) Typical detailing of anti-termite treatment of building foundations are shown in figure 200-3.



a) Load bearing wall structure b) Framed structure with RCC column

Fig. 200-3: Anti-termite treatment of building foundations.

d) Anti-termite treatment can be done either during the time of construction i.e. pre-constructional chemical treatment or after the building has been

constructed i.e. treatment for existing building.

e) Prevention of the termite, from reaching the super-structure of the building and its contents can be achieved by creating a chemical barrier between the ground, from where the termites come and other contents of the building which may form food for the termites. This is achieved by treating the soil beneath the building and around the foundation with a suitable insecticide. Care should be taken in the application of chemicals to see that they are not allowed to contaminate wells or springs which serve as source of drinking water.

f) Chemical treatment for the eradication and control of sub-terranean termites in existing building shall be done as per IS: 6313 (Part-3).

g) Treatment shall be got done only from the approved specialized agencies using the chemical procured directly from reputed and authorized dealers.

207 QUALITY CONTROL

a) The dry density/moisture content relationship will be determined by the heavy compaction test as per IS: 2720 (Part-8) for ensuring compaction of fill material at optimum moisture content.

b) The Contractor shall carry out moisture content determinations at frequent intervals or when there is a change in the material on the soils undergoing compaction so as to ensure that the moisture content of the soil is within the optimum range for the field compaction determined from compaction trials.

c) Density of the compacted layers shall be determined regularly or as and when required by the Engineer in accordance with IS: 2720 (Part-28) or by any appropriate method.

d) The control tests shall be carried out if the quantity of filling to be done is more than 50 m^3.

208 REFERENCES

1. IS: 1904 Design and construction of foundations in soils: General requirements.
2. IS: 3764 Code of safety for excavation work.
3. IS: 9758 Guidelines for dewatering during construction.
4. IS: 4081 Safety code for blasting and related drilling operation.
5. IS: 4988 (Part-4) Glossary of terms and classification of earth-moving machinery: *Excavators*
6. IS: 12138 Earthmoving equipments.
7. IS: 6313 (Part-2) (Part-3) Code of practice for anti-termite measures in buildings: *Pre-constructional chemical treatment measures.* *Treatment for existing buildings.*
8. IS: 6940 Methods of test for pesticides and their formulations.
9. IS: 632 Gamma–BHC (Lindane) emulsifiable concentrates.
10. IS: 8944 Chlorpyrifos emulsifiable concentrates.
11. IS: 8963 Chlorpyrifos –Technical specifications.
12. IS: 2720 (Parts 7 & 8) Methods of test for soils.

+++++++

SECTION 300 BUILDING FOUNDATIONS

301 GENERAL

This section consists of construction of foundation for buildings and auxiliary structures in accordance with the details shown in the Drawings and conforming to the requirements of the Specifications or as directed by the Engineer.

a) Foundations are broadly classified into shallow and deep foundations.
b) In areas which have already been developed, advantage shall be taken of existing local knowledge, records of trial pits, bore holes, etc, in the vicinity, and the behaviour of existing structures, particularly those of a nature similar to that of the proposed structure. In such cases, exploration may be limited to checking that the expected soil conditions are those as in the neighbourhood.
c) If the existing information is not sufficient or is inconclusive the site shall be explored in detail in accordance with the principles set in IS: 1892 so as to obtain the knowledge of the type, uniformity, consistency, thickness, sequence and dip of the strata and of the ground water conditions.

302 SHALLOW FOUNDATION

The shallow foundation shall be of three types:

i) Spread foundation which includes isolated and combined footing.
ii) Strip foundation for masonry wall as well as a row of columns.
iii) Raft foundation, laid normally to a depth of 3 m.

302.1 Materials

Generally building foundations are constructed with stone masonry or concrete. The quality aspects of materials are given in sections of concrete and masonry.

302.2 Requirements

a) Cuttings, excavations or sloping ground near foundations shall be avoided as it may increase the possibility of shear failure in the ground supporting the foundations.
b) New constructions may interfere with drainage regime of the ground and affect the stability of existing structure. Adequate precautions shall be taken to protect these.
c) Shallow foundations shall be avoided in places where the increase in moisture extent results in substantial loss of bearing capacity in case of certain types of soils which may lead to differential settlements.
d) In certain localities where considerable quantities of soluble salts are contained in ground water and soil, RCC members, especially thin members or buried metals are subjected to deterioration and corrosion. In industrial areas, corrosive action may arise from industrial wastes that have been dumped on the site. Chemical analysis of samples of ground water or soil (or sometimes both) should be done to assess the necessity of special precautions. The following are some of the suggested methods:
    i) Dense cement concrete M20 mix or richer may be used to reduce permeability and increase resistance to attack from sulphates as per IS: 456.

ii) Portland pozzolana cement may be used to control and reduce the activities of the sulphates.

iii) Special cements like high alumina cement, or super sulphated cement, which are sulphate resistant, may be used.

iv) A thick coating of bitumen/water proofing materials may be given over the exposed surfaces of foundation below the water table to prevent infiltration of water into the foundation as per IS: 5871.

v) A thick layer of cement concrete (with sulphate resistant cement) and coated with bitumen/water proofing materials may be laid before laying of foundation concrete to prevent infiltration of water from sulphate bearing soil.

e) Unless mentioned in the Drawing, the depth of foundations shall depend upon the following principal factors:

i) The depth at which adequate allowable bearing capacity is available

ii) The minimum depth of foundations shall be at least 50 cm below natural ground level. On rock or such other weather resisting natural ground, removal of the top soil may be all that is required. In such cases, the surface shall be cleaned and, if necessary, stepped or otherwise prepared so as to provide a suitable bearing and thus prevent slipping or other unwanted movements.

iii) Where there is excavation, ditch, pond, water course, filled up ground or similar condition adjoining or adjacent to the subsoil on which the structure is to be erected and which is likely to impair the stability of structure, either the foundation of such structure shall be carried down to a depth beyond the detrimental influence of such conditions, or retaining walls or similar works shall be constructed for the purpose of shielding from their effects.

iv) A foundation in any type of soil shall be below the zone significantly weakened by root holes or cavities produced by burrowing animals or works. The depth shall also be enough to prevent the rainwater scouring below the footings.

f) Where footings are adjacent to sloping ground or where the bottoms of the footings of a structure are at different levels or at levels different from those, of the footings of adjoining structures, the depth of the footings shall be such that the difference in footing elevations shall be subject to the following limitations.

i) When the ground surface slopes downward adjacent to a footing, the sloping surface shall not intersect a frustum of bearing material under the footing having sides which make an angle of 30° with the horizontal for soil. The horizontal distance from the lower edge of the footing to the sloping surface shall be at least 60 cm for rock and 90 cm for soil as shown in figure 300-1.

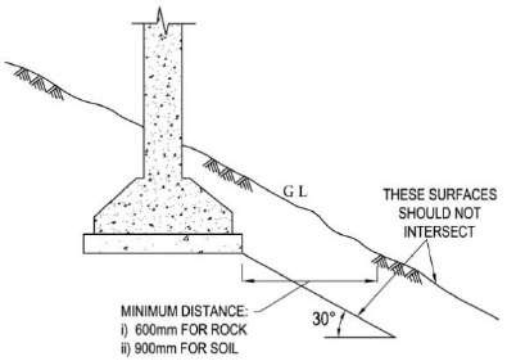
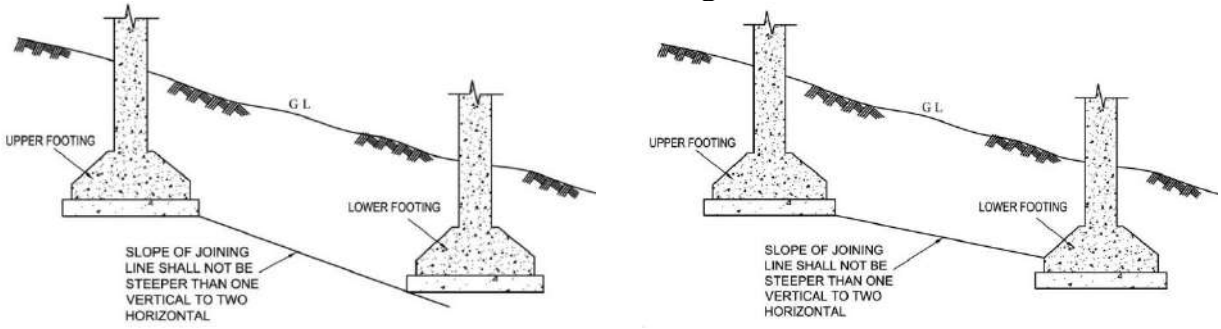


Fig. 300-1

ii) In the case of footings in granular soil, a line drawn between the lower adjacent edges of adjacent footings shall not have a steeper slope than one vertical to two horizontal as shown in figure 300-2.



a) In granular soil b) In clayey soil

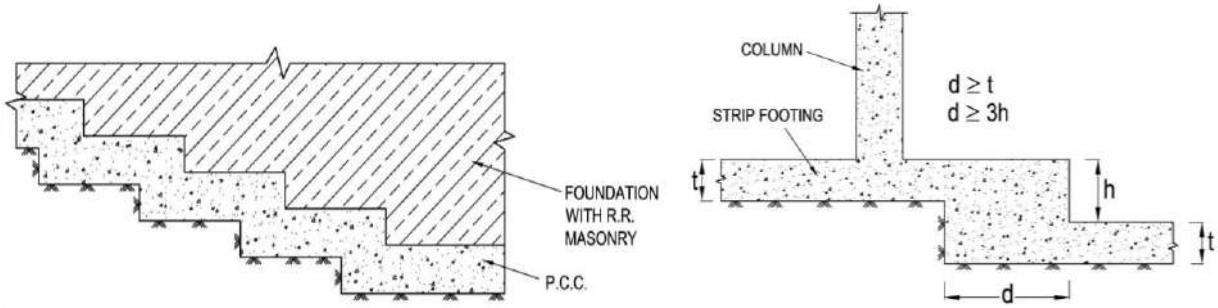
Fig. 300-2: Isolated footings in sloping ground.

iii) In case of footing of clayey soils a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of lower footing shall not have a steeper slope than one vertical to two horizontal as shown in figure 300-2.

g) The above requirement shall not apply under the following conditions:
   i) Where adequate provision is made for the lateral support (Such as with retaining walls) of the material supporting the higher footing.
   ii) When the factor of safety of the foundation soil against shearing is not less than four.

h) The construction of structures on slopes which are susceptible to landslip and sloping ground on clay soils shall be avoided.

i) On sloping sites, spread foundations shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or three times the height of the step, whichever is greater (Refer figure 300-3).



(a) Strip foundation for load bearing wall (b) Strip footing for column

Fig. 300-3: Foundation on sloping ground.

j) Cuttings, excavations or sloping ground near and below foundation level may increase the possibility of shear failure of the soil. The foundation shall be well beyond the zone of such shear failure.

k) If the probable failure surface intersects a retaining wall or other revetment, the latter shall be made strong enough to resist any unbalanced thrust. In case of doubt, as to the suitability of the natural slopes or cuttings, the structure shall be kept well away from the top of the slopes, or the slopes shall be stabilized.

l) On the uphill side of a building on a sloping site, land drainage requires special consideration for diverting the natural flow of water away from the foundations.

If excavation involves cutting through existing land drains, consideration shall be given for diverting into the ground-drainage system.

m) The minimum horizontal spacing between existing and new footings shall be equal to the width of the wider one.

n) If the required bearing capacity is available only at a greater depth, the foundation can be rested on a made up surface at a higher level, the making up being done in one of the following ways:

   i) Concrete of allowable compressive strength which is not less than the required bearing capacity. In soft/loose soils or where water table is high and interfering with foundation work, pre-cast cement concrete rings can be sunk to prevent collapse of the sides and filled with concrete.

   ii) Incompressible fill material like sand, gravel etc, duly compacted to the required density. The width of the fill should be more than the width of the foundation by an extent of dispersion of load from the base of the foundation on either side at the rate of 2 vertical to 1 horizontal or as suggested by the Engineer.

   iii) In both the above cases, the making up shall be done from the soil strata having the required bearing capacity to the level fixed for resting the foundation.

302.3 Workmanship

a) The excavation for foundation shall be carried out as per the Drawing and section 200 of this manual.

b) After excavation, the bottom of the trench shall be cleared of all loose soil and rubbish and shall be levelled, wherever necessary. The bed shall be wetted and compacted by heavy rammers to an even surface.

c) Excavation in clay or other soils that are liable to be affected by exposure to atmosphere shall be concreted as soon as they are dug.

d) Alternatively the bottom of the excavation shall be protected immediately by 8 cm thick layer of cement concrete not leaner than mix 1:4:8 over which shall come the foundation concrete.

e) The backfilling of the trench shall be done with care so as not to disturb the constructed foundation, and shall be compacted in layers not exceeding 15 cm thick with minimum quantity of water sprinkled for ensuring proper compaction.

f) Masonry shall be constructed over the base concrete after curing the base of concrete at least for 3 days. Before laying concrete, the bed of the foundation pit/trench should be thoroughly compacted by manual ramming.

303 DEEP FOUNDATIONS

Where the bearing soil is either loose or soft, the load from the structure has to be transferred to deeper firm strata. These foundations are classified as deep foundations. Pile foundation is the most commonly used deep foundation for buildings.

303.1 Pile foundation

a) Setting out of the main grid lines shall be done by the Contractor. The installation of marker pins at pile positions shall be located by the Contractor from the main grid lines of the proposed structure. Before installation of the

pile, the pile position relative to the main grid lines shall be got verified by the Engineer.

b) The Contractor shall submit to the Engineer, his proposed sequence and timing for boring piles, for avoiding damage to adjacent piles.

c) The Contractor shall carry out the work in such a manner and at such times as to minimise noise, vibration and other disturbance in order to comply with current environmental legislation.

d) If in the opinion of the Contractor, damage will be, or is likely to be, caused to services or adjacent structures, he shall submit to the Engineer his proposals for making preconstruction surveys, monitoring movements or vibrations, and minimising or avoiding such damage.

e) The Contractor shall ensure that during the course of the work, displacement or damage, which would impair either performance or durability, does not occur to completed piles.

303.1.1 Bored cast-in-situ piles

For construction of piles, guidance shall be taken from relevant Part/Section of IS: 2911. The following points shall be kept in mind while bored cast-in-situ piles are installed.

a) Piles shall not be bored so close to other recently completed piles as to damage them.

b) Where bored cast in-situ piles are used in soils liable to flow, the bottom of the casing shall be kept sufficiently in advance of the boring tool to prevent the entry of soil into the casing leading to formation of cavities and settlements in the adjoining ground.

c) The water level in the casing should generally be maintained at the natural ground water level for the same reasons.

d) A sample of the bentonite suspension shall be taken from the base of the boring using an approved sampling device. If the specific gravity of the suspension exceeds the value specified in IS: 2911, the placing of concrete shall not proceed. In this event the Contractor shall modify or replace the bentonite as approved to meet the specification.

e) Where the use of drilling fluid is specified for maintaining the stability of a bore, an adequate temporary casing shall be used in conjunction with the method so as to ensure stability of the strata near ground level until concrete has been placed.

f) Temporary casing of approved quality or an approved alternative method shall be used to maintain the stability of a pile bore which might otherwise collapse.

g) Where boring takes place through unstable water-bearing strata, the process of excavation and the depth of temporary casing employed shall be such that soil from outside the area of the pile is not drawn into the pile section and cavities are not created outside the temporary casing as it is advanced.

h) In the event of a rapid loss of drilling fluid from a pile excavation, the bore shall be backfilled without delay and the instructions of the Engineer shall be obtained before boring at that location is resumed.

i) All reasonable steps shall be taken to prevent the spillage of bentonite suspension on the site in areas outside the immediate vicinity of boring. Discarded bentonite shall be removed from the site without undue delay.

j) Pumping from pile bores shall not be permitted unless the bore has been sealed against further water entry by casing or unless the soil is stable and will allow pumping to take place without ground disturbance below or around the pile.

k) Before placing concrete, suitable measures shall be taken to ensure that there is no accumulation of silt or other material at the base of the boring, and the Contractor shall ensure that heavily contaminated bentonite suspension, which could impair the free flow of concrete from the tremie pipe, has not accumulated in the bottom of the hole.

l) For a pile constructed in a stable cohesive soil without the use of temporary casing or other form of support, the pile shall be bored and the concrete shall be placed without such delay as would lead to significant impairment of the soil strength.

m) Reinforcement for the pile as shown on the Drawing shall be tied in place to form a cage which is lowered into the pile shaft. Reinforcements at the bottom should not be provided with L-bends as these may interfere with cleaning of the pile base.

n) The grade of concrete, minimum cement content, water cement ratio and slump at the time of placement shall be as per the Drawings or as directed by the Engineer.

o) The concrete should invariably be poured through a tremie with a funnel, so that the concrete can be properly deposited in the hole without segregation.

p) The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the bore and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie and the water or drilling fluid. The pipe shall at all times penetrate the concrete which has previously been placed and shall be withdrawn at a rate such that there shall be a minimum concrete cover of 2 m over the end of the tremie pipe, until completion of concreting.

q) A sufficient quantity of concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water or drilling fluid.

r) The internal diameter of the tremie pipe shall be not less than 150 mm, and the maximum sized aggregate shall be 20 mm. It shall be so designed that external projections are minimised, allowing the tremie to pass within reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections.

s) Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted. During extraction the motion of the casing shall be maintained in an axial direction relative to the pile.

t) The concrete level within a temporary casing shall be topped up where necessary during the course of casing extraction in such a way that the base of the casing is always below the concrete surface until the casting of the pile has been completed.

u) Adequate precautions shall be taken in all cases where excess heads of water or drilling fluid could occur as the casing is withdrawn because of the displacement of water or fluid by the concrete as it flows into its final position against the walls of the pile bore.

v) It is desirable that the concrete above cut-off level is removed before the concrete is set. This may be done manually or by specially made bailer or other device. Such removal of concrete helps in preventing the damage of the good concrete below the cut-off level, which results from chipping by percussion method. The removal of concrete shall be within ±25 mm from the specified cut off level, preferably on the minus side.

303.1.2 Under-reamed piles

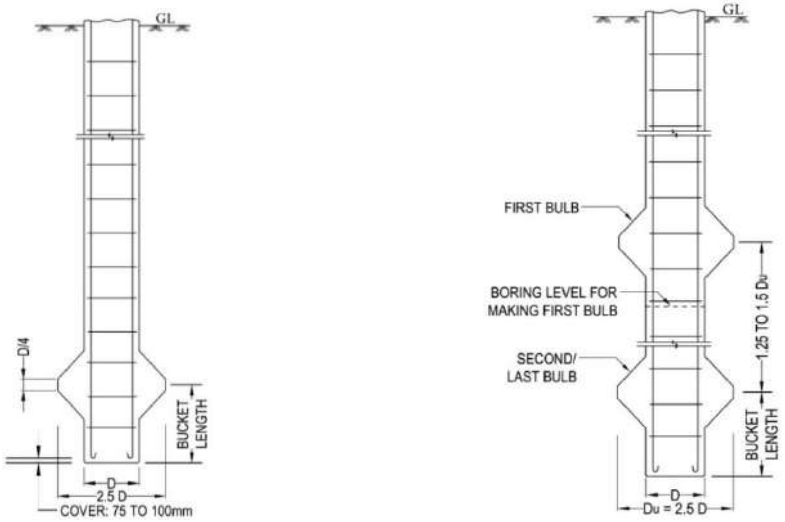
The following points shall be kept in mind while under-reamed piles are constructed.

a) The construction of under-reamed piles shall be as per the specifications in the Drawings or as per the stipulations given in IS: 2911(Part 3).
b) The selection of equipment and accessories shall depend upon the type of under-reamed piles, site conditions and nature of strata.
c) A typical list of equipment for manual construction is given in IS: 2911 (Part 3).
d) Bore holes may be made by earth augers. In case of manual boring, an auger boring guide shall be used to keep the bores vertical or to the desired inclination and in position.
e) After the bore is made to the required depth, enlarging of the base shall be carried out by means of an under-reaming tool.
f) In ground with high water table having unstable pile bores, boring and under-reaming may be carried out using a suitable drilling mud.
g) General guidelines for bentonite drilling mud are given in IS: 2911 (Part 3).
h) In normally met soil strata, drilling mud shall be poured from top while boring and under reaming can be done by normal spiral earth auger and under-reamer. The level of drilling mud should always be about one metre above water table or the level at which caving in occurs.
i) In case of very unstable strata with excessive caving in, continuous circulation of drilling mud using suitable pumping equipment and tripod, etc, along with modified auger and under reamer may be used.
j) Sometimes permeable strata overlying a rim clayey stratum may be cased and normal boring and under-reaming operation may be carried out in clayey stratum.
k) To avoid irregular shape and widening of bore hole in very loose strata at top, a casing pipe of suitable length may be used temporarily during boring and concreting.
l) For placing the concrete in bore holes full of drilling mud or subsoil water, tremie pipe of not less than 150 mm diameter with flap valve at the bottom should be used.
m) For batter under-reamed piles, the reinforcement cage should be placed guiding it by a chute or any other suitable method.
n) If concreting is not done by tremie, it should be done by chute.
o) In under-reamed compaction piles, suitable devices should be used for guiding the movement of drop weight and specified core assembly for its vertical driving. For operating the drop weights of adequate capacity, suitable winch with hoisting attachment should be used.
p) Under-reamed piles may be constructed by selecting suitable installation techniques at a given site depending on subsoil strata conditions and type of under-reamed pile and number of bulbs (Fig. 300-4).

q) In order to achieve proper under-reamed bulb, the depth of bore hole should be checked before starting under-reaming. It should also be checked during under-reaming and any extra soil at the bottom of bore hole removed by auger before reinserting the under-reaming tool.

r) The completion of desired under-reamed bulb is ascertained by i) the vertical movement of the handle, and ii) when no further soil is cut.

s) In double or multi-under-reamed piles, boring is first completed to the depth required for the first (top) under-ream only and after completing the under-reaming, boring is extended further for the second under-ream and the process is repeated.



a) Single under reamed pile b) Multi under reamed pile

Fig. 300-4: Types of under reamed piles.

304 TOLERANCES

a) Greater care shall be exercised in respect of installation of single pile or piles in two pile groups. Unless otherwise specified in the Drawing:
   i) For vertical piles a deviation of 1.5 percent should not normally be exceeded although in special cases a closer tolerance may be necessary.
   ii) Piles shall not deviate more than 75 mm or one-tenth of the diameter whichever is more in case of piles having diameter more than 600 mm from their designed positions at the working level of the piling rig.
   iii) In the case of a single pile in a column positional tolerance shall not be more than 50 mm (100 mm in case of piles having diameter more than 600 mm).

b) In case of piles deviating beyond these limits and to such an extent that the resulting eccentricity cannot be taken care of by a redesign of the pile cap of pile ties, the piles should be replaced or supplemented by one or more additional piles.

c) For piles cast in dry bores using temporary casing and without the use of a permanent lining, pile heads shall be cast to a level above the specified cut-off so that, after trimming, a sound concrete connection with the pile can be made.

d) The casting level shall be within the tolerance above the cut-off level shown in table 300-1, but shall not be above the original ground level.

e) No pile shall be cast with its head below standing water level unless approved measures are taken to prevent inflow of water causing segregation of the concrete as temporary casing is extracted, and, where approved by the

Engineer, the groundwater level for each pile shall be treated as the cut-off level for the purpose of calculating tolerance.

f) For piles cast in dry bores within permanent lining tubes or permanent casings, or where their cut-off levels are in stable ground below the base of any casing used, pile heads shall be cast to a level above the specified cut-off so that, after trimming, a sound concrete connection with the pile can be made. The casting level shall be within the tolerance above the cut-off level shown in table 300-1, but shall not be above the original ground level.

Table 300-1: *Casting tolerance above cut-off level for piles*

Cut-off distance below commencing surface (H)	*Casting tolerance above cut-off level in metres*
0.15 m to 10 m	$0.3 + H/12 + C/8$

NOTE: *C is the length of temporary casing below the commencing surface.*

g) For piles cast under water or drilling fluid, the pile heads shall be cast to a level above the specified cut-off so that, after trimming to remove all debris and contaminated concrete, a sound concrete connection with the pile can be made. The casting level shall be within the tolerance above the cut-off level shown in table 300-1, but shall not be above the commencing surface level. Cut-off levels may be specified below the standing groundwater level, and where this condition applies, the bore hole fluid level shall not be reduced below the standing groundwater level until the concrete has set.

305 TESTING OF PILES

a) Test piles which are used to arrive at the load carrying capacity shall not be incorporated in the structure.

b) All test piles shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.

c) Test piles which are not to be incorporated in the completed structure shall be removed to at least 600 mm below the proposed soffit level of pile cap and the remaining hole so formed shall be backfilled with earth or other suitable material.

305.1 Initial load test

a) The number of initial tests shall be determined by the Engineer taking into consideration the bore log and soil profile, design length, pile diameter and design pile capacity. However, it shall not be less than two for each category.

b) Initial load test for axial load capacity, including uplift capacity, if required on trial piles of the same diameter as of the design pile, shall be carried out after 28 days design strength is achieved.

c) The testing shall be done as per the procedure laid down in IS: 2911- Part4.

d) The load test shall be conducted for not less than 2 times the design load. The maintained load test can be performed for end bearing piles which do not rely on friction and for piles socketed in rock.

e) If the initial load test gives a capacity greater than 25 percent of the capacity calculated by static formula and if it is desired to take benefit of the higher capacity, another two load tests shall be carried out to confirm the earlier value and minimum of the three shall be considered as initial load test value.

f) Lateral load tests shall be carried out for estimating the lateral load capacity of the piles if required. The test procedure shall be carried out as per IS: 2911 - Part 4.

g) In particular cases where upper part of pile is likely to be exposed later due to scour, then the capacity contributed by that portion of the pile during load test, shall be accounted for.

305.2 Routine load test

a) The number of tests may generally be 0.5% of the total number of piles required. The number of the test may be increased up to 2% in a particular case depending upon nature, type of structure and strata condition. However in the case of sandy or clayey strata at least one pile shall be tested.
b) The testing shall be done as per the procedure laid down in IS: 2911 Part 4.
c) Pile test may be carried out on a single pile or a group of piles as required.
d) The load application and deflection observation shall be made at the pile top.
e) The test should be carried out at cut-off level wherever practicable, otherwise suitable allowance shall be made in the interpretation of the test results/test load if the test is not carried out at cut-off level.
f) Results of routine load tests done to reconfirm the allowable loads shall not be used for upward revision of design capacity of piles.

306 QUALITY CONTROL TESTS

Quality control tests relevant to the materials used for foundation viz masonry, concrete and reinforcement shall be done as stipulated in the respective sections of this Manual.

307 REFERENCES

1. IS: 1080 Design and construction of shallow foundations in soils. (Other than raft, ring and shell)
2. IS: 1888 Method of load test on soils.
3. IS: 1904 Design and construction of foundations in soils: General requirements.
4. IS: 2911 Design and construction of pile foundation.
   (Part 1/Sec.1) *Driven cast-in-situ concrete piles.*
   (Part 1/Sec.2 *Bored cast-in-situ concrete piles.*
   (Part 1/Sec.3) *Driven cast-in-situ concrete piles.*
   (Part 1/Sec.4) *Bored precast concrete piles.*
   (Part 4) *Load test on piles.*
5. IS: 2950 Design and construction of raft foundation.
6. IS: 6403 Determination of bearing capacity of shallow foundations.
7. IS: 8009 Calculation of settlement of foundations.
   (Part 1) *Shallow foundations subjected to static symmetrical vertical loads.*
   (Part 2) *Deep foundation subjected to static symmetrical vertical loads.*
8. IS: 9456 Design and construction of conical and hyperbolic. *Paraboloidal types of Shell foundations.*
9. IS: 9527 Design and construction of caissons.
10. IS: 9556 Design and construction of diaphragm wall.
11. IS: 11089 Design and construction of ring foundation.
12. IS: 13094 Selection of ground improvement techniques for foundation in weak soils - guidelines.
13. IS: 14893 Non-destructive integrity testing of piles (NDT) - Guidelines.
14. IS: 15284 Design and construction for ground improvement- guidelines.
    (Part 1) *Stone columns.*
    (Part 2) *Vertical drains.*

SECTION 400 MASONRY

401 GENERAL

a) Masonry is one of the main items of construction in a building, retaining walls, drains, abutments etc and needs special care for ensuring quality control.
b) It comprises masonry units such as brick, stone or concrete block laid in mortar. There are many varieties of masonry, but the ones which are predominantly used in the department are discussed here.
c) Some of the different types and grades of mortars used in masonry works are also included.

402 MASONRY MORTARS

402.1 Materials

a) Materials used for making mortars for masonry viz., cement mortars, lime mortars and cement-lime mortars are
   i) Inert materials such as sand and crushed stone.
   ii) Binder such as clay, lime and cement.
   iii) Pozzolana such as fly ash, burnt clay/surkhi.
   iv) Lime-pozzolana mixture.
   v) Plasticizers.
b) Most of these materials are covered by Indian Standards. Cement-sand mortar shall in general conform to IS: 2250.

402.1.1 Cement

Cement of any of the following types shall be used meeting the physical requirements given in table 400-1.

Table 400-1: *Physical requirements of cement for masonry works*

Type	*Grade*	*Code*
Ordinary Portland cement	33	IS: 269
Ordinary Portland cement	43	IS: 8112
Ordinary Portland cement	53	IS: 12269
Blast furnace slag cement	-	IS: 455
Portland pozzolana cement	Fly-ash based	IS:1489-Part I
Portland pozzolana cement	Calcined clay based	IS:1489-Part II
Sulphate resistant Portland cement*	-	IS:12330

**Use in masonry structures which are likely to be affected by the presence of sulphates in surrounding soil or in ground water in concentration of 0.2% and 0.03% respectively.*

402.1.2 Sand

Sand or manufactured sand produced by crushing rock/gravel or a combination of the above shall consist of hard, durable and clean particles of natural sand, crushed gravel, or suitable combinations thereof and shall conform to the requirements given in IS: 2116 and IS: 383 for sand and stone dust respectively.

402.2 Requirements

402.2.1 Workability

a) The mix shall be workable. Workability shall be measured by recording depth of penetration of a standard cone as detailed in IS: 2250.

b) Bureau of Indian Standards recommend the following values of penetration for different purposes:

For laying walls with solid bricks	: 90-130 mm.
For laying with perforated bricks	: 70-80 mm.
For filling cavities	: 130-150 mm.

402.2.2 Consistency and water retentivity

a) Cement-sand mortar shall in general conform to IS: 2250 and its consistency and water retentivity shall be determined as per BIS code. The recommended values of consistency and water retentivity are given in table 400-2.

b) A standard test for determination of water retentivity in masonry mortars is given in IS: 2250. In accordance with that standard, water retentivity of masonry mortar should not be less than 70%.

Table 400-2: *Consistency and water retentivity of mortars for masonry works.*

Property	*Work*	*Recommended values*
Consistency	Laying of solid brick walls	90-130 mm
	Filling cavities	130-150 mm
Water retentivity (Flow of suction)	Masonry work with high suction characteristics	More than 70% of flow before suction.

402.2.3 Rate of stiffening

a) Stiffening of mortar in masonry is caused either by loss of moisture or by the setting action of binder used in the mortar or by both.

b) Cement mortar stiffens mainly through setting action of cement. In cold regions, when nights are frosty, it is important that mortar should stiffen rapidly enough so that it is not damaged by frost by formation of ice crystals within the body of mortar.

c) For this reason, as a general rule, cement mortar shall not be leaner than 1:6 and cement- lime mortar leaner than1:½:4½.

d) In addition, some further precautions like preventing masonry units, sand and water from getting too cold, use of warm water for mixing of mortar, use of calcium chloride as an accelerator in cement mortar, covering the freshly laid masonry with tarpaulins at the close of the day's work etc, should be taken.

402.2.4 Strength

a) It is necessary that masonry shall attain the requisite strength by the time loads are imposed on it. With that in view, 28-day strength of a mortar is taken into consideration.

b) The compressive strength shall be determined in accordance with the procedure given in IS: 2250.

c) When mud mortar is used in brick or stone masonry, basic stress in masonry should be limited to 0.2 N/mm^2

d) Mud mortar should not be used in moist or wet situations like foundations of a wall. This mortar is also not suitable for use in areas infected with white ants.

402.2.5 Resistance to rain penetration

a) Rain water penetrates a masonry wall by three different modes:

i) Through pores of masonry units.
ii) Through pores of mortar.
iii) Through cracks between units and mortar.

b) From the view-point of rain penetration, bonding property of mortar is of great importance.

c) Mixes of composite mortars in common use are 1:½:1½, 1:1:6, 1:2:9 and 1: 3:12. Of these 4 mixes, 1:1:6 mix is in more common use since it has reasonably good strength and also, imparts to masonry, adequate resistance to rain penetration.

402.2.6 Durability requirements

a) For attaining durability, frost action before the mortar has gained sufficient strength shall be prevented.

b) Mortar shall not be exposed to repeated cycles of freezing and thawing.

c) The presence of soluble sulphates either in burnt clay bricks or in soil in contact with masonry in foundation adds to the process of deterioration.

d) Ingress of moisture through cracks of masonry shall be avoided.

e) The grades of masonry mortar shall be selected as specified in table 400-3 (Ref: IS: 2250). The grade of masonry mortar will be defined by its compressive strength in MPa at the age of 28 days as determined by the standard procedure detailed in IS: 2250.

Table 400-3: *Grade of masonry mortar*

Sl. No.	*Grade*	*Compressive strength at 28 days in MPa*	*Cement*	*Pozzolana (Fly Ash)*	*Sand*
1	MM 0.7	0.7 to 1.5	1	-	8.0
2			1	0.4*	10.0
3	MM 1.5	1.5 to 2.0	1	-	7.0
4			1	0.4*	8.75
5	MM 3	3.0 to 5.0	1	-	6.0
6			1**	0.21	4.2
7			1	0.4*	7.5
8	MM 5	5.0 to 7.5	1	-	5.0
9			1	0.4	6.25
10			1	0.4	5.0
11	MM 7.5	7.5 & above	1	-	4.0
12			1**	0.2*	2.1
13			1	-	3.0
14			1	0.4	3.75

**Pozzolana with minimum lime reactivity of 4 MPa.*

***This ratio by volume corresponds approximately to cement pozzolana ratio of 0.8:0.2 by weight. In this case, only ordinary Portland cement is to be used (IS: 269).*

f) In case of masonry exposed frequent to rain and where there is further protection by way of plastering or rendering or other finishes, the grade of mortar shall not be less than MM 0.7, but shall preferably be of grade MM 2.0.

g) Where no protection is provided, the grade of mortar for external wall shall not be less than MM 2.0.

h) In case of load bearing internal walls, the grade of mortar shall preferably be MM 0.70 or more for high durability, but in no case less than MM 0.5.
i) In the case of masonry work in foundations laid below damp proof course, when soil has little moisture, masonry mortar of grade not less than MM 0.7 shall be used.
j) Where soil is very damp, masonry mortar of grade preferably MM 2.0 or more shall be used. But in no case shall the grade of mortar be less than MM 2.0.
k) For masonry in building subject to vibration of machinery, the grade of mortar shall not be less than MM 3.0.
l) For parapets, where the height is greater than thrice the thickness, the grade of masonry mortar shall not be less than MM 3.0.
m) In case of low parapets, the grade of mortar shall be the same as used in the wall masonry.
n) The grade of mortar for bedding joints in masonry with large concrete blocks shall not be less than MM 3.0.

402.3 Stacking and storage

a) It is necessary that materials for construction are stacked and stored at site in a planned manner so as to minimize chances of deterioration and to facilitate subsequent handling for construction.
b) The recommendations in IS: 4082 shall be followed in this matter.

402.4 Curing

a) Curing of masonry shall begin as soon as partial set of mortar has taken place.
b) Curing shall be continued up to a minimum period of 7 days from date of laying of masonry, if Ordinary Portland Cement is used. In dry weather it shall be extended up to 10 days.
c) For Portland Pozzolana/slag cement, minimum curing period shall be 10 days.
d) No curing is required in case of mud masonry, since there is no setting action requiring the presence of moisture.

402.5 Quality control tests for masonry mortar

a) The cement mortar if unused for more than 30 minutes after addition of water shall be rejected and removed from site.
b) The mix proportion of cement : sand can be checked as follows:
    i) Take about 200 gm of green cement mortar and add 100 ml of water in a measuring jar and shake the contents well.
    ii) Allow the contents to settle. While the sand gets deposited at the bottom, cement shall settle above.
    iii) From the volumes of each, the approximate proportion of cement and sand can be determined.
c) Mortar consistency can be checked by the following:
    i) If a small quantity of mortar is dropped from a trowel, the trowel ought to be left perfectly clean.
    ii) A little mortar worked gently in the hands should be easily moulded into a ball; on the surface of which water would appear.
    iii) When the ball is dropped from a height of half a meter (500 mm) on a hard surface, it must retain its rounded shape.
d) The control tests for materials shall be as given in table 400-4.

Table 400-4: *List of tests for mortar ingredients*

Material	*Test*	*Code*	*Min. quantity of material for carrying out the test*	*Frequency of testing*
Water	i) pH Value ii) Limits of Acidity iii) Limits of Alkalinity iv) Percentage of solids: a) Chlorides b) Suspended matter c) Sulphates d) Inorganic solids e) Organic solids	IS: 3025	-	Water from each source shall be got tested before the commencement of work and thereafter once in every three months till the completion of the work. Water from municipal source need to be tested only once in six months. Number of tests for each source shall be 3.
Cement	Physical requirements: i) Fineness ii) Soundness iii) Setting time (Initial & Final) iv) Compressive strength v) Consistency of standard cement	IS:4031 (Part 2) IS: 4031 (Part 3) IS: 4031 (Part 5) IS: 4031 (Part 6) IS: 4031 (Part 6)	Each lot	Every 50 tonnes or part thereof. Each brand of cement brought to site shall be tested as per this frequency. For sample lot less than 50 bags these tests need not be insisted.
Sand	Deleterious constituents	IS: 2386 (Part 2)	20 m^3	Every 20 m^3 or part thereof or more frequently as decided by the Engineer.
	Silt Content	IS: 2386 (Part 1)	20 m^3	-do-
	Gradation	IS: 2386 (Part 1)	40 m^3	40 m^3 or part thereof.
	Bulking	IS: 2386 (Part 3)	20 m^3	Every 20 m^3 or part thereof or more frequently as decided by the Engineer.

403 BRICK MASONRY

403.1 General

a) For brick masonry to serve its purpose effectively, it is necessary that quality of materials used (brick and mortar), construction technique and workmanship shall be sound.

b) The bricks shall be sound, of compact structure (as seen when broken), free from cracks and flaws.
c) They should be regular in shape and of uniform size (dimensional accuracy) with plane faces and sharp edges.
d) The colour should be uniform and of deep red or copper colour.
e) The quality of bricks is generally assessed by compressive strength, efflorescence, dimensional accuracy, water absorption and evenness of baking.
f) First class bricks of any of the following two types shall be used in masonry works:
   i) Burnt clay bricks conforming to IS: 1077.
   ii) Clay fly-ash bricks conforming to IS: 13757.

403.2 Types of bricks

403.2.1 Burnt clay bricks

Compressive strength of brick depends on type of soil used for moulding brick, method of moulding, technique of burning, etc. Strength of common brick available generally varies from 2.5 to 25 MPa.

403.2.2 Burnt clay perforated building brick

It has the advantage over common brick of lightness in weight and better thermal insulation. Therefore it is used in load bearing walls as well as non-load bearing partitions and panels, where better thermal insulation and/or lightness in weight are required.

403.2.3 Burnt clay hollow block

It's properties and use are similar to perforated brick, except that percentage of voids is higher and thus masonry constructed with this unit is much lighter in weight. Its compressive strength is however low and thus this unit is mainly used for non-load bearing walls.

403.3 Classification

Bricks shall be classified on the basis of their minimum compressive strength as given in table in 400-5.

Table 400-5: *Classification of bricks*

Class designation	*Average compressive strength*	
	Not less than	*Less than*
	MPa (kgf/cm²)	*MPa (kgf/cm²)*
12.5 (125)	12.5 (125)	15 (150)
10 (100)	10 (100)	12.5 (125)
7.5 (75)	7.5 (75)	10 (100)
5 (50)	5 (50)	7.5 (75)
3.5 (35)	3.5 (35)	5 (50)

403.4 Physical requirements

The physical requirements of bricks for masonry works are given in table 400-6.

403.5 Construction

The following shall be ensured while carrying out brick masonry work.

a) Soak all bricks for a minimum period of one hour before use and remove from tank sufficiently in advance so that they are skin dry before actual laying.

b) Lay all brickwork in English bond, unless otherwise specified, even and true to line, plumb or specified batter and level. Break all joints in successive courses and lay joints accurately.

Table 400-6: Physical requirements of bricks for masonry works

Item	*Requirements*
Minimum compressive strength	Value specified in drawing or 7 MPa whichever is higher.
Water absorption	Up to 20% by weight (IS: 3495-Part 2).
Efflorescence	'Moderate' up to 50% of exposed area of brick covered with a thin deposit of salt but unaccompanied by powdering or flaking of surface (IS: 3495-Part 3).
Preferred nominal size	190 x 90 x 90 mm or 230 x 110 x 70 mm.

c) Lay all bricks with frogs up, if any, on a full bed of mortar. Slightly press the bricks so that the mortar gets into all hollow space of bricks to ensure proper adhesion. Flush all joints and pack with mortar, to fill all hollow spaces.

d) Build brickwork in uniform layers so that no part of brickwork shall rise more than one metre above the general construction level, to avoid unequal settlement and improper jointing.

e) Remove all loose bricks and mortar while joining partially set or entirely set brick masonry with new one. To achieve proper bond, roughen and wet with cement slurry. In case of vertical and inclined joints, achieve proper bond by inter-locking the bricks.

f) Tool all joints on exposed faces to give a concave finish, the thickness of joint not exceeding 10 mm.

g) Keep masonry work in cement mortar constantly moist on all faces for a minimum period of seven days. Leave the top of masonry work flooded with water at the close of the day. During hot weather, wet or cover all finished or partly completed work to prevent rapid drying of brickwork. Maintain watering and curing at the close of day's work or for other period of cessation of works.

h) Erect single scaffolding for plastering, pointing and any finishing in which one end of the put-logs/pole shall rest in the hole provided in the header course of brick masonry. Provide double scaffolding having two independent supports clear of the work when brick work is exposed and not to be finished.

403.6 Sampling and testing

Samples of bricks shall be subjected to the following tests:

i) Dimensional tolerance.
ii) Water absorption.
iii) Efflorescence.
iv) Compressive strength.

403.6.1 Sampling from a stack

The samples shall be taken as below:

a) The stack shall be divided into a number of real or imaginary sections and the required number of bricks drawn from each section.

b) For this purpose, bricks in the upper layers of the stack shall be removed to enable units to be sampled from places within the stack.

c) For other methods of sampling i.e. sampling in motion and sampling from lorries or trucks, IS: 5454 shall be referred.

d) Scale of sampling and criteria for conformity for visual and dimensional characteristics are given in table 400-7.

Table 400-7: *Scale of sampling and permissible number of defectives for visual and dimensional characteristics*

No. of bricks in the lot	*For visual characteristics specified for individual bricks*		*For dimensional characteristics for group of 20 bricks*	
	No. of bricks to be selected	*Permissible no of defective bricks in the sample*	*No. of bricks to be selected*	*Tolerance limit*
2001-10000	20	1	40	Refer table 400-9.
10001- 35000	32	2	60	
35001- 50000	50	3	80	

NOTE: In case the lot contains 2000 or less bricks, sampling shall be as per the direction of the Engineer.

e) Scale of sampling and criteria for conformity for physical characteristics are given in table 400-8.

Table 400-8: *Scale of sampling and permissible number of defectives for physical characteristics*

Lot size	*Sample size for compressive strength, water absorption and efflorescence*	*Permissible number of defectives for efflorescence*	*Warpage*	
			Sample size	*Permissible number of defects*
2001-10000	5	0	10	0
10001- 35000	10	0	20	1
35001- 50000	15	1	30	2

NOTE: In case the lot contains 2000 or less bricks, sampling shall be as per decision of the Engineer.

403.6.2 Criteria for visual characteristics

a) The bricks shall be selected and inspected for ascertaining their conformity to the requirements of the relevant specification.

b) The number of bricks to be selected from a lot shall depend on the size of lot and shall be in accordance with table 400-7 for visual characteristics, in all cases and dimensional characteristics, if specified for individual bricks.

c) If the number of defective bricks found in the sample is less than or equal to the corresponding number as specified in table 400-7, the lot shall be considered as satisfying the requirements of visual characteristics. Otherwise the lot shall be deemed as not having met the visual requirements.

403.6.3 Criteria for dimensional characteristics

a) The number of bricks to be selected for inspecting the dimensions and tolerance shall be in accordance with table 400-7.

b) The selected bricks will be divided into groups of 20 at random and each of the group of 20 bricks thus formed will be tested for all dimensions and tolerances.

c) A lot shall be considered having found meeting the requirements of dimensions and tolerance if none of the groups of bricks inspected fails to meet the specified requirements.

403.6.4 Criteria for physical characteristics

a) The lot which has been found satisfactory in respect of visual and dimensional requirements shall be next tested for physical characteristics like compressive strength, water absorption, efflorescence as specified in relevant material specification.

b) The bricks for this purpose shall be taken at random from those already selected above. The number of bricks to be selected for each of these characteristics shall be in accordance with relevant columns of table 400-8.

403.6.5 Tolerance limits

Permissible values of workmanship and tolerances for bricks and brick masonry are given in table 400-9.

Table 400-9: *Workmanship and tolerances for bricks and brick masonry.*

Item	*Permissible value*
Dimensions of bricks	±5% in size
Compressive strength of bricks	+2.5 MPa (No negative tolerance) on value specified or 7 MPa whichever is higher.
Thickness of joints for general brick work	Not more than 10 mm.
Thickness of joints for Arches	5 mm to 15 mm.
Plaster finish	Surface thickness, not less than specified thickness by more than 3 mm.

403.7 Quality control tests

a) The Quality Control checks on bricks shall be as given in table 400-10.

Table 400-10: *Quality control tests for brick masonry*

Test / Check	*Code*	*Frequency*
Colour and dimensional check	IS: 5454	As per table 400-7.
Water absorption	IS: 3495 (Part 2)	As per table 400-8.
Efflorescence	IS: 3495 (Part 3)	As per table 400-8.
Compressive strength	IS: 3495 (Part 1)	As per table 400-8.

b) Some of the simple tests to fairly assess the quality of bricks are given below:

i) In efflorescence test, a sample brick is soaked in water for 24 hours and its appearance after removal from water shall be free from white patches, the total area not exceeding 50%. In case the surface area exhibiting patches exceed 50% of total area, both the brick and water samples shall be subjected to further testing for ascertaining suitability.

ii) In water absorption test, a brick should not absorb more than one-fifth of its dry weight after immersion in water for 24 hours.

iii) Bricks are considered good when clear ringing sound is heard when two bricks are struck against each other. A sample brick should not break when dropped flat on hard ground from a height of about 1 m.

iv) Correct firing promotes toughness. The bricks should not be under-burnt. A well burnt brick when scratched with a finger nail should leave no impression.

c) The tests to be carried out during construction are indicated in table 400-11 below:

Table 400-11: *Quality control tests during construction*

Item of work	*Test / check*	*Frequency*
Bond and plumbness	English bond, verticality by plumb bob.	For each course.
Laying in mortar	Laying in full bed of mortar with proper lapping.	-do-
Individual course	Height of course and Joint thickness- (IS: 2212).	-do-
Top of coping (If provided)	Sloping to drain off water.	Daily.
Mortar for joints*	Mix proportions (Control on quantity of cement/lime by weight).	Each batch.
	Consistency and water retentivity (IS: 2250).	As required, at close intervals.
	Compressive strength (IS: 2250).	On a set of 3 cubes where specified.
Arches (Additional tests)	Dimensions of abutment-pier for multiple arches (IS: 2118).	Regularly.
	Centering for arch.	For each span.
	Compaction and thickness of filling material over crown and haunches.	Regularly.
	Thickness of joints.	Regularly.
Weep holes	Location, size and spacing.	For each work.
Structural components	Thickness, dimensions and laying.	For each work.

404 CONCRETE BLOCK MASONRY

404.1 General

a) Concrete blocks for use in masonry may be solid, hollow, lightweight or autoclaved cellular as per standard specifications

b) The concrete blocks shall confirm to IS: 2185 (Part 1, 2 and 3) and IS: 3115.

c) These are used for load bearing walls as well as non-load bearing panels and partitions.

d) Choice of blocks should be made carefully, taking into consideration type of structure, loads, climatic conditions, economy in cost, ready availability of blocks etc.

e) Concrete block masonry is very much prone to shrinkage cracks. Therefore, to avoid or minimise cracks, blocks must strictly conform to standard

specifications and suggestions for handling, storage, moistening before use, selection of mortar for laying masonry, curing and finishing.

f) Moreover, it should be ensured that concrete blocks are dried for a period of at least 28 days after curing so that the blocks undergo initial shrinkage before use in masonry work.

404.2 Dimensions and tolerances

a) Concrete blocks shall be made in sizes and shapes to fit different construction needs. They include stretcher, corner, double corner or pier, jamb, header, bull nose and partition block and concrete floor units.

b) Concrete block, hollow (Open or closed cavity) or solid shall be referred to by its nominal dimensions. The term nominal means that the dimension includes the thickness of the mortar joint. Actual dimensions (length and depth only) shall be 10 mm short of the nominal dimensions.

c) The nominal dimensions of concrete block shall be as follows:
   i) Length : 400, 500 or 600 mm
   ii) Height : 200 or 100 mm
   iii) Width : 50, 75, 100, 150, 200, 250 or 300 mm.

d) Blocks of half length viz., 200, 250 or 300 mm which correspond to the full length brick may also be used wherever required. Full length and half-length U-blocks may also be used for the purposes of band and lintels.

e) Blocks of sizes other than those specified above may also be used if they conform to the quality standards prescribed in the relevant codes.

404.3 Classification of concrete blocks

Concrete blocks are either hollow (Open and closed cavity) load bearing concrete blocks, hollow (Open and closed cavity) non-load bearing concrete blocks or solid load-bearing/non-load bearing concrete blocks.

a) *Hollow (Open or closed cavity) block*: A block having one or more large holes or cavities which either pass through the block (open cavity) or do not effectively pass through the block (closed cavity) and having the solid material between 50% and 75% of the total volume of the block calculated from the overall dimensions.

b) *Solid block*: A block which has solid material not less than 75% of the total volume of the block calculated from the overall dimensions.

c) The concrete blocks shall conform to the following three grades as per IS: 2185 (Part 1).
   i) *Grade A - Hollow concrete Blocks (Open and closed cavity)*: These are used as load bearing units and shall have a minimum block density of 15 kN/m^3. These shall be manufactured for minimum average compressive strength of 3.5, 4.5, 5.5,7,0, 8.5, 10.0, 12.5 and 15.0 MPa respectively at 28 days as given in table 400-12 (Ref: Table 2 of IS: 2185 Part 1).
   ii) *Grade B - Hollow concrete Blocks (Open and closed cavity*): These are also used as load bearing units and shall have a block density between 11 kN/m^3 and 15 kN/m^3. These shall be manufactured for minimum average compressive strength of 3.5 and 5.0 MPa respectively at 28 days as given in table 400-12 (Ref: Table 2 of IS: 2185 (Part 1)).
   iii) *Grade C - Solid concrete blocks*: These are used as load bearing units and shall have a block density not less than 18 kN/m^3. These shall be

manufactured for minimum average compressive strength of 4.0 and 5.0 MPa respectively as given in table 400-12 (Ref: Table 2 of IS: 2185 (Part 1)).

Table 400-12: *Physical requirements*

Type	*Grade*	*Density of block kN/m³*	*Minimum average compressive strength of units, MPa*	*Minimum compressive strength of individual units, MPa*
Hollow (Open and closed cavity) load bearing unit	A (3.5)	Not less than 15.0	3.5	2.8
	A (4.5)		4.5	3.6
	A (5.5)		5.5	4.4
	A (7.0)		7.0	5.6
	A (8.5)		8.5	7.0
	A (10.0)		10.0	8.0
	A (12.5)		12.5	10.0
	A (15.0)		15.0	12.0
	B (3.5)	Less than 15.0 but not less than 11.0	3.5	2.8
	B (5.0)		5.0	4.0
Solid load bearing unit	C (5.0)	Not less than 18.0	5.0	4.0
	C (4.0)		4.0	3.2

404.4 Physical requirements

a) All units shall be sound and free of cracks or other defects which interfere with the proper placing of the unit or impair the strength or performance of the construction. Minor chipping resulting from the customary methods of handling during delivery, shall not be deemed grounds for rejection.

b) Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks, or other imperfections, except that if not more than 5% of a consignment contains slight cracks or small chippings not larger than 25 mm, this shall not be deemed grounds for rejection.

404.5 Marking

Concrete masonry units used shall satisfy the specifications and standards prescribed and shall have the following information marked permanently on them.

i) Identification of the manufacturer.
ii) Grade of the unit.
iii) Year of manufacture.

404.6 Quality control tests for cement blocks

a) The Contractor shall furnish the manufacturer's test certificate for block density, compressive strength, water absorption and drying shrinkage of concrete blocks, which shall conform to IS: 2185 (Part 1).

b) The tests specified in clause (a) shall be carried out by the Contractor if manufacturer's certificate is not furnished or the Engineer is not satisfied with the manufacturer's test certificate.

c) The tests specified in clause (a) shall be carried out by the contractor, if the cement blocks are manufactured at Site.

405 STONE MASONRY

405.1 General

a) Types of stones commonly used in building construction are granite, trap, basalt, quartzite, limestone and sand stone. Another type of stone which is a semi weathered rock namely laterite, though not very durable and strong, is used for small and low cost structures.

b) There are three main varieties of stone masonry in common use namely random rubble, coursed rubble and ashlar, with some further sub varieties depending upon quality of stone, standard of dressing and laying of stones, standard of finish and workmanship and architectural style.

c) Stone for use in masonry should be hard, sound and free from weathering, decay, cavities, cracks, sand-holes, injurious veins, patches of loose or soft materials.

d) Stone should not contain cryptic crystalline silica or chert, mica, or other deleterious materials like iron oxide and organic impurities.

e) Selection of stone is usually based on past experience, and in order to ensure desired quality, it is customary to stipulate source of stone ie., particulars of quarries from which stone should be procured for use in a particular job.

405.2 Requirements

a) The principal requirements of a building stone are strength, density and durability. All stones other than those of sedimentary origin are suitable for stone masonry work.

b) Use stone which is hard, sound, free from cracks, decay, weathering, defects like cavities, flaws, sand holes and patches of loose or soft materials.

c) Do not use stones with round surface.

d) The Specifications and requirements of stones shall satisfy those given in table 400-13.

Table 400-13: *Physical requirements*

Item	*Code*	*Requirements*
Least dimension	IS: 1597 (Part I)	150 mm
Water absorption in stone	IS: 1124	5% of its weight.
Dressing of stone	IS: 1129 and IS: 1597	-
Minimum height of individual course		160 mm
Consumption of mortar in stone masonry		0.25 to 0.30 m^3 for each m^3 of stone masonry.

e) Normally use Coursed Rubble (CR) Masonry (First sort) for load bearing structures, CR masonry (Second sort) for culverts, wing/return walls of small bridges and Random Rubble (RR) Masonry for wing/return/toe walls of height less than 3 m.

f) The compressive strength of common types of stones shall be as per table 400-14 and the percentage of water absorption shall generally not exceed 5% for stones other than specified in table 400-14.
g) Test for compressive strength shall be carried out as per IS: 1121 (Part 1).
h) Test for water absorption shall be carried out as laid down in IS: 1124.

Table 400-14: *Physical requirements of various types of stones*

Type of stone	*Maximum water absorption % by weight*	*Minimum compressive strength (MPa)*
Granite	0.5	10.0
Basalt	0.5	40.0
Lime stone (Slab & tiles)	0.1	20.0
Sand stone (Slab & tiles)	2.5	30.0
Marble	0.4	50.0
Quartzite	0.4	80.0
Laterite (Block)	12	3.5

405.3 Workmanship

The following shall be ensured while carrying out stone masonry work:

a) The least dimension of the dressed stone shall not be less than 150 mm. The stones shall be immersed in water for 24 hours before use. Only rectangular shaped bond stones or headers shall be used.
b) The stones shall be laid on their natural beds in horizontal courses, height of each course shall be same.
c) Height of construction in a day should not exceed 1.0 m so as to avoid excessive load on fresh mortar. Connected masonry should be raised uniformly all over. However, if one part of masonry is to be left behind, the wall should be racked at an angle not steeper than 45°. Toothing in stone masonry should not be allowed.
d) Lay outer layers of masonry first, then fix the location of headers and bond stones and lay them. Lay the stones in the hearting, on their broadest face, to ensure that spaces between stones are filled.
e) Where there is variation in the height of the courses, place the larger courses at lower levels with the heights of courses decreasing gradually towards the top of the wall.
f) In tapered walls, the beds of the stones and planes of courses shall be kept right angle to the batter. In case of piers with batter on both sides, keep the course horizontal.
g) Lay all stones, fill mortar both in bed and vertical joints and settle carefully in place with a wooden mallet immediately on placement before the mortar has set.

h) Before laying first course of stone masonry on rock, place concrete levelling course of M10 grade, average thickness 150 mm.
i) In case any stone already set in mortar, is disturbed or the joint broken, take it out without disturbing the adjacent stones and joint. Reset the stone in fresh mortar after removing dry mortar and thoroughly cleaning the stones and joints.
j) Use selected quoin stones and arrange to bond alternately long and short in both directions.
k) Provide sufficient transverse bonds by the use of bond stones or set of bond stones extending from the front to the back of the wall from outside to the interior and vice versa, overlapping each other by 150 mm (Minimum).
l) Make vertical joints truly vertical and staggered as far as possible. Keep the distance between vertical joints of upper and lower layer, more than half the height of the course.
m) Masonry work over a concrete foundation block shall be done only after 48 hours of casting.

405.4 Simple field tests

Some of the requirements and simple tests are indicated below:

a) The stones should be hard, tough, compact grained and of uniform texture and colour.
b) They should be free from cracks, decay, weathering defects like cavities, flaws, veins, sand holes and patches of loose/soft material.
c) Break a stone with a hammer. The surface of a freshly broken stone should be bright, clean and sharp and should show uniformity of texture without loose grains and be free from any dull chalky or earthy appearance.
d) If a drop of dilute hydrochloric acid or sulphuric acid on a piece of stone causes effervescence, the stone contains weathering materials.
e) A sample of stone when struck with a 1 kg hammer should emit a ringing sound and should not break with one blow.
f) A pen-knife when scratched on surface should not make an impression on hard stone.

405.5 Quality control tests

a) The Quality control tests on stones for masonry are given in table 400-15.

Table 400-15: *Quality control tests prior to construction*

Sl. No.	*Test / check*	*Code*	*Frequency*
1	Shape and dimension	IS: 1597 (Part 1)	3 samples on receipt at site.
2	Water absorption	IS: 1124	3 samples on receipt at site.
3	Dressing of stones via hearting, bond, quoin, face stones, headers etc.	IS: 1129	One for each stock after selection for individual work.

b) The Quality control tests during construction are given in table 400-16.

Table 400-16: *Quality control tests during construction*

Materials/ Work	*Test/ Check*	*Frequency/ Stage*
Bond and plumbness	For stability and appearance with plumb bob	While laying each course.
Laying in mortar	Horizontality of courses verticality and staggering of joints.	-do-
Mortar for joints	i) Consistency and water retentivity (IS: 2250)	As required.
	ii) Mix proportions for different works.	Daily.
	iii) Compressive strength (IS: 2250).	On a set of 3 cubes where specified.
Individual course	Height joint thickness and laying (IS:1597 (Part I & 2) and IS: 2212)	-do-
Arches (Additional checks)	Centering and simultaneous commencement of work from both ends.	Check during erection.
	Compaction and thickness of filling material over crown and haunches.	As and when work is on hand.
	Erection of abutment pier for multiple arches.	As and when such work is on hand.
	Thickness of joints.	Check during construction
Top of coping (If provided)	Sloping to drain off water.	Once on either side of parapet.
Mortar	Quality of mortar.	For each component of work.
	Consumption per m3 of stone masonry work.	-do-
Weep holes	Location, size and spacing	For each work.
Structural components	Thickness, dimensions and laying.	For each work.
General workmanship	Colour, aesthetics, elegance, pin headers, corner stones and plumbness etc.	For each work.

406 LATERITE MASONRY

406.1 General

a) The term laterite stone has been applied generally to a group of rocks, which occur as surficial blankets. It is the residual weathering products of certain rocks, containing silicates, such as basalt, granite and slate.

b) The physical properties of this stone vary considerably from place to place. Freshly quarried laterite is soft and porous but when exposed to atmospheric conditions it hardens and makes a very tough material. Therefore, it is always desirable that these stones should be quarried sufficiently ahead of use. But only laterite stones of certain minimum physical properties are suitable for

masonry construction and therefore, a careful selection in the procurement of this stone is necessary before use.

406.2 Requirements

a) The stone blocks shall be without any soft veins, cracks, cavities, flaws and similar imperfections.

b) The block shall be exposed preferably for a period of three months before being used in the construction of masonry to ensure adequate stabilisation. However, exposure to rains should be avoided.

c) The standard size of laterite stone blocks shall be as specified in table 400-17.

Table 400-17: *Size of laterite stone blocks*

Length (mm)	*Breadth (mm)*	*Thickness (mm)*
390	190	190
490	190	190
590	290	290

d) Sizes other than those mentioned in table 400-17, may be supplied if approved by the Engineer.

e) Tolerance of ±5 mm shall be allowed on dimensions specified in table 400-17.

f) The physical properties of the laterite stone blocks shall conform to the requirements given in table 400-18.

Table 400-18: *Physical properties of laterite stone blocks*

Properties	*Code*	*Requirement*
Water absorption	IS: 1124	Not more than 12% by mass.
Specific gravity	IS: 1124	Not less than 2.5.
Compressive strength	IS: 1121 (Part 1)	Not less than 3.5 MPa.

406.3 Workmanship

a) The blocks shall be of uniform shape with straight edges at right angle.

b) The edges of the block shall be rough and chisel dressed as prescribed in IS: 1129.

406.4 Sampling and testing

a) In any consignment all the blocks from the same quarry shall be grouped together to constitute a lot.

b) Samples shall be selected and tested separately for each lot for determining its conformity or otherwise to the requirements of the specification.

c) The number of blocks to be selected for the sample shall depend upon the size of the lot and shall be in accordance with table 400-19.

Table 400-19: *Sampling and criteria for conformity*

Number of blocks	*Number of blocks to be selected in the sample*	*Permissible number of defectives*	*Sub-sample size number*
Up to 100	5	0	3
101 to 300	8	0	3
301 to 500	13	0	6
501 above	20	1	6

d) The blocks in the sample shall be selected at random and in order to ensure the randomness of selection, random number table may be used as per IS: 4905.

e) Any block failing in any one or more of the above requirements of physical properties shall be considered to be defective.

f) A lot shall be considered as conforming to these requirements if the number of defectives obtained is not more than the permissible number of defectives given in table 400-19.

g) The lot having been found satisfactory with respect to general requirements, dimension and workmanship, shall be tested for physical properties. For this purpose a sub-sample of size given in table 400-19 shall be selected at random. These blocks shall be first tested for compressive strength and then for water absorption and specific gravity. A lot shall be considered to have satisfied the requirements of physical properties, if none of the blocks tested for these requirements fails in any of these tests.

407 REFERENCES

1.	IS: 269	Specification for 33 grade ordinary Portland cement
2.	IS: 383	Specification for coarse and fine aggregate from natural source for concrete.
3.	IS: 455	Specification for Portland slag cement.
4.	IS: 460	Specification for test sieves.
5.	IS: 650	Specification for standard sand for testing of cement.
6.	IS: 1121	Method of tests for determination of strength properties of natural building stones:
	(Part 1)	*Compressive strength.*
7.	IS: 1124	Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones.
8.	IS: 1344	Specification for calcined clay Pozzolana.
9.	IS: 1489	Specification for Portland pozzolana cement.
10.	IS: 1542	Specification for sand for plaster.
11.	IS: 1727	Methods of test for pozzolanic materials.
12.	IS: 2116	Specification for sand for masonry mortar.
13.	IS: 2185	Concrete masonry units - specification.
14.	IS: 2250	Code of practice for preparation and use of masonry mortar.
15.	IS: 2386	Method of test for aggregate for concrete:
	(Part 1)	*Particle size and shape.*
	(Part 2)	*Estimation of deleterious materials and organic impurities.*
	(Part 3)	*Specific gravity, density, voids, absorption and bulking.*
16.	IS: 3025	Method of sampling and test for water.
17.	IS: 3115	Lime based blocks – specification.
18.	IS: 3406	Specification for masonry cement.
19.	IS: 3620	Specification for laterite stone block for masonry.
20.	IS: 3812	Specification for pulverized fuel ash:
	(Part 2)	*For use as admixture in cement mortar and concrete.*
21.	IS: 4031	Method of physical test for hydraulic cement.
22.	IS: 4032	Method of chemical analysis of hydraulic cement.

23.	IS: 8041	Rapid hardening Portland cement.
24.	IS: 8042	Specification for white cement.
25.	IS: 8043	Hydrophobic Portland cement.
26.	IS: 8112	Specification for 43 grade ordinary Portland cement.
27.	IS: 11652	Woven HDPE sacks for packing cement.
28.	IS: 11653	Woven polypropylene sacks for packing cement.
29.	IS: 12174	Jute synthetic union bags for packing cement.
30.	IS: 12269	Specification for 53 grade ordinary Portland cement.

+++++++

SECTION 500 SCAFFOLDINGS

501 GENERAL

Scaffolding is a temporary structure erected during construction for supporting labour and materials in order to execute masonry, plastering and other items of work. It is very essential that scaffolding should be strong enough and safe so that accidents do not occur due to its failure.

a) A scaffold consists of upright members called standards, longitudinal horizontal members parallel to the wall called stringers and cross horizontal members at right angle to the wall called putlogs. Over the putlogs, planks are provided to form a platform which serves as working space for workers and stacking space for materials.
b) In order to distribute concentrated loads from standards on the ground, these are supported on base plates of suitable size. On the other side of the platform, plank on edge called 'toe board' is provided to prevent falling down of materials, and also a guard rail is provided for safety of workers.
c) Sometimes, it is necessary for workmen to execute certain items of work – such as application of finish coats to external walls at a height which cannot be reached by ladders and it is not economical to go in for normal scaffolding for that purpose. In such situations, a cradle with working platform, suspended by ropes from the roof terrace, is provided. The cradle is held in position or moved sideways or up and down by a few workers stationed on the terrace.

502 DIFFERENT SYSTEMS

There are two systems of scaffolding, namely 'single scaffolding' and 'double scaffolding'.

a) In case of single scaffolding there is only one row of standards at some distance from the wall and putlogs are supported by stringers on one end and on wall masonry at the other end.
b) In case of 'double scaffolding' two rows of standards are provided and two ends of putlogs rest on stringers only.

Two types of scaffold namely 'timber/bamboo scaffold' and 'steel scaffold' are mainly used in construction.

503 TIMBERS/BAMBOO SCAFFOLDING

Timber or Bamboo scaffolding could be either single or double.

503.1 Single scaffolding

Row of standards should be at a distance of 1.2 to 1.5 m from the wall.

a) Standards should be 1.8 to 2.4 m apart and connected horizontally by stringers, spaced vertically at 1.5 to 1.8 m centres.
b) Putlogs with one end resting on stringers and tied to them and the other end resting in holes in masonry, should be spaced horizontally 1.2 m or less apart (usually half the spacing of standards).

c) Nominal diameter of standards should not be less than 8 cm subject to a minimum of 5 cm at the thin end. When it is necessary to extend a standard, overlap between two standards should be at least 60 cm.

503.2 Double scaffolding

a) One row of standards should be close to the wall and the other 1.2 to 1.5 m away from the wall.
b) Nominal diameter of standards should not be less than 10 cm, subject to minimum of 5 cm at the thin end.
c) For extension of standards over-lapping should be done as for single scaffolding.
d) Inside and outside scaffolding should be interconnected by cross-ledgers passing through openings in masonry with a view to obtain better stability.

503.3 Requirements

a) Scaffolding should be provided with diagonal bracings for stiffening it in the longitudinal direction so as to prevent its distortion.
b) It should also be tied to the structure at suitable intervals to prevent it from leaning away from the structure.
c) In case of a tall structure with a view of increasing stability of scaffolding, it is desirable to embed the standards in ground to extend of 60 cm, supported over base plate. If it is not feasible, standards may be supported in steel barrels of about 60 cm height, filled with soil which should be well rammed after filling it into the barrels.
d) Standards, stringers and putlogs shall be of round poles and planks for the platform shall have section of 20 cm x 3.5 to 4.0 cm.
e) Ends of planks may be hooped to prevent their splitting, thus prolonging their life.
f) Standards, stringers and putlogs could also be of sawn timber in which case their minimum sections should be 7x7 cm, 7x5 cm and 5x5 cm respectively.
g) Lashing of various members of scaffolding should be done with strong fibre ropes, applying non-slip knots.
h) When bamboo poles are used as standards, horizontal members should be tied to the verticals just above a knot of the vertical bamboo.
i) Toe boards and guard rails are fixed to platform/standards by nailing. Planks of the platform at their heading joints are butted with two putlogs placed at this part about 10 cm apart to support the ends.
j) Scaffolding for stone masonry structures has to be stronger than that for brick masonry structures, in view of heavier weight of masonry units. This could be done by reducing the spacing of standards and putlogs and using thicker planks for the platform.

504 STEEL SCAFFOLDING

Metal scaffoldings have advantages over the conventional type of timber scaffoldings such as ease and rapidness with which they may be erected, dismantled, stored and reused, rigidity of construction and more reliable assessment of their performance.

a) Metal scaffoldings can be constructed from steel or aluminium alloy tubes and fittings. But almost all the metal scaffoldings used in country at present are constructed from steel tubes and fittings.

b) Tubes and fittings covered in this section are intended only for the usage and loading conditions customary in normal building construction practice.

504.1 Independent scaffold

a) The scaffolding is supported on two rows of uprights, independent of the structure under construction. It may be either 'individual component type' or 'unit frame type'.

b) For tall buildings, the independent scaffolding is tied to the structure at suitable intervals for additional stability.

504.2 Putlog scaffold

The scaffold supported by single row of uprights in combination with load bearing parts of the structure. It may be either 'individual component type' or 'unit frame type'.

504.3 Individual component type scaffold

Independent or Putlog scaffold consists of an assembly of individual tubes and fittings.

504.4 Unit frame type scaffold

Independent or Putlog scaffold consisting of an assembly of prefabricated frames suitably connected or fitted and used in combination with or without individual tubes.

504.5 Materials

a) Steel tubes for individual component type scaffolding shall be heavy class welded or seamless tubes of 40 mm nominal bore conforming to IS: 1161.

b) For other types of scaffoldings, the individual tube or tubes forming part of the unit frame shall conform to the requirements of IS: 1161.

c) The sizes of such tubes shall be governed by the design requirements stated below and the minimum thickness of metal for such tubes shall conform to IS: 806.

505 REQUIREMENTS

All types of scaffoldings shall be capable of carrying and transmitting to the ground, all resultant loads by themselves or jointly with load carrying parts of the building, which have achieved adequate strength for this purpose.

a) The loading on the scaffoldings shall comply with the appropriate requirements of relevant Indian Standards regarding loading on temporary structures and scaffoldings.

b) All scaffoldings shall be adequately stiffened, both longitudinally and transversely to take up horizontal loading due to wind pressure on the scaffolding or tensioning ropes, if any, or both; and the forces resulting from inclined supports or support derived from the parts of a structurally stable building, lifting tackle, etc.

c) The scaffoldings shall be adequately rigid at all stages of erection and dismantling.

d) Where the supports cannot be fixed vertically due to any reason, the eccentricity of the loading so carried should also be taken into account.

e) The braces should be designed to carry, in addition to any applied horizontal loads, and the horizontal loads induced by the non-vertical supports, an additional horizontal load equal to 1/100 of the vertical loads carried by each platform and applied on its upper surface, and 1/100 of vertical loads carried by the ground applied at the base of scaffolding.

f) The permissible stresses and other design considerations shall comply with the appropriate requirements of relevant Indian Standards on structural design of tubular steel scaffolding.

506 STEEL FITTINGS

All fittings shall be manufactured from steel which when analysed in accordance with the relevant part of IS: 228 shall not indicate more than 0.06% of sulphur, 0.06% of phosphorous and shall also conform to steels of schedule II of IS: 1570.

506.1 Steel sections, bars and rivets

a) Steel sections and bars shall conform to IS: 226.
b) Rivet bars shall conform to IS: 1148.

506.2 Bolts and nuts

Bolts and nuts shall have mechanical properties not less than those specified in IS: 1367 and shall also conform to the requirements of IS: 1362.

506.3 Finish

a) If not galvanized and unless otherwise specified, the tubes and frames shall be painted or varnished externally throughout their exposed surface.
b) The steel sections shall also be suitably painted or otherwise treated for protection against rust and corrosion.
c) All fittings shall be suitably treated so as to render them resistant to corrosion.

507 DISMANTLING OF METAL SCAFFOLDS

Dismantling sequence should be planned and that sequence of dismantling sections of the scaffold should be logical and determined with due consideration of the safety of the labourers carrying out the work.

a) Dismantling work should proceed generally from the top in horizontal sections.
b) Scaffolds should not be dismantled in vertical sections from one end towards the other unless special consideration is given to ties and bracings.
c) All materials should be lowered to the ground and not stored on the scaffold.

508 REFERENCES

1. *Hand book on masonry design and Construction* (First revision) published by Bureau of Indian Standards.
2. *Code of practice for metal scaffolding safety* by Occupational Safety and Health branch of Labour Department (Hong Kong).
3. IS: 226 Specification for structural steel.
4. IS: 228 Methods of chemical analysis for steel.
5. IS: 806 Code of practice for use of steel tubes in general building construction.
6. IS: 1148 Steel rivet bars (medium and high tensile) for structural purposes for structural purposes.
7. IS: 1161 Steel tubes for structural purposes.
8. IS: 1362 Dimension for screw threads for general purposes.
9. IS: 2750 Specification for steel scaffoldings.

+++++++

SECTION 600 CONCRETE CONSTRUCTION

601 GENERAL

This section consists of quality control aspects of concrete work including the materials required such as cement, fine and coarse aggregates, water, admixtures reinforcing steel and form work. The quality requirements for cement, fine aggregate and water used for masonry and other cement related works shall also comply with the requirements listed in this section.

602 CEMENT

The quality of various cements is to be determined on the basis of its conformity to the performance characteristics given in the respective BIS Specification for those cement. Any trade name indicating any special features not covered in the standard or other special performance characteristics sometimes claimed/indicated on the bags alongside the 'Statutory Marking' shall not be a criteria for selecting cement.

602.1 Cement identification

Prior to carrying out a concrete mix design, cement identification should be recorded. Cement Identification chart shall be prepared with the following identification markings on the cement bag.

i) Name of cement company.
ii) Place of the factory.
iii) Type of cement (Ordinary Portland cement, Portland Pozzolana cement etc.).
iv) Grade of cement (28 day compressive strength) with the relevant BIS code number.
v) Date of manufacture.

602.2. Requirements

a) The various types of cement shall comply with the respective BIS code as specified below:

i) Ordinary Portland cement 33 grade	-	IS: 269.
ii) Ordinary Portland cement 43 grade	-	IS: 8112.
iii) Ordinary Portland cement 53 grade	-	IS: 12269.
iv) Rapid hardening Portland cement	-	IS: 8041.
v) Portland pozzolana cement	-	IS: 1489 (Part-1).
vi) Portland blast furnace slag cement	-	IS: 455.
vii) Sulphate resistant Portland cement	-	IS: 12330.

b) Cement shall be delivered to the Site in sealed and branded bags, or in the manufacturer's containers, bearing the manufacturer's name, cement type and date of manufacture, in batches not exceeding 100 tonnes.

c) Cement shall be stored at the Site in such a manner, as to prevent its deterioration, intrusion of moisture and foreign matter. It must be kept dry at all times. Immediately upon arrival at the Site, the Contractor shall store the cement in:

i) Bins or silos designed for the purpose. It shall be tight and provide for free movement to discharge opening, or

ii) Dry, weather tight and properly ventilated structures with floors raised a minimum of 450 mm above the ground with adequate provision to prevent absorption of moisture.

d) All storage facilities shall be subject to the approval of the Engineer, and shall be such as to permit easy access for inspection and identification. Prolonged storage of cement at Site is to be avoided. An indicative rate of such deterioration is given in table 600-1.

Table 600-1: *Rate of deterioration of cement against storage period*

Period of storage of cement	*Minimum expected reduction in strength at 28 days (%)*
Fresh	0
3 months	20
6 months	30
1 year	40
2 years	50

e) Cement used in the Works shall be free flowing and free from lumps.

f) In no case shall bagged cement be stored in stacks more than eight bags high.

g) A free passage of at least 1 m shall be left between the cement and the side walls of the structure.

h) Different types of cement shall be kept in clearly marked separate storage facilities.

i) Cement delivered to Site in drums or bags by the supplier or manufacturer shall be stored in the drums or bags until used in the Works.

j) Any cement in drums or bags which have been opened shall be used immediately.

k) It is good practice to move cement out of the storage shed using the 'first–in-first-out' scheme.

l) Cement that has partially or fully caked in storage will not be permitted in work and shall be immediately removed from the storage area. Any bag or package or sample of cement which has been damaged, or rebagged or in any way has deteriorated shall be rejected either as an individual bag or package or as the whole consignment in which such bag, package or sample is contained, as advised by the Engineer.

m) Where site limitations preclude the storage of cement in Site, cement shall be stored at a central location and shall be delivered daily as required to specific job sites.

n) The Contractor shall provide weighing machines which shall be kept permanently in each shed for checking the weight of the bags or barrels of cement. The weighing machines shall be calibrated by an independent agency. The Engineer shall have access at all times to the cement storage sheds.

o) During transport and storage, the cement shall be fully protected from all weather elements.

p) Any consignment of cement not used within two months from the date of manufacture and cement which in the opinion of the Engineer is of doubtful quality shall not be used in the Works, until it has been retested and test result sheets showing that it complies in all respects with the specification and relevant standards have been delivered to the Engineer.

q) Cement stored for longer than 28 days shall be tested prior to use to check for deterioration, and any cement which fails the test shall not be used in the Works.

602.3. Sampling and testing

a) The Contractor shall produce manufacturer's certificate for each supply of cement.
b) The cement must be subjected to various tests indicated in table 600-2 as stipulated in BIS Specifications.
c) Sampling of cement for testing shall be as per IS: 3535.
d) The minimum weight of the final sample taken should be 6 kg and shall be stored in an airtight container until testing.
e) Unless specified, the following tests shall be carried out for cement in comply with respective Indian Standards as specified in table 600-2.

Table 600-2: *Test for cement*

Test	*Code*	*Permissible value*	*Frequency*
Fineness	IS: 4031 (Part 1, 2 & 15)	Specific surface not less than 225 m^2/kg	1 test for every 50 tonnes or part thereof. (Same grade and brand)
Soundness	IS: 4031 (Part 3)	Not to exceed 10mm in Le-Chatelier mould	- do -
Setting time	IS: 4031 (Part 1)	Initial setting time >30 mins. Final setting time <600 mins.	- do -
Compressive strength	IS: 4031 (Part 6)	33 Grade / 43 Grade / 53 Grade	3 specimens for each lot.
At 72±1 hours		16MPa / 23MPa / 27 MPa	
At 168±2 hours		22MPa / 33MPa / 37 MPa	
At 336±3 hours		33MPa / 43MPa / -	
At 672±4 hours		- / - / 53 MPa	

NOTE: For sample lots less than 50 bags, these tests need not be insisted.

602.4. References

1. IS: 269 — 33 Grade ordinary Portland cement.
2. IS: 455 — Portland slag cement.
3. IS: 1489 — Portland pozzolana cement.
   (Part- 1) — *Fly ash based.*
   (Part- 2) — C*alcined clay based.*
4. IS: 3535 — Methods of sampling hydraulic cements.
5. IS: 4031 (Part- 1 to 14) — Methods of physical tests for hydraulic cements.
6. IS: 4032 — Methods of chemical analysis of hydraulic cements.
7. IS: 4845 — Definitions and terminology related to hydraulic cement.
8. IS: 4905 — Methods for random sampling.
9. IS: 8041 — Rapid hardening Portland cement.
10. IS: 8043 — Hydrophobic cement.
11. IS: 8112 — 43 Grade ordinary Portland cement.
12. IS: 12269 — 53 Grade ordinary Portland cement.
13. IS: 12330 — Sulphate resisting Portland cement.
14. IS: 12600 — Low heat Portland cement.

603 AGGREGATES

This portion covers the quality control requirements for aggregates, crushed or uncrushed, derived from natural sources such as river terraces, river beds, rocks, boulders, gravels etc for use in production of mortar or concrete for normal structural purposes including mass concrete works.

603.1 Requirements

a) Fine aggregate consist of natural clean sand, gravel, manufactured sand produced by crushing rock/gravel or a combination of the above, conforming to the requirements of physical and chemical properties stipulated in BIS codes and subject to Engineer's acceptance.

b) Coarse and fine aggregates shall consist of tough, hard, durable and uncoated particles containing no harmful material in quantities sufficient to adversely affect the concrete or reinforcing steel, and shall contain no materials likely to cause staining or otherwise disfigure the concrete surface.

c) Coarse and fine aggregates which shall be obtained from a source approved by the Engineer, shall comply with the requirements of BIS codes and subject to Engineer's acceptance. If required by the Engineer, the aggregates shall be washed with water.

d) The nominal maximum size of coarse aggregate shall be as large as possible within the limits specified but in no case greater than ¼ of the minimum thickness of the member or ¾ the minimum clear spacing between individual reinforcing bars or wires.

e) The gradation of fine aggregate for concrete and mortar shall be in accordance with the gradation designations in IS: 383 and subject to Engineer's acceptance.

f) Each batch of aggregate delivered to the Site shall be kept separate from previous batches, and shall be stored to allow for inspection and tests to be carried out.

g) The storage area for the clean washed sand shall be shaded from the direct rays of the sun and shall be screened for protection from dust. The area in the neighbourhood of stockpile/mixing plant shall be watered as necessary, to reduce the rising of dust.

h) The aggregates shall be properly stored and labelled without intermingling as classified at any storage area.

i) No aggregate deliveries shall be made to the Site until the Engineer has approved the samples as complying with the specification.

j) The Contractor shall provide means of storing aggregate at each point where concrete is made such that:
   i) Each nominal size of coarse aggregate and the fine aggregate shall be kept separated at all times.
   ii) Building stockpiles are to prevent harmful segregation and breakage.
   iii) Stockpiles shall be on hard and clean surfaces with not more than 5% slope.
   iv) Contamination of the aggregates by the ground or other foreign matter shall be effectively prevented at all times.
   v) Each heap of aggregate shall be capable of draining freely.
   vi) Stockpiles shall be protected from direct sunlight.
   vii) Intermingling of aggregates shall not be approved.
   viii) Unloading of aggregate shall prevent harmful segregation and breakage.

k) The preparation, location and size of any stockpiles and the methods of segregation shall be approved by the Engineer.

l) Wet aggregates in stockpiles shall be taken frequently to determine the moisture content and the amount of water to be added to the mix.

603.2 Sampling and testing

a) The Contractor shall provide samples of both fine and coarse aggregate to the Engineer, in accordance with the requirements of IS: 2430 for testing at least two weeks before delivering to the Site.

b) All samples shall be taken in the presence of the Engineer.

c) Samples of aggregates shall be tested in accordance with the requirements of IS: 2386 as specified in tables 600-3 and 600-4.

Table 600-3: *Tests for coarse aggregates*

Test	*Code*	*Frequency*
Gradation	IS: 2386 (Part 1)	One test per 40 m^3 or part thereof for each source.
Flakiness index	IS: 2386 (Part 1)	- do -
Deleterious constituents	IS: 2386 (Part 2)	If in doubt, one test per source.
Water absorption	IS: 2386 (Part 3)	Once for each source.
Aggregate impact value	IS: 2386 (Part 4)	One test per source.
Soundness	IS: 2386 (Part 5)	- do -

Table 600-4: *Tests for fine aggregates*

Property	*Code*	*Frequency*
Gradation	IS: 2386 (Part 1)	One test per 40 m^3 or part thereof for each source.
Deleterious constituents	IS: 2386 (Part 2)	If in doubt, one test per source.
Silt content	IS: 2386 (Part 1)	One test per 40 m^3 or part thereof for each source.
Bulking	IS: 2386 (Part 3)	- do -

603.3 References

1. IS: 383 Specification for coarse and fine aggregates from natural sources for concrete
2. IS: 2386 Methods of tests for aggregate for concrete:
   - (Part 1) *Particle size and shape*
   - (Part 2) *Estimation of deleterious materials and organic impurities*
   - (Part 3) *Specific gravity, density, void, absorption and bulking*
   - (Part 4) *Mechanical properties*
   - (Part 5) *Soundness*
   - (Part 6) *Measuring mortar making properties of fine aggregate*
   - (Part 7) *Alkali aggregate reactants*
   - (Part 8) *Petrographic examinations*
3. IS: 2430 Methods for sampling of aggregates

604 WATER

Water used for concrete mixes, washing of aggregates and equipment, wetting of surfaces or ponding during curing or for wetting formwork and washing reinforcement shall conform to the following.

604.1 Requirements

a) Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

b) Potable water is best suitable for use in concrete. Water from different sources such as underground water, natural surface water etc shall be tested to prove that its quality shall conform to water quality requirements of BIS and chemical limitations listed in Table 1 of IS: 456.

c) In case of doubt regarding development of strength, the suitability of water for producing concrete shall be ascertained by the compressive strength and initial setting time tests.

d) The pH value of water used in concrete works shall not be less than 6.

e) Temperature of water for concrete shall not be less than 5°C and not more than 40°C.

f) Water may be cooled to not less than 5°C by the gradual addition of chilled water or ice as follows:
   i) No ice particles shall be present in the mix.
   ii) Alternatively, flaked ice may be used.

g) Every effort should be made to protect water pipes and tanks from the sun by burying, shading, insulation or painting white.

h) Mixing or curing of concrete with sea water is not recommended because of the presence of harmful salts in sea water.

604.2 Supply and storage

a) The Contractor shall make his own arrangements and obtain the approval of the Engineer for the supply of water.

b) Storage of water should be such that contamination is prevented from occurring. Any measures taken to avoid contamination of water shall be subjected to the approval of the Engineer.

604.3 Sampling and testing

a) The Contractor shall take samples of the water being used or which it is proposed to use for mixing concrete and test them for quality as directed by the Engineer.

b) The sample of water taken for testing shall represent the water proposed to be used for concreting. The sample shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

c) Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average of strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the requirements of IS: 516.

d) The initial setting time of test block made with the appropriate cement and the water proposed to be used shall not be less than 30 minutes and shall not

differ by 30 minutes from the initial setting time of control test block prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of IS: 4031 (Part 5).

e) No source of water shall be approved until the required tests have demonstrated its suitability for use in concrete.

f) The use of water from a municipal or government supply does not preclude the requirement for testing.

g) Water shall be tested as indicated in table 600-5.

Table 600-5: *Quality control tests for water for use in concrete*

Sl. No.	*Test*	*Code*	*Permissible value*	*Minimum frequency of sampling*
1	Suspended matter	IS: 3025 (Part 17)	2000 mg/litre	Water from each source before commencement of work and thereafter every three months till completion of work.
2	Organic contents	IS: 3025 (Part 16)	200 mg/litre	- do -
3	Inorganic contents	IS: 3025 (Part 19)	3000 mg/litre	- do -
4	Sulphates (as SO_2)	IS: 3025 (Part 24)	400 mg/litre	- do -
5	Chlorides (as Cl)	IS: 3025 (Part 32)	2000 mg/litre (PCC) 500 mg/litre (RCC)	- do -
6	pH value		Not less than 6	- do -

604.4 References

1. IS: 3025 Methods of sampling and test (physical and chemical) for water and waste water.

605 ADMIXTURES

605.1 General

a) Admixtures are materials added to the concrete during mixing for the purpose of altering the properties of the concrete mix.

b) Chemical and air-entraining admixtures including superplasticizers, solid or liquid or emulsion may be added to cement concrete at the time of mixing so as to achieve the desired property in concrete, in the plastic or hardened state.

c) Approval of admixtures shall be subject to extensive trials to demonstrate the suitability, adequacy of dosing arrangements and performance.

d) The manufacturer or supplier shall furnish a series of at least ten trial mixes which clearly indicate that the use of the admixture has consistently manifested the required properties of concrete including absorption, permeability and poring values.

605.2 Type of admixtures

a) *Mineral admixtures*: A material other than water, aggregates, cement and additives like pozzolana or slag used as an ingredient of concrete and added to the batch immediately before or during its mixing to modify one or more of the properties of concrete in the plastic or hardened state.

b) *Fibre reinforcement admixtures*: Fibres shall serve as secondary reinforcement for concrete, and to protect concrete from stresses which cause cracking initially after placement.
c) *Accelerating admixture or accelerator*: An admixture when added to concrete, mortar or grout, increases the rate of hydration of cement, shortens the time of set, or increases the rate of hardening or strength development.
d) *Retarding admixture or retarder*: An admixture which delays the setting of cement paste, and hence of mixtures, such as mortar or concrete containing cement.
e) *Water reducing admixture or workability aid*: An admixture which either increases workability of freshly mixed mortar or concrete without increasing water content or maintains workability with a reduced amount of water.
f) *Air-entraining admixtures*: An admixture for concrete or mortar which causes air to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase workability.
g) *Superplasticizing admixtures*: An admixture for mortar or concrete which imparts very high workability or allows a large decrease in water content for a given workability.
h) *Retarding superplasticizing admixture*: Superplasticizing admixture that imparts prolonged workability retention and retards setting.

605.3 Requirements

a) Admixtures shall comply with the requirements of IS: 9103. In addition to the standard requirements for the approval of materials, approval of admixtures shall be subject to extensive trials to demonstrate the suitability, adequacy of dosing arrangements and performance, when a proven history of performance can be provided to the satisfaction of the Engineer.
b) Concrete made with admixtures when compared with identical concrete made without the admixture shall conform to the requirements appropriate to the type of admixture given in table 1A and table 1B of IS: 9103.
c) The methods of use and the quantities of admixture used shall be in accordance with the manufacturer's instruction and subject to the Engineer's approval after evaluation in trial mixes and shall in no way limit the Contractor's obligations under the Contract to produce concrete with the specified strength, workability and durability.
d) Admixtures should not impair durability of concrete nor combine with the constituent to form harmful compounds nor increase the risk of corrosion of reinforcement.
e) The relative density of liquid admixtures shall be checked for each drum containing admixtures and compared with the specified value before acceptance.
f) If two or more admixtures are used simultaneously in the same concrete mix, data should be obtained to assess their interaction and to ensure their compatibility.
g) A report of the effects of accidental overdose of the admixture and the remedial measures to be taken if an overdose occurs shall be provided by the Contractor to the Engineer.
h) No admixtures containing chlorides shall be used. In particular, the use of acceleration admixtures containing calcium chloride shall not be used.

i) The use of the admixtures shall be strictly controlled to ensure correct dosages as prescribed by the manufacturer and justified by trial mixes to be used. A calibrated dispenser or flow meter shall be used to for the addition of the admixture.

605.4 References

1. IS: 6925 Methods of test for determination of water soluble chlorides in concrete admixtures.
2. IS: 9103 Concrete admixtures - Specifications.

606 REINFORCING STEEL

606.1 General

This portion includes the quality aspects of tension, compression, and temperature reinforcing steel, including welded wire fabric. The work includes furnishing, fabrication, and placement of reinforcement for cast-in-place concrete, including bars, welded wire fabric, ties, and supports.

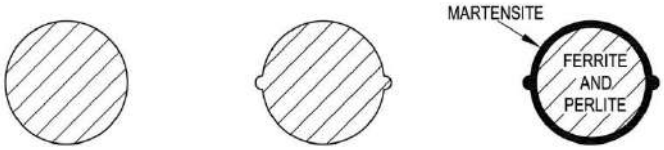
606.2 Requirements

a) All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean the reinforcement.
b) Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures.
c) The Contractor shall submit the manufacturer's records of chemical and physical properties of each batch of billet steel bars and a certificate that the respective material furnished meets the requirements for the steel reinforcement specified. The manufacturer's records shall include certificates of chemical analysis, tensile and bend tests of the reinforcement.

606.2.1 Reinforcing bars

Reinforcing steel shall consist of Mild Steel (MS), Cold Twisted Deformed (CTD) or Thermo Mechanically Treated (TMT) bars.

a) *Mild steel bars*: Mild steels are hot-rolled steels having a yield region on their stress-strain curves and exhibit considerable elongation at failure.
b) *Cold twisted deformed bars*: Hot rolled steel is artificially strengthened by working on it in a cold state, adopting methods such as extrusion, flattening, drawing, twisting etc. The use of steel hardened by extrusion and cold-worked by flattening as reinforcement in members subjected to repeated loads (Such as bridges) is not recommended. As cold-worked steels have no clearly marked yield point, exhibit brittle failure (Elongation less than 3 to 4%).
c) *Thermo mechanically treated bars*: Thermo mechanical treatment is a process of manufacturing high strength deformed bars in which the bars are intensively cooled immediately after rolling. Sudden reduction in temperature creates an extremely brittle and strong surface layer (Martensite) with a relatively more ductile and less strong core (Ferrite and perlite). This process improves the strength and ductility (Elongation as high as 20%) compared to CTD.
d) The typical cross sections of the bars shall be as shown in figure 600-1.
e) The various grades and definitive properties of reinforcing bars as adopted by the relevant BIS are given in table 600-6.



a) Mild steel b) CTD c) TMT

Fig. 600-1: Typical cross sections of MS, CTD and TMT bars.

Table 600-6: *Grades of reinforcing steel*

Type	*Code*	*Grade designation*
MS	IS: 432	Fe250
CTD, TMT	IS: 1786	Fe415, Fe500, Fe550, Fe500D, Fe550D, Fe600

f) If the steel has excessive surface rust, dust or other deleterious material then it shall be sand blasted. Sand for blasting shall not contain materials deleterious to the durability of the reinforcement or concrete.

g) All reinforcement shall be pressure washed with fresh water after erection and immediately before placing concrete.

606.2.2 Welded steel wire fabric

a) Steel fabric reinforcement shall comply with the requirements of IS: 1566 and shall be delivered to Site in flat mats.

b) Welded intersections shall not be spaced more than:
   i) 300 mm for plain round bars.
   ii) 400 mm apart for deformed high yield bars in direction of calculated stress except when used as stirrups.

606.2.3 Tie wire

a) Tie wire shall conform to the requirements of IS: 280.

b) Tie wires shall be black annealed mild steel having diameter not less than 1mm.

606.3 Storage and handling

a) On delivery, bars in each lot shall be legibly tagged by the manufacturer.

b) Storage of reinforcement shall be on suitable structures, built at minimum 450 mm above the ground surface, to prevent damage and accumulation of dirt, rust and other deleterious matter (See figure 600.2).

Fig. 600-2: Proper storage of reinforcement steel

c) Storage facilities shall be such as to permit easy access for inspection and identification.
d) Reinforcement bundles shall be clearly tagged with bar schedule and bar mark reference.
e) The reinforcement shall not be roughly handled, dropped from a height or subjected to shock loading or mechanical damage.
f) Steel reinforcing bars shall be kept clean and shall be free from pitting, loose rust, mill scale, oil, grease, earth, paint, or any other material which may impair the bond between the concrete and the reinforcement.
g) The reinforcement shall be covered to ensure protection from condensation and other deleterious materials.

606.4 Placing of reinforcement

a) Rough handling, shock loading (prior to embedment) and the dropping of reinforcement from a height shall be avoided. Reinforcement shall be secured against displacement outside the specified limits.
b) Spacers, chairs and other supports detailed on drawings, together with such other supports as may be necessary, should be used to maintain the specified nominal cover to the steel reinforcement.
c) Spacers or chairs should be placed at a maximum spacing of l.0 m and closer spacing may sometimes be necessary. Spacers, cover blocks should be of concrete of same strength or PVC.

606.5 Welded joints or mechanical connections

a) Welding of high strength deformed bars and wires shall be permitted if the Carbon Equivalent (CE) is more than 0.53 when micro alloys are used and 0.42 when micro alloys are not used. The value of CE is determined as per IS: 1786.
b) Welding of reinforcements shall be done in accordance with the recommendations of IS: 2751 and IS: 9417.
c) When welded joints or mechanical connections (See fig. 600-3) in reinforcement are used, quality tests as per IS: 1786 shall be carried to prove that the joints are of the full strength of bars connected. The frequency of tensile and bending tests is one for every 100 joints or as decided by the Engineer.

Fig. 600-3: Couplers for reinforcing bars

606.6 Tolerances

a) Unless otherwise specified in the Drawing, the reinforcement shall be placed within the following tolerances:
   i) For effective depth equal to 200 mm or less - ±10 mm
   ii) For effective depth more than 200 mm - ±15 mm

b) Unless specified otherwise, actual concrete cover shall not be deviated from the required nominal cover +10 mm. No tolerance is allowed for clear cover.

606.7 Inspection, sampling and testing

a) Representative samples of reinforcing steel of all sizes that the Contractor proposes to use in the Works must be submitted to the Engineer along with the manufacturer's certificate, before a work is commenced, for his written approval.

b) Manufacturer's certificates shall clearly state for each sample:
   i) The place and date of manufacture.
   ii) Quantity delivered.
   iii) All relevant details of chemical composition, manufacture, strengths and other qualities of steel.

c) Allow 14 days for review and approval of samples by the Engineer.

d) Steel shall be delivered at Site only after approval of samples by the Engineer.

e) After delivery at Site, Contractor shall carry out tests for reinforcing steel for each bar size required for 1st tier quality control at least two weeks before commencement of concrete works.

f) Tests shall be carried out in accordance with BIS.

g) The tests include those for dimensions, weight, tensile strength, bend and/or rebend, at his own cost, for each size of bar to be used in the concrete construction.

h) Frequency of sampling and the method of quality control shall be in accordance with IS: 10790 (Part 2).

i) Where epoxy coated steel is used, 0.3 kg samples of the coating, material from each batch be supplied in an airtight container and identified by the batch number.

j) Tensile tests providing information on following shall be done as per frequency detailed in table 600-7:
   i) Elastic limit.
   ii) Ultimate strength.
   iii) Stress/strain curve.
   iv) Cross-sectional area.
   v) Deformation/bond characteristics of deformed bars.

k) Manufacturer's certificate shall be sufficient for chemical analysis. The Contractor shall arrange for chemical analysis of the steel supplied, at his own cost, if the manufacturer's certificate is not available.

l) Tests shall be repeated if the source of supply of reinforcement changes.

m) For checking nominal mass, mechanical properties, bend test and rebend test, test specimen of sufficient length shall be cut from each size of the finished bar/wire at random at a frequency not less than that specified in table 600-7.

n) The Engineer shall instruct the Contractor to break out and remove completely all sections of the work already constructed under any of the following circumstances:

i) Reinforcing steel sample under test fails to meet the specification requirements at any time.
ii) The Engineer considers that samples which were presented to him for test were not truly representative.
iii) It becomes apparent that reinforcing steel which has not been approved has been used on the Works.

Table 600-7: *Test for reinforcing steel*

	Test	*Code*	*Frequency*
1.	a) Tensile strength b) Proof stress c) Percentage elongation d) Elongation at maximum force	IS: 1608, IS: 2062 and IS: 1786	2 per cast (For Casts/Heats below 100 tonnes) 3 per cast (For Casts/Heats of 100 tonnes or more)
2.	Bend test and Rebend test	IS: 1599 and IS: 1786	-do-

NOTE: Reinforcing steel need not be tested for first tier quality control after delivery at Site, if the total requirement of each size of bar for a work is less than 500 kg. Manufacturer's certificate submitted initially would be sufficient.

606.7.1 Field test for TMT bars

a) To ensure that TMT bars have a concentric tempered martensite periphery with a softer ferrite-perlite core structure, the Etching test or Ring test as per Annex A of IS: 1786 shall be carried out.
b) A small piece (about 12 mm long) can be cut and the transverse face lightly ground flat on progressively finer emery papers up to '0' size.
c) The sample can be macro etched with nital (5% nitric acid in alcohol) at ambient temperature for a few seconds which shall then reveal a darker annular region corresponding to martensite microstructure and a lighter core region as shown in figure 600-4.

(a) Uniform martensite (15-30% of area) (b) Over quenched poor ductility (c) Non-uniform hardened martensite (d) Eccentric martensite

Fig. 600-4: Typical cross sections of ideal (a) and poor quality (b, c & d) TMT bars.

d) However, this test is not to be regarded as a criterion for rejection, but based on the acceptance criteria described under Clause 606.8.

606.8 Acceptance criteria

a) Acceptance or rejection of reinforcement steel is mostly based on tensile strength. However, other test results of the steel such as chemical composition, bend/rebend is also important.
b) The test results of reinforcing steel shall deemed to comply with the criteria specified in tables 600-8 and 600-9.

Table 600-8: *Chemical composition of high strength deformed bars and wires*

Sl. No.	*Constituents*	*Permissible maximum percentage*						
		Fe415	*Fe415D*	*Fe500*	*Fe500D*	*Fe550*	*Fe550D*	*Fe600*
1	Carbon	0.30	0.25	0.30	0.25	0.30	0.25	0.30
2	Sulphur	0.060	0.045	0.055	0.040	0.055	0.040	0.040
3	Phosphorous	0.060	0.045	0.055	0.040	0.050	0.040	0.040
4	Sulphur and phosphorous	0.110	0.085	0.105	0.075	0.100	0.075	0.075

Table 600-9: *Nominal cross sectional area, mass and tolerances of steel bars & wires*

Nominal size (mm)	*Cross sectional area (mm^2)*	*Mass per metre (kg)*	*Tolerances in nominal mass (%)*	
			Batch	*Individual*
4	12.6	0.099	±7	-8
5	19.6	0.154	±7	-8
6	28.3	0.222	±7	-8
8	50.3	0.395	±7	-8
10	78.6	0.617	±7	-8
12	113.1	0.888	±5	-6
16	201.1	1.580	±5	-6
20	314.3	2.470	±3	-4
25	491.1	3.850	±3	-4
28	615.8	4.830	±3	-4
32	804.6	6.310	±3	-4
36	1018.3	7.990	±3	-4
40	1257.2	9.860	±3	-4

NOTE: For the purpose of checking the nominal mass, the density of steel shall be taken as 0.00785 kg/mm^2 of the cross-sectional area per metre.

Table 600-10: *Mechanical properties of high strength deformed bars and wires*

Test	*Fe415*	*Fe415D*	*Fe415S*	*Fe500*	*Fe500D*	*Fe500S*	*Fe550*	*Fe550D*	*Fe600*
0.2 % proof stress/ yield stress *Min.* (MPa)	415	415	415	500	500	500	550	550	600
0.2 % proof stress/ yield stress *Max.* (MPa)	-	-	540	-	-	625	-	-	-
TS/YS ratio (MPa)	≥1.10, but TS not less than 485	≥1.12, but TS not less than 500	1.25	≥1.08, but TS not less than 545	≥1.10, but TS not less than 565	1.25	≥1.06, but TS not less than 585	≥1.08, but TS not less than 600	≥1.06, but TS not less than 660
Elongation *Min.* (%)	14.5	18.0	20.0	12.0	16.0	18.0	10.0	14.5	10.0
Total elongation at max. force *Min.* (%)	-	5	10	-	5	8	-	5	-

NOTE: TS – Tensile strength; YS -0.2 % proof stress/yield stress

c) When any test results do not conform to the relevant standard, the reinforcement steel shall be removed from the Site at the Contractor's own cost.

606.9 References

1. IS: 228 (Parts 1 to 24) Methods for chemical analysis of steels.
2. IS: 226 Structural steel.
3. IS: 442 Specification for mild and medium tensile steel bars and hard drawn steel wire for concrete reinforcement:
   (Part-1) *Mild steel and medium tensile steel bars.*
   (Part-2) *Hard drawn steel wire.*
4. IS: 280 Mild steel wire for general engineering purposes.
5. IS: 432 Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement:
   (Part 1) *Mild steel and medium tensile steel bars.*
6. IS: 1786 Specification for high strength deformed steel bars and wires for concrete reinforcement.
7. IS: 1566 Specification for hard-drawn steel wire fabric for concrete reinforcement.
8. IS: 13620 Fusion bonded epoxy coated reinforcing bars –specification
9. IS: 10790 Methods of sampling of steel for prestressed and reinforced concrete:
   (Part 2) *Reinforcing steel.*
10. IS: 1387 General requirements for the supply of metallurgical materials
11. IS: 1599 Method for bend test.
12. IS: 1608 Metallic materials - tensile testing at ambient temperature
13. IS: 2062 Hot rolled low, medium and high tensile structural steel (6^{th} revision).
14. IS: 2502 Code of practice for bending and fixing of bars for concrete reinforcement.
15. IS: 2770 Methods of testing bond in reinforced concrete:
    (Part 1) *Pull-out test.*
16. IS: 2751 Code of practice for welding of mild steel plain and deformed bars for reinforced concrete construction.
17. IS: 9417 Recommendations for welding cold-worked steel bars for reinforced concrete construction.
18. IS: 11587 Structural weather resistant steels.

607 CONCRETE

Quality control of concrete works involves correct procedures of proportioning, batching, mixing, transporting, placing, compacting and curing.

607.1 Requirements

a) For building works, the concrete shall be in grades designated as per table 600-11 (Ref: Table 2 of IS: 456-2000) and is classified as Ordinary concrete, standard concrete and high strength concrete.
b) The characteristic strength is defined as the strength of material below which not more than 5% of the test results are expected to fall.

c) Ordinary concrete is made on the basis of nominal mix proportioned by weight of its main ingredients. Proportion by volume may be allowed with the permission of the Engineer, only where proportion by weight is not practical.

d) Standard concrete is made on the basis of design mix proportioned by weight of its ingredients and may contain chemical admixtures to achieve certain target values of various properties in fresh condition.

e) High strength/performance concrete is similar to standard concrete but contains additional one or more mineral admixtures providing binding characteristics and partly acting as inert filler material which increase its strength, reduce its porosity and modify its other properties in fresh as well as hardened condition.

Table 600-11: *Grades of concrete*

Group	*Grade Designation*	*Characteristic compressive strength in 28 days (MPa)*
Ordinary concrete	M10	10
	M15	15
	M20	20
Standard concrete	M25	25
	M30	30
	M35	35
	M40	40
	M45	45
	M50	50
	M55	55
High strength concrete	M60	60
	M65	65
	M70	70
	M75	75
	M80	80

607.2 Workmanship

607.2.1 Proportioning

a) The proportions of cement, aggregates and water to attain the required characteristic strengths shall be made by designing the concrete mix (Design mix concrete) or by adopting nominal concrete mix (Nominal mix concrete).

b) Design mix concrete is preferred to nominal mix. Design mix shall invariably be used for grade M25 and higher.

c) The proportions of materials for nominal mix concrete shall be in accordance with table 600-12. (Ref: Table 9 of IS: 456-2000)

Table 600-12: *Nominal mix for 50 kg of cement*

Grade of concrete	*Total quantity of dry aggregate (CA+FA) by mass (kg)*	*Quantity of water (litres)*
M5	800	60
M7.5	625	45
M10	480	34
M15	330	32
M20	200	30

NOTE: Proportion of fine aggregate (FA) to coarse aggregate (CA) is generally 1:2, but varies from 1:1.5 (Zone-I) to 1:2.5 (Zone-III).

Example, 1:1.5 for Maximum size of aggregate (MSA) = 10 mm,
1:2.0 (Zone-II) for MSA = 20 mm,
1:2.5 (Zone-III) for MSA = 40 mm for an average grading of FA (Zone-II of Table 7.4 of IS: 383).

d) The Contractor shall carry out the mix design as per IS: 10262 and the mix so designed shall be approved by the Engineer.
e) The detailed procedure of concrete mix design is given in Appendix B of PWD Quality Control Laboratory Manual.
f) Mix design shall be revised, if there is either change of the source or in the quality of the materials.
g) The materials and their proportion as established by the mix design shall invariably be followed.

607.2.2 Volume batching

a) Volume batching may be allowed with the permission of Engineer, only where weigh-batching is not practical.
b) In such cases, accurate bulk densities of materials to be used in concrete shall be determined earlier. Allowance for bulking shall be made in accordance with IS: 2386 (Part 3).
c) The mass volume relationship should be checked as frequently as necessary, the frequency for the given job being determined by Engineer to ensure that the specified grading is maintained.
d) Volume batching shall be done by measuring boxes having capacity in multiples of volumes of one bag of cement.
e) It is important to maintain the water-cement ratio constant at its correct value. For this, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, according to weather conditions.
f) The quantity of water to be added shall be adjusted to compensate for any observed variations in the moisture content determined as per IS: 2386(Part 3).

607.2.3 Plant batching and mixing

a) Ready-mixed concrete (RMC) supplied by ready-mixed concrete plant shall be preferred. For large and medium project sites the concrete shall be sourced from ready mixed concrete plants or from on site or off site batching and mixing plants.
b) The quantity of both cement and aggregate shall be determined by mass, solid admixture by mass, liquid admixture measured in volume or mass, water shall be weighed or measured by volume in a calibrated tank (Also refer IS: 4925).
c) The accuracy of the weigh batcher shall be periodically checked and the needle should be adjusted to zero when the hopper is empty.
d) The mix recipe for the mixes to be produced shall be readily available to the mixer operator.
e) Sequencing and blending of the ingredients during charging of the mixers shall be carried out in such a way as to obtain uniformity and homogeneity in the concrete.
f) During batching, aggregates shall be measured in a manner to maintain their desired grading, and all materials shall be weighed to the tolerances required to produce the approved design mix.

g) The coarse aggregate shall be controlled to minimize segregation and undersized material.
h) Fine aggregate shall be controlled to minimize variations in gradation, giving special attention for keeping finer fractions uniform and exercising care to avoid excessive removal of fines during processing.
i) Avoid blending two sizes of fine aggregate by placing alternate amounts in bins or stockpiles or when loading in trucks. Satisfactory results are achieved when different size fractions are blended as they flow into a stream from regulating gates or feeders.
j) Stockpiling of coarse aggregate shall be kept to a minimum because fines tend to settle and accumulate. When stockpiling is necessary, use proper methods to minimize the problems with fines, segregation, aggregate breakage, excessive variation in gradation, and contamination.
k) Stockpiles shall be built up in horizontal or gently sloping layers, not by end-dumping. Trucks, loaders, and dozers, or other equipment shall not be operated on the stockpiles because, in addition to breaking the aggregate, they frequently track dirt onto the piles.
l) Storage facilities for bulk cement shall include separate compartments for each type of cement used. The interior of a cement silo shall be smooth, with a minimum bottom slope of 50 ° from the horizontal for a circular silo and 55° to 60 ° for a rectangular silo.
m) Silos shall be equipped with non-clogging air diffuser flow pads through which small quantities of dry, oil free, low pressure air can be introduced intermittently at approximately 20 to 35 kPa to loosen cement that has settled tightly in the silos. Storage silos shall be drawn down frequently, preferably once per month, to prevent cement caking.
n) Each bin compartment from which cement is batched shall include a separate gate, screw conveyor, air slide, rotary feeder, or other conveyance that effectively allows both constant flow and precise cut off to obtain accurate batching of cement.
o) All bins and silos shall be properly tagged at silos, bins and near charging hose.
p) Bags of cement should be stacked on pallets or similar platforms to permit proper circulation of air. For a storage period of less than 60 days, stack the bags in not more than 14 layers, and for longer periods, in not more than 7 layers.
q) The quantity of water actually entering the mixing drum should be checked with the reading of the gauge or valve setting, when starting a job.
r) The water batcher and the water pipes should be leak free.

607.2.4 Process of plant batching and mixing

a) *Manual control batching*: Manual plants are acceptable for small jobs having low batching rate requirements.
b) *Semi-automatic control batching*: In this system, aggregate bin gates for charging batchers are opened by manually operated push buttons or switches. Gates are closed automatically when the designated weight of material has been delivered.
c) *Automatic control batching*: Automatic batching of all materials is electrically activated by a single starter switch. However, interlocks shall interrupt the

batching cycle when the scale has not returned to ±0.3% of zero balance or when weighing tolerances are exceeded.

d) Batch plant bins shall be of sufficient size to effectively accommodate the production capacity of the plant. Compartments in bins separate the various concrete materials, and the shape and arrangement of aggregate bins shall prevent aggregate segregation and leakage.

e) Weigh batchers shall be charged with easy-operating clam shells or undercut radial-type bin gates.

f) Gates used to charge semi-automatic and fully automatic batchers shall be power operated and equipped to obtain the desired weighing accuracy. They shall be calibrated by the plant supplier for the types of aggregate used at the standard range of moisture contents.

g) Weigh batchers shall be accessible for obtaining representative samples, and they shall be arranged to obtain the proper sequencing and blending of aggregates during charging of the mixer.

h) The amount of concrete mixed in any one batch shall not exceed the rated capacity of the mixer.

i) All mixing and batching plants shall be maintained free of set concrete or cement and shall be clean before commencing mixing.

j) For each different type of cement at use at the plant, a separate silo shall be provided.

k) Each batch shall be so charged into the mixer that some of the water will enter in advance of the cement and aggregates. Controls shall be provided to prevent batched ingredients from entering the mixer before the previous batch has been completely discharged.

l) The first batch of concrete through the mixer shall contain an excess of cement to allow for coating of the inside of the mixing drum without reducing the required mortar content of the mix.

m) All water should be in the drum by end of the first 15 seconds of the specified mixing time. Each batch would be mixed until the concrete is uniform in colour at least for a period of two minutes after all the materials and water are in the drum.

n) Mixing plant that has been out of action for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed in it.

o) When a change of mix is made to one using a different type/grade of cement, the mixing plant shall be thoroughly cleaned of all traces of the previously used cement, whatever is the time interval between successive mixes.

607.2.5 Tolerances in batching

a) The accuracy of the measuring equipment shall be within +2% of the quantity of cement being measured and within +3% of the quantity of aggregate, admixtures and water being measured. Standard test weights shall be available to permit the checking of scale accuracy.

b) Testing of the weighers shall be at three month intervals. If water is dispensed by flow meter, the frequency of testing shall be at three-month intervals. Such testing shall be undertaken by a calibration agency approved by the department.

c) Test certificates shall be displayed in the plant in prominent positions.

d) Cement supplied in bags shall be placed directly from the bag into the intake of the mixing plant and each batch must contain one or more complete bags of cement. No mixer having a rated capacity of less than a one-bag batch shall be used and the mixer shall not be charged in excess of its rated capacity.

607.2.6 Hand mixing

a) Hand mixing shall be avoided as far as possible.
b) Engineer may permit hand mixing for small jobs when mixing by mixer is not possible due to practical reasons.
c) It shall be done on a smooth water tight platform large enough to allow efficient turning over of the ingredients of concrete before and after adding water.
d) Mixing platform shall be so arranged that neither foreign material shall get mixed with concrete nor the water for mixing shall flow out.
e) Cement bags of required number shall be placed in a uniform layer on top of the measured quantity of fine aggregate, which shall also be spread in a layer of uniform thickness on mixing platform.
f) Dry sand and cement shall then be mixed thoroughly by turning over to get a mixture of uniform colour.
g) Water required for the mix shall then be added gradually and the mass turned over till the mixture obtained is of uniform colour and required consistency.
h) Measured quantity of aggregate shall then be placed on the mixing platform and mixed till the mortar and mixture obtained is of uniform colour and required consistency.
i) In hand mixing, quantity of cement shall be increased by 10% more than the quantity actually required by the design mix at the cost of Contractor.

607.2.7 Transportation

a) The Contractor shall submit for the approval of the Engineer, the details of the equipment and operating techniques for the transportation and placing of concrete.
b) A method statement shall be submitted for approval for major concrete placements, which shall address:
    i) The planned rate of placing.
    ii) Number of batching plants.
    iii) Number of trucks.
    iv) Number and positioning of pumps.
    v) Number of labours engaged.
    vi) Pour sequence.
    vii) Quality control measures.
    viii) Standby equipment.
    ix) Any other factors that might affect the placing of concrete.
c) The method statement should be submitted at least three days in advance of the planned pour. If required by the Engineer a pre-pour planning meeting may be arranged with representatives from the ready-mix supplier, Contractor and Engineer.
d) The Engineer must satisfy himself that the arrangement for transportation of concrete will ensure a nearly continuous flow of concrete during placing.
e) Sufficient lighting arrangements shall be made if concreting is allowed in the night.

f) Concrete shall be conveyed from the mixer to the location of work as rapidly as possible by methods which will prevent segregation or drying out and ensure that the concrete is of the required workability at the point and time of placing.
g) If segregation is noticed in the concrete, the materials shall be remixed to the satisfaction of the Engineer or discarded. The cause of the segregation shall be determined and further occurrences prevented.
h) The Contractor shall ensure that the time between placing of different lifts or layers of concrete is short enough to prevent the formation of cold joints.
i) The Contractor shall ensure that there is a back up plant that can be used in the event of a breakdown, and that adequate provision has been made for the number of delivery trucks.
j) The concrete shall be transported to the site in an approved type of truck mixer or agitator truck. The discharge chute and other dirty areas shall be washed down after delivery to prevent spillage on the roads.
k) If a truck mixer or a truck body with an agitator is used for central-mixed concrete, limit the volume of concrete charged into the truck to 80% of the drum or truck volume. If shrink mixing is approved by the Engineer, limit the volume of concrete charged into the truck to 63% of the drum volume.
l) All trucks shall be rotated 30 revolutions at mixing speed before discharging concrete to assure uniformity.
m) The insides of concrete mix trucks shall be inspected periodically, and any build up of concrete removed that may impair the efficiency of the mixing action.

607.2.8 Pumped concrete

a) Access for the pump shall be checked prior to the pour. If access cannot be assured, the Contractor shall not continue with concreting operations.
b) If approval is obtained for pumped concrete, the Contractor shall ensure that shock is not transferred from the pipeline to the formwork and previously laid concrete.
c) During placing of concrete by pumping, the end hose must never reach into the concrete. All measures shall be taken to avoid blockage of the delivery hose system.
d) Grout shall be pumped through the concrete pump to provide initial lubrication. The initial discharge of any pumped concrete shall not be incorporated in the permanent works.
e) Where concrete is conveyed by chuting or pumping, the plant shall be of a size and design to ensure continuous flow in the chute or pipe.
f) The slope of the chute or the pressure of the pump shall allow the concrete to flow without the use of any water additional to that approved by the Engineer to produce the required consistency and without segregation of the ingredients.
g) The delivery end of the chute or pipe shall be thoroughly flushed with water before and after each working period and kept clean. The water used for this purpose shall be discharged outside and away from any permanent works.

607.2.9 Preparation before placing concrete

a) No concrete shall be placed until the Engineer has inspected and approved in writing the surfaces upon which the concrete is to be placed, the formwork, and reinforcing steel.

b) The Contractor shall give the Engineer at least 24 hours notice to enable this inspection to be carried out. If concrete is not placed within 24 hours of approval being given, approval shall be obtained again before concreting. An inspection shall be made immediately prior to concreting to check the cleanliness of the forms.
c) Wood forms, unless lined, shall be oiled or wetted with water in advance of placing concrete so that joints will tighten and prevent seepage of cement grout from the mix.
d) Reinforcement shall be secured in position, inspected, and accepted by the Engineer before placing the concrete. A small quantity of water shall be sprayed on the reinforcement prior to starting the pour.
e) All inserts, anchor bolts, sleeves and other embedded items shall be accurately located, using templates where appropriate, and held securely to prevent displacement during the placing of the concrete. Aluminium items shall be completely covered and protected when embedded in the concrete.
f) Except where shown on the drawings, no fixtures shall be attached to the concrete by shot fixing or drilling without acceptance by the Engineer.
g) Water shall be removed from excavations before concrete is deposited. Any flow of water shall be diverted through proper side drains and shall be removed without washing over freshly deposited concrete.
h) Hardened concrete, debris, and foreign materials shall be removed from interior of forms and from inner surfaces of mixing and conveying equipment.
i) Before depositing new concrete on or against concrete that has set, existing surfaces shall be thoroughly roughened and cleaned of laitance, foreign matter and loose particles.
j) Forms shall be re-tightened and existing surfaces slushed with a grout coat of mortar consisting of cement and fine aggregate in the same proportion in the mix, but not leaner than 1:2, after the existing surface has been moistened.
k) New concrete shall be placed before the grout has attained initial set.
l) Horizontal construction joints shall be given a brush coat of grout consisting of cement and fine aggregate in the same proportion as concrete to be placed, followed by approximately 75 mm of concrete of regular mix, except that the proportion of coarse aggregate shall be reduced to 50%.

607.2.10 Placing of concrete

a) Concrete shall be placed in its final position before initial set has commenced and shall not be subsequently disturbed. All concrete shall be placed within 15 minutes of mixing unless carried in purpose made agitators.
b) Concrete shall be carefully placed in horizontal layers which shall be kept at an even height throughout the work. The depth of layers and time between placing of layers shall be such that each layer can be properly merged into the preceding layer before initial set takes place, the depth of layer shall be determined from the type of plant the Contractor proposes to use.
c) Concrete shall be allowed to slide or flow down sloping surfaces like chute or pipe or shovelled into position.
d) Concrete placed in horizontal slabs from barrows or other tipping vehicles shall be tipped into the face of the previously placed concrete.
e) Concrete dropped into place shall be dropped vertically. It shall not strike the formwork between the point of its discharge and its final place in the work, and

except by approval of the Engineer it shall not be dropped freely through a height greater than 1.5 m.

f) Chutes and conveyor belts shall be so designed that there is no segregation or loss of mortar and shall be provided with a vertical tapered down pipe, or other device, to ensure that concrete is discharged vertically into place.

g) Concrete shall not be placed in standing water in the formwork.

h) Concrete that has attained its initial set or has contained its water content for more than 1.5 hours or 300 drum revolutions, whichever comes first, shall not be deposited in the work.

i) During wet weather, the concrete shall be adequately protected as soon as it is in position.

j) No concreting shall be carried out during periods of continuous heavy rain unless it is completely covered during mixing, transporting and placing.

k) Underwater placing of concrete is allowed only for unreinforced components, the placing being effected exclusively with stationary tremies or with a bottom-opening watertight boxes and shall be in accordance with the requirements of design or equivalent as accepted.

l) Underwater concrete is to be placed continuously without interruption. For water depths up to 1m the concrete may be placed without tremie. In the case of water depths exceeding 1m the concrete is to be placed in such a way that it does not fall freely through the water.

m) The tremies must at all times, dip sufficiently far into the freshly placed concrete to ensure that the concrete emerging from the tremie does not come into contact with the water.

n) All works connected with the placing of concrete under water shall be designed, directed and inspected with due regard to local circumstances and purposes.

o) Stops in concrete, at the end of a period of work, shall be made only at construction joint locations shown on the drawings and/or positions accepted.

p) Where the positions of construction joints are not indicated on the drawings, these may be assumed, for estimating purposes, to occur at 5 m intervals in foundations and retaining walls and at one-third to one-quarter of span in slabs and beams subject to a maximum spacing of approximately 9 m.

q) At construction joint location, the surface of the completed concrete shall be prepared by wire brushing or chipping so that it is free from all laitance, scum and loose material and shows a slightly roughened texture and tips of the coarse aggregate exposed. Before continuing concreting the exposed concrete face shall be thoroughly wetted and grouted with rich mix.

r) Engineer's acceptance shall be obtained by the Contractor, prior to start of work, on the casting sequence and the layout of joints.

s) Waterstops shall be carefully maintained in position prior to concreting on accurately profiled stop boards to create rigid conditions.

t) The type of waterstops to be used shall suit the joint and purpose according to water bar manufacturer's recommendations.

607.2.11 Compaction

a) Mechanical vibrators used shall comply with IS: 2506, IS: 2514 and IS: 4656.

b) Concrete shall be thoroughly compacted by vibration during the operation of placing and thoroughly worked around the reinforcement, around embedded fixtures and into corners or the formwork to form a solid mass free from voids.

c) When vibrators are used to compact the concrete, vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation of the constituents of the concrete.

d) A sufficient number of vibrators in serviceable condition shall be on site to ensure that spare equipment is always available in the event of breakdown.

e) Operators shall be trained in the use of vibrators. Foremen shall have sufficient experience in the supervision of placing concrete.

f) The diameter of needle vibrator shall be decided from the consideration of the spacing between the reinforcing bars in the formwork.

g) The preferred frequency of needle vibrator shall be between 3000 and 6000 rpm with an acceleration of 4 gm to 10 gm.

h) The spacing of vibrator immersion depends on the radius of influence of vibrator (See figure 600-5) and it shall be preferable to immerse the vibrator into concrete at intervals of not more than 600 mm or 8 to 10 times the diameter of the needle vibrator.

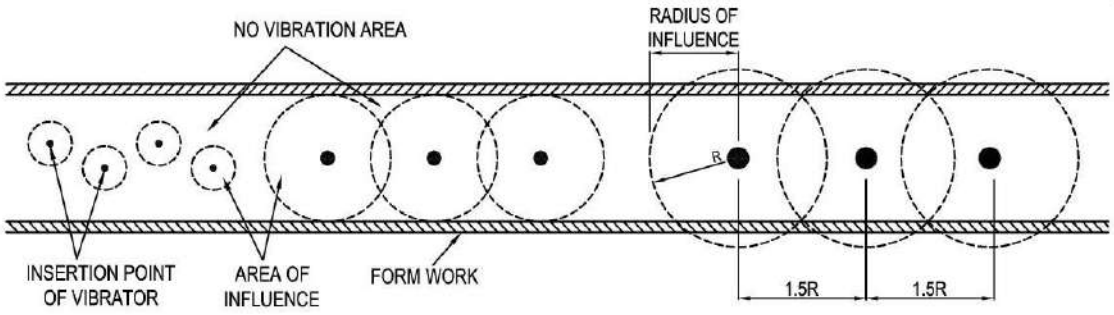


Fig. 600-5

i) The period of vibration required shall be of the order of 30 seconds to 2 minute. The concrete shall be placed in layers not more than 600 mm high.

j) Plunge the vibrator vertically into the concrete and do not use the vibrator to move concrete horizontally. Vibration of the concrete shall not be applied by way of the reinforcement.

k) Allow the vibrator to sink by means of its own weight to the bottom of the lift and penetrate the previous lift about 100 mm.

l) Manipulate the vibrator with an up-and-down motion for 5 to15 seconds to knit the two layers together.

m) Withdraw the vibrator gradually with a series of up-and-down motions so air bubbles are worked upward in front of the vibrator.

n) Rapidly extract the vibrator from the concrete when the head becomes partially exposed. If the vibrator hole does not close, partially and quickly reinsert the vibrator a short distance away from the hole.

o) During the placing of all reinforced concrete, a competent steel fixer and a competent carpenter shall be in attendance on each concreting gang. They shall ensure the reinforcement, embedded fittings and forms are kept in position as work proceeds.

607.2.12 Curing

a) The Contractor shall submit to the Engineer the proposed method of curing for approval.
b) The Contractor shall ensure that curing is provided for 24 hours per day including holidays and that all related necessary plant and labour resources are also available.
c) Freshly placed concrete shall be protected from sun, wind, exposure and excessive drying out. Moisture curing shall be commenced at the earliest after placing of concrete.
d) Immediately following form removal, the surfaces shall be kept continuously wet by a water spray or water-saturated fabric or until the membrane-forming curing compound is applied.
e) The Contractor shall adopt curing measures that preclude the possibility of thermal shock to the concrete during curing. This may be achieved by ensuring that the temperature of the water used for curing does not differ from that of the concrete by more than 15°C.
f) Curing shall continue for at least 7 days and until it attains an in-place compressive strength of the concrete of at least 70% of the specified compressive or flexural strength, whichever period is longer. Curing shall not stop unless otherwise approved by the Engineer.
g) When low water to cement ratio is used, the concrete shall be preferably cured by water.
h) Special attention shall be given to the curing of vertical and overhanging surfaces to ensure satisfactory curing.
i) All fresh concrete shall be cured by liquid membrane curing compound or equivalent as soon as possible, provided that the surface water has evaporated. The liquid membrane curing shall not be applied if bleed water is forming or is present on the concrete surface.
j) If the concrete is cured by liquid membrane, the applied film should be protected from rain for at least 3 hours and care should be taken to ensure that the film is not broken.
k) All concrete shall be cured for a period of time required to obtain the full specified strength, but not less than seven consecutive days. The method of curing shall be by water for the first seven days and by water or membrane until the concrete has reached the full specified strength.
l) For mixtures with a low to zero bleeding rate, or in the case of aggressively evaporative environments, or both, the curing shall start at early anytime between placement and final finishing of the concrete. The curing shall be by reducing the moisture loss from surface using fogging systems and the use of evaporation reducers such as monomolecular water curing compound.
m) The method of curing shall ensure that sufficient moisture is present to complete the hydration of the cement, and shall be to the approval of the Engineer. The method of curing shall not:
    i) Disfigure permanently exposed surfaces.
    ii) Affect bonding of subsequent coatings.
    iii) Increase the temperature of the concrete.
n) During the curing period, exposed concrete surface shall be protected from the direct rays of the sun.

Curing of formed surfaces:

a) Formed surfaces, including the underside of beams, girders, supported slabs and the like, by moist curing with the forms in place for the full curing period, or until the forms are removed.
b) In case of formed concrete if liquid membrane curing is used, it should be applied immediately after de-shuttering (Removal of the form). In such a case the concrete surface must be dampened with clean water prior to the application.

Moisture curing:

a) Moisture curing shall be performed by:
   i) Covering the surface of the concrete with water and keeping it continuously wet.
   ii) Continuous use of fine fog water sprays.
   iii) Covering the surface with a saturated absorptive cover and keeping it continuously wet.
   iv) Jute mats, cotton mats, and other absorbent materials can be used to hold water on horizontal or vertical surfaces.
   v) Wet straw or hay can be used for wet-curing small areas, but there is the danger that wind might displace it unless it is held down with screen wire, burlap, or other means.
b) Where method (i) is employed, the bunds used shall not be made from fill from excavations or any other areas where there is the possibility of chloride contamination.

Moisture retaining cover curing:

a) The concrete surface shall be covered with a suitable absorptive covering.
b) The absorptive covering shall be overlaid with a 1000 gauge polythene sheet.
c) The cover shall be in the widest practical widths and shall have 200 mm side and end laps.
d) The laps shall be sealed with adhesive tape.
e) Any penetrations or tear in the covering shall be repaired with the same material and waterproof tape.

Liquid membrane curing:

a) Membrane forming curing compounds shall be applied in accordance with the manufacturer's recommendations immediately after any water sheen which may develop after finishing has disappeared from the surface and within 2 h of stripping formwork on formed surfaces.
b) Membrane forming curing compounds shall not be used on surfaces against which additional concrete or other material is to be bonded unless:
   i) It is proven that the curing compound will not prevent bond, or
   ii) Positive measures are taken to remove it completely from those areas which are to receive bonded applications on fair faced concrete surfaces.

Steam curing:

a) An enclosure shall be formed around the concrete using tarpaulin or other suitable means.
b) Application of steam shall not be commenced until at least 2 hours after final placement of concrete.
c) Steam shall be applied at a temperature between 65°C and 80°C.

d) Excessive rates of heating and cooling shall be prevented during steam curing and temperatures in the enclosure shall not be allowed to increase or decrease by more than 22°C per hour.
e) The maximum steam temperature shall be maintained in the enclosure until concrete has reached its specified strength.

607.2.13 Ready mixed concrete

The requirements and testing of ready mixed concrete (RMC) shall be as per the requirements laid down in Section 3300 of Part C of this Manual.

607.3 Field checks to be effected during concrete work

a) In proportioning concrete, the quantity of both cement and aggregate shall be determined by weight.
b) Where the weight of cement bag as given by the manufacturer is accepted, a reasonable number of bags shall be weighed separately to check the net weight.
c) Where cement is weighed from bulk stock at site and not by bag, it shall be weighed separately from the aggregates.
d) Water shall either be measured by volume in calibrated tanks or weighed separately from the aggregates.
e) All measuring equipment shall be maintained in a clean and serviceable condition. Their accuracy shall be periodically checked.
f) The specified water-cement ratio shall always be kept constant and at its correct value.
g) Moisture content in both fine and coarse aggregates shall be determined as frequently as possible, the frequency for a given job being determined by the Engineer according to the weather conditions. The amount of water to be added shall then be adjusted to compensate for variations in the moisture content.
h) For the determination of moisture content in the aggregates IS: 2386 (Part 3) shall be referred. Suitable adjustments shall be made in the weight of aggregates to allow for the variation in weight due to variation in their moisture content.
i) It shall be ensured that any cut-outs or openings provided in any structural member to facilitate erection of formwork are closed with the same grade of concrete as that of the structure, after formwork is removed.
j) Provision for safe access to the formwork shall be made at all levels as required.
k) Close watch shall be maintained to check for settlement of formwork during concreting and any settlement shall be promptly rectified.
l) Natural ground shall be checked for bearing capacity and likely settlement before erection of the staging.
m) It shall be ensured that water used for curing or rain water does not stagnate near the base plate of the staging.
n) For shutters used for deep and narrow member, temporary openings in the side shall be provided to facilitate pouring and compaction of concrete.

607.4 Sampling and testing

a) Unless the Engineer directs otherwise, the Contractor shall include at least the tests on fresh concrete as specified in table 600-13.

Table 600-13: *Tests for concrete (Refer Cl.15.2.2 of IS: 456-2000)*

Sl. No.	*Test*	*Code*	*Quantity of concrete poured in the work*	*Number of tests/ samples*
1	Slump test	IS: 1199	Up to 5 m^3	1
2	Cube test*	IS: 516	5 to 15 m^3 16 to 30 m^3 31 to 50 m^3 Greater than 50 m^3	2 3 4 4+1 each, for every 50m^3 or part thereof.

NOTE:*For less than 5 m^3, test may be carried out as required by the Engineer.

b) Samples from fresh concrete shall be taken as per IS: 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS: 516.

c) In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72+2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test.

d) For this purpose the values should be arrived at based on actual testing. In all cases, the 28 days compressive strength as specified shall alone be the criterion for acceptance or rejection of the concrete.

e) A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested, that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

f) The minimum frequency of sampling of concrete of each grade shall be in accordance with table 600-13.

g) Three test specimens shall be made for each sample for testing at 28 days. Additional samples may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. The specimen shall be tested as described in IS: 516.

h) Additional samples may also be required for testing samples cured by accelerated methods as described in IS: 9103.

i) The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15% of the average. If more, the test results of the sample are invalid.

j) The concrete shall be deemed to comply with the strength requirements when both the following condition are met:
   i) The mean strength determined from any group of four consecutive test results compiles with the appropriate limits in table 600-14.
   ii) Any individual test result complies with the relevant limits in table 600-14.

k) Concrete of each grade shall be assessed separately.

l) To ensure that the construction complies with the design, an inspection procedure should be set up covering materials, records, workmanship and construction.

m) Concrete is liable to be rejected if it is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been met. However, the hardened concrete

may be accepted after carrying out suitable remedial measures to the satisfaction of the Engineer.

Table 600.14: *Characteristic compressive strength compliance requirements*

Specified grade	*Mean of the group of 4 non-overlapping consecutive test results (MPa)*	*Individual test results (MPa)*
M15	≥ f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 MPa) or f_{ck} +3 MPa, whichever is greater.	≥ f_{ck} - 3
M20 or above	≥ f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 MPa) or f_{ck} + 4 MPa, whichever is greater.	≥ f_{ck} - 4

NOTE: In the absence of established value of standard deviation, values given in table 8 of IS: 456-2000 may be assumed and attempt should be made to obtain result of 30 samples as early as possible to establish the value of standard deviation.

607.5 Inspection and testing of structures

607.5.1. Inspection

a) Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects shall be either removed or made good before concrete has thoroughly hardened.
b) Concrete members shall be inspected within 15 days for occurrence of cracks due to shrinkage, temperature, local restraint, undue deflection and deformation.

607.5.2. Testing of concrete in structures

In case of doubt regarding the grade of concrete in the structure, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete shall be carried out by core tests and/or non-destructive tests.

607.5.2.1 Core test

a) Cores shall be prepared and tested as described in IS: 516.
b) The location from which samples are to be taken and the number of samples required shall be decided so as to be representative of the whole concrete concerned. In no case the number of samples shall not be less than three.
c) Concrete tested shall be acceptable if the average equivalent cube strength of the cores is equal to at least 85% of the characteristic strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75%.

607.5.2.2 Non-destructive tests

a) Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of core specimen tested.
b) The methods used for non-destructive tests are Schmidt's Rebound Hammer test (IS: 13311 Part-2) and ultra sonic pulse velocity test (IS: 13311 Part-1).

607.5.3. Load test on structures

In case the core test and non-destructive test do not satisfy the strength requirements, load test may be carried out on superstructures as per SP: 51.

607.6 References

1.	IS: 456	Code of practice for plain and reinforced concrete.
2.	IS: 516	Method of test for strength of concrete.
3.	IS: 716	Specification for pentachlorophenol.
4.	IS: 1199	Method of sampling and analysis of concrete.
5.	IS: 1791	Specification for batch type concrete mixes.
6.	IS: 2502	Code of practice for bending and fixing bars for concrete reinforcement.
7.	IS: 2506	General requirements for concrete vibrators, screed board type
8.	IS: 2514	Specification for concrete vibrating tables.
9.	IS: 4656	Specification for form vibrators for concrete.
10.	IS: 2751	Recommended practice for welding of mild steel, plain and deformed bars for reinforced construction.
11.	IS: 4925	Specification for concrete batching and mixing plant.
12.	IS: 10262	Recommended guidelines for concrete mix design.
13.	IS: 13311	Non-destructive testing of concrete:
	(Part-1)	*Method of test for ultrasonic pulse velocity.*
	(Part-2)	*Method of testing by rebound hammer.*

608 FORMWORK

This part includes formwork and false work for structural cast-in-place concrete.

608.1 Requirements/workmanship

a) The Contractor shall submit samples of all proposed formwork materials and samples of ties proposed for use in general situations above the water table and for fair faced concrete.

b) Formwork and associated false-work for buildings shall be designed to comply with the requirements of IS: 14687.

c) Forms shall be of wood, metal or other material acceptable to the Engineer.

d) The design of formwork shall be the responsibility of the Contractor.

e) Form oil and form sealer shall be of approved quality.

f) The erection of formwork and associated false-work shall be executed and supervised by fully skilled and qualified personnel having a minimum of three years experience.

g) The Contractor shall obtain approval to load any particular section of the works from the Engineer.

h) The erected formwork shall be watertight from the ingress of external liquids and the egress of internal liquids. Adjustable steel supports and shores shall allow form boards and framework to be accurately adjusted to line and level.

i) The Contractor shall ensure that adequate ground support for false work is available, and if not, shall take measures to make them suitable.

j) Formwork shall be designed to be sufficiently rigid to maintain the correct position, shape and profile so that the final concrete structure is within the dimensional tolerances specified in Clause 608.2.

k) Formwork shall be designed to be demountable without causing shock, disturbance or damage to the concrete.

l) Care shall be taken to ensure that the finish to the exposed concrete on the external and internal surfaces are of the highest quality to produce a smooth

concrete surface of uniform texture and appearance without visible imprint of grains, steppings or ridges.

m) The resulting concreting shall be free from honeycombing, stains, fins, lipping, nail and screw marks, raised grain marks or any other imperfections and shall be of a uniform surface texture and colour. Only very minor surface blemishes caused by entrapped air or water will be accepted provided that they do not exceed 0.5% by area of each square metre considered separately and in addition they shall not be concentrated in a manner such that they are noticeable.

n) All exposed concrete corners and edges shall have 20 mm x 20 mm chamfers. Fillet and chamfer strips shall be PVC or timber to the approval of the Engineer.

o) Formwork in contact with the concrete shall be treated with a suitable release agent to prevent adherence of the concrete.

p) Forms for exposed surfaces shall be coated with oil before reinforcement is placed. Forms for unexposed surfaces may be thoroughly wetted with water in lieu of oiling, immediately before placing of concrete.

q) Excessive oiling of the forms shall not be permitted in order to prevent discoloration of the cement plaster. Where concrete surface is to be painted, the form-oil must not affect the bond between concrete and paint.

r) Care shall be taken to prevent the oil from coming in contact with reinforcement or with concrete at construction joints. Any oil on reinforcing steel shall be removed.

s) Tapes to be used to seal joints of formwork panels for smooth finish concrete shall be plastic faced adhesive tape approved by the Engineer.

t) Where formwork to external faces will be permanently exposed, all horizontal and vertical formwork joints shall be so arranged that joint lines will form a uniform pattern on the face of the concrete.

u) Where the Contractor proposes to make up the formwork from standard sized manufactured formwork panels, the size of such panels shall be approved by the Engineer before they are used in the construction of the Works.

v) The finished appearance of the entire elevation of the structure and adjoining structures shall be considered when planning the pattern of joint lines caused by the formwork and by the construction joints to ensure continuity of horizontal and vertical lines.

w) Faces of formwork in contact with concrete shall be free from adhering foreign matter, projecting nails and the like, splits or other defects, and all formwork shall be clean and free from standing water, dirt, shavings, chippings or other deleterious matter.

x) The Contractor shall verify lines, levels and measurement before proceeding with formwork erection.

y) Formwork shall be provided for the top surfaces of sloping work where the slope exceeds 15° from the horizontal (except where any such top surface is specified as a spaded finish).

z) The formwork shall be anchored to enable the concrete to be properly compacted and to prevent flotation.

608.1.1 Conduits

a) Conduits or pipes shall be located so as not to reduce the strength of the construction.
b) In no case shall pipes other than conduits be placed in a slab 125 mm or less in thickness.
c) Conduits embedded in a concrete slab shall not have an outside diameter greater than one-third the thickness of the slab nor be placed below the bottom reinforcing steel or over the top reinforcing steel.
d) Pipes and conduits where embedded shall be placed as nearly as possible to the centre line of the concrete section.

608.1.2 Stripping of formwork

a) Forms shall not be released until the concrete has achieved strength of at least twice the stress to which the concrete may be subjected at the time of removal of formwork.
b) The period of time elapsing between the placing of the concrete and the striking of the formwork shall be approved by the Engineer after consideration of the loads likely to be imposed on the concrete and shall in any case be not less than the periods as shown in table 600-15 (Clause 11.3.1 of IS: 456).

Table 600-15: *Stripping time of formwork (When OPC is used)*

No.	*Type of formwork*	*Minimum period before striking formwork*
1.	Vertical formwork to columns, walls, beams	16 to 24 hrs
2.	Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
3.	Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
4.	Props to slabs: i) Spanning up to 4.5 m ii) Spanning over 4.5 m	 7 days 14 days
5.	Props to beams and arches: i) Spanning up to 6 m ii) Spanning over 6 m	 14 days 21 days

NOTE: For other cements and lower temperature, the stripping time recommended above may be suitably modified.

c) The number of props left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch as the case may be together with any live load likely to occur during curing or further construction.
d) Where the shape of the element is such that the formwork has re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set to avoid shrinkage cracking occurring due to the restraint imposed.
e) Stripping of the formwork within the time limits listed above does not relieve the Contractor from successfully crushing test cubes and achieving the compressive strength as specified.

f) Notwithstanding the foregoing, the Contractor shall be held responsible for any damage arising from removal of formwork before the structure is capable of carrying its own weight and any incidental loading.

608.2 Tolerances

a) Deviations of specified dimensions of cross sections of beams and columns shall be +12 or -6 mm.
b) Deviations of specified plan dimensions of footings shall be +50 or -12 mm.
c) Deviations of specified thickness of footings shall be ± 0.05 times the specified thickness.

608.3 References

1. IS: 14687 False work for concrete structures - guidelines.

SECTION 700 DOORS AND WINDOWS

701 GENERAL

The main function of a door in a building is to serve as a connecting link between the internal parts and to allow free movement to the outside of the building. Windows are generally provided for the proper ventilation and lighting of a building and their size and number should be properly determined as per the requirements. The requirements for wooden, steel, aluminium, PVC doors and windows are given in this section.

702 TIMBER

a) The timber shall be free from decay, fungal growth, boxed heart, pitch pockets or streaks on the exposed edges, splits and cracks.
b) The timber shall be graded as first grade and second grade on the basis of the permissible defects in the timber as given in Appendix A (Clause 9.1) of CPWD Specifications 2009.
c) For both the grades, knots should be avoided over a specified limit.

702.1 Moisture content

a) Control on moisture content of timber is necessary to ensure its proper utility in various climatic conditions. For specifying the permissible limit of moisture content in the timber the country has been divided into four climatic zones.
b) In each of the zones, maximum permissible limit of moisture content of timber for different uses, when determined in accordance with the procedure detailed below shall be as per table 700-1.
c) Moisture content of timber shall be checked for every 1 m^3 or part thereof by electrical moisture meters as per IS: 287.
d) Average moisture content of all the samples from a lot shall be within +3% and moisture content of individual samples within +5% of maximum permissible moisture content specified in table 700-1. These tolerances are the absolute values over the percentage moisture content for Sl. Nos. 1 & 2 of table 700-1. No tolerance on moisture content is permitted for Sl. Nos. 3 & 4 of table 700-1 as described in IS: 287.

Table 700-1: *Maximum permissible moisture content of timber*

Sl. No.	*Use*	*Zone I*	*Zone II*	*Zone III*	*Zone IV*
1.	Beams, Rafters & Posts	12	14	17	20
2.	Doors and windows:				
	i) Thickness 50 mm and above.	10	1	14	16
	ii) Thinner than 50 mm.	8	1	12	14
3.	Flooring strips	8	1	10	12
4.	Furniture and cabinet making	10	12	14	15

NOTE: Zones I, II, II and IV represents various regions in India which are marked in figure 700-1.

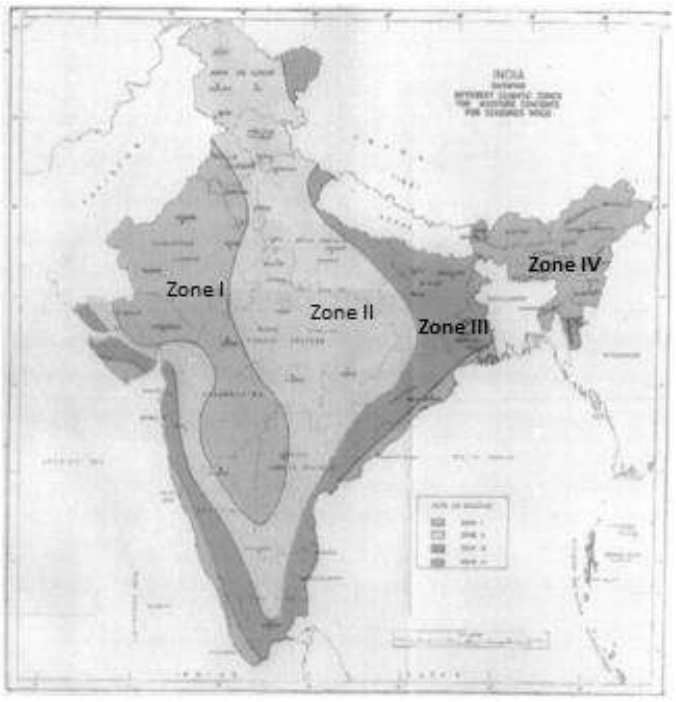


Fig. 700-1

702.2 Seasoning of timber

a) The process of drying timber under controlled conditions is called seasoning of timber. Timber shall be either air seasoned or kiln seasoned and in both cases moisture content of the seasoned timber shall be as specified in table 700-1. Unless otherwise specified, air seasoned timber shall be used. Kiln seasoning of timber, where specified, shall be done as per IS: 1141 in a plant approved by the Engineer.

b) Preservative treatment of timber shall be done as per IS: 401 in a plant approved by the Engineer.

702.3 Quality control tests

Table 700-2: *Moisture content test for timber*

Test	*Code*	*Frequency of testing*
Moisture content (Laboratory/field)	IS: 287	One test for every 1 m^3 or part thereof.

703 FRAMES FOR DOOR, WINDOW AND VENTILATOR

a) Timber for door, window and ventilators frames shall be as specified.

b) The frames shall be got approved by the Engineer before being painted, oiled or otherwise treated and before fixing in position.

c) A minimum of two hold fasts shall be fixed on each side of door frame one at centre point and other at 30 cm from bottom of the frame.

d) In case of window frames, at least one hold fast shall be fixed on each side at centre point of the frames. For windows more than 1.5 m height, minimum two hold fasts shall be fixed on each side of the frame one at each quarter point.

704 SHUTTERS – PANELLED, GLAZED OR PANELLED AND GLAZED

a) Panelled or glazed shutters for doors, windows, ventilators and cupboards shall be constructed in the form of timber frame work of stiles and rails with

panel inserts of timber, plywood, block board, veneered particle board, fibre board wire gauze or float glass.

b) The shutters may be single or multi-panelled, as per the Drawings or as directed by the Engineer.

c) Standard sizes of door frames are covered in IS: 4021 and IS: 4351.

d) Window and ventilator shutters shall conform to IS: 1003 (Part 2).

705 FLUSH DOOR SHUTTERS

a) Flush door shutters shall have a solid core and may be of the decorative or non-decorative (Paintable type as per IS: 2202-Part 1).

b) Thickness and type of shutters shall be as specified.

c) Width and height of the shutters shall be as shown in the drawings or as indicated by the Engineer.

d) All four edges of the shutters shall be square.

e) The shutter shall be free from twist or warp in its plane.

f) The moisture content in timbers used in the manufacture of flush door shutters shall be not more than 12 per cent when tested according to IS: 1708 (Part 1).

705.1 Quality control tests for flush doors

a) Samples of flush door shutters shall be subjected to the following tests viz., end immersion test, knife test and glue adhesion test.

b) One end of each sample shutter shall be tested for end immersion test.

c) Two specimens of 150 mm x 150 mm size shall be cut from the two corners at the other end of each sample shutter for carrying out glue adhesion test.

d) Knife test shall be done on the remaining portion of each sample shutter.

e) For knife test, glue adhesive test and end immersion test, the number of shutters for test shall be as per table 700-3.

Table 700-3: *Sample size and criteria for conformity*

Lot size	*Field sample*	*Test sample for laboratory test*	*Permissible number of defective*
From 21 to 50	8	1	0
51 – 100	13	2	1
101 – 150	20	2	1
151 – 300	32	3	1
301 – 500	50	4	2
501 and above	80	5	2

f) The frequency of tests shall be as given in table 700-4.

Table 700-4: *Quality tests for door shutters*

Test	*Code*	*Minimum sample size*	*Frequency of Testing*
End immersion test	IS: 4020 (Part 13) IS: 2202 (Part 1)	21 shutters	As per sampling and testing specified in table 700-3.
Knife test	IS: 4020 (Part 14) IS: 2202 (Part 1)		
Glue adhesion test	IS: 4020 (Part 15) IS: 2202 (Part 1)		

706. STEEL DOORS AND WINDOWS

706.1 Materials

a) Rolled steel sections for the fabrication of steel doors, windows, ventilators and fixed-lights shall conform to IS: 7452. Steel used in the manufacture of these sections shall conform to IS: 7452.
b) The fabricated steel doors and windows shall confirm to IS: 1038.
c) Glass panes shall be at least at 3 mm thick and shall conform to IS: 2835. All glass panes shall have properly squared corners and straight edges.
d) Screw threads of machine screws used in the manufacture of steel doors, windows, ventilators and fixed-lights shall conform to the requirements of IS: 4218 (Parts 1 to 6)
e) Fixed and open frame shall be constructed of sections which have been cut to length and mitred. The corners of fixed and opening frames shall be welded to form solid fused welded joint conforming to the requirements. All frames shall be square and flat. The process of welding adopted may be flash butt welding or any other suitable method which gives the desired requirements.
f) All the steel surface shall be thoroughly cleaned free of rust, millscale, dirt, oil, etc.
g) All doors, windows, ventilators and fixed-lights shall carry an identification of the manufacturer or trade-mark, if any and the process of welding adopted.
h) Each unit shall be marked with BIS certification mark.
i) All doors, windows and ventilators shall be despatched with the opening parts suitably secured to preserve alignment when fixing and glazing.
j) Fixing lugs, couplings, fittings and all hardware shall be despatched separately.
k) Composite windows shall be despatched uncoupled.

706.2 Sampling and criteria for conformity

a) The number of doors/windows/ventilators/fixed-lights to constitute the sample, to be selected from a lot shall depend upon the size of the lot and shall be in accordance with table 700-5.

Table 700-5: *Scale of sampling*

Lot size (no. of doors/windows/ ventilators/ fixed-lights in the lot)	*Sample size (no. of doors/windows/ ventilators, fixed-lights, to be selected in the sample)*	*Permissible no. of defectives*	*Sub sample size*	*Permissible no. of defectives in the sub-sample*
Up to 50	5	0	2	0
51 to 150	8	0	3	0
151 to 300	13	1	5	0
301 to 500	20	2	8	0
501 to 1000	32	3	13	1
1001 to 3000	50	5	20	2

b) The doors/windows/ventilators/fixed-lights for the sample shall be selected at random from the lot.
c) In order to ensure the randomness of selection of the sample procedures given in IS: 4905 may be followed.
d) The doors windows/ventilators/fixed-lights selected in the sample shall be inspected for dimensions, tolerances, materials, fabrication except positioning of holes, fixing screws and lugs, finishing and glazing.

707 PRESSED STEEL DOORS AND WINDOWS

a) Mild steel sheet, round bars, square bars and other sections used in the fabrication shall conform to grade Fe410W A of IS: 2062.
b) CR-sheet used in the fabrication shall conform to IS: 513.
c) Pressed steel shutters/frames for door/windows shall be de-rusted, degreased & painted with one coat of metal primer.
d) Rolling and cutting tolerances shall conform to IS: 1852.
e) The finished products shall be reasonably free from surface flaws, laminations, rough/jiggered and imperfect edges and other harmful defects.
f) The stores shall be marked for the identity of the manufacturer.
g) At the time of supply, the Contractor shall produce manufacturer's test certificate for the steel used.

708 PRE-COATED GALVANISED STEEL DOORS AND WINDOWS

a) Galvanised pre-coated steel sections are unique roll formed closed sections with seaming edges and are subsequently fabricated into doors, windows, partitions, structural glazing etc. using high quality accessories and EPDM gaskets.
b) The sections are fabricated from Galvanized Pre-coated steel sheets through roll forming into closed sections in intricate shapes with seamed edges (Base steel as per IS 513 'D' quality, galvanized as per IS: 277 with zinc of 120 gm/m^2) with total coated thickness of 0.6 mm.
c) The coatings of zinc, primer and polyester paint ensures unmatched protection to steel against corrosion. Sections shall be coated with primer coat of epoxy primer of 5 to 7 microns thick, finish painted with a polyester paint of 12 to16 microns thick and back coated with Alkyd backer of 5 to 7 microns, or powder coated with pure polyester powder up to 50 to 60 microns thick.
d) The requirements of the coatings shall be tested as per the codes given in table 700-6.
e) The scientifically designed EPDM gaskets around the glass and the shutter give perfect sealing and eliminate leakages when the windows are closed. This reduces load on air conditioning apart from providing sound insulation.

Table 700-6 : *Requirements of coatings*

Sl. No.	*Property*	*Code*
1	Specular gloss	ASTM D 523
2	Pencil hardness	ASTM D 3363
3	Scratch resistance	BS 3900
4	Reverse impact	BS 3900
5	Bend test	BS 3900
6	Erichsen test	IS: 10175
7	Adhesion	BS 3990
8	Corrosion resistance: a) Salt spray b) Humidity c) QUV weatherometer	 ASTMB- 117-73 BS 3900 ASTM G-53-84
9	Fire performance a) Ignitability b) Fire rating	 BS 476 BS 476
10	Detergent resistance	ASTM D-2248

708.1 Openable window systems

a) The sections used shall be as detailed under clause 708(b) and precoated as detailed under clause 708(c).
b) Section for shutter frame shall be of nominal size 46 mm x 46 mm x 0.6 mm and outer frame shall be of 46 mm x 52 mm 0.6 mm. Section for glass beading shall be of 18 mm x 25 mm 0.6 mm and center mullion shall be of 46 mm x 70 mm x 0.6 mm.
c) The frame and shutter sections shall be cut to length and mitre joined with corner bracket made of nylon. Mullion section should be joined with frame/ mullion using Nylon Mullion Cap Ethyl Propylene Diamine Monomer (EPDM) gasket shall be used all around glass in shutter, between frame and glazed shutter and both sides of fixing glass.
d) Handle shall be made of powder coated galvanised Iron and with nylon receiver. Gaskets made of Ethyl Propylene Diamine Monomer (EPDM). Corner brackets made of Nylon. Mullion caps made of glass filled nylon.
e) Glass shutter shall be provided with a glass of 4 mm plain float glass
f) Window frame shall be fixed to brick / concrete masonry by using Nylon self-expanding caps and driving MS electroplated 80 mm long screws into the caps through frames.
g) Guard bars shall be fixed at 15 cm gap (Centre to centre) made of 10 mm nominal square rods with one coat of metal primer and one coat of enamel paint of approved colour, in required length, with 5mm diameter holes with 6mm countering, drilled as required and fixed to the window frame and mullions with 3x3/16 aluminium popup rivets.

708.2 Openable Door systems

a) The sections used shall be as detailed under clause 708(b) and precoated as detailed under clause 708(c).
b) Sections for shutter shall be of nominal size 46 mm x 46 mm x 0.58 mm and external frame should be of 46 mm x 52mm x 0.58 mm, middle and bottom rail (Lock rail and Kick rail) of size shall be 23 mm x 130 mm x 0.58 mm.
c) The frame and shutter sections shall be cut to length and mitre joined with corner bracket made of CRCA electroplated. Ethyl Propylene Diamine Monomer (EPDM) gasket shall be used all around glass in shutter, between frame and glazed shutter and both sides of fixed glass.
d) Hinges shall be made of 2.5 mm thick CRCA powder coated.
e) Glass shutter shall be provided with a glass of 5 mm plain float glass. BSL wooden particle board for interior and cement particle board for exterior may be used upto a maximum thickness of 10 mm.
f) The frame shall be fixed to brick/ concrete masonry by using nylon self-expanding caps and driving MS electroplated 80 mm long screws into the caps through frames.

708.3 Sliding window systems

a) The sections used shall be as detailed under clause 708 (b) and precoated as detailed under clause 708 (c).
b) The frame and shutter sections shall be cut to length and mitre joined with corner bracket made of nylon. EPDM gasket should be used all around glass in shutter.

c) Corner brackets are made of polypropylene. Shutters to be provided with aluminium push lock, wool pile for lap strip and a bump stop made of plastic & rubber and nylon rollers.
d) Glass shutter shall be provided with a glass of 4 mm plain float glass.
e) Window frame shall be fixed to brick/concrete masonry by using nylon self-expanding caps and driving MS electroplated 80 mm long screws into the caps through frames.

709 PVC/UPVC DOORS

a) The PVC shutters and solid PVC door frames shall be fabricated at factory as per the Specifications and directions of the Engineer.
b) Shutter shall be made of PVC material conforming to IS: 10151.

709.1 Quality control tests

Quality tests prescribed for door shutters are detailed below:

a) *Dimension and squareness test:* Door shutters when tested in accordance with IS: 4020 (Part 2) the dimensions of nominal width and height will be within a limit of ±5 mm. The door shutter shall not deviate by more than 1 mm on a length of 500 mm. The thickness of the door shutter shall be uniform throughout with the permissible variation of not more than 0.8 mm between any two points. The nominal thickness of the shutter shall be within a limit of ±1.5 mm.
b) *General flatness test:* Door shutter, when tested in accordance with IS: 4020 (Part 3) the twist, cupping and warping shall not exceed 6 mm.
c) *Local planeness test:* Door shutters, when tested in accordance with IS: 4020 (Part 4), the depth of deviation measured at any point shall not be more than 0.5 mm.
d) *Impact indentation test:* Door shutters, when tested in accordance with IS: 4020 (Part 5), shall have no defects such as cracking, tearing or delamination and the depth of indentation shall not be more than 0.2 mm.
e) *Edge loading test* - Door shutters, when tested in accordance with IS: 4020 (Part 7) the deflection of the edge at the maximum load shall not be more than 5 mm. On removal of the loads, the residual deflection shall not be more than 0.5 mm, failing which the test may be repeated on the other edge in the reverse direction. Also there shall be no lateral buckling by more than 2 mm during loaded condition and no residual lateral buckling after removal of the load.
f) *Shock resistance test:* Door shutters, when tested in accordance with IS: 4020 (Part 8), there shall be no visible damage in any part of the door after twenty five blows on each end.
g) *Buckling test:* Door shutters, when tested in accordance with IS: 4020 (Part 9), shall not show any deterioration and any residual deformation more than 5 mm after 15 minutes of unloading and the initial deflection also shall not be more than 50 mm.
h) *Slamming test:* Door shutters, when tested in accordance with IS: 4020 (Part 10), shall not have any damage in any part of the door at the end of successive impacts. Door shutters, when tested in accordance with IS: 4020 (Part 10), shall not have any visible damage in part of the door at the end of 100 successive impacts.

i) *Misuse test:* Door shutters, when tested in accordance with IS: 4020 (Part 11), there shall not be any permanent deformation of the fixing or any other part of the door set in hindering its normal working after the test.
j) *Screw holding test:* Door shutters, when tested in accordance with IS: 4020 (Part 16), the load shall not be less than 1000 N.
k) *End immersion test:* Door shutters, when tested in accordance with IS: 4020 (Part 13), the shutter shall not show any delamination.
l) *Knife test:* Door shutter, when tested in accordance with IS: 4020 (Part 14), the grading shall be standard and excellent.
m) *Glue adhesion test:* Door shutters when tested in accordance with IS: 4020 (Part 15d, shall not show any delamination.

710 ALUMINIUM DOORS AND WINDOWS

a) Material, fabrication and dimensions of aluminium doors, windows and ventilators manufactured from extruded aluminium alloy sections of standard sizes and designs complete with fittings, ready for being fixed into the building shall be as per IS: 1948.
b) In the case of composite windows and doors, the different units are to be assembled first. The assembled composite units shall be checked for line, level and plumb before final fixing is done.
c) Where aluminium comes into contact with stone masonry, brick work, concrete, plaster or dissimilar metal, it shall be coated with an approved insulation lacquer, paint or plastic tape to ensure that electrochemical corrosion is avoided. Insulation material shall be trimmed off to a clean flush line on completion.
d) The contractor shall be responsible for the doors, windows etc. being set straight, plumb, level and for their satisfactory operation after fixing is complete.
e) Aluminium alloy extruded sections used in the manufacture of extruded window sections shall conform to IS: 733. Hollow aluminium alloy sections used shall conform to IS: 1285.
f) Glass panes shall weigh at least 7.5 kg/m^2 and shall be free from flaws, specks or bubbles. All panes shall have properly squared corners and straight edges.
g) Screws threads of machine screws used in the fabrication of aluminium doors, windows and ventilators shall conform to IS: 1362.
h) Frames shall be square and flat, the corners of the frame being fabricated to a true right angle. Both the fixed and opening frames shall be constructed of sections which have been cut to length, mitred and welded at the corners. Where hollow sections are used with welded joints, argon-arc welding or flash butt welding shall be employed (gas welding or brazing not to be done). Subdividing bars of units shall be tenoned and riveted into the frame.
i) Aluminium doors, windows and ventilators may be supplied in either matt, scratch-brush or polished finish. They may, additionally, also be anodized, if so required by the Engineer. If colour anodizing is to be done then only approved light-fast shades should be used.
j) All doors, windows and ventilators shall be dispatched with the opening parts suitably secured to preserve alignment when fixing and glazing. Fixing lugs, coupling fittings and all hardware shall be dispatched separately. Composite

windows shall be dispatched uncoupled.

k) All doors, windows and ventilators shall be suitably marked on the frames with a mark identifying the manufacturer and the type. The units may also be marked with the BIS certification mark.

l) The aluminium alloy for cast hinges shall conform to BIS Designation A-5-M of IS: 617.

m) Specification for aluminium and aluminium alloy ingots and castings for general engineering purpose and for extruded section of hinges to BIS Designation HE10-WP or HE30-WP of IS: 733.

n) The aluminium hinges for top-hung ventilators shall be either cast or fabricated out of extruded sections and shall be riveted to the fixed rail after cutting a slot in it.

o) Centre hung ventilators shall be hung on two pairs of cup pivots of aluminium alloy to BIS designation NS-4 of IS: 737 and BIS designation A-5-M of IS: 617 or on brass or bronze cup pivots which should be either chromium or cadmium plated and riveted to the inner and outer frames of the ventilators to permit the ventilator to swing through an angle of approximately 85°.

710.1 Fittings for aluminium doors and windows

a) *Stainless steel friction stay:* The stainless steel friction stays of make approved by the Engineer shall be used. The SS friction stays shall be of grade AISI-304 and of sizes specified in nomenclature of item.

b) *Lockable handles:* The lockable handle shall be of make approved by the Engineer and of required colour to match the colour of powder coated /anodized aluminium window sections.

c) *Hydraulic floor spring:* The hydraulic floor spring shall be heavy duty double action floor spring of make approved by the Engineer suitable for door leaf of weight minimum 100 kg.

d) *Tubular handle:* The tubular handle bar shall be aluminium polyester powder coated minimum 50 micron of required colour/anodized AC 15. Outer dia of tube shall be 32 mm, tube thickness 3.0 mm and centre to centre length of 2115 ±5 mm.

e) *Louvers:* Aluminium extruded sections (anodized or power coated) are used for providing louvers in aluminium door, window and partition for ventilation.

f) *Brass lock:* This should generally conform to IS: 2209. False lever shall not be used. Lever shall be fitted with one spring of phosphor-bronze or steel wire and shall withstand the test as provided in IS: 2209. Locking-bolt spring and strike plate shall conform to IS: 2209. Two keys shall be provided with each lock.

711 FIBRE GLASS REINFORCED PLASTIC (FRP) DOORS

FRP doors and shutters shall be manufactured as per specifications laid down in IS: 14856, nomenclature of items and direction of the Engineer.

712 SOLID PVC FOAM PROFILE DOORS

a) Solid PVC foam profile frame doors are made from solid PVC foam profiles 60 x 30 mm with integral skin cut to required size.

b) Doors are provided with naturally strong stiffener frame and sandwich panelled to offer sound and heat insulation with pressure laminate/infill panel to provide scratch resistance surface.

c) Tests on PVC foam profiles shall be as per table 700-7.

Table 700-7: *Quality tests for PVC foam profile doors*

Sl. No.	*Property*	*Test method*	*Acceptable value*
1	Density (at 27°C)	ASTM D 792	0.5-0.7 gm/cc
2	i) Tensile strength at yield ii) Elongation at break	ASTM D 638 ASTM D 638	2000 psi 20%
3	Tensile modulus (Modulus of elasticity)	ASTM D 638	200 MPa
4	Impact strength (Charpy unnotched)	ASTM D 256	7 ftlb/in^2
5	Durometer hardness	DIN 53505	70 shore D
6	Vicat softening point (at 10N Load)	ASTM D 1525	75°C
7	Flammability	UL 94	Self extinguishing.

713 LAMINATED VENEER LUMBER (LVL)

Laminated veneer lumber door frames and shutters shall conform to IS: 14616.

714 UPVC DOOR FRAME

UPVC door frame shall be made of PVC material conforming to IS: 10151.

715 DOOR/WINDOW FITTINGS

715.1 Butt hinges

These shall be of the following types according to the material used.

(i) Mild steel butt hinges (medium).

(ii) Cast brass butt hinges light/ordinary or heavy.

(iii) Extruded aluminium alloy butt hinges.

715.2 Parliament hinges

These shall be of mild steel cast brass or as specified, and shall generally conform to IS: 362.

715.3 Spring hinges

These shall be made of MS or brass as specified, and shall generally conform to IS: 453.

715.4 Door handles (for Doors and windows)

These should generally conform to IS: 208.

715.5 Floor door stopper

a) The floor door stopper shall conform to IS: 1823.

b) Aluminium stopper shall be anodised and anodic film shall not be less than grade AC-10 of IS: 1868.

715.6 Door closers

The nominal size of door closers in relation to the weight and the width of the door size to which it is intended to be fitted shall be as per table 700-8 (Ref. IS:3564).

Table 700-8: *Type and designation of door closers*

Designation of closers	*Mass of the door (kg)*	*Width of the door (mm)*	*Remarks*
1	Upto 35	Upto 700	For light doors such as double leaved and toilet doors.
2	36 to 60	701 to 850	Interior doors, such as of bed rooms, kitchen and store.
3	61 to 80	851 to 1000	Main doors in a building, such as entrance doors.

715.7 Mortice locks

715.7.1 Test for mortice locks

Test for mortice locks are carried out as per IS: 2209. The frequency of tests shall be as given in table 700-9. At the time of supply, the Contractor shall produce manufacturer's certificate as required.

Table 700-9: *Test for mortice lock*

Material	*Code*	*Min. quantity of material for carrying out the test*	*Frequency of testing*
Mortice locks	IS: 2209	50 Nos.	100 or part thereof.

716 REFERENCES

1. IS: 204 (Part 1) (Part 2) Specification for tower bolts: *Ferrous bolt.* *Non ferrous metals.*
2. IS: 205 Specification for non ferrous metal butt hinges.
3. IS; 206 Specification for Tee and strap hinges.
4. IS: 207 Specification for gate and shutter hook and eye.
5. IS: 208 Specification for door handles.
6. IS: 281 Specification for mild steel door bolts for use with pad locks.
7. IS: 287 Recommendations for maximum permissible moisture contents of timber used for different purpose.
8. IS: 303 Specification for plywood for general purposes.
9. IS: 362 Specification for parliament hinges.
10. IS: 363 Specification for hasps and staple.
11. IS: 364 Specification for fan light catch.
12. IS: 401 Code of practice for preservation of timber.
13. IS: 419 Putty for use on window frames.
14. IS: 451 Technical supply condition for wood screws.
15. IS: 452 Specification for door spring rat tail type.
16. IS: 453 Specification for double acting spring hinge.
17. IS: 707 Glossary of terms applicable to timber technology and utilization.
18. IS: 710 Specifications for marine plywood.
19. IS: 723 Specification for steel counter sunk head wire nails.
20. IS: 729 Specification for drawer lock, cupboard lock and box locks.
21. IS: 848 Specification for synthetic resin adhesive for plywood (phenoic and amino plastic).

22.	IS: 851	Specification for synthetic resin adhesive for const. work (non structural in wood).
23.	IS: 852	Specification for animal glue for general wood work purpose.
24.	IS:1003 (Part 2)	Specification for timber panelled and glazed shutter: *Window and ventilator shutter.*
25.	IS: 1038	Specification for steel doors, windows and ventilators.
26.	IS: 1141	Specification for code of practice for seasoning of timber.
27.	IS:1200 (Part 12) (Part 14)	Method of measurement of building and civil engineering works: *Wood work and joinery.* *Glazing.*
28.	IS: 1328	Specification for veneered decorative plywood.
29.	IS: 1341	Specification for steel butt hinges.
30.	IS: 1378	Specification for oxidized copper finishes.
31.	IS: 1566	Specification for hard drawn steel wire fabric.
32.	IS: 1568	Specification for wire cloth for general purposes.
33.	IS: 1658	Specification for hard drawn steel wire fabric.
34.	IS: 1659	Specification for block boards.
35.	IS: 1708	Testing of small clear specimen for timber.
36.	IS: 1734	Determination of density and moisture content.
37.	IS: 1823	Specification for floor door stopper.
38.	IS: 1868	Specification for anodic coating on aluminium and its alloy.
39.	IS: 2046	Decorative thermosetting synthetic resin bonded laminated sheet.
40.	IS: 2095	Specification for gypsum plaster board.
41.	IS: 2096	Specification for asbestos cement flat sheet.
42.	IS: 2202 (Part 1) (Part 2)	Specification for wooden flush door shutter, solid core type: *Plywood face panels.* *Particle boards and hard board face panels.*
43.	IS: 2209	Specification for mortice lock: *Vertical type*
44.	IS: 2380	Method of test for wood particle board and board for lignocelluloses material.
45.	IS: 2547	Specification for gypsum plaster.
46.	IS: 2753	Method for estimation of preservatives in treated timber and in treating solutions.
47.	IS: 2681	Specification for non-ferrous metal sliding door bolts use with pad locks.
48.	IS: 3087	Specification for wood particle boards (Medium density) for general purpose.
49.	IS: 3097	Specification for veneered particle board.
50.	IS: 3828	Specification for ventilator chain.
51.	IS: 3400 (Part 2) (Part 4) (Part 9)	Method of test for vulcanized rubber: *Hardness.* *Accelerated aging.* *Density.*
52.	IS: 3564	Specification for door closer (hydraulically regulated).
53.	IS: 3618	Phosphate treatment of iron and steel for protection against corrosion.
54.	IS: 3813	'C' hooks for use with swivels.
55.	IS: 3818	Specification for continuous (Piano) hinges.

56.	IS: 3847	Specification for mortice night latch.
57.	IS: 4835	Specification for polyvinyl acetate dispersion based adhesive for wood.
58.	IS: 4948	Specification for welded steel wire fabric for general use.
59.	IS: 4992	Specification for rebated mortice lock.
60.	IS: 5187	Specification for flush bolts.
61.	IS: 5509	Specification for fire retardant plywood.
62.	IS: 5930	Specification for mortice latch.
63.	IS: 6318	Specification for plastic wire window fasteners.
64.	IS: 6607	Specification for rebated mortice lock (Vertical type).
65.	IS: 6760	Specification for slotted counter sunk head wood screws.
66.	IS: 7196	Specification for hold fast.
67.	IS: 7534	Specification for sliding locking bolts for use with pad lock.
68.	IS: 7638	Wood/lignocellulosic based panel products - method for sampling.
69.	IS: 8756	Specification for mortice ball catch for use in wooden almirah.
70.	IS: 9308	Specification for mechanically extracted coir fibres.
	(Part 1)	*Mattress coir fibres.*
	(Part 3)	*Decorated coir fibres.*
71.	IS: 11215	Moisture content of timber and timber products method of determination.
72.	IS: 12049	Dimensions and tolerance relating to wood based panel materials.
73.	IS: 12406	Specification for medium density fibre board.
74.	IS: 12817	Specification for stainless steel butt hinges.
75.	IS: 12823	Specification for wood products – prelaminated particle boards.
76.	IS: 14616	Specifications for laminated veneer lumber.
77.	IS: 14842	Specification for coir veneer board for general purposes.
78.	IS: 14856	Specification for glass fibre reinforced plastic (FRP) panel type door.
79.	IS: 14900	Specifications for transparent float glass.

+++++++

SECTION 800 FINISHING

801 GENERAL

Finishing of a building includes finishing works of floor, wall, ceiling etc. Several types of finishes can be provided based on the materials used, environmental conditions and cost.

802 CEMENT PLASTER

a) The cement plaster shall be 9 mm, 12 mm, 15 mm or as specified in the item.
b) Ceiling plaster shall be completed before commencement of wall plaster. All corners, arrises, angles and junctions shall be truly vertical or horizontal as the case may be and shall be carefully finished.
c) Rounding or chamfering corners, arrises, provision of grooves at junctions etc. where required shall be done without any extra payment. Such rounding, chamfering or grooving shall be carried out with proper templates or battens to the sizes required.
d) No portion of the surface shall be left out initially to be patched up later on.
e) The plastering and finishing shall be completed within half an hour of adding water to the dry mortar.
f) The plaster shall be finished to a true and plumb surface and to the proper degree of smoothness as required.
g) The work shall be tested frequently as the work proceeds with a true straight edge not less than 2.5 m long and with plumb bobs.
h) All horizontal lines and surfaces shall be tested with a level and all jambs and corners with a plumb bob as the work proceeds.
i) Curing shall be started as soon as the plaster has hardened sufficiently and shall not get damaged when watered.
j) The plaster shall be kept wet for a period of at least 7 days. The dates on which the plastering is done shall be legibly marked on the various sections plastered so that curing for the specified period thereafter can be watched.
k) Any cracks which appear in the surface and all portions which sound hollow when tapped, or are found to be soft or otherwise defective, shall be cut out in rectangular shape and redone as directed by the Field Engineers.

802.1 Cement plaster with a flushing coat of cement

a) The cement plaster shall be 12 or 15 mm thick, finished with a flushing coat of cement or as specified in the item.
b) All relevant points for ensuring quality control for cement plaster are applicable to this type of finishing also.

802.2 Plastering on top of walls for bearing of slabs

a) Cement plaster shall be 6 mm thick finished with a floating coat of neat cement on top of walls for bearing of slabs.
b) A layer of tar felt paper of suitable thickness shall be placed over the plastered surface before the slab is cast.

c) All relevant points for ensuring quality control for cement plaster are applicable to this type of finishing also.

802.3 Rough cast plaster

a) Rough cast finish comprises of a mixture of sand and gravel in specified proportions dashed over a freshly plastered surface.
b) It shall be ensured that the base surface which is to receive rough cast mixture is in plastic state.
c) The rough cast mixture shall consist of sand or gravel or crushed stone of uniform colour from 2.36 mm to 12.5 mm size or as specified and in the proportions as specified accurately to the effect required.
d) The mixture shall be wetted and shall be dashed on the plaster base in plastic state by hand scoop so that the mix gets well pitched into the plaster base.
e) The mix shall again be dashed over the vacant spaces, if any, so that the surface represents homogeneous surfaces of sand mixed with gravel.
f) A sample of rough cast plaster shall be got approved by the Field Engineers.
g) All relevant points for ensuring quality control for cement plaster are applicable to this type of finishing also.

802.4 Plain bands of cement mortar

a) Plain band is a plaster strip of uniform width not exceeding 30 cm and of uniform thickness, provided for decorative or other purpose flush with, sunk below or projecting beyond, the wall plaster.
b) A flush band is one where due to the difference in mix or shade of the mortar, the band is executed as a separate and distinct operation from the wall plaster.
c) The horizontal or vertical lines of bands shall be truly parallel and straight and the surfaces shall be finished truly plane and smooth.
d) The lines and surfaces shall be checked with fine threads for straightness, level and accuracy.

802.5 Moulded bands of cement mortar

a) Moulded band is a plaster strip of uniform width but with varying thickness across its section formed over wall plaster for decorative purposes. The sectional periphery of the band is formed by a combination of straight lines or of curves or of straight lines and curves.
b) Proper templates conforming to the sectional periphery of the moulded band, at the stages of the under coat and the finished final coat, shall be made and got approved and used at the proper stages in executing the bands to true and accurate profile.
c) The lines of the bands as finally completed shall be truly parallel and straight and the surfaces smoothly finished.

802.6 Cement water proofing compound

a) It shall be used for cement mortar for plastering.
b) Integral cement water proofing compound conforming to IS: 2645 and of approved brand and manufacture, enlisted by the Field Engineers shall be used.
c) The contractor shall bring the materials to the site in their original packing.
d) The containers will be opened and the material mixed with dry cement in the proportion by weight, recommended by the manufacturers or as specifically

described in the description of the item.

e) Care shall be taken in mixing, to see that the water proofing material gets well and integrally mixed with the cement and does not run out separately when water is added.

803 POINTING ON BRICK WORK, TILE WORK AND STONE WORK

a) The mortar shall be pressed into the raked out joints, with a pointing trowel, either flush, sunk or raised, according to the type of pointing required.

b) The mortar shall not spread over the corner, edges or surface of the masonry.

c) The pointing shall then be finished with the proper tool.

d) The pointing lines shall be truly horizontal and vertical except where the joints are slanting as in random rubble masonry.

e) Lines of joints from different directions should meet neatly at the junctions instead of crossing beyond.

f) The pointing shall be kept wet for seven days. During this period it shall be suitably protected from all damages.

804 WHITE WASHING

a) White washing shall be done using lime or similar products available in the market as specified in the item.

b) The white wash shall be applied with brushes of specified standards to the specified number of coats.

c) The operation for each coat shall consist of a stroke of the brush given from the top downwards, another from the bottom upwards over the first stroke, and similarly one stroke horizontally from the right and another from the left before it dries.

d) Each coat shall be allowed to dry before the next one is applied.

e) No portion of the surface shall be left out initially to be patched up later on.

f) For new work, two coats shall be applied till the surface presents a smooth and uniform finish through which the plaster does not show.

g) The finished dry surface shall not show any signs of cracking and peeling nor shall it come off readily on the hand when rubbed.

h) The white washed surface should present a uniform finish through which the plaster patches do not appear.

i) The washing on ceiling should be done prior to that on walls.

j) Doors, windows, floors, articles of furniture etc. and such other parts of the building not to be white washed, shall be protected from being splashed upon.

k) Splashings and droppings, if any shall be removed and the surfaces cleaned.

805 COLOUR WASHING

a) The mineral colours not affected by lime, shall be added to white wash.

b) No colour wash shall be done until a sample of the colour wash of the required tint or shade has been got approved from the Field Engineer.

c) The colour shall be of even tint or shade over the whole surface.

d) If it is blotchy or otherwise badly applied, it shall be redone.

e) The finished dry surface shall not be powdery and shall not readily come off

on the hand when rubbed.

f) All relevant points for ensuring quality control for white washing are applicable to this type of finishing also.

806 DRY DISTEMPERING

a) Dry distemper of required colour (IS: 427) and of approved brand and manufacture shall be used.
b) The shade shall be got approved by the Engineer before application of the distemper.
c) The dry distemper of approved colour shall be stirred slowly in clean water using 600 ml of water per kg of distemper or as specified by the manufacturers.
d) Warm water shall preferably be used.
e) It shall be allowed to stand for at least 30 minutes (or if practicable, over night) before use.
f) The mixture shall be well stirred before and during use to maintain an even consistency.
g) Distemper shall not be mixed in larger quantity than is actually required for one day's work.

806.1 Oil emulsion (Oil bound) washable distempering

a) Oil emulsion (Oil bound) washable distemper (IS: 428) of approved brand and manufacture shall be used.
b) The primer used in new work shall be cement primer or distemper primer as specified in the item.
c) These shall be of the same manufacture as distemper.
d) The distemper shall be diluted with water or any other prescribed thinner in a manner recommended by the manufacturer.
e) Only sufficient quantity of distemper required for day's work shall be prepared.
f) The distemper and primer shall be brought by the Contractor in sealed tins in sufficient quantities.
g) Oil bound distemper is not recommended to be applied, within six months of the completion of wall plaster. However, newly plastered surfaces if required to be distempered before a period of six months shall be given a coat of alkali resistant priming paint conforming to IS: 109 and allowed to dry for at least 48 hours before distempering is commenced.
h) For old work, no primer coating is necessary.

807 CEMENT PRIMER COAT

a) Cement primer coat is used as a base coat on wall finish of cement, lime or lime cement plaster or on non-asbestos cement surfaces before oil emulsion distemper paints are applied on them.
b) Primer coat shall be preferably applied by brushing and not by spraying.
c) Hurried priming shall be avoided particularly on absorbent surfaces.
d) New plaster patches in old work should also be treated with cement primer before applying oil emulsion paints etc.

808 CEMENT PAINT

a) The cement paint shall be of approved brand and manufacture conforming to IS: 5410.
b) The cement paint shall be brought to the site of work in its original containers in sealed condition.
c) The materials shall be brought in at a time in adequate quantities for the whole work.
d) The lids of cement paint drums shall be kept tightly closed when not in use, as by exposure to atmosphere the cement paint rapidly becomes air set due to its hygroscopic qualities.
e) In case of cement paint brought in gunny bags, once the bag is opened, the contents should be consumed in full on the day of its opening. If the same is not likely to be consumed in full, the balance quantity should be transferred and preserved in an airtight container to avoid its exposure to atmosphere.
f) Water proof cement paint shall not be applied on surfaces already treated with white wash, colour wash, distemper dry or oil bound, varnishes, paints etc.
g) It shall not be applied on gypsums, wood and metal surfaces.
h) If water proofing cement is required to be applied on existing surface, previously treated with white wash, colour wash etc., the surface shall be thoroughly cleaned by scrapping off all the white wash, colour wash etc. completely.
i) Thereafter, a coat of cement primer shall be applied followed by two coats of water proof cement.

809 PAINTING ON EXTERIOR WALL

a) Before pouring into smaller containers for use, the paint shall be stirred thoroughly in its container, when applying also the paint shall be continuously stirred in the smaller containers so that its consistency is kept uniform.
b) Dilution ratio of paint with potable water can be altered taking into consideration the nature of surface, climate and as per recommended dilution given by manufacturer.
c) In all cases, the manufacturer's instructions and directions of the Engineer shall be followed meticulously.
d) The lids of paint drums shall be kept tightly closed when not in use as by exposure to atmosphere the paint may thicken and also be kept safe from dust.

810 PAINTING PRIMING COAT ON WOOD, IRON OR PLASTERED SURFACES

a) The primer for wood work, iron work or plastered surface shall be as specified in the description of item.
b) Primer for plaster/wood work/iron and steel/aluminium surfaces shall be as specified in table 800-1.
c) Mineral turpentine i.e. petroleum distillate which has the same rate of evaporation as vegetable turpentine (Distillate product of oleoresin of conifers) shall be used. It shall have no grease or other residue when allowed to evaporate. It shall conform to IS: 533.

d) All the above materials shall be of approved manufacture and brought to site in their original packing in sealed condition.

Table 800-1: *Selection of primer for various surfaces*

Sl. No.	*Surfaces*	*Primer to be used*
1	Wood work (Hard and soft wood)	Pink conforming to IS: 3536.
2	Resinous wood and plywood	Aluminium primer conforming to IS: 3585.
3	Aluminium and light alloys	Zinc chromate primer conforming to IS: 104.
4	Iron, steel and galvanized steel	Red oxide zinc chromate primer conforming to IS: 2074.
5	Cement/concrete/RCC/brickwork, plastered surfaces, non-asbestos surfaces to receive oil bound distemper or paint finish	Cement primer conforming to IS: 109.

811 PAINTING SYNTHETIC ENAMEL PAINT OVER GS SHEETS

a) Paint, suitable for painting over GS sheets, of approved brand and manufacture and of the required shade shall be used.

b) New or weathered GS sheets shall be painted with a priming coat of one coat of red oxide zinc chromate paint. Primer shall be applied before fixing sheets in place.

812 PAINTING RAIN WATER/SOIL/WASTE/VENT PIPES AND FITTINGS OF CAST IRON

a) The primer shall be of approved brand and manufacture as specified in the item.

b) Paint shall be anti-corrosive bitumastic paint, aluminium paint or other type of paint as specified in the description of the item.

813 PAINTING WITH WOOD PRESERVATIVE

a) Oil type wood preservative of specified quality and approved make, conforming to IS: 218 shall be used.

b) Generally, it shall be creosote oil type - I or anthracene oil.

814 COAL TARRING

a) Coal tar of approved manufacture conforming to IS: 290 shall be used.

b) The tar, to every litre of which 200 gm of un-slaked lime has been added, shall be heated till it begins to boil.

c) It must then be taken off the fire and kerosene oil added to it slowly at the rate of one part of kerosene oil to six or more parts by volume and stirred thoroughly.

d) The addition of lime is for preventing the tar from running.

815 WALL PAINTING WITH PLASTIC EMULSION PAINT

a) Plastic emulsion paint shall confirm to IS: 5411 and shall be of the approved

brand and manufacture.

b) The plastic emulsion paint is not suitable for application on external, wood and iron surface and surfaces which are liable to heavy condensation.
c) These paints are to be used on internal surfaces except wooden and steel.
d) Plastic emulsion paint specially made for exterior surfaces shall be used for painting exterior surfaces.
e) The shade shall be got approved from the Engineer before application of the distemper.
f) Each coat shall be allowed to dry before the next one is applied.
g) Painting of external surface should not be done in adverse weather condition like hail storm and dust storm.
h) No portion of the surface shall be left out initially to be patched up later on.
i) The painting on ceiling should be done prior to that on walls.
j) Doors, windows, floors, articles of furniture etc. and such other parts of the building shall be protected from being splashed upon. Splashing and droppings, if any shall be removed and the surfaces cleaned.
k) Plastic emulsion paint shall not be applied on surfaces already treated with white wash, colour wash, distemper dry or oil bound, varnishes, paints etc.
l) If plastic emulsion paint is required to be applied on existing surface, previously treated with white wash, colour wash etc., the surface shall be thoroughly cleaned by scrapping off all the white wash, colour wash etc. completely. Thereafter, a coat of cement primer shall be applied followed by two coats of plastic emulsion paint.
m) It shall not be applied on wood and metal surfaces.
n) In all cases, the manufacturer's instructions and directions of the Engineer shall be followed meticulously.
o) The paint shall be brought to the site of work in its original containers in sealed condition.
p) The materials shall be brought in at a time in adequate quantities to suffice for the whole work.
q) The lids of paint drums shall be kept tightly closed when not in use as by exposure to atmosphere the paint may thicken.
r) It shall also be kept safe from dust.
s) Manufacturer's test certificate is mandatory if the area of painting is greater than 300 m^2.

816 PAINTING WITH SYNTHETIC ENAMEL PAINT

a) Synthetic enamel paint of approved brand and manufacture conforming to IS: 2933 and of the required colour shall be used.
b) At the time of delivery the paint shall be in such a condition that manual stirring readily produces a uniform product.
c) During the twelve months storage period, the rating for degree of settling shall not drop to zero, when tested as per IS: 101 (Part 6/Sec. 2).
d) The paint shall be free from coarse particles, suspended particles of gel and foreign matter, when tested as per IS: 101 (Part 1/Sec. 2).
e) The paint shall show no skin formation, when examined visually at the time of delivery.
f) The paint shall be capable of being readily mixed with the petroleum

hydrocarbon, solvent grade (IS: 1745) or with a suitable thinner as agreed to between the purchaser and the supplier, without showing any precipitation.

g) The material shall be supplied in brushing consistency, suitable for application by brushing and air spraying.

h) Manufacturer's test certificate is mandatory if the area of painting is greater than 250 m^2.

817 PAINTING WITH ALUMINIUM PAINT

a) Aluminium paint shall be of approved brand and manufacture conforming to IS: 2339.

b) If the paint comes in compact dual container with the paste and the medium separately, the two shall be mixed together to proper consistency before use.

c) As aluminium paste is likely to settle in the container, care shall be taken to frequently stir the paint during use.

d) Also the paint shall be applied and laid off quickly, as surface is otherwise not easily finished.

818 PAINTING WITH ANTI-CORROSIVE BITUMASTIC PAINT

a) Ready mixed paint shall be of approved brand and manufacture conforming to IS: 158.

b) It shall be black, lead free and acid-alkali-heat-water resistant.

819 VARNISHING

a) Varnish for the finishing and undercoats shall be of the approved manufacturer conforming to IS: 347.

b) Ordinary copal varnish or superior quality spray varnish shall be used.

c) The work includes sizing of transparent wood filler.

d) Rubbing down and flatting the surface shall be done after each coat except the final coat with fine sand paper.

e) The work shall be allowed to dry away from droughts and damp air. The finished surface shall then present a uniform appearance and fine glossy surface free from streaks, blister etc.

f) Any varnish left over in the small container shall not be poured back into the stock tin, as it will render the latter unfit for use.

g) Special fine haired varnishing brushes shall be used and not ordinary paint brushes. Brushes shall be well worn and perfectly clean.

820 FRENCH POLISHING

Readymade polish conforming to IS: 348 shall be used.

821 BEES WAXING OR POLISHING WITH READY MADE WAX POLISH

The polishing shall be done with readymade wax polish of approved brand and manufacture.

822 REMOVING OLD PAINT

a) *With patent paint remover:* Patent paint removers shall consist of volatile organic liquids thickened with waxes and other ingredients to retard the evaporation of the liquid and to enable a substantial layer of remover to be

applied to the surface. The paint remover shall be of a brand and manufacture approved by the Engineer. It shall be free from alkaline matter and non-caustic so that it can be handled by workmen without injury. It shall be of non-inflammable quality as far as possible.

b) *With caustic soda solution:* Caustic soda, as its name implies, is a corrosive liquid and care should be taken to see that no liquid spills over the skin or clothing.

c) *With blow lamp:* The paint shall be removed either with a blow lamp or air-acetylene equipment. The flame shall be allowed to play upon the paint just enough to soften it without charring either the paint or the background. The softened paint shall then be removed with a stripping knife following the flame as it is moved up the surface. Burning off shall begin at the bottom of the vertical surface and shall proceed upwards. Removal with blow lamp shall not be done on narrow or carved undercut surfaces or where there is risk of damage to neighbouring materials such as panes in glazed windows.

823 REFERENCES

1. IS: 16 Shellac:
   (Part 1) *Hand made shellac.*
   (Part 2) *Machine made shellac.*
2. IS: 75 Linseed oil raw and refined.
3. IS: 77 Linseed oil boiled for paints.
4. IS: 102 Ready mixed paint, brushing, red lead, non-setting, priming.
5. IS: 104 Specification for ready mixed paint, brushing, zinc chrome, priming.
   IS: 109 Ready mixed paint, brushing, priming plaster to indian standard colour No.361, 631 white and off white.
7. IS: 117 Ready mixed paint, brushing, finishing exterior, semi-gloss for general purposes to Indian Standards colours.
8. IS: 133 Enamel, interior (a) under coating (b) finishing.
9. IS: 137 Ready mixed paint, brushing, matt or egg shell flat, finishing interior to Indian standard colour as required.
10. IS: 158 Ready mixed paint, brushing, bituminous black, lead free, acid, alkali and heat resisting.
11. IS: 217 Specification for cut back bitumen.
12. IS: 218 Specification for creosote and anthracene oil for use as wood
13. IS: 290 Coal tar black paint.
14. IS: 337 Varnish, finishing interior.
15. IS: 341 Black Japan, Types 'A', 'B' & 'C'
16. IS: 347 Varnish, shellac for general purposes.
17. IS: 348 French polish.
18. IS: 419 Putty for use on window frames.
19. IS: 427 Distemper, dry colour as required.
20. IS: 428 Distemper, oil emulsion, colour as required.
21. IS: 524 Varnish, finishing, exterior, synthetic air drying.
22. IS: 533 Gum spirit of turpentine (Oil of turpentine).
23. IS: 712 Specification for building limes.

24. IS: 1200 Method of measurements of building and civil engineering:
    (Part 12) *Plastering and pointing.*
    (Part 13) *White washing, colour washing distempering and painting of buildina surfaces.*
    (Part 15) *Painting, polishing, varnishing etc.*
25. IS: 2339 Aluminium paint for general purposes, in dual container.
26. IS: 2547 Gypsum building plasters:
    (Part 2) *Premixed light weight plasters.*
27. IS: 2932 Enamel, synthetic, exterior (a) undercoating, (b) finishing.
28. IS: 2933 Enamel, exterior: (a) undercoating (b) finishing
29. IS: 5410 Cement paint.
30. IS: 5411 Plastic emulsion paint:
    (Part 1) *For interior use.*
31. IS: 6278 White washing and colour washing.

+++++++

SECTION 900 PANELLING AND PARTITIONS

901 GENERAL

A partition wall may be defined as a wall or division made up of bricks, studding, glass or other such material and provided for the purpose of dividing one room or portion of a room from another. It can have additional functions such as load bearing, acoustic insulation, partition of living units, housing distribution channels for machinery, electricity, water supply and other elements.

Depending upon the material used, partition walls may be divided into the following types:

a) Brick partitions.
b) Hollow brick partitions of clay, terra-cotta or concrete.
c) Glass partitions.
d) Concrete partitions-plain or reinforced.
e) Ferro-cement partition.
f) Metal lath and plaster partitions.
g) AC sheet or GI sheet partitions.
h) Timber partitions.

Wall panelling is an architectural element that can be installed in residential or commercial buildings. Decorative wall panelling is installed over walls to add aesthetic appeal, while other types of paneling may be added for their functional or structural characteristics.

Some panelling and partitions adopted in the department are discussed in this section. Quality tests and requirements of materials used for panelling and partitions are detailed under relevant clauses. Contractor shall furnish the necessary manufacturer's certificate during supply and installation.

902 WOODEN PANELLING

902.1 Requirements

a) Timber panels shall be preferably made of timber of larger width. The minimum width and thickness of a panel shall be 150 mm and 15 mm respectively.
b) When made from more than one piece, the pieces shall be joined with a continuous tongue and groove joint, glued together and reinforced with metal dowels.
c) The panels shall be designed such that no single panel exceeds 0.5 m^2 in area.

902.2 Quality control tests

The details and requirements of quality control tests for timber shall be as given in Section 700 of this manual.

903 PLYWOOD/PLYWOOD BOARDS

903.1 Requirements

a) Plywood boards are formed by gluing and pressing three or more layers of veneers with the grains of adjacent veneers running at right angles to each other.

b) Plywood shall be of BWP grade or BWR grade as per IS: 303.

903.2 Quality control tests

a) One sample for every 100 m^2 or part thereof shall be taken and testing done as per IS: 303. However, testing may not be done if the total requirement of plywood boards is less than 30 m^2. All the samples tested shall meet the requirements of physical and mechanical properties of plywood boards specified in table 900-1.

Table 900-1: *Shear strength requirements of plywood*

For BWR type	*Minimum shear strength N*	
	Dry state	*Resistance to moisture*
Average	1350	1000
Individual	1100	800

b) Moisture content of the plywood boards when tested in accordance with IS: 1734 (Part 1) shall not be less than 5% and not more than 15%.

c) *Procedure for edge straightness test:* The straightness of the edge and ends of plywood shall be verified against a straight edge not less than the full length of the plywood. If the edge on the end of the plywood is convex, it shall be held against the straight edge in such a way as to give approximately equal gap at each end. The largest gap between the straight edge and the edge shall be measured to the nearest millimetre and recorded.

d) *Procedure for squareness test***:** The squareness of plywood shall be checked with a 1200 mm x 1200 mm square by applying one arm of the square to the plywood. The maximum width of the gap shall be recorded.

904 MARINE PLYWOOD

a) Marine plywood shall be generally conforming to IS: 710. Selection of timber species for manufacture of plywood used shall be as prescribed in IS: 710. As far as possible, plywood manufactured from a single species of timber shall be used.

b) Each plywood board shall be legibly marked or stamped with following particulars along with such other marks as the purchaser may stipulate at the time of placing order.
   i) Manufacturer's name, initials or recognized trade mark, if any.
   ii) Year of manufacturing.
   iii) Abbreviation indicating the species of timber used in each ply as indicated in column 3 of tables 1 and 2 of IS: 710.
   iv) Batch number
   v) The plywood board shall also be marked with the standard mark, governed by the BIS Act 1986.

904.1 Tests for marine plywood

a) The method of drawing representative samples and criteria for conformity shall be as prescribed in IS: 7638.

b) Test pieces cut from each board shall be subjected to following tests.

c) These tests shall be carried out as specified in IS: 710.
   i) Moisture content.
   ii) Glue adhesive in dry state.
   iii) Water resistance test.

iv) Tensile strength.
v) Mycological test
vi) Retention of preservative.

905 VENEERED DECORATIVE PLYWOOD

a) Decorative plywood shall be of two grades namely BWR and MR Decorative. Plywood shall be of two types, Type I and type 2 and shall conform to IS: 1328.
b) The dimensions of plywood boards shall be as follows:
   i) 2400 mm x 1200 mm.
   ii) 2100 mm x 900 mm.
   iii) 2100 mm x 1200 mm.
   iv) 1800 mm x 900 mm.
   v) 1800 mm x 1200 mm.
c) The thickness of plywood board shall be 3 mm, 4 mm, 6 mm, 9 mm, 12 mm, 19 mm and 25 mm.
d) Any other dimensions (length, width and thickness), if required by the Engineer may also be used.
e) Each plywood board shall be legibly marked or stamped with the following on the face of board near one corner.
   i) Indication of the source of manufacture.
   ii) Year of manufacture.
   iii) Batch number.
   iv) Type of plywood.
   v) Criteria for which the plywood has been labelled as ECO mark.
   vi) The decorative veneered plywood may also be marked with standard mark, governed by the BIS Act 1986.

905.1 Tests for veneered decorative plywood

Boards shall be subjected to following tests:

a) *Moisture content*: Decorative veneered plywood of either type when tested in accordance with IS: 1734 (Part 1) shall have a moisture content not less than 5% and not more than 15%.
b) *Water resistance*: Three test specimen of size 250 mm x 100 mm shall be prepared for each of the boards selected and submerged in water at 62±2˚C for a period of 3 hours and dried for 8 hours at a temperature of 65±2˚C and then followed by two more cycles of soaking and drying under same conditions described above. Decorative veneered plywood of either type shall not show delamination or blister formation.

906 FIRE RETARDANT PLYWOOD

a) Fire retardant plywood shall generally conform to IS: 5509.
b) The plywood to be given fire retardant treatment shall conform to BWR grade of IS: 303 to be able to stand pressure impregnation.
c) Plywood for treatment shall be clean, free from oil or dirt patches on the surface and at a moisture content not exceeding 15%.
d) In case of veneered decorative plywood, care shall be taken that colour of the solution does not spoil the decorative surface.
e) For Ecomark, the plywood shall conform to the requirements of Ecomark specified in IS: 303.

f) Dimension and tolerances shall conform to IS: 2049. The tolerance for thickness shall conform to IS: 303.
g) Each board shall be legibly and indelibly marked near the edge with the following:
   i) Manufacturer's name or recognized trade mark, if any.
   ii) Year of manufacture.
   iii) Type of treatment.
   iv) Criteria for which the plywood has been labelled as Ecomark.
   v) Each board may also be marked with standard mark governed by the BIS Act 1986.

906.1 Sampling for tests

a) The method of drawing representative sample and the criteria of conformity shall be as prescribed in IS: 7638.
b) From each of fire retardant plywood selected as above, following test specimens shall be cut from portions 150 mm away from the edges for tests specified below:
   i) *Flammability:* Six test specimens 125 mm x 125 mm in full thickness of material from each sample.
   ii) *Flame Penetration:* Three test specimens 125 mm x 125 mm in full thickness of material from each sample.
   iii) *Rate of Burning:* Three test specimen 100 mm x 12.5 mm in full thickness of material from each sample.

906.2 Tests for fire retardant plywood

a) *Moisture content:* Shall not exceed 20%.
b) *Flammability:* When tested as per IS: 1734, time taken for second ignition shall not be less than 30 minutes.
c) *Flame penetration:* When tested as per IS: 1734, time taken for flame penetration shall not be less than 15 minutes for every 6 mm thickness.
d) *Rate of burning:* When tested as per IS: 1734, the time taken to lose weight from 30 % to 70 % shall not be less than 20 minutes.

907 PARTICLE BOARDS

a) Particle boards shall be of medium density and manufactured from particles of agro waste, wood or lignocellulose i.e. material blended with adhesive and formed into solid panels under the influence of heat, moisture, pressure etc.
b) The particle boards shall be flat pressed three layered or graded and of grade-I as per table 1 of IS: 3087. Both surfaces of the boards shall be sanded to obtain a smooth finish and shall conform to IS: 3087.

907.1 Tests for particle board

a) One sample for every 100 m^2 or part thereof shall be taken and testing done as per IS: 3087.
b) However, testing need not be done if the total requirement of particle boards in a work is less than 30 m^2.
c) All the samples tested shall meet the requirement of physical and mechanical properties of particle boards specified in table 900-2.

Table 900-2: *Physical and mechanical properties of FPT or graded particle board*

Sl. No.	*Properties*	*Flat pressed three layer multi-layer and graded*	
		Grade-I	*Grade-II*
1	Density variation (%)	±10	±10
2	Water absorption (%): a) 2 hours soaking b) 24 hours soaking	 10 20	 40 80
3	Linear expansion (swelling in water), 2 hours soaking (%): a) Length b) Width	 0.5 0.5	 0.5 0.5
4	Thickness - swelling (%), 2 hours soaking	8	12
5	Swelling in thickness due to surface absorption (%)	6	9
6	Modulus of rupture (MPa): a) Average b) Minimum	 15 13	 11 10
7	Modulus of elasticity (MPa): a) Average b) Minimum	 2500 2250	 2000 1800
8	Tensile strength perpendicular to surface (MPa): a) Up to 20 mm thickness b) Above 20 mm thickness	 0.45 0.40	 0.3 0.3
9	Tensile strength perpendicular to surface (MPa): a) After cyclic test* b) Accelerated water resistance test**	 0.2 0.15	 - -
10	Screw withdrawal strength (N): (a) Face (b) Edge (for thickness >12mm)	 1250 850	 1250 700

**Cyclic test: Specimens are immersed in water at 27±2°C for a period of 72 hours, followed by drying in air at 27±2°C for 24 hours and then heating in dry air at 70°C for 72 hours. Three such cycles are to be followed and then the specimens are tested for tensile strength perpendicular to surface.*

***Accelerated water resistance test: Specimens are immersed in water at 27± 2°C and water is brought to boiling and kept at boiling temperature for 2 hours. Specimens are then cooled in water to 27±2°C and then tested for tensile strength perpendicular to surface.*

908 PRE-LAMINATED PARTICLE BOARDS

a) Pre-laminated particle boards are available in two grades namely grade I and II as per IS: 12823. Each grade is further classified in four types namely, Type I, II, III and IV.
b) Edge straightness and squareness shall be tested as per IS: 12823.
c) The pre-laminated particle boards shall be selected at random as per IS: 4905.
d) Each pre-laminated particle board shall be legibly marked on any of its edges with following :

i) Indication of source of manufacturer.
ii) Grade and type of pre-laminated particle board.
iii) Thickness.
iv) Batch number and year of manufacture.

909 VENEERED PARTICLE BOARDS

a) Veneered Particle Boards shall be of two grades namely, grade I and grade II. Each shall be of the following four types as per IS: 3097.
   i) Type I: Veneered particle boards of solid core with faces of veneer of general purpose type.
   ii) Type II: Veneered particle boards of solid core faced with decorative veneers on one or both side.
   iii) Type III: Veneered particle boards with tubular core and faced with veneer of general purpose type.
   iv) Type IV: Veneered particle boards with tubular core faced with decorative veneers on one or both side.

b) One sample for every 100 m^2 or part thereof shall be taken and testing done as per IS: 3097. However, testing may not be done if the total requirement of veneered particle boards in a work is less than 30 m^2.

c) All the samples tested shall meet the requirements of physical and mechanical properties of veneered particle boards are given in table 900-3.

Table 900-3: *Physical and mechanical properties of veneered particle board*

Sl. No.	*Properties*	*Requirement*
1	Moisture content	5-15%
2	Water absorption: (a) 2 hours soaking (b) 24 hours soaking	 Not more than 25%. Not more than 50%.
3	Water resistance	No sign of disintegration or delamination after 3 hours boiling in water.
4	Swelling in water: (a) General absorption for 2 hours immersion. (b) Surface absorption for 2 hours	 Not more than 7%. Not more than 5%.
5	Adhesion of plies	Knife test.

910 NON-ASBESTOS FIBRE BOARDS

Fibre boards shall be of medium density cement board reinforced with wood fibre, produced by fiberizing steamed wood under pressure, blended with adhesive and wax and formed into solid panels under controlled conditions of heat and pressure as per IS: 14862.

911 WIRE CLOTH (WIRE GAUZE)

a) Wire cloth which shall generally conform to IS: 1568 shall be regularly woven with equally spaced galvanised mild steel wires in both warp and weft directions. The wire cloth shall be properly selvedged by one or more wires in each edge.

b) Width of aperture and diameter of wire cloth shall be as specified. Unless otherwise stated, wire cloth of 1.40 mm average aperture width woven with

0.63 mm nominal diameter galvanised mild steel wire shall be used.

c) Fly-proof wire cloth (Aperture 1.40 mm) is generally provided in kitchen and dining areas while wire cloth of smaller aperture is used in mosquito proof shutters.

912 COIR VENEER BOARD

a) Coir veneer board is manufactured with a combination of coconut fibre needled felt, veneer and jute fibres with kraft paper coconut fibre. Needled felt can be used as core cross bands or as outer skin formed with jute fibres and kraft paper. However, the composite ply should be a balanced construction on either side of central ply. The blended mass of glued fibres is laid to form a mat which is pre needled.

b) Coir veneer board generally shall conform to IS: 14842.

c) Coir veneer board shall be of uniform thickness and density throughout the length and width of board.

d) The squareness and edge straightness of the board shall be as per of IS: 14842.

e) Each coir veneer board shall be legibly and indelibly marked or stamped with the following near a corner.

   i) Identification of source.
   ii) Year of manufacturing.
   iii) Batch number.
   iv) The grade and type as boiling water resistant (BWR) and moisture resistant (MR).
   v) Coir veneer board may also be marked with the standard mark governed by the BIS Act 1986.

912.1 Quality control tests

a) The tests shall be carried out as specified in IS: 14842.

b) Coir veneer board when tested in accordance with IS: 3734 (Part 1) shall have a moisture content not less than 5% and not more than 15%.

c) *Procedure for edge straightness:* The straightness of the edges and ends of coir veneer board shall be verified against a straightedge not less than the full length of the coir veneer board. If the edge on the end of coir veneer board is convex, it shall be held against the straight edge in such a way as to give approximately equal gap at each end. The largest gap between the straightness and the edge shall be measured to the nearest millimeter and recorded.

d) *Procedure for squareness:* The squareness of coir veneer board shall be checked with a 1200 mm x 1200 mm square, by applying one arm of the square to the coir veneer board. The maximum width of the gap shall be recorded.

913 DECORATIVE THERMOSETTING SYNTHETIC RESIN BONDED LAMINATED SHEETS

a) Decorative thermosetting synthetic resin bonded laminated sheets shall generally conform to IS: 2046.

b) This material is intended for interior use and is not intended for load bearing applications.

914 ALUMINIUM PARTITIONS

914.1 Aluminium sections

a) Aluminium sections used for fixed/openable windows, ventilators, partitions, frame work & doors etc. shall meet the proposed architectural designs.

b) Engineer shall approve the sections for technical, structural, functional and visual considerations.

c) The aluminium extruded sections shall conform to IS: 733 and IS: 1285 for chemical composition and mechanical properties. The stainless steel screws shall be of grade AISI 304.

d) The permissible dimensional tolerances of the extruded sections shall be as per IS: 6477 and shall be such as not to impair the proper and smooth functioning /operation and appearance of door and windows.

e) Standard aluminium extrusion sections, in various sizes and shapes in wide range of solid and hollow profiles with different functional shapes for architectural, structural glazing, curtain walls, doors, window and ventilators and various other purposes shall be anodized/electro coated in uniform colour and shades. The anodized extrusions are tested regularly under strict quality control adhering to BIS.

f) Each lot and type of aluminium extrusions shall be accompanied with the certificate from the manufacturer along with the test report of the following tests carried out at the manufacturer's test facility or an independent approved laboratory:
   i) Certificate of mechanical properties and chemical composition.
   ii) Certificate of dimensional tolerance to DIN standard.
   iii) Certificate of temper.

g) The Contractor shall certify minimum anodizing thickness for each lot and type of aluminium extrusions.

h) Aluminium extruded sections (Anodized or powder coated) are also used for providing louvers in aluminium door, window and partition for ventilation. The louvers shall be fixed at inclination and spacing as per the item description and Drawings. Louver blades shall be visibly straight and shall be storm resistant. The louvers shall not deflect or sag under self weight, therefore adequate aluminium structural framing shall be designed and provided.

i) The powder used for powder coating shall be epoxy/polyester powder of make approved by the Engineer. The contractor shall give detailed program for powder coating in advance, to facilitate the inspection by Engineer or his authorized representative. The powder coating shall be applied as per the specification approved by the Engineer.

j) The finish on significant surfaces shall show no scratches when illuminated and is examined at an oblique angle, no blisters, craters, pinholes or scratches shall be visible from a distance of about 1 m.

k) There shall not be any visible variation in the colour of finished surfaces of different sections and between the colours of different surfaces of same section.

l) When a coated test piece is tested using a spacing of 2 mm between each of the six parallel cuts (the cut is made through the full depth of powder coating so that metal surface is visible) and a piece of adhesive tape, approximately 25 mm x 150 mm approved by the Engineer is applied firmly to the cut area and then removed rapidly by pulling at right angles to the test area, no pieces of the

finish other than debris from the cutting operation shall be removed from the surface of the finish.

m) It is mandatory that all aluminium members shall be wrapped with self-adhesive non-staining PVC tape, approved by the Engineer.

914.2 Aluminium sheet

a) Aluminium sheets for use as panels shall be 1.25 mm thick aluminium alloy sheet conforming to IS: 737.

b) Aluminium alloy sheet for use in general panelling work shall be of types and thickness as specified and conforming to the requirement of IS: 737.

c) Aluminium sheets shall be of approved make and manufacture. Aluminium panel may be prefabricated units manufactured on modular or non-modular dimension.

914.3 Float glass

a) The glass shall be clear float glass and should be approved by the Engineer. It shall be clear, float transparent and free from cracks subject to allowable defects. The float glass shall conform to the IS: 14900.

b) The thickness of float glass shall depend on the size of panel.

c) The allowable defects shall be as per table 900-4.

Table 900-4: *Permissible defects of float glass*

Sl. No.	*Nature of defects*	*Central*	*Outer*	*Remarks*
1	Gaseous inclusion (Max. size in mm)	3.0	6.0	Separated by at least 30 cm.
2	Opaque gaseous inclusion (Max. size in mm)	3.0	6.0	Separated by at least 60 cm.
3	Knots, dirt and stones (Max size in mm)	1.0	1.0	Separated by at least 30 cm.
4	Scratches, rubs and crush	Faint	Light	Separated by at least 30 cm.
5	Waviness	Nil	Nil	-
6	Sulphur stains	Nil	Nil	-
7	Corner breakage and chip	Not more than nominal thickness of float glass		-

d) The allowable cluster of defects mentioned under Sl. Nos. 1, 2 and 3 of table 900-4 shall be as per IS: 14900.

e) The thickness of float glass shall be measured with micrometers or a caliper which is graduated to 0.01 mm or with a measuring instrument having an equivalent capacity.

914.4 EPDM Gaskets

a) The EPDM gaskets shall be of size and profile as shown in Drawings and as called for, to render the glazing, doors, windows, ventilators etc. air and water tight.

b) Samples of gaskets shall be submitted for approval and the EPDM gasket approved by the Engineer shall only be used.

c) The Contractor shall submit documentary proof of using the above material in

the work to the entire satisfaction of the Engineer.

d) The EPDM gasket shall meet the requirements given in table 900-5.

Table 900-5: *Requirements of EPDM gasket*

Sl. No.	*Property*	*Code*	*Requirement*
1	Tensile strength (kgf/cm^2)	ASTM D412	70 (Min)
2	Elongation at break (%)	ASTM D412	250 (Min)
3	Modulus 100% (kgf/cm^2)	ASTM D412	22 (Min)
4	Compression set at 0°C for 22 hours (%)	ASTM D395	50 (Max)
5	Ozone resistance	ASTM D1149	No visible cracks.

914.5 Sealant

a) The sealants of approved grade and colour shall only be used. The silicone for perimeter joints (Between aluminium section and RCC/stone masonry) shall be of make approved by the Engineer.

b) A tolerance of +3 mm shall be allowed in the width of silicone joints. The depth of the joints at throat shall not be less than 6 mm.

914.6 Reflective glass

a) This is an ordinary float glass with a metallic coat to reduce solar heat. Clear glass transmits most of the sunlight that shines upon it, and most of the solar heat as well; the metallic coated glass i.e. reflective glass has better shading coefficients because they reflect rather than absorb infrared energy. However, most of reflective glazing blocks day light more than solar heat.

b) The reflective glass shall be tested for the following parameter specified in table 900-6.

Table 900-6: *Performance of reflective glass*

Sl. No.	*Parameter*	*Threshold ratio (%)*
1	Visible light: - Transmittance (%) - Reflectance (%)	 15-46 12-24
2	Total solar energy: - Transmittance (%) - Reflectance (%)	 16-24 8-12
3	Ultra violet rays: - Transmittance (%)	 2-10
4	U- value: - Summer - Winter	 0.58 0.45
5	Shading coefficient	0.25-0.35

915 ALUMINIUM COMPOSITE PANEL CLADDING

a) Aluminium composite panel cladding material shall be rigid and of adequate strength. It shall have architectural flatness for creating smooth monolithic

surface. It shall satisfy all the performance parameters.

b) The PVDF/ lumiflon-based fluropolymer resin coating shall meet or exceed all the requirements of International Standards.
c) The resin content of the PVDF coating shall be minimum 70%.
d) Specular gloss as per international standards shall be 30±5%. The coated surface shall comply with the "Specification for coated coil for exterior building applications" issued by European coil coating association.
e) The reverse side of the panel shall be chromatised before applying primer and shall have service coat of polyester based coating (Total protection: 3 to 7 micron thick).
f) The cladding panels shall have uniform colour and gloss over the entire installation.
g) The fabrication and installation of the cladding systems shall be carried out as per manufacturer's instructions with invisible/concealed fastenings, aluminium structural framework, weather silicone sealants etc.
h) All cladding panel sheet shall be obtained in one lot from the manufacturer, including keeping provisions for wastage and damaged sheets.
i) Each individual panel shall be true to line, level and squareness and shall be guaranteed for a flatness of ±0.8 mm from the true face after installation under no wind conditions.
j) Deviations from the true alignment of adjoining panels shall not be cumulative.
k) Full load deflections shall be kept to the minimum possible. Each panel shall be capable of withstanding 3kN/m^2 wind pressure without any permanent deformation.
l) The cladding system shall be adequately ventilated.
m) The fabrication process including cutting, grooving, benching, punching, shearing, brake-forming, roll-forming, folding, drilling, joining, routing, bolting and riveting as well as installation shall be performed as per manufacturer's instructions and as specified .
n) The panel shall be backed by aluminium support framework fabricated for design loads, as per the approved shop drawings, fixed to the RCC/masonry with aluminium brackets.
o) The aluminium composite cladding panel shall be visually inspected for flatness, edge damage, dimpling, buckling, oil canning, bulge and/or delamination, if any. Defective material, if any shall be rejected. Also, it shall be free of dirt, stains, grease marks, discolouration etc.
p) The finished surface shall be protected with a 80 micron thick self-adhesive protective tape film tested to withstand at least six months of exposure to local environment without losing the original peel-off characteristics or causing stains or damages.
q) The PVDF coating/lumiflon-based fluoropolymer resin coating shall be guaranteed for colour retention, chalking resistance, humidity resistance, hardness and gloss retention etc. as specified.

915.1 Quality control tests

The composite aluminium panel cladding material shall satisfy the mechanical properties, coating properties and fire codes requirements.

a) Each lot and type of aluminium composite panel cladding material shall be

accompanied with the certificate from the manufacturer along with the test report, in conformance with BS 476 of the following tests carried out at the manufacturer's test facility or an independent approved laboratory:

Mechanical properties:

i) Tensile strength and yield strength of composite panels.
ii) Tensile and yield strength of aluminium skin.
iii) Elongation.
iv) Punching shear resistance.
v) Impact test for denting (DUPONT)(0.5 kg and 1kg steel balls at 500 mm height).

Fire resistance properties:

i) Flame spread and smoke developed indices.
ii) UBC26-9 & NFPA for 30 minutes intermediate scale multistory apparatus test to prove no flame spread beyond area exposed directly to fire source.

Coating properties satisfying:

i) Corrosion resistance.
ii) Salt spray resistance.
iii) Weathering.
iv) Colour retention.
v) Chalking resistance.
vi) Gloss retention.
vii) Resistance to abrasion.
viii) Hardness, adhesion and formability.

b) The coating agency shall certify the minimum thickness of PVDF/lumiflon based fluro polymer resin coating. The Contractor shall also arrange for checking the thickness of PVDF/lumiflon based fluro polymer resin coating in an independent laboratory/manufacturer's test facilities and shall submit test reports to the Engineer.

916 ALUMINIUM FABRICATION

The following points shall be given attention while carrying out aluminium fabrication works.

a) All works shall be performed by skilled workmen, specially trained and experienced in the applicable trades and in full conformity with the specifications and approved Drawings.
b) All works shall be carefully fabricated and assembled with proper and approved provisions for thermal expansion and contraction, other building movements, fabrication and installation tolerances and design criteria etc.
c) All forming and welding operations shall be done prior to finishing, unless otherwise noted.
d) All works shall be true to detail with sharp, clean profiles, straight and free from defects, dents, marks, waves or flaws of any nature impairing strength or appearance; fitted with proper joints and intersections and with specified finishes.
e) All works shall be erected true to plumb, level, square to line, securely anchored, in proper alignment and relationship to work of other trades and free from waves, sags or other defects.
f) The Contractor shall obtain and submit to the department the manufacturer's

certificate for compliance of the various materials to be used in the work, as per the manufacturer's specifications and also copy of the manufacturer's test report for the record.

g) The Contractor shall adequately protect all aluminium sections, glazing, cladding sheets, components and accessories from damage during shipment, storage, erection and till date of completion of work and handing over the building to the department by use of protective coverings of approved non-staining quality.

h) At such time as may be directed by the Engineer, the Contractor shall remove all protective coverings and clean the surfaces. All cleaning agents to be used shall not cause any damage to the aluminium, glass, aluminium composite panel and coatings etc. Any defective material shall be replaced by the Contractor at his own cost.

917 REFERENCES

1.	IS: 303	Specification for plywood for general purposes.
2.	IS: 710	Specifications for marine plywood.
3.	IS: 733	Wrought aluminium and aluminium alloys, bars, rods and sections.
4.	IS: 737	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes –specification.
5.	IS:1285	Wrought aluminium and aluminium alloy, extruded round tube and hollow sections (For general engineering purposes)– specification.
6.	IS: 1734	Methods of test for plywood.
	(Part 1)	*Determination of density and moisture content.*
7.	IS: 1568	Specification for wire cloth for general purpose.
8.	IS: 2046	Decorative thermosetting synthetic resin bonded laminated sheet.
9.	IS: 2049	Colour code for the identification of wrought steel for general engineering purposes.
10.	IS: 3087	Specification for wood particle boards (Medium density) for general purpose.
11.	IS: 3097	Specification for veneered particle board.
13.	IS: 3828	Specification for ventilator chain.
14.	IS: 4905	Method of random sampling.
15.	IS: 5509	Specification for fire retardant plywood.
16.	IS: 6477	Dimensions of extruded hollow section and tolerances.
17.	IS: 7638	Wood/lingocellulosic based panel products – Methods of sampling
18.	IS: 12823	Specification for wood products -prelaminated particle boards.
19.	IS: 14842	Specification for coir veneer board for general purposes.
20.	IS: 14862	Fibre cement flat sheets – specification.
21.	IS: 14900	Specifications for transparent float glass.

+++++++

SECTION 1000 ROOFING AND CEILING

1001 ROOFING

Roof is the upper most part of a building provided to protect the building from rain, wind, sun, snow etc. Functional requirements of a roof are as under:

a) It should have adequate strength and stability to carry the superimposed dead and live loads without excessive deflection. The roof should be stable against movement due to temperature and moisture changes.
b) It should effectively protect the building against rain, sun, wind, snow etc. It should have efficient drainage and be capable of taking good waterproofing treatment.
c) The roof and roof covering should be fire–resistant.

1001.1 Terminology

a) *Accessories*: Purpose made fittings, such as apron flashing pieces, barge boards, bottom glazing flashing, corner piece (Corner flashing), eaves filler pieces, expansion joints, hip capping, hip tile or cap, ridge capping, ridge finials, roof lights, ventilators, with which the roof is furnished.
b) *Eaves:* The lower edge of the inclined roof.
c) *Finial:* A decorative fitting used at the junction of ridges and hips to form a water proof covering and at the top of conical, pyramidal, or dome roofs.
d) *Flashing:* A strip of impervious material, usually metal used to exclude water from the junction between a roof covering and another part of the structure.
e) *Gable:* Part of wall above the general eaves level at tie end of ridged or partially hipped roof.
f) *Gutter:* Any form of roof water channel.
g) *Hip:* The outer angle (more than 180°) formed by the inclined ridge between two intersecting roof slopes.
h) *Pitch*: The angle of inclination with the horizontal of the rafters or substructure surface on which the roof coverings are laid. In patent glazing, the angle at which the plane of a stretch of glazing is inclined to the horizontal.
i) *Pitched Roof*: A roof, the pitch of which is greater than 10° to the horizontal.
j) *Ridge:* The horizontal inter-section at the apex of the two rising roof surfaces inclined in opposite directions.
k) *Valley:* The re-entrant angle formed by the inter-section of two inclined roof surfaces.
l) *Verge:* Free edge of a roof surface ending at a gable.

1001.2 Galvanised steel sheet roofing

1001.2.1 Materials

a) Galvanised plain steel sheets are supplied in any combination of the following lengths, widths and thickness.
   i) Length: 2500 and 3000 mm.
   ii) Width: 900 and 1000 mm.
   iii) Thickness: 0.50, 0.63, 0.80, 1.00 mm.
b) In case of sheets supplied in coil, the internal diameter of coil shall be 450, 510 and 610 mm and the mass of each coil shall not exceed 12 tonne.

c) Corrugated galvanised sheets shall have a length of 2500 or 3000 mm.
d) The thickness shall be as specified in the description of the item.
e) The roofing sheets shall conform to IS: 277.
f) The sheets shall be of 275 grade of coating unless otherwise specified in the description of item.
g) The sheets shall be free from cracks, split edges, twists, surface flaws etc.
h) They shall be clean, bright and smooth.
i) The galvanising shall be non-injurious and in perfect condition.
j) The sheets shall not show signs of rust or white powdery deposits on the surface.
k) The corrugations shall be uniform in depth and pitch and parallel with the side.
l) Purlins shall be of the specified material or MS rolled sections of requisite size.
m) The bolts for fixing the roof shall be sufficiently long so that after fixing they project above the top of the nuts by not less than 10 mm.
n) The grip of J or L hook bolt on the side of the purlin shall not be less than 25 mm.
o) The galvanised coating on J or L hooks, and bolts shall be continuous and free from defects such as blisters, flux stains, drops, excessive projections or other imperfections which would impair serviceability.

1001.2.2 Requirements

a) Roof shall not be pitched at a flatter slope than 1 vertical to 5 horizontal.
b) The normal pitch adopted shall usually be 1 vertical to 3 horizontal.
c) The purlins shall not be spaced at more than the following distances.

Table 1000-1: *Maximum spacing of purlins*

Thickness of CGS sheet (mm)	*Maximum spacing of purlins (m)*
1.00	2.0
0.80	1.8
0.63	1.6

d) The top surfaces of the purlins shall be uniform and plane. They shall be painted before fixing on top.
e) Embedded portions of wooden purlins shall be provided with anti termite treatment.
f) The galvanised coating on J and L hooks should conform to IS: 1367-Part 13. The mass of coating per square meter of the surface is given in table 1000-2.

Table 1000-2: *Mass and equivalent thickness of coating*

Minimum mass (gm/m^2)	*Average thickness (µm)*	*Individual thickness (µm)*
375	54	_
300	-	43

1001.2.3 Laying and fixing

a) The sheets shall be laid on the purlins to a true plane, with the lines of corrugations parallel or normal to the sides of the area to be covered unless otherwise required as in special shaped roofs.
b) The sheets shall be laid with a minimum lap of 15 cm at the ends and 2 ridges of corrugations at each side.

c) For flatter slopes the minimum permissible end lap shall be 20 cm. The minimum lap of sheets with ridge, hip and valley shall be 20 cm measured at right angles to the line of the ridge, hip and valley respectively.
d) Lapping in CGS sheets shall be painted with a coat of approved steel primer and two coats of painting with approved paint suitable for GS sheet, before the sheets are fixed in place.
e) They shall be bent up along their side edges close to the wall and the junction shall be protected by suitable flashing or by a projecting drip course, the latter to cover the junction by at least 7.5 cm.
f) Sheets shall be fixed to the purlins or other roof members such as hip or valley rafters etc. with galvanised J or L hook bolts and nuts, 8 mm diameter, with bitumen and GI limpet washers or with a limpet washer filled with white lead as directed by the Engineer. While J hooks are used for fixing sheets on angle iron purlins, and L hooks are used for fixing the sheet to RS joists, timber or precast concrete purlins.
g) There shall be a minimum of three hook bolts placed at the ridges of corrugations in each sheet on every purlin and their spacing shall not exceed 30 cm.
h) Where slopes of roofs are less than 21.5° (1 vertical to 2.5 horizontal), sheets shall be joined together at the side laps by galvanised iron bolts and nuts 25 mm x 6 mm size, each bolt provided with a bitumen and a GI limpet washer or a GI limpet washer filled with white lead. As the overlap at the sides extends to two corrugations, these bolts shall be placed zigzag over the two overlapping corrugations, so that the ends of the overlapping sheets shall be drawn tightly to each other.
i) The spacing of these seam bolts shall not exceed 60 cm along each of the staggered rows. Holes for all bolts shall be drilled and not punched in the ridges of the corrugations from the underside, while the sheets are on the ground.
j) Wind ties shall be of 40 mm x 6 mm flat iron section or of other size as specified. These shall be fixed at the eaves of the sheets. The fixing shall be done with the same hook bolts which secure the sheets to the purlins.
k) The roof when completed shall be true to lines and slopes and shall be leak proof.
l) Manufacturer's test certificate shall be produced by the Contractor if the area of roofing sheets exceeds 150 m^2.

1001.2.4 Ridges and hips of plain galvanised steel sheets

1001.2.4.1 Requirements

a) Ridges and hips of CGS roof shall be covered with ridge and hip sections of plain GS sheet with a minimum lap of 20 cm on either side over the CGS sheets.
b) The end laps of the ridges and hips and between ridges and hips shall also be not less than 20 cm.
c) The ridges and hips shall be of 60 cm overall width plain GS sheet, 0.6 mm or 0.8 mm thick as given in the description of the item and shall be properly bent in shape.

1001.2.4.2 Fixing

a) Ridges shall be fixed to the purlins below with the same 8 mm dia GI hook bolts and nuts and bitumen and GI limpet washers which fix the sheets to the purlins.
b) Hips shall be fixed to the roof members below such as purlins, hip and valley rafters with the same 8 mm dia GI hook bolts and nuts and bitumen and GI limpet washers which fix the sheets to those roof members. At least one of the fixing bolts shall pass through the end laps of ridges and hips, on either side. If this is not possible extra hook bolts shall be provided.
c) The end laps of ridges and hips shall be joined together with CGS sheet by galvanised iron seam bolts 25 x 6 mm size each with a bitumen and GI washer or white lead as directed by the Engineer. There shall be at least two such bolts in each end lap.
d) Surface of CGS sheets of ridge and hip sections and the roofing sheets which overlap each other shall be painted with a coat of approved primer and two coats of approved paint suitable for painting GS sheets before they are fixed in place.
e) The edges of the ridges and hips shall be straight from end to end and their surfaces should be plane and parallel to the general plane of the roof. The ridges and hips shall fit in squarely on the sheets.

1001.2.5 Valley and flashing of plain galvanised steel sheets

1001.2.5.1 Requirements

a) Valley shall be 90 cm wide overall plain GS sheet 1.6 mm thick or other size as specified in the item bent to shape and fixed.
b) They shall lap with the CGS sheets not less than 25 cm width on other side.
c) The end laps of valley shall also be not less than 25 cm.
d) They shall lap not less than 15 cm over the roofing sheets.
e) The end laps between flashing pieces shall not be less than 25 cm.

1001.2.5.2 Laying and fixing

a) Flashing and valley sheets shall be fixed to the roof members below, such as purlins and valley rafters with the same 8 mm diameter GI hook bolts and nuts and bitumen and GI limpet washers which fix the sheets to those roof members.
b) At least one of the fixing bolts shall pass through the end laps of the valley pieces on other side. If this is not possible extra hook bolts shall be provided.
c) The free end of flashing shall be fixed at least 5 cm inside masonry with the mortar of mix 1: 3 (1 cement: 3 coarse sand).
d) Surface of GS sheets under overlaps shall be painted with a coat of approved primer and two coats of approved paint suitable for painting GS sheets.
e) The edges of valley and flashing should be straight from end to end. The surfaces should be true and without bulges and depressions.

1001.2.6 Gutters made of plain galvanised steel sheets

1001.2.6.1 Requirements

a) Gutter shall be fabricated from plain GS sheets of thickness as specified in the item.
b) Eaves gutters shall be of the shape and section specified in the description of the item.

c) The overall width of the sheet referred to therein shall mean the peripheral width of the gutter including the rounded edges.
d) The longitudinal edges shall be turned back to the extent of 12 mm and beaten to form a rounded edge. The ends of the sheets at junctions of pieces shall be hooked into each other and beaten flush to avoid leakage.

1001.2.6.2 Laying and fixing

a) Gutter shall be laid with a minimum slope of 1 in 120.
b) Gutter shall be supported on and fixed to MS flat iron brackets bent to shape and fixed to the requisite slope. The maximum spacing of brackets shall be 1.20 m.
c) Where these brackets are to be fixed to the sides of rafters, they shall be of 40 mm x 3 mm section bend to shape and fixed rigidly to the sides of rafters with 3 Nos. 10 mm diameter bolts, nuts and washers.
d) The brackets shall overlap the rafter not less than 30 cm and the connecting bolts shall be at 12 cm centres.
e) The gutter shall be fixed to the brackets with 2 Nos. GI bolts and nuts 6 mm diameter each fitted with a pair of GI and bitumen washers. The connecting bolts shall be above the water line of the gutters.
f) For connection to down take pipes, a proper drop end or funnel shaped connecting piece shall be made out of GS sheet of the same thickness as the gutter and riveted to the gutter, the other end tailing into the socket of the rain-water pipe. Wherever necessary stop ends, angles etc. should be provided.
g) The gutters when fixed shall be true to line and slope and shall be leak proof.

1001.3 Non-asbestos high impact poly propylene reinforced cement corrugated sheet roofing

1001.3.1 Materials

a) The sheets shall be of the approved quality and shall conform to IS: 14871.
b) The sheets shall be free from cracks, chipped edges or corners and other damages.
c) It shall be composed essentially of an inorganic hydraulic binder or a calcium silicate binder formed by the chemical reaction of a silicate binder or a siliceous and calcareous material reinforced by organic fibres and/or inorganic synthetic fibres.
d) The inorganic hydraulic binder shall be either 33 grade ordinary Portland cement conforming to IS: 269 or 43 grade ordinary Portland cement conforming to IS: 8112 or 53 grade ordinary Portland cement conforming to IS: 12269 or Portland pozzolana (Fly ash based) cement conforming to IS: 1489. (Part 1) or Portland pozzolana cement (Calcined clay based) conforming to IS: 1489 (Part 2) or rapid hardening cement conforming to IS: 8041 or Portland slag cement conforming to IS: 455. Fly ash used shall be conforming to IS: 3812.
e) In case of Portland pozzolana cement and Portland slag cement, addition of pozzolanic materials and slag shall not be permitted.

1001.3.2 Classification

a) Sheets may be classified according to thickness as under:
   i) *Type A*: The thickness of the sheets shall be approximately constant throughout the width of profile.
   ii) *Type B*: The thickness of the sheets shall vary regularly between the valley and the crown for corrugated sheets or between the lower part and the

upper part of ribs for asymmetrical section sheets, in the same cross-section.

b) The sheets shall be categorized based on height of corrugations, 'h' and minimum thickness 'e' as given in table 1000-3.

Table 1000-3: *Category and class (Minimum breaking load N/m)*

Category	*Minimum thickness 'e' (mm)*	*Class*									
A (15 mm ≤h ≤55 mm)	3	600	800	1000	1400	-	-	-	-	-	-
B (25 mm ≤h ≤55 mm)	4			1000	1400	2000	2500	3300	-	-	-
C (40 mm ≤h ≤80 mm)	4.5	-	-	-	1400	2000	2500	3300	4250	-	-
D (60 mm ≤h ≤50 mm)	5.5	-	-	-	-	-	-	3300	4250	5600	7400

1001.3.3 Laying

a) The roof shall not be pitched at flatter slope than 1 vertical to 5 horizontal. The normal pitch adopted shall usually be 1 vertical to 3 horizontal.

b) The sheets shall be laid on purlins and other roof members as indicated in the working Drawings or as instructed by the Engineer.

c) The maximum spacing of purlins under the sheets shall be 1.40 m in the case of 5.5 mm thick sheets and these shall in no case be exceeded.

d) Ridge purlins shall be fixed at 75 mm to 115 mm from the apex of the roof.

e) The top bearing surfaces of all purlins and of other roof members shall be in one plane so that the sheets when being fixed shall not require to be forced down to rest on the purlins.

f) The finished roof shall present a uniform slope and the line of corrugations shall be straight and true.

g) The sheets shall be laid with the smooth side upward.

h) The sheets shall be laid with a side lap of half a corrugation and an end lap of 15 cm minimum in the case of roofs with a pitch flatter than 1 vertical to 2.5 horizontal (Approx. 22º) or in the case of very exposed situations, the minimum permissible end lap shall be 20 cm. Side laps should be laid on the side facing away from the prevailing monsoon winds.

i) The free overhang of the sheets at the eaves shall not exceed 30 cm.

j) Corrugated sheets shall be laid from left to right starting at the eaves. The first sheet shall be laid uncut but the remaining sheets in the bottom row shall have the top left hand corners cut or mitred. The sheets in the second and other intermediate rows except the first and the last sheets shall have both the top left hand corner and bottom right hand corner cut. The last or top row sheets shall all have the bottom right hand corner cut with the exception of the last sheet which shall be laid uncut. If for any reason such as on considerations of the direction of prevailing winds, laying is to be started from the bottom right hand corner, then the whole procedure should be reversed.

k) The 'Mitred' described above is necessary to provide a snug fit where four sheets meet at a lap. It is cut from a point 15 cm (Or whatever the length of the end lap may be) up the vertical side of the sheet to a point 5 cm along the horizontal edge. This cutting may be done with an ordinary wood saw at site.

1001.3.4 Fixing

a) Sheets shall be secured to the purlins and other roof members by means of 8 mm diameter polymer coated iron J or L hook bolts and nuts. While, J hooks are used for fixing to angle iron purlins, L hooks are used for fixing to RS joists, timber or precast concrete purlins.

b) The grip of the J or L hook bolt on the side of the purlin shall not be less than 25 mm. Each iron J or L hook bolt shall have a bitumen washer and a galvanised iron washer placed over the sheet before the nut is screwed down from above. On each purlin there shall be one hook bolt on the crown adjacent to the side lap on either side. Bitumen washer shall be of approved manufacture. Polymer coating of hooks, bolts and nuts shall be as per IS: 14871.

c) The GI flat washer shall be 25 mm in diameter, 1.6 mm thick and the bitumen washer shall be 35 mm in diameter and 1.5 mm thick. The length of J bolt or crank bolt shall be as specified in table1000-4.

Table 1000-4: *Number and length of J bolts*

Sl. No.	*Situation*	*No. of bolts and washers*	*Length of bolts*
1.	At horizontal (end) laps of sheets, at eaves when filler pieces are used and at ridge when sheets and ridge pieces are secured by the same bolt.	Twice the no. of sheets in one horizontal course.	Depth of purlin plus 90 mm.
2.	At eaves when filler pieces are not used, at ridge when corrugated sheets and ridge pieces are not secured by the same bolt.	Twice the no. of sheets in the horizontal course.	Depth of purlin plus 75 mm.
3.	At intermediate purlins where horizontal laps do not occur.	Twice the no. of sheets in the horizontal.	Depth of purlin plus 75 mm.

d) Each nut shall be screwed lightly at first. After a dozen or more sheets are laid, the nuts shall be tightened to ensure a leak proof joint.

e) Holes for hook bolts etc. shall be drilled and not punched, always through the crown of the corrugation and not in valleys, in locations to suit the purlins while the sheets are on the roof in their correct position. The diameter of holes shall be 2 mm more than the diameter of the fixing bolts. No hole shall be nearer than 40 mm to any edge of a sheet or any accessory.

f) Roof ladders or planks shall always be used when laying and fixing the sheets, to avoid damage to the sheets, and to provide security to the workmen.

g) Wind ties may be provided where the situation justify their provision. These shall be of 40 mm x 6 mm flat iron section or of other size as specified. These shall be fixed at the eave ends of the sheets. The fixing shall be done with the same hook bolts which secure the sheets to the purlins.

h) The completed roof shall present a neat and uniform appearance and be leak proof.

i) Manufacturer's test certificate shall be produced by the Contractor if the area of roofing sheets exceeds 150 m^2.

1001.4 Non-asbestos high impact poly propylene reinforced cement semi-corrugated sheet roofing

1001.4.1 Materials

a) These shall be of the specified thickness and of approved quality and shall conform to IS: 14871.

b) They shall be free from cracks, chipped edge corners or other damages.

1001.4.2 Laying and fixing

a) The sheets shall be laid with the end stamped 'Top' on the smooth side pointing towards the ridge.

b) The sheets shall invariably be laid from right to left starting at the eaves with the procedure for mitring etc. as described under clause 1001.3.

c) The side laps provided will be of one corrugation, the left hand small corrugation of each sheet being covered by the right hand large corrugation of the next sheet.

d) Asbestos cement expansion joints shall be inserted every 45 m or so in the length of the roof. Specially manufactured expansion joint pieces shall be used for the purpose. The end lap of expansion joints shall not be less than 150 mm. If the expansion joints may be between the purlins, these should be stitched with seam bolts.

e) The procedure for fixing shall be same as described in 1001.3.4 except that along each line of purlin there shall be a hook bolt in every vertical side lap corrugation and at the two verges and there shall be an additional hook-bolt through one of the two intermediate corrugations on each sheet.

f) When sheets are supported over intermediate purlins as in the case of length over1.40 m for 5.5 mm thick sheets, fixing accessories are required on the intermediate purlins, through each side lap and the verges only.

g) The number and length of bolts and number of bituminous felt and galvanised iron washers are given in table 1000-5.

Table 1000-5: *Number and length of bolts and washers*

Sl. No.	*Situation*	*No. of bolts and washers*	*Length of bolts*
1.	At horizontal (end) laps of sheets, at eaves when filler pieces are used and at ridge when sheets and ridge pieces are secured by the same bolt.	Short bolts: The number of sheets in one horizontal course plus two. Long bolts: The number of Sheets in one course less one.	Depth of purlin plus 75 mm. Depth of purlin plus 90 mm.
2.	At eaves when filler pieces are not used, at ridge when sheets and ridge pieces are not secured by the same bolt.	Twice the number of sheets in one horizontal course plus one.	Depth of purlin plus 75 mm.
3.	At intermediate purlin when horizontal laps do not occur.	The number of sheets in one horizontal course plus one.	Depth of purlin plus 75 mm.

h) Wind ties shall be provided as detailed under 1001.3.4(g).
i) The roof when completed shall be true to lines and slopes and shall be leak proof.
j) Manufacturer's test certificate shall be produced by the Contractor if the area of roofing sheets exceeds 150 m^2.

1001.4.3 Ridges and hips of non-asbestos high impact polypropylene reinforced cement roofing sheets

1001.4.3.1 Materials

a) Ridges and hips shall be of the same manufacture as the corrugated or semi-corrugated sheets used for roof, unless specifically permitted in writing by the Engineer.
b) The sections shall be free from cracks, chipped edges or corners or other damages.
c) Ridges shall be of the type specified in the item, such as:
   i) One piece plain angular.
   ii) Serrated or plain wing adjustable.
   iii) Close fitting adjustable.
   iv) North light adjustable and appropriate for the corrugated or semi-corrugated roof. 'Plain wing angular' type ridges can be used only if the slope of the roof is exactly 30°. Hips shall be of 'under-rated adjustable for hips' sections.
   v) Un-serrated adjustable.

1001.4.3.2 Laying and fixing

a) The ridge sections shall be laid as per manufacturer's instructions with the rolls of the two wings in the case of adjustable ridges fitting closely and with the serrations of serrated ridges registering correctly with the sheets underneath. The stagger lapping or two wings of an adjustable ridge section and the laps between adjacent pieces on the same wing of the ridges shall be as per manufacturer's instructions.
b) The end portions of the wings of the adjustable ridges which project beyond the verges of the roof shall be cut and trimmed off neatly. Asbestos cement expansion joint ridge pieces shall be provided approximately every 45 m of ridge where the latter is of the semi-corrugated serrated adjustable type.
c) In laying hip pieces, serrations to suit the corrugations in the sheets below should be cut in them so that they will be a snug fit over the sheets.
d) The wings of ridges shall be fixed to the sheets below with the seam bolts and nuts 8 mm diameter polymer coated J or L hook bolts and nuts and bitumen and GI washers which fix the sheets to the purlins. In addition, in north light adjustable ridges the curves of the two wings shall be joined together at their crown with 8 mm diameter polymer coated seam bolts and nuts, at the rate of 2 numbers per pair of wings. Each seam bolt shall be provided with 1 bitumen washer and a pair of GI washers.
e) Where 'Plain wing angular' or 'Plain wing adjustable' ridges are used, the gaps formed by the roofing corrugations and the wings shall be filled with cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate 12.5 mm nominal size) upto the full length of the overlap. The exposed face shall be finished perpendicular to the sheeting.

f) Wing of hips shall be fixed to the roof members below with the same 8 mm diameter polymer coated or L hook bolts and nuts which fix the sheet to those members. In addition, they shall be secured to the sheets below with 8 mm diameter polymer coated seam bolts, nuts and washers, so that taken together with hook bolts there shall be bolt on each wing at least every 5th corrugation of the sheet below in the case of 'corrugation' and at least every 2nd corrugation of the sheet below in the case of 'semi corrugated' sheets. The seam bolts shall each be provided with 1 bitumen washer and a pair of GI washers.

1001.4.4 Roofing accessories of non-asbestos high impact polypropylene reinforced cement roofing sheets

1001.4.4.1 Materials

a) The accessories that may be required to be used on a roof are:
   i) Finishing pieces, eaves filler pieces, north light and ventilator curves, barge boards and expansion joint sheets.
   ii) Ridge finials, cowl type ventilators, curved boards for north light, curves, roof light expansion joints for ridge and expansion joints for north light curves.
   iii) 'S' type louver.
b) The accessories shall be of the type appropriate for use with corrugated or semi corrugated sheets which form the roofing.
c) The accessories shall be of the same manufacture as the corrugated or semi-corrugated sheets used for the roof.
d) The pieces shall be free from cracks, chipped edges or corners and other damages.

1001.4.4.2 Laying and fixing

a) These shall be laid and secured with the same polymer coated hook bolts which secure sheets to the roof members below where possible or with separate polymer coated hook bolts to the roof members below and/or with 8 mm diameter polymer coated seam bolts, nuts and washers to the sheeting, generally as per manufacturer's printed instructions and as ordered by the Engineer.
b) 'S' type louvers shall be fixed to ventilators to timber, MS angle or flat iron verticals spaced not more than 1.65 m centres. The laps of adjacent pieces over the verticals shall not be less than 10 cm. The upper flat of the top most row of louvers shall be fixed to the vertical by 10 mm diameter polymer coated bolts and nuts and bitumen and polymer coated washers.
c) The lower flats of the top and intermediate rows of louvers and the flat of the louvers pieces below shall be secured together to the verticals behind by 10 mm diameter GI separating bolts threaded at both ends and of suitable length. Each of these bolts shall be equipped with 2 pair of nuts, GI and bitumen washers. The louver flats of the lowest line of louvers shall also be fixed to the verticals at the proper distance from the same by the use of similar separating bolts and nuts.

1001.4.5 Eaves and valley gutters of non-asbestos high impact polypropylene reinforced cement roofing sheets

1001.4.5.1 Materials

a) Eaves gutters shall be of the type specified in the item such as
   i) Plain ended eaves.
   ii) Boundary wall.
   iii) Socketed eaves ogee.
   iv) Socketed half round.
b) These shall be of approved manufacture, standard size as stipulated in the item and approved by the Engineer.
c) Valley gutters shall be of the 'Plain' ended valley types and of size as stipulated in the item.
d) The gutter sections and their accessories such as drop ends, stop ends, nozzles, angles and union clips shall be free from cracks, chipped edges or corners and other damages.
e) The size of outlet of drop ends and nozzles shall be of the same size as the size of the rain water pipes into which they shall be discharging the water.

1001.4.5.2 Laying and fixing

a) Gutters shall be laid with a minimum slope of 1 in 120, which should be increased where possible.
b) They shall be true to line and slope and shall be laid with the requisite accessories such as drop ends, stop ends, nozzles, angles and union clips as shown in the working drawing or as ordered by the Engineer.
c) Gutters and their accessories shall be supported by MS flat iron bracket. Where these brackets are to be fixed to the sides of rafters, they shall be of 40 mm x 3 mm section bent to shape and fixed rigidly to the sides of the rafter with 3 Nos. 10 mm diameter bolts, nuts and washers. The brackets shall overlap the rafter not less than 30 cm and the connecting bolts shall be 11.5 cm centres.
d) Where the brackets are to be fixed to the purlins they shall consist of 50 mm x 3 mm MS flat iron bent to shape with one end turned at a right angle, and fixed to the purlin face with a 10 mm dia bolt, nut and washer. The perpendicular over hang portion of 50 mm x 3 mm bracket shall be stiffened by another 50 mm x 3 mm flat, bent to right angle shape with its lower leg connected to the bracket with 2 Nos. 6 mm dia MS bolts, nuts and washers and its shorter leg fixed to face of purlin with one number 10 mm dia bolt, nuts and washers. The overhang of the vertical portion of the flat iron bracket from the face of the purlin shall not exceed by 22.5 cm with this arrangement.
e) The requisite slope in the gutters shall be given in the line of the bracket. The brackets shall be placed at not more than 90 cm centres.
f) The gutters shall be fixed to the brackets with 2 Nos. 8 mm dia polymer coated seam bolts and nuts, each bolt and nut being equipped with a pair of bitumen and polymer coated washers. These connecting bolts shall be above the water line of the gutters.
g) Spigot and socket ends of gutters of 'socketed eaves ornamental' or 'socketed half round' type and their accessories shall be connected together at their laps with one row of 8 mm dia polymer coated bolts and nuts, each bolt and nut

being provided with a pair of bitumen and a pair of polymer coated washers. The gap between the socket and spigot shall be packed with approved plastic roofing compound, flanked on both sides with 6 mm dia non-asbestos rope. The connecting polymer coated bolts are then tightened so that the lapped joints become leak proof. The outer faces of the packed non asbestos rope shall not be farther than 6 mm from the edges of the spigot and socketed ends.

h) Where both ends of gutters and or their accessories to be connected together are of spigot ends they shall be laid as butt joints with 1.5 mm gap in between over union clips (loose socket pieces). The union clip shall be connected to the two butt ends of the gutter or other section on both ends with two rows (one row per ends) of 8 mm dia polymer coated bolts and nuts, each bolt and nut being provided with a pair of bitumen and a pair of GI washers. The gap between the union clips and the butt ends of the gutter sections or accessories shall be packed with approved plastic roofing compound flanked at both edges by 6 mm dia non-asbestos rope as before. The whole joint shall be made leak proof by tightening the bolts.

i) The ends of 'plain' ended eaves or boundary wall type and 'plain' ended valley type gutters and their accessories shall be laid with butt joints over union clips and connected together in the same manner as for connecting spigot and socket ends described in (g) above.

j) The gutters and accessories when fixed shall be true to line and slope and shall be ridged. All the joints shall be leak proof.

1001.5 Galvalume/zincalume and colour coated roofing sheets

1001.5.1 Materials

a) These sheets are available as corrugated, ribbed and tile profile.

b) They shall conform to ASTM A792/A792M.

c) Galvalume/Zincalume roofing sheets are galvanised steel sheets provided with a coating of the 55% aluminum and 45% zinc alloy. The coating greatly improves their corrosion resistance.

d) These sheets are available both with bare coating of 55% Al-Zn alloy, or further painted in numerous colours over the bare coating to enhance their aesthetics.

e) The base material for colour coated steel sheets is carbon steel having yield strength of 240-550 MPa. The sheets after cold rolling to desired thickness are coated with zinc, or 55% Al - Zn alloy in a hot dip galvanizing/coating line. Generally three coats of paint are applied on both sides of sheets - backer, primer and top coat.

f) IS : 14246 specifies that the top side coating shall be 20 microns minimum and the bottom side coating shall be 7 microns minimum.

g) Based on duration of salt spray test in hours, the coatings are classified in three grades as Class I (350 hours), Class II (500 hours), Class III (750 hours) for the top side and 200 hours for the bottom side for all the three classes.

h) There shall be no peeling or cracking of paint film on the bent portion in the 'bent test' performed in specified manner.

1001.5.2 Purlin spacing

Maximum allowable support spacing for Galvalume/Zincalume/Colour coated sheets are as indicated in the table 1000-6.

Table 1000-6: *Spacing of purlins*

Type of span	*0.50 mm TCT steel (550 MPa)*	*0.50 mm TCT steel (240 MPa)*
Roof		
Single span	900 mm	800 mm
Internal span	1800 mm	1400 mm
End span	1200 mm	1000 mm
Overhangs		
Without edge stiffening	150 mm	150 mm
With edge stiffening	300 mm	300 mm
Walls		
Single	1500 mm	1100 mm
Internal span	2000 mm	1400 mm
End span	1800 mm	1200 mm
Overhangs	300 mm	300 mm

1001.5.3 Laying and fixing

a) Surfaces to receive roofing shall be smooth and free from projections that would puncture the metal material or destroy its effectiveness.
b) Roofing sheets may be fastened by conventional crest fixing to timber of steel supports, in each case there shall be four fixings per sheet at all supports. Use only crest fixing for roofs. Wall cladding may be fixed by crest or valley fixing. All fasteners located in pan should be as close as possible to ribs.
c) The sheets for laying shall be lifted on to roof supports with ribs up and with all overlapping ribs (female) facing towards starting edge.
d) The direction of sheet laying shall be opposite to the prevailing wind direction.
e) The first sheet shall be placed in position with the female rib in line with other building elements. Fasten it with the self – drilling fastener as recommended by the manufacturer or direction of the Engineer.
f) The sheets shall be lapped such that the female rib of the second sheet comes over the male rib of the first sheet. Insert the recommended side lap fastener to hold the lap firmly in place before fastening the second sheet to supports.
g) The laying procedure of the second sheet shall be followed for the subsequent sheets.
h) Should it be necessary to use two or more end lapped sheets to provide coverage for the full length of the roof run, lay each line of end lapped sheets complete from bottom to top of the roof before proceeding to the next line of sheets.
i) Minimum end lap should be 150 mm. The lap should be sealed with recommended sealant.
j) Manufacturer's test certificate shall be produced by the Contractor if the area of roofing sheets exceeds 150 m^2.

1001.5.4 Flashing and accessories

Pre-formed light gauge metal is used for fabrication of flashing, capping gutters and accessories.

1001.6 Polycarbonate (PC) sheets

1001.6.1 Materials

a) Polycarbonate sheets are transparent like glass and are available as clear and colour (Blue, bronze/green) sheets in thickness ranging from 1 mm to 8 mm. Generally, 1.2 mm and 2 mm thick sheets are used for roofing.

b) They come in variety of profiles - compact, embossed, multiwall or corrugated.
c) They shall conform to specifications detailed in IS: 14443.
d) The sheets shall be UV stabilized and shall be tested for accelerated weathering conforming to ISO 4892.
e) The guaranteed service life of the polycarbonate sheets shall be a minimum 10 years covering discoloration (yellowing), loss of light transmission, and loss of strength due to weathering.

1001.6.2 Laying and fixing

Fabrication practices for polycarbonate sheets are detailed under Annexure A of IS: 14443.

1001.6.3 Sampling and tests

a) The sampling and testing of polycarbonate sheets shall be done as per IS: 14443.
b) Typical properties and tests for polycarbonate sheets are given in table1000-7.

Table 1000-7: *Tests for polycarbonate sheets*

Property	*Test method*	*Unit*	*Value*
Light transmission	ASTM D1003	%	89
Solar transmission	DIN 67507	%	89
Hail impact resistance	TNO test	M/s	>21
Falling dart impact strength	Gardener test, IS: 14443	J	>4kg at 1 m
K- value	DIN 52612	W/m^2	5.9
Oxygen index	ASTM D 2863	%	25
Sound insulation	DIN52210	dB	20

c) Manufacturer's test certificate shall be produced by the Contractor if the area of polycarbonate sheets exceeds 60 m^2.

1001.7 Plastic translucent sheets (Glass fibre reinforced)

1001.7.1 Materials

a) The material shall be composed of a thermo-setting styranated or acrylated polyester resin system reinforced with glass fibre. This system may include curing agents, catalysts and light stabilizers. Fire retardant grade of resin and colouring matter shall be used only in special cases as specified in the Contract.
b) The glass fibre used as reinforcement shall be in the form of chopped strand mat having a highly soluble modified polyester binder in accordance with IS: 11551 having a density of 450 gm/m^2 and minimum width of 500 mm.
c) Fixing accessories such as hooked, cranked, 'U', 'J' and square bend hook bolts, L-bolts, roof washers etc. shall conform to IS: 730.
d) The nominal weight of 1·10+0·15 mm thick plain sheet shall be 1.85 kg/m^2.

1001.7.2 Laying and fixing

a) Laying of plastic translucent sheets made from thermosetting polyester resin (Glass fibre reinforced) alone or in conjunction with asbestos cement sheets/steel sheets/aluminium sheets are detailed in IS: 15224.
b) Plastic translucent sheets made from thermosetting polyester resin (Glass fibre reinforced) shall be cut as necessary with a hacksaw with 6/8 teeth per cm.
c) When plastic translucent sheets made from thermosetting polyester resin (Glass fibre reinforced) are laid either fully or in chequer board or eaves to ridge layouts in conjunction with asbestos cement/steel/aluminium sheets, before

the actual laying of sheets are started, the purlin spacing and the length of the sheets shall be checked to ensure that the arrangement will provide the laps required and the specified overhang at the eaves.

d) The required total number of plastic translucent sheets shall be distributed over the entire roof area at equal pitch to ensure even daylight.

e) When the roof of a building is laid fully with plastic translucent sheets, the side of end laps of the sheets shall be in accordance with IS: 15224.

f) When the roof of building is laid using plastic translucent sheets in conjunction with asbestos cement/steel/aluminium sheets in chequerboard or eaves to ridge layouts, the side and end laps of plastic translucent sheet with asbestos cement/steel/aluminium sheets shall be governed by the respective code of practice for laying asbestos cement /steel/aluminium sheets. In either case, the course of sheets shall be so laid that the corrugations run in continuous straight lines.

g) When a roof is being fully laid with plastic translucent sheets for sinusoidal profile plastic translucent sheets, fixings shall be located through the crowns of the sheets.

h) Trough section profile plastic translucent sheets shall be fixed direct to the supporting structure with cadmium plated or stainless steel self-tapping screws located in the bottom flat troughs of sheets, nuts or screws shall be tightened lightly at first, and then fully tightened when a dozen or more sheets have been laid.

i) Manufacturer's test certificate shall be produced by the Contractor, if the area of plastic translucent sheets exceeds 150 m^2.

1001.7.3 Sampling and testing

a) The sampling and testing of plastic translucent sheets for tests shall be done as per IS: 12866. The details of the tests are given in table 1000-8.

Table 1000-8: *Recommended tests for plastic translucent sheets*

Sl. No.	*Test*	*Annexure in IS: 12866*	*Value*
1	Glass content	A	Not less than 30%
2	Water absorption	B	Not more than 0.3%
3	Hardness	C	Shall not increase by more than 30% of its initial value.
4	Bolt shear	D	Not less than 250N
5	Load deflection test	E	Shall not rupture, minor cracking around the areas of support or loading permitted.
6	Light diffusion	F	Refer table1000-9
7	Light transmission	G	Refer table 1000-10

Table 1000-9:*Light diffusion gradient constant*

Diffusion classification	*Description*	*Gradient constant G*
I	Clear	>0.80
II	Moderately diffusing	0.32 - 0.80
III	Heavily diffusing	0.10 - 0.32
IV	Very heavily diffusing	<0.10

Table 1000-10: *Minimum transmission*

Diffusion classification	*Minimum total transmission*
I	80
II	75
III	70
IV	60

1001.8 Prepainted galvanised steel sheets

1001.8.1 Requirements

a) Pre-painted sheets are produced by uniformly coating and baking durable synthetic resin paint, for example, alkyd, epoxy, polyester, acrylic etc over one or both surfaces of galvanised sheets using cold rolled sheets as base conforming to IS: 277, IS: 513 and IS: 14246.

b) The requirements for pre-painted galvanized steel sheets are given in table 1000-11.

Table1000-11: *Requirements for pre-painted galvanized sheets*

Properties	*Code*	*Requirement*
Zinc coating	ASTM A653, ASTM A755, IS: 277, IS: 513, IS: 4246, AS1397, JISG: 3302,G3312	Z 120 GSM (gm/m^2)
Primer service coat		5 microns epoxy/PU on both sides..
Paint coating		Regular modified polyester (optional – silicon modified polyester & PVF2)
Painting thickness (Top)		20 microns (Min).
Painting thickness (Bottom)		7 microns (Min).
Surface paint reflection		Semi-gloss/matt finish.
Yield strength		300 – 550 MPa.

c) Base metal for pre-painted galvanised sheets conforms to IS: 513 with zinc coating as per IS: 277.

d) One sample for bend test, pencil hardness test, impact resistance test and cross hatch adhesion test shall be taken from every 10 tonnes of sheets or part thereof or one coil of the same quality, dimensions, grade of zinc coating and colour.

e) Standard pencils of hardness as given in table 1000-12 shall be used for the pencil hardness test.

f) The test specimen shall be bent through an angle of 180° around a mandrel having diameter specified in table 1000-12 with a hand vice or any other suitable means (Ref. IS: 14246).

Table 1000-12: *Physical properties of paint coating for roofing*

Tests	*Requirements*
Bend test	4t
Pencil hardness test	2H

t -nominal thickness of the sheet

H -hardness of pencil

g) Recommendations for the use of pre-painted steel sheets for external applications are given in table 1000-13 (Ref. IS: 14246).

Table1000-13: *Recommendations for the use of pre-painted steel sheets for external applications*

Type of coating	*Material of coating*	*Thickness in micron*	*Remarks*
Top coat	Epoxy	20-30	For external and internal applications.
	Polyester Polyurethane	20-30	For external and internal application.
	PVDE	20-30	For external applications. Very good corrosion and weathering resistant.
	Silicon modified polyester	20-30	For external applications. Very good corrosion and weathering resistant.
Back Coat	Alkaloid epoxy or polyester	7 (Min)	Mainly one coat system or two coat system (Optional with primer).

h) Manufacturer's test certificate shall be produced by the Contractor, if the area of roofing sheets exceeds 150 m^2

1001.9 Aluminium roofing sheets

Aluminium roofing sheets are being increasingly adopted in various factories and workshop sheds, godowns etc. Apart from being corrosion resistant, the aluminium roofing sheets are lighter in weight and have high scrap value. Aluminium roofing sheets are costlier as far as initial material cost is concerned.

1001.9.1Materials

a) General requirements relating to the supply of aluminium and aluminium alloy sheet shall conform to IS: 10259.
b) The material shall be sound and free from harmful defects for the intended application.
c) The chemical composition, mechanical, physical or other properties of the material shall be in accordance with IS: 737, IS: 1254, IS: 2676 and IS: 10259.
d) The corrugated aluminium sheet shall be made from aluminium alloy conforming to the specification listed in tables 1000-14 and 1000-15.

Table 1000-14: *Chemical composition of wrought aluminium and aluminium alloy sheet*

Design –ation	*Cu*	*Mg*	*Si*	*Fe*	*Mn*	*Zn*	*Ti and/or other grain refining element*	*Cr*	*Al*
31000	0.1	0.1	0.6	0.7	0.8-1.5	0.2	0.2	0.2	Remainder
31500	0.2	0.6-1.3	0.4	0.7	1.0-1.5	0.2	0.2	-	Remainder
40800	0.2	0.1	0.6-0.95	0.6-0.95	0.1	0.2	0.2	-	98.0 (min)
51300	0.3	0.2-0.9	0.6	0.9	0.2-0.7	0.4	0.2	0.2	Remainder

Table 1000-15: *Mechanical properties of wrought aluminium and aluminium alloy sheet*

Design-ation	*Cond-ition*	*Tensile strength (MPa)*		*Elongation on 50 mm gauge length, percent for thickness (t)*				*Bend test - Radius of bend*
		Min	*Max*	*0.5 to 0.8 mm*	*Over 0.8 to 1.3 mm*	*Over 1.3 to 2.6 mm*	*Over 2.6 to 6.3 mm*	
31000	H4	130	180	3	4	5	5	½ t
31500	H4	190	245	3	4	5	5	½ t
40800	H4	125	160	3	4	5	5	½ t
51300	H4	150	200	4	4	5	6	1 t

e) Designation, characteristics and available forms of alloys used for roofing are given in table 1000-16.

Table 1000-16: *Designation, characteristics and available forms of alloys for roofing*

Design ation	*Characteristics*	*Available forms*
31000	Stronger and harder than 19000* but has good workability, weldability and corrosion resistance	Sheet, plate, extrusion, wire, tube and forgings.
31500	Strength between alloys 31000 and 52000. It has good formability, weldability and corrosion resistance	Sheet and strip.
40800	Strength comparable to alloy 31000 and ductility comparable to alloy 19000. This alloy is fine grained and has excellent drawability.	Sheet, strip and plate.
51300	Stronger and harder than alloy 19000. Strength between alloys 31000 and 31500. It has good weldability.	Corrugated sheet, sheet and strip

**Aluminium of grade 19000 is commercially pure, very ductile and excellent in corrosion resistant aluminium.*

f) Manufacturer's test certificate shall be produced by the Contractor, if the area of roofing sheets exceeds 150 m^2

1001.10 Sandwich polyurethane foam panels

1001.10.1 Materials

a) Sandwich panels are made out of GI pre-coated sheet on its outer and inner surfaces with the core injected with high density polyurethane foam.

b) The chemical and mechanical properties of GI pre-coated sheet shall conform to IS: 14246.

c) Polyurethane foam is an organic insulation material made from a reactive mixture of two principal liquid components and a number of additives, to produce highly cross linked polymers with a closed cell structure.

d) The technical specifications of polyurethane foam shall conform to IS: 12436.

e) Manufacturer's test certificate shall be produced by the Contractor, if the area of roofing sheets exceeds 150 m^2.

f) The requirements of PUF foam are given in table 1000-17.

Table 1000-17: *Requirements for PUF foam*

Physical properties	*Average measured value*	*Test standard*
Overall density (kg/m^3)	40±2%	ASTM D 1622-88, DIN 53420
Core density (kg/m^3)	32 to 34	ASTM D 1622-88, DIN 53420
Thermal conductivity (W/K-m)	0.017-0.023	ASTM C 518-56, DIN 52612
Closed cells (%)	>95	ASTM D 2826, ISO DP 2246
Compressive strength (kg/cm^2)	1.7 to 1.9	ASTM D 1621
Tensile strength (kg/cm^2)	2.8 to 3.0	ASTM D 1621
Flame spread	40 (Max)	ASTM 1692
Self-extinguishing time	40 (Max)	ASTM 1692

1001.10.2 Installation of roof panels

a) Sandwich panels are fixed with tongue and groove method.
b) Roof panels shall be continuous from ridge to eave for buildings 18 m wide or less, where end laps are required, the width shall be approximately 150 mm and shall occur over a roof purlin.
c) All laps of roof panels shall be sealed with a continuous ribbon of tape sealer.
d) Roof panels shall be secured to intermediate framing members metal screws at a maximum spacing of 333 mm. At end laps, the maximum spacing of screws shall be 111 mm.
e) Side laps of roof panels shall be stitched through the high rib with two, equally spaced metal screws between supports (screw spacing not to exceed 525 mm).

1001.11 Fibre-reinforced plastic sheets

1001.11.1 Materials

a) Fibre –reinforced plastic (FRP) also fibre – reinforced polymer is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, basalt or asbestos.
b) The polymer is usually an epoxy or a polyester thermosetting plastic.
c) They are normally available in 0.4 to 5.0 mm thickness.
d) They are also available in transparent and opaque varieties.
e) The test standards of the FRP sheets are given in table 1000-18.

Table 1000-18:*Tests standards for FRP sheets*

Sl. No.	*Physical properties*	*Code*
1	Tensile strength	ASTM D 638
2	Tensile modulus	ASTM D 638
3	Flexural strength	ASTM D 790
4	Flexural modulus	ASTM D 790
5	Coefficient of linear thermal expansion	ASTM D 696
6	Thermal transmittance (U Value)	ASTM C 1363
7	Thermal conductivity(k)	ASTM C 177
8	Izod impact test	ASTM D 256
9	Barcol hardness	ASTM D 2583
10	Limiting oxygen index	ASTM D 2863
11	Smoke density	ASTM D 2843
12	Flammability	UL 94

f) Manufacturer's test certificate shall be produced by the Contractor, if the area of roofing sheets exceeds 150 m^2.

1001.12 Polyvinyl chloride roofing sheets

Polyvinyl chloride is one of the most versatile thermoplastics in use today. It is produced by polymerization of vinyl chloride monomer, a gas produced by reaction of ethylene with oxygen and hydrochloric acid. PVC resin is a rigid substance to which plasticizers, stabilizers and other components must be added to provide the desired properties for the PVC's intended use.

1001.12.1 Materials

a) PVC membranes consist primarily of a PVC resin modified with a plasticizer, coupled with other additives.
b) The additives can include colorant, fire retardant, biocide, lubricants, ultraviolet stabilizers and ultraviolet absorbers.
c) The PVC membrane may be reinforced, reinforced with random fibres or reinforced with a scrim depending on the vintage.
d) The thickness of reinforced sheets with fibre glass should conform to ASTM D 638 and with polyester should conform to ASTM D 751.
e) The standard specifications for polyvinyl chloride sheets should conform to ASTM D 4434.
f) The requirements of PVC sheets are given in table 1000-19.

Table 1000-19: *Requirements for PVC sheets*

Sl. No.	*Physical properties*	*Code*
1	Tensile strength	ASTM D 882/ ASTM D 638
2	Elongation	ASTM D 882/ ASTM D 638
3	Tear strength	ASTM D 1004
4	Ply adhesion	ASTM D 413
5	Abrasion loss	ASTM D 3389
6	Thickness	ASTM D 1593
7	Specific gravity	ASTM D 792
8	Water vapor transmission	ASTM E 96
9	Water absorption	ASTM D 570
10	Dimensional stability	ASTM D 1204
11	Smoke density	ASTM D 2843
12	Flammability	UL 94

g) Manufacturer's test certificate shall be produced by the Contractor, if the area of roofing sheets exceeds 150 m^2.

1001.13 Unpalsticized polyvinyl chloride roofing sheets

1001.13.1 Materials

a) Unplasticized Polyvinyl chlorine roofing sheets shall be fabricated from unplasticized PVC compounds as defined in ISO: 1163.
b) Compounds may contain additives such as stabilizers, lubricants, processing aids, impact modifiers, flame retardants and colourants.
c) Compounds and additives of unknown identity and composition shall not be used for the processing of sheets.
d) Sheets are classified into four groups by the numerical value of two important properties, i.e. the tensile impact strength and the vicat softening temperature.
e) The surface shall be free of noticeable flaws, cracks, mottling, voids, bubbles, impurities and other defects which are not acceptable for the application envisaged.
f) The sheet shall have smooth surface, except for embossed sheets which shall have a uniform pattern.
g) The properties of sheets of each group and class shall be as specified in table 1000-20.

Table 1000-20: *Properties of UPVC sheets*

Property	*Test method*	*Unit*	*Requirements*						
			Group 1		Group 2		Group 3		Group 4
			Class 1	Class 2	Class 1	Class 2	Class 1	Class 2	
Tensile Stress at yield	ISO 527-3	MPa	≥40	≥40	≥40	≥40	≥40	≥40	≥40
Nominal strain at break	ISO 527-3	%	≥20	≥20	≥20	≥20	≥20	≥20	≥20
Tensile impact strength	ISO 8256	kJ/ m^2	-	-		≥300	≥300	≥400	≥400
Vicat Softening temperature	ISO 306	°C	≥60	≥70	≥60	≥70	≥60	≥70	≥90

h) Requirements of UPVC sheets shall be tested as per the codes given in table 1000-21.

Table 1000-21: *Tests standards for UPVC sheets*

Sl. No.	*Physical properties*	*Code*
1	Tensile strength	ASTM D 638
2	Elongation at break	ASTM D 638
3	Density	ASTM D 792
4	Vicat softening temp	ASTM D 1525
5	HDT at 1.8MPa	ASTM D 648
6	Flexural strength	ASTM D 790
7	Oxygen index	ASTM D 2863
8	Chemical resistance	ASTM D 543
9	Water absorption	ASTM D 570

i) Manufacturer's test certificate shall be produced by the Contractor if the area of roofing sheets exceeds 150 m^2

1001.14 Asphaltic roofing

The asphalt roofing products include asphalt saturated felt, surfaced and smooth roll roofing, fiberglass and organic (felt-based) shingles, and modified bitumen membranes. The production process typically involves six stages, and asphalt is the primary input.

1001.14.1 Asphalt felt characteristics

Asphalt felts are used as inner roof coverings and serve as protectants and sealants. They are suited for this use because they are water repellent, able to tolerate temperature fluctuations, and resistant to breakdown and decay caused by exposure to the elements.

1001.14.2 Roll roofing characteristics

Both surfaced and smooth roll roofing are outer roof coverings commonly used for low-cost housing and utility buildings in place of asphalt shingles. They are purchased in rolls that are 36 to 38 feet long and approximately 36 inches wide, thereby simplifying the roof application process.

1001.14.3 Asphalt shingle characteristics

Asphalt shingles have different characteristics depending on their base, such as organic felts and glass-fiber base mats. Organic felts are produced from paper fibers, rags, wood, or a combination of the three, while glass-fiber base mats are manufactured from inorganic, thin glass fibers. Interlocking shingles come in various shapes and with different locking devices, which provide not only a mechanic interlock but also resistance to strong winds.

1001.14.4 Modified bitumen membrane characteristics

Modified bitumen membranes have a number of uses. They can be applied as the primary material for new roofs, as a cover for existing roofs, and as cap sheets in built-up roofing (BUR) applications. For each of these applications, styrenebutadiene-styrene (SBS) based membranes are installed using hot asphalt, a torch, cold process adhesives, or self-adhesives. Atactic polypropylene (APP) based membranes are usually installed with a torch or cold process adhesives.

1001.14.5 Asphalt corrugated roofing sheet

a) Asphalt corrugated roofing sheets made from processed mineral and organic fibres and impregnated with bitumen (Asphalt) are also available.
b) The sheets are nominally 2000 mm x 1250 mm x 3 mm and have a nominal finished weight of 3.32 kg/m^2.
c) The sheets have 35 mm deep corrugations spaced at 102 mm on centre, continuous along the length.
d) The roofing sheets must be installed on roofs with a minimum slope of 3:12.
e) The sheets must be installed with a minimum side lap of one corrugation. The minimum end lap must be 178 mm for sheets.
f) The sheets are fastened at the corrugation crowns through the underlayment to the roof sheathing with the nails. The fasteners must be of sufficient length to penetrate a minimum of 19 mm into the sheathing or through the sheathing.

1002 CEILING

A ceiling is an overhead interior surface that covers the upper limit of a room. It is not generally considered as a structural element, but as a finished surface concealing the underside of the floor or roof structure above. Ceilings are classified according to their appearance or construction. For area of ceiling work more than 100 m^2, Contractor shall produce manufacturer's certificate for tests prescribed in the relevant BIS codes.

1002.1 Wooden ceiling

1002.1.1 Materials

a) Wooden ceiling boards shall be of the class of timber and of finished thickness as specified in the description of the item and shall be in accordance with the general specifications for wood work.
b) Only selected boards of uniform width shall be used. Unless otherwise specified the width of boards selected for use shall not be less than 100 mm nor more than 150 mm.
c) The specific width of boards once selected within these two limits shall be maintained throughout and shall not be varied except in the first and last lines of boards adjacent to the two walls, where remaining odd width shall be adjusted equally on both sides.
d) The maximum length of the board in the finished work shall be 180 cm.

e) The minimum length of board in the finished work shall be such that it will span at least two spacing of the supporting frame work except where shorter lengths are unavoidable, depending on the arrangements of the lines of heading joints which shall be carried out to the pattern ordered by the Engineer.
f) Timber frame of the class of timber and section specified in the description of the item or as approved by the Engineer shall be provided.
g) The width of the frame scantling shall not be less than 50 mm.
h) They shall be of the slotted counter sunk head type of length not less than the thickness of the board plus 20 mm.
i) The designation number shall not be less than 9 for screws of length 40 mm to 50 mm and shall not be less than 6 for screws of length 25 mm to 35 mm.

1002.1.2 Installation

a) The wooden ceiling boards shall be planed true on the exposed side.
b) Unless stipulated otherwise in the description of the item, the longitudinal joints of the boards shall be tongued and grooved, while the heading joints shall be of the square butt type and shall occur under the centre line of the supporting joint.
c) Heading joints in adjacent boards shall not be placed over the same joists, those in alternate boards being arranged in the same line, except where the joints are to be concealed by headings.
d) The arrangements and spacing of the frame scantling shall be as per design furnished.
e) The frame shall be given two coats of approved preservative paint before the boarding is screwed.
f) The bottom surface of the frame shall be checked and corrected to true plans and slopes.
g) The outer lines of boards shall be accurately fixed, parallel and close to the wall. Each subsequent plank shall be carefully jointed up.
h) The boards shall be fixed to the frame scantling above with two screws at each of frames and one at every intermediate joist.
i) The screws shall be counter sunk and the screw holes filled with putty or sloping out wax.
j) The unexposed faces of planks shall be painted with wood preservative before fixing.
k) The exposed side of the boards shall be level and plane.
l) The joints shall be truly parallel and/or perpendicular to the walls.
m) Beadings shall then be fixed to the ceiling, to the size and pattern, if required.

1002.2 Ceiling with fibre insulating building boards

1002.2.1 Materials

a) The insulating building boards shall be of approved quality as per IS: 3348 and, unless otherwise specified, shall have square edges.
b) The dimension shall be subjected to the tolerances given in the table 1000-22.
c) Frame of the class of timber and section specified in the description of the relevant item or approved by the Engineer shall be provided. The width of the scantlings provided shall be sufficient to provide a minimum nailing surface of 50 mm.

Table 1000-22: *Dimensions and tolerances*

Type of board	*Nominal Thickness mm*	*Tolerance on thickness mm*	*Length cm*	*Width cm*	*Tolerance on length and width*
Fibre insulation board, ordinary or flame retardant type	9 12 18 25	±0.75 ±0.75 ±1.00 ±1.25	365, 300 270, 140 210, 180 150, 120 100, 90 60, 45 and 30	180, 150, 120, 100, 90, 60 45 and 30	For 120 cm and below ±3 mm and for above 120 cm ±6 mm.

1002.2.2 Installation

a) The longitudinal and header scantlings shall be so arranged that
   i) The boards can be fixed to form the panel arrangements required as per Drawings or as ordered by the Engineer.
   ii) The longitudinal scantling to which the boards are mainly fixed are spaced at 30 to 45 cm centres, the actual spacing selected depending on the width of the cut board in the panel arrangement.
   iii) All edges of the cut board units are supported either on the longitudinal scantlings or on the header scantlings or on both.

b) The frame shall be given two coats of approved preservative paint (To be paid separately) before the board is nailed on. MS angles or other sections shall be used for suspending the frame.

c) Where the joints in the board are to be covered with beadings, the frames should allow 3 mm to 6 mm space between boards.

d) The bottom surface of the frame shall be checked and corrected to true planes and slopes.

e) The sheets shall be fixed to the frame scantling with GI headless nails 2.24 mm dia when the joints are to be left exposed.

f) Where the joints will be covered with beadings, the sheets are to be fixed to the frames scantlings with GI felt headed (clout) nails 2.5 mm dia.

g) The length of the nails shall generally be equal to thickness of sheet plus 25 mm so that their grip on the framing members will not be less than 25 mm.

h) The boards shall be laid with lengths parallel to all joints centered over the framing members. Where joints are to be covered, the boards may be spaced 3 to 6 mm apart as described in the respective manufacturers' specifications. Where joints are to be left exposed the sheets shall be butt laid with their edges abutting in moderate contact, but without having to force them into place.

i) The boards shall be supported and held tight to the frame with timber pieces the later being moved outwards as the nailing proceeds. The boards are first nailed to the intermediate framing member proceeding from the centre of the board outwards, the edges being nailed last.

j) Where the joints are to be left exposed, the outer rows of nails are placed at 10 cm centres and about 12 mm from the edge of the sheet. In the rows in the middle of the sheets, the nails are placed 20 cm apart. The nails should be counter sunk in the underside of board with a suitable punch. Care shall be taken in driving the nails so that the sheets are not marked by hammer blows.

k) Where the joints are to be covered with beadings, felt headed (clout) nails shall be used instead of nails without head. The spacing of the nails in the interior rows in boards shall be the same as in the preceding paragraph. In the outer rows at edges to be covered by beadings, the nails will be spaced at 20 cm centres in each row with the nails staggered. The beadings will then be fixed over the sheets with screws at 20 cm centres in each row with the screws in the two rows staggered and passing through beading, sheet and framing so that ultimately the spacing of the fixing (nails and screws taken together) in each row will be at 10 cm centres so far as the sheets and frames are concerned.

l) The exposed side of the board shall be truly level and plane without any local bulges or sags. The joints shall be truly parallel and/or perpendicular to the walls. The width of joints shall be uniform. Care shall be taken to see that the uniformity of colour of the sheets is not spoilt during the fixing operations.

m) Where the joints are required to be covered, beadings of size, pattern and material as approved by Engineer shall be fixed with screws.

1002.3 Particle board/multipurpose cement board ceiling

1002.3.1 Materials

a) *Particle board:* Particle board flat pressed 3 layers medium density shall be graded particleboard grade-1 conforming to IS: 3087 of specified thickness.

b) *Multipurpose cement board:* (High Pressure Steam cured). This shall be conforming to IS: 14862 and of thickness specified in the item.

c) The specifications as described in 1002.2.2 shall apply except that the maximum spacing of the longitudinal scantlings shall be 40 cm centres.

d) The specifications for nails, fixing and finishing shall be the same as in 1002.2.2.

1002.4 Plain/semi perforated particle board tiles ceiling

1002.4.1 Materials

a) Ceiling tiles shall be of 12 mm plain/semi perforated or with design BWP type phenol formaldehyde synthetic resin bonded particle board.

b) It shall conform to IS: 3087.

1002.4.2 Installation

a) The frame work shall consist of anodized aluminium T sections for main runners /cross runners of size specified in the item with anodic coating of 15 micron and perimeter wall angle of anodized aluminium section of size specified by the Engineer with anodic coating of 15 micron fixed to the wall with MS screws 50 mm long and PVC raw plugs.

b) The frame work shall be executed in a manner so as to form a grid of 600 mm x 600 mm or as specified in the item.

c) The frame work shall be suspended from ceiling by level adjusting hangers made of 6 mm dia. MS rods fixed to slab by means of MS ceiling cleats. The ceiling cleats shall be fixed to the slab by means of mechanical dash fasteners 6 mm dia and 50 mm long.

d) MS hangers and ceiling cleats shall be painted with a coat of yellow zinc chromate primer and two coats of synthetic enamel paint.

e) The ceiling tiles shall be placed over the aluminium frame and fixed to the frame with help of 25 mm long CP brass screws with minimum 2 screws on each side of the grid.
f) The CP brass screws shall be counter sunk star head screws.
g) Tiles shall be finished with a coat of aluminium primer on both side and edges and two coats of synthetic enamel paint of approved quality and shade on exposed faces of the tiles.

1002.5 Gypsum board ceiling

1002.5.1 Materials

a) Gypsum board is the name for a family of board products consisting of a non-combustible core, primarily of gypsum, with a paper surfacing on the face, back and long edges.
b) The gypsum board used for ceilings shall conform to IS: 2095, Parts 1, 2 and 3.

1002.5.2 Installation

a) The frame work shall consist of sections by power pressing of MS sheets and galvanising with zinc coating of 120 gm/m^2 (Both side inclusive) as per IS: 277 or anodized aluminium T sections for main runners/cross runners of size specified in the item with anodic coating of 15 micron and perimeter wall angle of anodized aluminium section of size specified by the Engineer with anodic coating of 15 micron fixed to the wall with MS screws 50 mm long and PVC raw plugs.
b) The frame work shall be executed in a manner so as to form a grid of 400 mm x 400 mm or as specified in the item.
c) The frame work shall be suspended from ceiling by level adjusting hangers made of 6 mm dia. MS rods fixed to slab by means of MS ceiling cleats. The ceiling cleats shall be fixed to the slab by means of mechanical dash fasteners 6 mm dia and 50 mm long.
d) Gypsum board shall be applied first to ceiling at right angles to framing members, then to walls.
e) Boards of maximum practical length shall be used so that an absolute minimum number of end joints occur.
f) Board edges shall be brought into contact with each other but shall not be forced into place.
g) Joint compound is used for filling the joints, taping and finishing.
h) The ceiling is finished with two coats of plastic emulsion paint as soon as joint compound is dry, about one week after joints are completed.

1002.6 PVC ceiling

1002.6.1 Materials

The PVC panels shall be of the required thickness as specified in the item for the work.

1002.6.2 Installation

a) The frame work shall consist of anodized aluminium T-sections for main runners /cross runners of size specified in the item with anodic coating of 15 micron and perimeter wall angle of anodized aluminium section of size specified by the Engineer with anodic coating of 15 micron fixed to the wall with MS screws 50 mm long and PVC raw plugs.

b) The frame work shall be executed in a manner so as to form a grid to suit the size of the PVC panels or as specified in the item.
c) The frame work shall be suspended from ceiling by level adjusting hangers made of 6 mm dia MS rods fixed to slab by means of MS ceiling cleats. The ceiling cleats shall be fixed to the slab by means of mechanical dash fasteners 6 mm dia and 50 mm long.
d) MS hangers and ceiling cleats shall be painted with a coat of yellow zinc chromate primer and two coats of synthetic enamel paint.
e) The PVC panels shall be fully attached to the frame by snapping one side of the panel into position first, followed by the second side. When properly installed, the strips shall be firmly secured, and fully level.

1002.7 Translucent white acrylic plastic (PMMA) sheet ceiling

1002.7.1 Materials

The ceiling tiles shall be made of translucent white acrylic plastic sheet conforming to IS: 14753 of thickness specified in the item.

1002.7.2 Workmanship

The frame for the acrylic plastic sheet ceiling and fixing of sheets shall be as detailed under clause 1002.4.2.

1002.8 Plaster of paris (Gypsum anhydrous) ceiling over wooden strips

1002.8.1 Materials

a) The plaster of paris shall be of the calcium sulphate semi-hydrate variety.
b) Its fineness shall be such that when sieved through a sieve of IS sieve 3.35 mm for 5 minutes, the residue left on it after drying shall not be more than 1% by weight.
c) It shall not be too quick setting. Initial setting time shall not be less than 13 minutes.
d) The average compressive strength of material determined by testing 5 cm cubes after removal from moulds, after 24 hours and drying in an oven at 40°C till weight of the cubes is constant, shall not be less than 84 kg/m^2.

1002.8.2 Installation

a) The frame work shall be of the specified wood. In case of sloping roofs, wooden battens of suitable section (Depending upon the span and load to be carried) shall be firmly fixed as main supports, to the underside of the tie beams of the trusses at required spacing by means of bolts and nuts of proper size.
b) In case of flat roofs, the battens shall be securely fixed to the walls and pillars by holding down bolts and shall be fastened to the slabs above with iron straps of suitable sections and encroached therein. Cross battens of 50 x 40 mm sections at 40 cm centres or so, shall then be fixed at right angles to the main battens.
c) The frame work shall be treated with approved wooden preservative before fixing. The underside of the frame work shall be true to planes and slopes.
d) Wooden strips of size 25 mm x 6 mm of first class kailwood, (Unless otherwise stipulated specifically in the description of the item) shall be fixed to the cross battens, in the parallel rows with gaps of 10 mm in between adjacent rows, by means of felt headed (Clout) nails.
e) The strips shall be fixed butt jointed and not overlapped.
f) The joints shall be staggered.

g) The minimum length of strips to be used shall be 1.5 m depending upon the length of strips required.
h) Rabbit wire mesh shall then be fixed to the underside of wooden strips and their junctions with the battens fixed with nails at a pitch of 15 cm to 20 cm.
i) The rabbit wire mesh shall be straight, tight and perfectly true to planes and slopes and without any sagging and shall be slightly below the underside of the laths to allow the plaster to encase the metal round.
j) The plaster of paris shall be mixed with water to a workable consistency and applied to the underside of the laths over the rabbit wire mesh in suitable sized panels and finished to a smooth surface true to plane, slopes or curves, as required.
k) The plaster shall be applied in such a manner that it fully fills the gaps between the laths and the thickness over the laths is as specified in the description of the item.
l) The joints shall be finished flush to make the ceiling in one piece. The finished surface shall be smooth and true to plane, slopes or curves as required.

1002.9 Thermal insulation for roofing with cellular concrete

1002.9.1 Types and grades

a) Cellular concrete is a light weight concrete formed by producing gas or air bubbles in cement slurry or a cement sand slurry. Cellular concrete shall conform to IS: 6598 and shall be of following two types depending on the manner of manufacture.

Type I: High pressure steam cured (auto-claved) materials in the form of precast blocks.

Type II: Materials cured under natural conditions (that is under ambient pressure and temperature) by water. The material may be either cast in situ or may be in the form of precast blocks.

b) *Grades* - Each of these two types of the material shall have three grades, namely:
   i) Grade A - Light weight cellular concrete.
   ii) Grade B - Medium weight cellular concrete.
   iii) Grade C - Heavy weight cellular concrete.

1002.9.2 Materials

a) *Aggregate*: A variety of siliceous fines, such as ground quartz, sand, shale, fly ash and granulated slag may be used in the manufacture of cellular concrete.
b) Water and binder shall conform to para 3.1.1 and 3.1.2 of CPWD Specifications 2009.
c) *Gassing agents*: Organic foaming agents based on resin soap, glue, surface active agents, or fine aluminium powder, zinc, dust, calcium carbide, calcium by pocheride etc. may be used for gassing the concrete.
d) *Dimensions*: The dimensions of the type I and type II precast cellular concrete block shall be either 50 or 60 cm in length, 20, 25 or 30 cm in width and 7.5, 10, 15, 25 or 40 cm in thickness.
e) *Tolerance:* A tolerance of ±3% shall be allowed on width and height and ±1% on thickness.

1002.9.3 Requirements

The requirements of cellular concrete are detailed in table 1000-23.

Table 1000 -23: *Requirements of cellular concrete*

Sl. No.	*Code*	*Characteristics*	*Grade A*	*Grade B*	*Grade C*
1	IS: 5688	Density (kg/m^3)	Upto 320	321 to 400	400 to 500
2	IS: 5688	Crushing strength, kg/cm^2 - type 1	7.0	12.0	20.0
		-do- type 2	2.5	4.5	8.0
3	IS: 3346	Thermal conductivity (kW/cm °C)	0.7	0.85	1.0
4	Capillary absorption not to exceed 20% in case of type I cellular concrete when tested as per Appendix A of IS: 6598.				

1002.9.4 Sampling

a) In a consignment, cellular concrete of the same type and grade and manufactured approximately in the same period shall be grouped to form a lot.
b) If it is in the form of blocks, a lot shall be made up of not more than 1000 blocks. If the material is in-situ, not more than 10 tonnes of materials shall constitute a lot.
c) If the material is transported in trucks and received as such, the material in the lorry (Or vehicle load) may be conveniently termed as lot.
d) Each lot shall be tested for all the requirements separately.
e) If the lot is made up of precast blocks, the number of sample blocks to be tested shall be selected at random as per table 1000-24.

Table 1000-24: *Sampling of a lot of precast blocks*

Lot size	*Sample size (Block to be sampled) (n)*	*Permissible No. of defectives (Visual and dimensional requirements) (a)*
Up to 100	5	0
101 to 300	8	0
301 to 500	13	0
501 to 1000	20	1

f) Cellular concrete, if done with precast blocks, shall be laid on terrace slab after thoroughly cleaning the surface. The blocks shall be laid over a layer of 12 mm average thick cement mortar 1:4 and the joints shall also be filled properly with neat cement slurry.
g) The joints shall be staggered. Thickness of joints shall be minimum as possible and not more than 5 mm.

1002.10 Thermal insulation for roofing with resin bonded fibre glass wool (Bonded mineral wool)

1002.10.1 Material

a) The material shall be mineral wool made from rock slag or glass processed from a molten state into fibrous form and shall be bonded with a suitable binder.
b) Bonded mineral wool shall conform to specifications of group I of IS: 8183.
c) The bonded mineral wool shall be supplied in width of 50, 60, 75 and 100 cm, and length of 100, 120 and 140 cm and the thickness of the bonded mineral wool shall be 25, 40, 50, 65 or 75 mm.
d) For width and length, the dimensional tolerances of the bonded mineral wool slabs shall be -½%. For nominal thickness in the range 25 to 75 mm the tolerance shall be -2 mm. An excess, in all dimensions is permitted.

1002.10.2 Requirements for fibre glass wool

The requirements of fibre glass wool are given in table 1000-25.

Table 1000-25: *Requirements for fibre glass wool*

Sl. No.	*Properties*	*Code*	*Requirements*
1.	Bulk density	IS: 3144	12 to 15 kg/m^3.
2.	Recovery after Compression	Annexure A of IS: 8183	Not less than 90% of original thickness.
3.	Shot content (Max)	IS: 3144	500 micron (5%), 250 micron (15%).
4.	Moisture content and absorption	IS:3144	Not more than 2%.
5.	Incombustibility	IS:3144	Incombustible.
6.	Thermal conductivity at mean temperature 50°C	IS: 3346	0.49 mW/cm°C.
7.	Sulphur content	IS: 3144	Not more than 0.6%.

1002.10.3 Installation

a) Bonded mineral wool insulation can be either laid over false ceiling or alternatively it can be fixed to the ceiling when the space above false ceiling is being used for carrying return air.
b) In the first case the bonded mineral wool can either be fixed with suitable adhesive to the false ceiling board or else it can simply be rolled over the suspended false ceiling.
c) In the second case when space above false ceiling is to be used for carrying return air 38 mm x 38 mm slotted angle (75 mm length) shall be fixed to the ceiling by means of raw plugs at 50 mm spacing.
d) Draw 14 gauge tie wires from the slots. Make a mat of mineral wool insulation backed with scrim cloth with a light coating of plaster of paris or polythene faced hessian and 24 gm x 25 mm wire mesh netting.
e) The joints of wire netting should be butted and tightly laced down with GI wire. Stretch the mat tightly across the angles holding it in place by means of tie wires.

1002.11 Thermal insulation for roofing with expanded polystyrene

1002.11.1 Material

a) Expanded polystyrene shall conform to IS: 4671. It is of two types as given below:
   i. Type N - Normal
   ii. Type SE - It shall be of self extinguishing type when tested in accordance with Appendix E of IS: 4671.
b) The size of the finished boards shall be 1.0 × 0.5 m or as specified and having a thickness of 15, 20, 25, 40, 50, 60, 75 or 100 mm.
c) The tolerances on length, width and thickness of the finished board shall be ±2 mm.

1002.11.2 Requirements

The requirements for expanded polystyrene for general use shall be as given in table 1000-26.

Table 1000-26: *Requirements for expanded polystyrene for general use*

Sl. No.	*Characteristics*	*Requirements at various nominal apparent densities in kg/m³*					*Code*
		15	*20*	*25*	*30*	*35*	
1.	Thermal conductivity (K value) (a) at 0°C (b) at 10°C	 0.34 0.37	 0.32 0.35	 0.30 0.33	 0.29 0.32	 0.28 0.30	IS: 3346
2.	Compressive strength at 10% deformation in kg/cm² (Min)	0.7	0.9	1.1	1.4	1.7	IS: 4671 Appendix A
3.	Cross breaking strength in kg/cm² (Min)	1.4	1.6	1.8	2.2	2.6	IS: 4671 Appendix B
4.	Water vapour permeance in gm/m², 24 hours (Max)	50	40	30	20	15	IS: 4671 Appendix C
5.	Thermal stability % (Max)	1	1	1	1	1	IS: 4671 Appendix D
6.	Water absorption %	2	1	1	1	1	IS: 4671 Appendix E

1002.11.3 Sampling

a) In a single consignment all the items of the same type, shape and dimensions belonging to the same batch of manufacture shall be grouped together to constitute a lot.

b) For the purpose of judging conformity to the requirements each lot shall be considered separately.

c) The number of sample items for this purpose shall depend on the size of the lot and shall be in accordance with column 1 and 2 of table 1000-27.

d) The sample shall be taken at random from the lot.

Table 1000-27: *Sampling of items*

No. of items in the lot	*No. of sample items*	*Permissible number of defective sample items*
Upto 25	3	0
26 to 100	5	0
101 to 300	8	0
301 to 1000	13	0
1001 to 3000	20	1
3001 and above	32	2

e) All the sample items selected from the lot shall be tested for all requirements of the specifications.

f) Any item failing in one or more of the requirements shall be regarded as defective.

g) Expanded polystyrene can either be fixed with suitable adhesive to the false ceiling board or else it can simply be rolled over the suspended false ceiling.

1003 REFERENCES

1. IS: 73 Specification for paving bitumen.
2. IS: 277 Galvanised steel sheets (plain and corrugated).
3. IS: 513 Cold reduced low carbon steel sheets and strips.
4. IS: 651 Terminology glazed stoneware pipes and fittings.
5. IS: 702 Specification for industrial bitumen.
6. IS: 737 Wrought aluminium and aluminium alloy sheet and strip for

		general engineering purposes.
7.	IS: 1199	Methods of sampling and analysis of concrete.
8.	IS: 1200	Method of measurements of building and civil engineering works:
	(Part 9)	*Roof covering (Including cladding).*
9.	IS: 1200	Method of measurements of building and civil engineering works:
	(Part -10)	*Ceiling and lining.*
10.	IS: 1230	Cast iron rain water pipes and fitting.
	IS: 1254	Corrugated aluminium sheet.
11.	IS: 1367	Technical supply conditions for threaded steel fasteners:
	(Part 13)	*Hot dip galvanized coating on threaded fasteners.*
12.	IS: 2095	Gypsum plaster boards:
	(Part 1)	*Plain gypsum plaster boards.*
13.	IS: 2115	Code of practice for flat roof finish: mud phuska.
14.	IS: 2633	Method of testing uniformity of coating on zinc coated articles.
15.	IS: 2645	Specification for integral water proofing compounds for cement mortar and concrete
16.	IS: 2676	Dimension of wrought aluminium and aluminium alloy sheet and strip.
17.	IS: 3007	Code of practice for laying of asbestos cement sheets:
	(Part 1)	*Corrugated sheets.*
	(Part 2)	*Semi corrugated sheets.*
18.	IS: 3087	Particle boards of wood and other lignocellulogic materials (medium density) for general purposes – specifications.
19.	IS: 3144	Methods of test for mineral wool thermal insulation materials.
20.	IS: 3346	Method of the determination of thermal conductivity of thermal insulation materials.
21.	IS: 3348	Specification for fibre insulation boards.
22.	IS: 3384	Specification for bitumen primer for water proofing and damp proofing.
23.	IS: 4671	Expanded polystyrene for thermal insulation purposes.
24.	IS: 5382	Specification for rubber sealing rings for gas mains, water mains and sewers.
25.	IS: 5688	Methods of test of performed block type and pipe covering type thermal insulations.
26.	IS: 6598	Cellular concrete for thermal insulation.
27.	IS: 7193	Specification for glass fibre base coal tar pitch and bitumen felts (Amendment I).
28.	IS: 8183	Bonded mineral wool.
29.	IS: 10192	Specifications for synthetic resin bonded glass fibre (SRBGF). for electrical purposes
30.	IS: 10259	General conditions of delivery and inspection of aluminium and aluminium alloy products.
31.	IS: 11551	Glass fibre chopped strand mat for the reinforcement of epoxy, phenolic and polyester resin systems.
32.	IS: 12436	Preformed rigid polyurethane (Pur) and polyisocyanurate (Pir)

		foams for thermal insulation.
33.	IS: 12866	Plastic translucent sheet made from thermosetting polyester resin (Glass fibre reinforced).
34.	IS: 13592	Unplasticised polyvinyl chloride (UPVC) pipes for soil and Waste discharge system for inside and outside building.
35.	IS: 14246	Continuously pre painted galvanized steel sheets and coils.
36.	IS: 14753	Specifications for polymethyl methacrylate arylic (PMMA) sheets.
37.	IS: 14862	Fibre cement flat sheets-specifications.
38.	IS: 14871	Specifications for products in fibre reinforced cement-Long corrugated or asymmetrical section sheets and fittings for roofing and cladding.
38.	IS: 15224	Laying of plastic translucent sheets made from thermosetting polyester resin (Glass fibre reinforced) alone or in conjunction with asbestos cement sheets/steel sheets/aluminium sheets-code of practice.

+++++++

SECTION 1100 FLOORING

1101 GENERAL

a) The purpose of a floor is to provide a horizontal sanitary surface to support the occupants of a building, furniture and equipment.
b) Floor finishes depend on the expected load, the desired resistance to abrasion and wear, speed of execution and the architectural and aesthetic requirements of a building.

The floor finishes in common use are discussed in this section.

1102 CEMENT CONCRETE FLOORING

1102.1 Materials

Cement concrete of specified mix grade shall be used and it shall conform to the requirements given under Section 600 for concrete.

1102.2 Requirements

a) Base concrete, if provided shall be with the slopes required for the flooring. Flooring in verandah, courtyard, kitchen & bath shall have slope ranging from 1:48 to 1:60 depending upon location.
b) Floors in water closet (WC) portion shall have slope of 1:30 to drain off washing water. Further, necessary drop in flooring in bath, WC, kitchen near floor traps ranging from 6 mm to 10 mm will also be provided to avoid spreading of water. Necessary margin to accommodate this drop shall be made in the base concrete. Plinth masonry off set shall be depressed so as to allow the base concrete to rest on it.
c) Flooring shall commence preferably within 48 hours of the laying of base concrete. Immediately before laying the flooring, the base shall be wetted and a coat of cement slurry @ 2 kg per m^2 area spread to get a good bond between the base and concrete floor.
d) If the cement concrete flooring is to be laid directly on an RCC slab, the top surface of RCC slab shall be cleaned and the laitance shall be removed and a coat of cement slurry shall be applied as mentioned in (c).

1102.3 Workmanship

a) The thickness of floor shall be as specified in the item.
b) *Laying in panels* - The border panels shall not exceed 450 mm in width and the joints in the border shall be in line with panel joints. The panels shall be of uniform size and no dimension of a panel shall exceed 2 m and the area of a panel shall not be more than 2 m^2. The joints of borders at corners shall be mitred for provision of strips.
c) *Laying of flooring with strips* - Normally cement concrete flooring shall be laid in one operation using glass/aluminium/PVC/brass strips/stainless steel strips or any other strips as required at the junction of two panels. This method ensures uniformity in colour of all the panels and straightness at the junction of the panels. 4 mm thick glass strips or 2 mm PVC strips or 2 mm aluminium or brass strips shall be fixed with their tops at proper level, giving required slope. Use of glass and metallic strips shall be avoided in areas exposed to sun.

d) *Concreting* - Cement concrete shall be placed in the panels and be levelled with the help of straight edge and trowel. It shall be properly compacted by suitable means. The evenness of the surface shall be checked with straight edge. Surface of flooring shall be true to the required slope. While laying concrete, care shall be taken to see that the strips are not damaged/disturbed. The top of strips shall be visible clearly after finishing with cement slurry. Laying of cement concrete flooring in alternate panels may be allowed in case strips are not to be provided.

e) *Finishing* - The finishing of the surface shall follow immediately after compaction. The surface shall be left untouched till moisture disappears from it. Use of dry cement or cement-sand mixture to absorb excessive moisture shall not be permitted. Excessive trowelling shall be avoided. The men engaged on finishing operations shall be provided with raised wooden platform to sit on so as to prevent damage to new work.

f) *Curing* - The curing shall be done for a minimum period of ten days. Covering with empty cement bags shall be avoided as the colour of the flooring is likely to be bleached due to the presence of cement dust from the bags.

g) For cement concrete pavement in courtyard and terrace etc., the panels shall be of uniform size and no dimension of a panel shall exceed 1.25 m and the area of panel should not exceed 1.25 m^2 for the thickness of panels up to 50 mm. Concreting shall be done in alternate panels only and no glass/asbestos strips shall be provided.

1103 CEMENT PLASTER IN RISERS OF STEPS, SKIRTING, DADO

1103.1 Workmanship

a) Plaster at the bottom of wall not exceeding 30 cm in height above the floor shall be classified as skirting.

b) The work shall be preferably carried out simultaneously with the laying of floor. The corners and junctions with floor shall be finished neatly as specified.

c) The joints shall be raked out to a depth of at least 15 mm in masonry walls. In case of concrete walls, the surfaces shall be roughened properly. The surface shall be cleaned thoroughly, washed with water and kept wet before skirting is commenced.

d) Skirting with specified mortar and to specified thickness shall be laid immediately after the surface is prepared.

e) It shall be laid and finished along with the border or adjacent panels of floor. The joints in skirting shall be kept true and straight in continuation of the line of joints in borders or adjacent panels.

f) The skirting shall be finished smooth with top truly horizontal and joints truly vertical except where otherwise indicated.

g) The cement to be applied in the form of slurry for smooth finishing shall be at the rate of 2 kg of cement per litre of water applied over an area of 1 m^2.

h) Where skirting is flush with plaster, a groove 10 mm wide and up to 5 mm depth shall be provided in plaster at the junction of skirting with plaster.

i) Curing shall be commenced when the plaster has hardened sufficiently but not later than 16 hours after finishing and shall be continued for a minimum period of 7 days.

1104 TERRAZO (MARBLE CHIPS) FLOORING LAID IN-SITU

1104.1 Materials

a) The marble chips shall be of quality and colour as specified.
b) It shall be hard, sound, dense and homogenous in texture with crystalline and coarse grains.
c) It shall be uniform in colour and free from stains, cracks, decay and weathering.
d) The mix for terrazzo shall consist of cement with or without pigment, marble powder, marble aggregate (marble chips) and water.

1104.2 Requirements

a) The maximum thickness of the top layer for various sizes of marble aggregates (marble chips) shall be 6 mm to 12 mm depending on the aggregate size.
b) Where aggregate of size larger than 10 mm are used, the minimum thickness of topping shall not be less than one and one third times the maximum size of the chips.
c) Where large size chips such as 20 mm or 25 mm are used, they shall be used only with a flat shape and bedded on the flat face so as to keep the minimum thickness of wearing layer.

1104.3 Workmanship

a) Cement concrete of specified mix shall be used for the base layer.
b) The flooring shall be provided in panels which shall be of uniform size, not exceeding 2 m^2 in area or 2 m in length for inside situations.
c) In exposed situations, the length of any side of the panel shall not be more than 1.25 m.
d) Cement slurry @ 2.0 kg per m^2 shall be applied before laying of the terrazzo over the cement concrete/RCC flooring.
e) For providing panels, 4 mm thick glass strips or 2 mm thick PVC/ aluminium/brass/stainless steel/copper strips, unless otherwise specified, shall be fixed with their top at proper level to the required slope.
f) Strips of stone or marble or of any other material of specified thickness can also be used if specifically required.
g) Use of glass and metallic strips shall be avoided in areas exposed to sun.
h) Laying and fixing of strips shall be as specified in clause 1102.
i) The cement and marble powder shall be mixed in the proportion of three parts of cement to one part marble powder by weight.
j) The cement to be used shall be ordinary grey cement, white cement, cement with admixture of colouring matter of approved quality in the ratio specified in the description of the item in the ratio to get the required shade as directed by the Engineer.
k) Colouring materials where specified shall be mixed dry thoroughly with the cement and marble powder and then marble chips added and mixed as specified above.
l) The full quantity of dry mixture of mortar required for a room shall be prepared in a lot in order to ensure a uniform colour. This mixture shall be stored in a dry place and well covered and protected from moisture.
m) The dry mortar shall be mixed with water in the usual way as and when required. The mixed mortar shall be homogenous and stiff and contain just sufficient water to make it workable.

n) The terrazo topping shall be laid after the base layer has hardened sufficiently to prevent cement from rising to the surface. This is normally achieved between 18 to 24 hours after the under layer has been laid.

o) The surface of the top layer shall be trowelled over, pressed and brought true to required level by a straight edge and steel floats in such a manner that the maximum amount of marble chips come up and are spread uniformly over the surface.

p) A cement slurry preferably of the same colour as the topping shall be brushed on the surface laid to a uniform thickness slightly more than that specified in order to get the specified finished thickness after rubbing.

q) The surface shall be left dry for air-curing for duration of 12 to 18 hours depending on atmospheric temperature conditions. It shall then be cured by allowing water to stand in pools over it for a period of not less than 4 days.

r) The grinding and polishing may be commenced not before 2 days from the time of completion of laying for manual grinding and not before 7 days for machine grinding. For polishing by machines, the surface shall be watered and ground evenly with machine fitted with special rapid cutting grit blocks (Carborandum stone) of coarse grade (No. 60) till the marble chips are evenly exposed and the floor is smooth.

s) After the first grinding, the surface shall be thoroughly washed to remove all grinding mud and covered with a grout of cement and colouring matter in same mix and proportion as the topping in order to fill any pin holes that appear. The surface shall be allowed to dry for 24 hours and wet cured for 4 days and then rubbed with machine fitted with fine grit blocks (No. 120).

t) Curing shall be done again by ponding of water between panels formed with fine sand. The surface is cleaned and repaired as before and allowed to cure again for 3 to 5 days.

u) Finally the third grinding shall be done with machine fitted with mere fine grade grit blocks (No. 320) to get even and smooth surface without pin holes. The finished surface should show the marble chips evenly exposed.

v) Where use of machine for polishing is not feasible or possible, rubbing and polishing shall be done by hand, in the same manner as specified for machine polishing except that carborandum stone of coarse grade (No. 60) shall be used for the 1st rubbing, stone of medium grade (No. 80) for second rubbing and stone of fine grade (No. 120) for final rubbing polishing.

w) After the final polish either by machine or by hand, oxalic acid shall be dusted over the surface @ 33 gm per m^2 area, sprinkled with water and rubbed hard with a pad of woollen rags. The following day, the floor shall be wiped with a moist rag and dried with a soft cloth and finished clean.

x) Wax polish shall be of approved brand and manufacture and in sealed containers. It shall be applied in uniform layer to the dry surface of the floor/skirting. When the layer of the wax is stiffened and surface of floor is saturated with the polish, polishing shall be resorted with machine fitted with bobs (pad of rags) and shall be done until shades of all chips have appeared and glossy surface is obtained.

1105 CRAZY MARBLE STONE FLOORING

a) Crazy marble stone flooring shall be laid on cement concrete base.

b) The base concrete shall be provided with slope required for the flooring in verandahs and courtyards to drain off washing and rain water.
c) The guidelines for base concrete detailed under clause 1102 shall strictly be adhered to.
d) The crazy marble flooring shall be laid on a cement concrete layer of thickness 25 mm or as specified over the base concrete.
e) The mix shall normally be 1:2:4 using graded stone aggregate 12 mm nominal size by volume, unless otherwise specified. It shall conform to the requirements given under clause 1102.
f) The mix of crazy marble stone flooring shall consist of white cement with or without pigment, marble powder, marble chips and marble stone pieces and water.
g) The marble stone pieces shall be hard, sound, dense and homogenous in texture with crystalline and coarse grains.
h) It shall be uniform in colour and free from stains, cracks, decay and weathering. The marble stone pieces shall be of approved size. Before starting the work the contractor shall get the sample of marble stone approved by the Engineer.
i) For 50 mm thick floor, the thickness of marble pieces will be 25 mm while for 40 mm thick floor, the thickness will be 15 mm.
j) The white cement and marble powder shall be mixed in proportion of three parts of cement and one part of marble powder by weight, and the proportion of marble chips to binder mix by volume shall be 7 parts of marble chips to 4 parts of binder mix.
k) A coat of cement slurry at the rate of 2 kg of cement per m^2 of area shall be spread and then the marble stone pieces shall be set by hand in such a manner that the top surface of all the set marble stones shall be true to the required level and slopes.
l) After fixing the stones, the cement marble chips mixture shall be filled in between the gaps of laid marble stone pieces. The filled surface then shall be trowelled over, pressed and brought to the level of the laid marble stone pieces.
m) Curing and finishing and wax polishing shall be as described in clause 1104.

1106 TERRAZZO TILE FLOORING

1106.1 Materials

a) Terrazzo tiles shall generally conform to IS: 1237.
b) The size of tiles shall be 250 x 250 x 22 mm, 300 x 300 x 25 mm or as directed by the Engineer.
c) Half tiles for use with the full tiles shall be such as to make two half tiles when joined together, match with the dimensions of one full tile.
d) The minimum finished thickness of tiles for risers of steps, skirting and dado shall however be 12 mm.
e) The tiles shall be manufactured in a factory under pressure process subjected to hydraulic pressure not less than 140 kg/cm^2 and shall be given the initial grinding with machine and grouting of the wearing layer before delivery to site.
f) The wearing layer shall be free from projections, depressions, cracks, holes, cavities and other blemishes. The edges of wearing layer may be rounded.

g) The proportion of cement to aggregate in the backing of tiles shall be not leaner than 1:3 by weight. Where colouring material is used in the wearing layer, it shall not exceed 10 per cent by weight of cement used in the mix.

h) The finished thickness of the upper layer shall not be less than 5 mm for size of marble chips ranging from the smallest up to 12 mm and not less than 6 mm for size of marble chips varying from the smallest up to 20 mm.

1106.2 Workmanship

a) The surface on which the tiles are to be laid shall be cleaned wetted and mopped.

b) The bedding for tiles shall be with cement mortar 1:4 or of specified mix.

c) The minimum thickness of bedding mortar at any place shall be 10 mm.

d) Bedding mortar shall be spread, tamped and corrected to proper levels.

e) After laying bedding mortar, neat grey cement slurry of honey like consistency shall be spread over the bedding mortar at the rate of 4.4 kg of cement per m^2.

f) Tiles shall be washed cleaned and shall be fixed into this grout butting one at another, each tile being gently tapped with a wooden mallet till it is properly bedded, and is in level and line with the adjoining tiles.

g) The joints shall be kept as thin as possible and in straight lines.

h) The surface shall be checked with a straight edge during laying to obtain a true surface.

i) After the tiles have been laid surplus cement grout shall be cleaned off.

j) Machine grinding and finishing shall be done as detailed under clause 1104.

k) For small areas or where circumstances so require, hand grinding/polishing with hand grinder may be permitted in lieu of machine polishing after laying. For hand polishing the following carborandum stones, shall be used:

   i) First grinding - coarse grade stone (No. 60).

   ii) Second grinding - medium grade (No. 80).

   iii) Final grinding - fine grade (No. 120).

l) In all other respects, the process shall be similar as for machine polishing.

m) After the final polish, oxalic acid shall be dusted over the surface at the rate of 33 gm/m^2 sprinkled with water and rubbed hard with a pad of woollen rags. The following day, the floor shall be wiped with a moist rag and dried with a soft cloth and finished clean.

n) If any tile is disturbed or damaged, it shall be refitted or replaced, properly jointed and polished.

o) The finished floor shall not sound hollow when tapped with a wooden mallet.

p) The plaster for receiving tiles for risers of steps, skirting and dado shall be roughened with wire brushes or by scratching diagonal lines 2 mm deep at approximately 7.5 cm centres both ways.

q) Plastering for risers of steps, skirting and dado shall be done as detailed under clause 1103.

r) Top of skirting or dado shall be truly horizontal with projection from finish wall surface not more than tile thickness and joints truly vertical except where otherwise indicated.

s) Wax polishing shall be done as detailed under clause 1104.

1106.3 Tolerances

Tolerances on length and breadth shall be plus or minus one millimetre, and tolerance on thickness shall be plus 5 mm. The variation of dimensions in any one delivery of tiles shall not exceed 1 mm on length and breadth and 3 mm on thickness.

1106.4 Sampling

a) The tiles required of carrying out test described below shall be taken by 'random sampling'. Each tile sample shall be marked to identify the consignment from which it was selected.

b) Minimum quantity of tiles for carrying out the test and frequency of test shall be as specified in the list of mandatory tests given under table 1100-1. The number of tiles selected for each mandatory test shall be as follows:
   i) For conformity to requirements on shape and dimensions, wearing layer, and general quality - 12 tiles.
   ii) For wet transverse strength test - 6 tiles.
   iii) For resistance to wear test - 6 tiles.
   iv) For water absorption test - 6 tiles.

c) The tests on the tiles shall not be carried out earlier than 28 days from the date of manufacture.

d) The tiles selected for tests under b (i) may as well be used for tests under b (ii) also after verification of the requirements.

Table 1100-1: *Quality tests for terrazzo tiles*

Test	*Code*	*Min. quantity of material for carrying out the tests*	*Frequency of testing*
1. Transverse strength 2. Water absorption 3. Abrasion	IS:1237	5000 Nos. (No testing to be done if the total number of tiles of all types of all sizes from all manufacturers used in a work is less than 5000)	One test for every 10,000 tiles or part thereof for each type and size from a single manufacturer. (One test to be done even if the number of terrazzo tiles of any type and size from a single manufacturer is less than 5000, if the total number of tiles used in the work exceeds 5000).

e) The requirements of transverse strength tests specified in table 1100-1 shall not apply when the tiles used are less than 20 mm thick.

f) When tested for flatness of tile surface according to procedure laid down in IS: 1237, the amount of concavity and convexity shall not exceed 1 mm.

g) When tested for perpendicularity in accordance with the procedure laid down in IS: 1237, the longest gap between the arm of the square and edge of the tile shall not exceed 2% of the length of edge.

h) When tested for straightness as per IS: 1237, the gap between the thread and the plane of tile shall not exceed 1% of the length of edge.

i) In water absorption test, the average water absorption shall not exceed 10%.

j) Six full size tiles shall be tested for the determination of wet transverse strength. When tested according to the procedure laid down in IS: 1237, the average wet transverse strength shall not be less than 3 N/mm^2 (30 kgf/cm^2)

k) When tested according to IS: 1237 for resistance to wear, average wear shall not exceed 3.5 mm and the wear on any individual specimen shall not exceed 4

mm, for general purpose tiles. This shall be 2 mm and 2.5 mm for heavy duty floor tiles.

1107 CHEQUERED TILE FLOORING

The chequered tiles shall be cement tiles, or terrazzo tiles as specified in the item.

1107.1 Requirements

a) The tiles shall be of nominal sizes such as 20 × 20 cm, 25 × 25 cm and 30 × 30 cm or of standard sizes with equal sides. The size of tiles to be used shall be as specified in the item or as directed by the Engineer.
b) The centre to centre distance of chequers shall not be less than 2.5 cm and not more than 5 cm.
c) The overall thickness of the tiles shall not be less than 30 mm.
d) The grooves in the chequers shall be uniform and straight.
e) The depth of the grooves shall not be less than 3 mm.
f) The thickness of the upper layer, measured from the top of the chequers shall not be less than 6 mm.
g) The terrazzo tiles shall be given the first grinding with machine before delivery to site.
h) The tiles shall conform to the specifications for plain cement concrete or terrazzo tiles in respect of method of manufacture and the mix of the backing and wearing layers.
i) For tiles in treads of stairs, the tiles shall satisfy the following conditions
    i) The length of the tiles including nosing shall be as specified.
    ii) The nosing edge of the tile shall be rounded.
    iii) The minimum thickness of the tile shall be 30 mm.
    iv) The front portion of the tile for a minimum length of 75 mm from and including the nosing shall have grooves running parallel to the nosing and at centres not exceeding 25 mm. Beyond that the tiles shall have the normal chequer pattern.
    v) The nosing shall also have the same wearing layer as the top.
j) For tiles in treads of stairs, the square end of the tile shall, as far as possible butt against the riser face of the concrete or brick tread and in any case shall be embedded under the side wall plaster, skirting or dado and under the riser tile or other finish to a depth of not less than 10 mm.

1107.2. Workmanship

a) Laying, curing, polishing and finishing shall be as specified in Clause 1104 except that the polishing of the tiles and the chequer grooves, after laying, may be done by hand.
b) Special care shall be taken to polish the grooves in such a manner as to get a uniform section and that their finish shall match with the finish of flat portion of the tiles.
c) Cement concrete tiles normally do not require polishing but where polishing is required the same shall be done as described above.
d) The plaster for receiving tiles for risers of steps, skirting and dado shall be roughened with wire brushes or by scratching diagonal lines 2 mm deep at approximately 7.5 cm centres both ways.
e) Plastering for risers of steps, skirting and dado shall be done as detailed under Clause 1103.

1108 ACID OR ALKALI RESISTANT TILES

1108.1 Requirements

a) The tiles shall be conforming to IS: 4457.
b) The tiles shall be of vitreous ware and free from deleterious substances.
c) The iron oxide content allowable in the raw material shall not exceed two percent.
d) The tiles shall be vitrified at the temperature of 1100°C and above and shall be kept unglazed.
e) The finished, tile, when fractured shall appear fine grained in texture, dense and homogenous.
f) The tiles shall be sound, true to shape, flat and free from flaws and manufacturing defects affecting their utility.
g) The tiles shall be square shaped. Half tiles rectangular in shape shall also be available. Half tiles for use with full tiles shall have dimensions which shall be such as to make two half tiles, when joined together, match with the dimension of full tile.
h) The depth of the grooves on the underside of the tile shall not exceed 3 mm.
i) Tiles shall be legibly marked on the back with the name of manufacturer or his trade mark, manufacturer's batch number and year of manufacture.
j) Each tile shall also be marked with the ISI certification mark.

1108.2 Workmanship

a) Preparation of surface and laying to be according to clause 1109, except the cement used to be acid and/or alkali resistant cement and cement mortar to be used to be acid and/or alkali resistant mortar.
b) Thickness of bedding of mortar for flooring to be 10 mm or specified on the item and for dado/skirting to be 12 mm or specified on item.
c) Pointing and finishing shall be as per as per clause 1109, except that cement used for pointing to be acid and or alkali resistant cement.

1108.3 Tolerances

Tolerance on length, breadth and thickness of tiles shall be +2%.

1108.4 Sampling and testing

a) Sampling procedure for acceptance tests and criteria for conformity to be as per IS: 4457. The number of tiles to be selected from a lot shall be in accordance with table 1100-2.

Table 1100-2: *Scale of sampling and acceptance number*

Sl. No.	*No of tiles in the lot*	*Sample size*	*Acceptance No.*
1	Upto 8	5	0
2	9-25	8	0
3	26-50	13	0
4	51-100	20	1
5	101-500	32	2
6	501 and above	50	3

b) The tiles to be tested for water absorption, breaking strength, acid resistance as per IS: 4457.
c) Tiles shall be checked for squareness and warp as per IS: 4457.
d) The tiles when tested shall conform to be requirement specified in IS: 4457.

e) The maximum percentage of loss in abrasion of the ceramic unglazed vitreous acid resistant tiles determined in accordance with the procedure laid down in IS: 1237, shall be as mentioned in IS: 4457.

1109 PRESSED CERAMIC TILE FLOORING

1109.1 General

The pressed ceramic tile flooring includes flooring with different types of ceramic tiles including vitrified tiles detailed in IS: 15622.

1109.2 Requirements

a) The tiles shall be of approved make and shall generally conform to IS: 15622.
b) Glazed pressed ceramic tiles, both modular and non-modular, shall be made square or rectangular in sizes as per IS: 15622.
c) They shall be flat, and true to shape and free from blisters, crazing, chips, welts, crawling or other imperfections detracting from their appearance when viewed from a distance of one metre.
d) Classification and characteristics of pressed ceramic tiles shall be as per IS: 13712.
e) Size and thickness shall be as specified in the item.
f) The top surface of the tiles shall be glazed. Glaze shall be either glossy or matt as specified. The underside of the tiles shall not have glaze on more than 5% of the area in order that the tile may adhere properly to the base.
g) The edges of the tiles shall be preferably free from glaze. However, any glaze if unavoidable, shall be permissible on only upto 50 % of the surface area of the edges.
h) Only the glaze shall be coloured as specified.
i) Decorated tiles having white or coloured back ground tiles shall have size as per IS: 15622.

1109.3 Workmanship (Flooring)

a) Base concrete or the RCC slab on which the tiles are to be laid shall be cleaned, wetted and mopped.
b) The bedding for the tile shall be with cement mortar 1:4 or as specified.
c) The average thickness of the bedding shall be 20 mm or as specified while the thickness under any portion of the tiles shall not be less than 10 mm.
d) Mortar shall be spread, tamped and corrected to proper levels and allowed to harden sufficiently to offer a fairly rigid cushion for the tiles to be set and to enable the mason to place wooden plank across and squat on it.
e) Over this mortar bedding neat grey cement slurry of honey like consistency shall be spread @ 3.3 kg of cement per m^2 over an area up to 1 m^2.
f) Tiles shall be soaked in water washed clean and shall be fixed in this grout one after another, each tile gently being tapped with a wooden mallet till it is properly bedded and in level with the adjoining tiles.
g) The joints shall be kept as thin as possible and in straight lines or to suit the required pattern. Joint width shall be upto 2 mm for unrectified floor tiles and upto 1 mm for rectified floor tiles. The joint in case of spacer lug tile shall be as per spacer.
h) The surface of the flooring during laying shall be frequently checked with a straight edge about 2 m long, so as to obtain a true surface with the required slope.

i) In bath, toilet, kitchen and balcony/verandah flooring, suitable tile drop will be given in addition to required slope to avoid spread of water. Further tile drop will also be provided near floor trap.
j) Where full size tiles cannot be fixed these shall be cut (sawn) to the required size, and their edge rubbed smooth to ensure straight and true joints.
k) Tiles which are fixed in the floor adjoining the wall shall enter not less than 10 mm under the plaster, skirting or dado.
l) After tiles have been laid surplus cement slurry shall be cleaned off.
m) The joints shall be cleaned off the grey cement slurry with wire/coir brush or trowel to a depth of 2 mm to 3 mm and all dust and loose mortar removed. Joints shall then be flush pointed with white cement added with pigment if required to match the colour of tiles. This shall be followed for skirting and dado.
n) Where spacer lug tiles are provided, the half the depth of joint shall be filled with polysulphide or as specified on top with under filling with cement grout without the lugs remaining exposed.
o) The floor shall then be kept wet for 7 days. After curing, the surface shall be washed and finished clean.
p) The finished floor shall not sound hollow when tapped with a wooden mallet.

1109.4 Workmanship (Skirting and dado)

a) For skirting and dado, the joints shall be raked out to a depth of at least 15 mm in masonry walls.
b) In case of concrete walls, the surface shall be roughened with wire brushes. The surface shall be cleaned thoroughly, washed with water and kept wet before skirting or dado is commenced.
c) The plaster made with cement mortar 1:3 for skirting or dado shall be roughened with wire brushes or by scratching diagonal lines 2 mm deep at approximately 7.5 cm centres both ways.
d) Plastering for risers of steps, skirting and dado shall be done as detailed clause 1103.
e) Top of skirting or dado shall be truly horizontal and joints truly vertical except where otherwise indicated.
f) Skirting and dado shall rest on the top of the flooring.
g) Skirting /dado shall not project from the finished “surface of wall” by more than the tile thickness, undulations if any shall be adjusted in wall.

1109.5 Sampling and testing

a) The tiles shall be tested as per IS: 13630.
b) The tiles shall conform to table10 of IS: 15622 with water absorption 3% to 6% (Group B II).
c) The tiles shall conform to IS: 15622 for dimensional tolerance, physical and chemical properties.
d) The tests and frequencies are given in table 1100-3.
e) Manufacturer’s test certificate is not mandatory if the number of tiles used for work is less than 3000 or if the finished floor area is less than 500 m^2 (whichever is less).

Table 1100-3: *Quality tests for pressed ceramic tiles*

Test	*Code*	*Min. quantity of material for carrying out the test*	*Frequency of testing*
1. Dimensions and surface quality 2. Physical properties 3. Chemical properties	IS: 13630	3000 Nos	3000 Nos. or part thereof.

1110 TILE FIXING WITH QUICK SET ADHESIVE (WATER BASED)

1110.1 General

a) When tile flooring is to be laid over the existing flooring without dismantling old flooring it can be laid with adhesive.
b) The old flooring shall be thoroughly cleaned. Undulations, if any shall be rectified with cement mortar 1:3.
c) Old cement concrete surface shall be roughened and cleaned off to have proper bond with the old surface.

1110.2 Materials

High polymer modified quick set tile adhesive shall conform to IS: 15477.

1110.3 Workmanship

a) High polymer modified quick set tile adhesive (conforming to IS: 15477) shall be thoroughly mixed with water and a paste of zero slump shall be prepared so that it can be used with in 1.5 to 2 hours.
b) It shall be spread over an area not more than one m^2 at one time. Average thickness of adhesive shall be 3 mm
c) The adhesive so spread shall be combed using suitable trowel.
d) Tiles shall be pressed firmly in to the position with slight twisting action checking it simultaneously to ensure good contact gently being tapped with wooden mallet till it is properly backed with adjoining tiles.
e) The tiles shall be fixed within 20 minutes of application of adhesive. The surplus adhesive from the joints, surface of the tiles shall be immediately cleaned.
f) The surface of the flooring shall be frequently checked during laying with straight edge of above 2 m long so as to attain a true surface with required slope.
g) Where spacer lug tiles are provided these shall be filled with grout with lugs remaining exposed.

1111 VITRIFIED TILE FLOORING

1111.1 Materials

a) The tiles shall be of approved make and shall generally conform to the approved standards.
b) They shall be flat and true to shape, free from cracks, crazing spots, chipped edges and corners.
c) The tiles shall be square or rectangular sizes and thickness as specified in the item or as directed by the Engineer.

1111.2 Requirements

a) Technical specifications of the tiles given in table 1100-4 shall be followed for guidance.

Table 1100-4: *Technical specifications for vitrified tiles*

Sl. No.	*Property*	*Expected standards*
1	Deviation in length	±0.6%
2	Straightness of sides	±0.5%
3	Rectangularity	±0.6%
4	Surface flatness	±0.5%
5	Water absorption	<0.50%
6	Moh's hardness	>6
7	Flexural strength	>27 N/mm^2
8	Abrasion resistance	<204 mm^2
9	Skid resistance (friction coefficient)	>0.4
10	Glossiness	Min. 85% reflection

b) The tiles shall conform to the relevant standards in all respects.

c) Samples of tiles shall be got approved from the Engineer before bulk procurement for incorporation in the work.

d) As directed by the Engineer, the tiles shall be cleaned by mild acid (However, hydrofluoric acid and its derivatives should not be used). After the tiles have been laid in a room or the days fixing work is completed, the surplus cement grout/adhesive that may have come out of the joints shall be cleaned off before it sets. The dado/skirting shall be thoroughly cleaned.

e) In the case of flooring, once the floor has set, the floor shall be carefully washed clean and dried.

f) When drying, the floor shall be covered with oil free dry sawdust. It shall be removed only after completion of the construction work and just before the floor is used.

g) Vitrified tiles are resistant to all chemicals (except hydrofluoric acid and its derivatives), hence commercially available detergents and cleaning agents can also be used for regular maintenance. Any spills and stains must be removed immediately. If left dry, they may leave stains, which may be difficult to remove completely.

h) Manufacturer's test certificate is not mandatory if the finished floor area is less than 500 m^2.

1112 MARBLE STONE FLOORING

1112.1 Materials

a) Marble used for flooring shall be as specified in the item.

b) The size of marble blocks, slabs and tiles shall be as given in table 1100-5.

Table 1100-5: *Sizes of marble blocks, slabs and tiles*

Type	*Length (cm)*	*Width (cm)*	*Thickness (cm)*
Block	30 to 250	30 to 100	30 to 90
Slabs	70 to 250	30 to 100	2 to 15
Tiles	10 to 60	10 to 60	0.8 to 2.4

c) The length and width of the blocks shall be in multiples of 30 cm.

d) Length and width of slab shall be in multiples of 10 cm and thickness in multiples of 1 cm.
e) Tiles shall be square cut and linear dimensions in multiples of 10 cm.
f) Slabs and tiles shall be machine cut and factory made.
g) For 8 mm thick tiles, special precautions will be required for fixing them like using special adhesive as per manufacturer's specifications. Such tiles are not suitable for outside veneering work exposed to rains/sun if used in large areas in continuous stretches.
h) For tiles of thickness 20 mm and above cramps may be provided if approved by the Engineer.
i) The physical properties required for marble used in flooring are given in table 1100-6.

Table 1100-6: *Physical properties of marble*

Test	*Requirements*	*Test procedure*
Moisture absorption after 24 hrs immersion in cold water.	0.4% (Max)	IS: 1124
Hardness	3 (Min)	Moh's scale
Specific gravity	2.5 (Min)	IS: 1122

j) Quality control tests shall be carried out if the area of flooring is greater than 500 m^2.

1112.2 Requirements

a) Every stone shall be cut to the required size and shape, fine chisel dressed on all sides to the full depth so that a straight edge laid along the side of the stone shall be fully in contact with it.
b) The top surface shall also be fine chisel dressed to remove all waviness.
c) In case machine cut slabs are used, fine chisel dressing of machine cut surface need not be done provided a straight edge laid anywhere along the machine cut surfaces is in contact with every point on it.
d) The sides and top surface of slabs shall be machine rubbed or table rubbed with coarse sand before paving.
e) All angles and edges of the marble slabs shall be true, square and free from chippings and the surface shall be true and plane.
f) The thickness of the slabs for flooring, risers of steps and skirting shall be as specified in the item.

1112.3 Workmanship

a) Base concrete or the RCC slab on which the slabs are to be laid shall be cleaned, wetted and mopped. The bedding for the slabs shall be with cement mortar 1:4 or as specified in the item.
b) The average thickness of the bedding mortar under the slab shall be 20 mm and the thickness at any place under the slab shall be not less than 12 mm.
c) The slab shall be washed clean before laying. It shall be laid on top, pressed, tapped with wooden mallet and brought to level with the adjoining slabs. It shall be lifted and laid aside.
d) The top surface of the mortar shall then be corrected by adding fresh mortar at hollows. The mortar is allowed to harden a bit and cement slurry of honey like

consistency shall be spread over the same with cement at the rate of 4.4 kg/m^2.

e) The edges of the slab already paved shall be buttered with grey or white cement with or without admixture of pigment to match the shade of the marble slabs as specified in the item.
f) The slab to be paved shall then be lowered gently back in position and tapped with wooden mallet till it is properly bedded in level with and close to the adjoining slabs with as fine a joint as possible.
g) Subsequent slabs shall be laid in the same manner. After each slab has been laid, surplus cement on the surface of the slabs shall be cleaned off.
h) The flooring shall be cured for a minimum period of seven days.
i) The surface of the flooring as laid shall be true to levels, and slopes as instructed by the Engineer.
j) Joint thickness shall not be more than 1 mm.
k) Due care shall be taken to match the grains of slabs. The slabs shall be matched as shown in drawings or as instructed by the Engineer.
l) Slabs which are fixed in the floor adjoining the wall shall enter not less than 12 mm under the plaster skirting or dado. The junction between wall plaster and floor shall be finished neatly and without waviness.
m) Marble slabs flooring shall also be laid in combination with other stones and/or in simple regular pattern/design as described in item of work and/or drawing.
n) Slight unevenness at the meeting edges of slabs shall then be removed by fine chiselling and finished in the same manner as specified in clause 1106 above.
o) Finishing including polishing shall be done in the same manner as specified in clause 1106 above except that cement slurry with or without pigments shall not be applied on the surface before each polishing.
p) For skirting, the wall plastering shall be cut uniformly to the requisite depth so that the skirting face shall have the minimum projection from the finished face of wall.
q) In any case masonry shall not be cut to accommodate skirting as the cross sectional area of the masonry may not be sufficient for the loads transmitted.
r) The skirting or a step riser face shall be checked for plane and plumb and corrected.
s) The top line of skirting and risers shall be truly horizontal and joints truly vertical, except where otherwise indicated.
t) Wax polishing shall be done as detailed under clause 1106 above.

1112.4 Tolerances

Tolerance of +3% shall be allowed for the thickness specified. In respect of length and breadth of slabs, a tolerance of +2% shall be allowed.

1113. KOTA STONE FLOORING

1113.1 Materials

a) The slabs shall be of selected quality, hard, sound, dense and homogeneous in texture free from cracks, decay, weathering and flaws.
b) They shall be hand or machine cut to the requisite thickness.
c) They shall be of the colour indicated in the drawings or as instructed by the Engineer.

d) The slabs shall have the top (exposed) face polished before being brought to site, unless otherwise specified.
e) The slabs shall conform to the size required.

1113.2 Requirements

a) Every slab shall be cut to the required size and shape and fine chisel dressed on the sides to the full depth so that a straight edge laid along the side of the stone shall be in full contact with it. The sides (edges) shall be table rubbed with coarse sand or machine rubbed before paving.
b) All angles and edges of the slabs shall be true, square and free from chippings and the surface shall be true and plane.
c) The thickness of the slab, risers in steps and skirting after it is dressed shall be as specified in the item.

1113.3 Workmanship

a) The workmanship shall be as per clause 1112 except that the edges of the slabs to be jointed shall be buttered with grey cement, with admixture of pigment to match the shade of the slab.
b) The thickness of the joints shall be minimum, as possible. In any location, it shall not exceed 1 mm.
c) Preparation of surface for risers of steps, skirting and dado shall be as specified in clause 1112.
d) Polishing and finishing shall be as described for marble flooring except that first polishing with coarse grade carborandum stone shall not be done and that cement slurry with or without pigment shall not be applied on the surface before polishing.
e) Laying shall be as specified in clause 1112 except that the joints of the slabs shall be set in grey cement mixed with pigment to match the shade of the slabs.
f) Wax polishing shall be done as per requirement as detailed under clause 1112.

1113.4 Tolerances

Tolerance of ±2 mm shall be allowed for the thickness specified. In respect of length and breadth of slabs, tolerance of ±5 mm for hand cut slabs and ±2 mm for machine cut slabs shall be allowed.

1114 GRANITE FLOORING

1114.1 Materials

a) The granite slab/tile shall be of the approved colour, selected quality, hard, sound, dense and homogeneous in texture free from cracks, decay, weathering and flaws as specified in the item.
b) The slabs shall be machine cut to the requisite thickness along planes parallel to the natural bed of stone and should be of uniform size, if required.
c) The slabs shall have the top (exposed) face polished before being brought to site, unless otherwise specified.
d) The physical properties required for granite used in flooring are given in table 1100-7.

Table 1100-7: *Physical properties of granite*

Test	*Requirement*	*Test procedure*
Moisture absorption after 24 hrs immersion in cold water.	0.50% (Max) by weight	IS:1124
Specific gravity	2.6 (Min)	IS:1122

e) Quality control tests shall be carried out if the area of flooring is greater than 500 m^2.

1114.2 Requirements

a) The thickness of slab/tile shall not be less than 12 mm for size up to 90 cm x 60 cm and not less than 20 mm for sizes above 90 cm x 60 cm.
b) A straight edge laid anywhere along the machine cut surface shall be in contact with every point on it.

1114.3 Workmanship

a) Base concrete on which the slabs are to be laid shall be cleaned, wetted and mopped.
b) The bedding for the slab/tile shall be with cement mortar 1:5 or as specified in the item.
c) The average thickness of the bedding mortar under the slabs shall be 20 mm and the thickness at any place under the slabs shall not be less than 12 mm.
d) The slab/tile shall be washed clean before laying.
e) The tiles shall then be laid on top, pressed and laid, so that all hollows underneath get filled and surplus mortar works up through the joints.
f) The top shall be tapped with a wooden mallet and brought to level and close to the adjoining tiles with thickness of joint not exceeding 1 mm. Subsequent tiles shall be laid in the same manner.
g) The granite slab shall be laid as specified for marble slab flooring under clause 1112.

1115 WOODEN FLOORING

1115.1 Materials

a) The material for wooden flooring shall be wooden blocks/panels of the class of timber specified in the item.
b) The size of blocks/panels shall be as specified.
c) The blocks/panels shall be truly rectangular in shape with clean sharp edges and true faces. The top and sides shall be planed true.

1115.2 Requirements

a) The timber used for making the blocks/panels shall be thoroughly seasoned in accordance with IS: 1141.
b) After seasoning, the timber shall be treated with preservatives in accordance with IS: 401.
c) The thickness of the blocks/panels shall be as specified.
d) The wooden block shall be placed on a 25 mm thick levelling course of cement concrete 1:2:4 using 10 mm nominal size aggregates by volume unless otherwise specified in the item.

1115.3 Workmanship

a) The surface of levelling concrete shall be finished with a wooden float to give a sand paper finish, plane and true to level.
b) The finished level of the concrete shall be lower than the proposed finished level of the flooring by the specified thickness of the wooden blocks/panels plus a minimum of 1.5 mm.
c) The levelling concrete shall be cured for a week and then allowed to dry thoroughly, before paving with wood blocks/panels.
d) The wood blocks/panels shall be first laid 'dry' to the margin and pattern shown in the drawings or as directed by the Engineer.
e) The blocks/panels shall fit closely and sides and end shall be planed further if necessary to get closed and even joints.
f) After the blocks/panels have been fitted and matched they shall be removed and stacked in such a way as to facilitate their repaving in the same order.
g) The surface of the levelling course shall be thoroughly cleaned and shall be coated with a thin layer of approved adhesive.
h) The wood blocks/panels shall then be taken in turn serially, the bottom and part of the sides coated thoroughly with the adhesive and pressed into place to the required patterns on the previously coated concrete surface.
i) The joints of the work shall be very thin and fine.
j) When all the blocks/panels shall have been set in position, the surface shall be cleaned, machined level and smooth.
k) The floor shall then be given a final smooth finish by rubbing down with sand paper.
l) No wood of any kind shall be placed within 60 cm of any fire place or chimney.
m) The floor shall be Bees waxed or polished with readymade wax polish or given any other finish as required.

1116 REFERENCES

1. IS: 269 Specification for 33 grade ordinary Portland cement.
2. IS: 401 Code of practice for preservation of timber.
3. IS: 451 Technical supply conditions for wood screws.
4. IS: 455 Specification for Portland slag cement.
5. IS: 661 Code of practice for thermal insulation of cold storages.
6. IS: 702 Specification for industrial bitumen.
7. IS: 1122 Method of test for determination of true specific gravity of natural building stones.
8. IS:1124 Method of test for determination of water absorption, apparent Specific gravity and porosity of natural building stones.
9. IS: 1130 Specification for marble (Blocks, slabs and tiles).
10. IS: 1141 Code of practice for Seasoning of timber.
11. IS: 1100 Method of measurements of building and civil engineering work (Part 11) paving, floor finishes, dado and skirting.
12. IS: 1237 Specification for cement concrete flooring tiles.
13. IS: 1322 Specification for bitumen felts for water proofing and damp-proofing.
14. IS: 1443 Code of practice for laying and finishing of cement concrete flooring tiles.

15.	IS: 1489	Specification for Portland pozzolana cement:
	(Part-I)	*Flyash based.*
	(Part 2)	*Calcined clay based.*
16.	IS:1580	Specification for bituminous compounds for waterproofing and caulking purpose.
17.	IS: 2114	Code of practice for laying in situ terrazzo floor finish.
18.	IS: 2571	Code of practice for laying in situ cement concrete flooring.
19.	IS: 3622	Specification for sand stone (Slab & tiles)
20.	IS: 3670	Code of practice for construction of timber floors.
21.	IS: 4457	Acid and/or alkali Resistant tiles.
22.	IS: 5318	Code of practice for laying of hard wood parquet and wood block floors.
23.	IS: 5766	Code of practice for laying of burnt clay brick floor.
24.	IS: 8041	Specification for rapid hardening Portland cement.
25.	IS: 8042	Specification for white Portland cement.
26.	IS: 8043	Specification for hydrophobic Portland cement.
27.	IS: 8112	Specification for 43 grade ordinary Portland cement.
28.	IS: 12330	Specification for sulphate resisting Portland cement.
29.	IS: 13630	Methods of Testing of ceramic tiles.
30.	IS: 13712	Specification for ceramic tiles, definition, classification, characteristic and making.
31.	IS: 15622	Specification for pressed ceramic tile.

+++++++

SECTION 1200 STRUCTURAL STEEL WORK

1201 GENERAL

This section provides guidelines regarding quality control measures for material procurement, fabrication, assembly, storage, transportation, erection and painting of all types of bolted and/or welded structural steel works for the construction of buildings.

a) Steel structures generally consist of structural steel members (rolled section or fabricated sections) and structural fasteners. Apart from this there will be non-structural members like gratings, chequered plates, handrails etc.
b) The Contractor shall prepare all the fabrication drawings, supply and fabricate all steelwork and furnish all connection materials in accordance with the approved drawings. The method of painting, marking, packing and delivery of all fabricated materials shall be as per the specification for the item in the contract.

1202 REQUIREMENTS

The aspects we have to look in to for ensuring the quality of various structural steel works are shown in figure 1200-1.

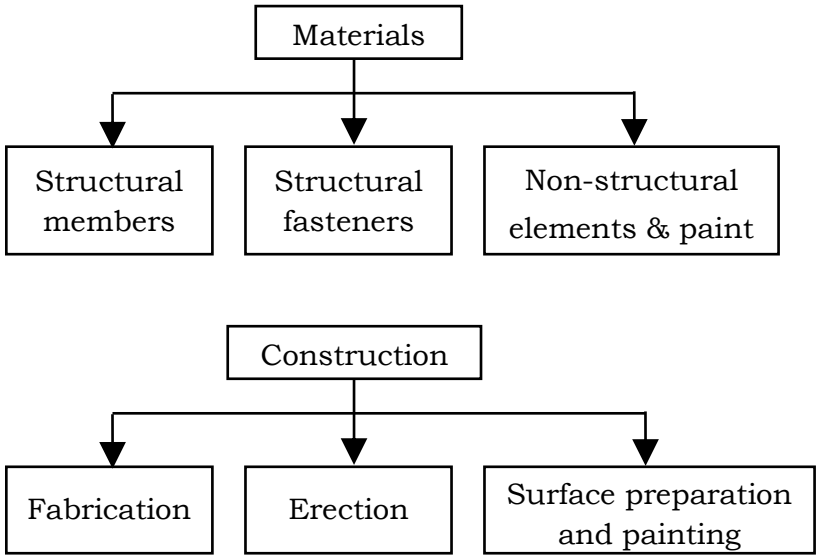


Fig.1200-1: Flow chart for ensuring quality of structural steel works.

a) The Contractor shall establish and maintain quality control procedures for different items of work and materials to ensure that all works are performed as per the specification for the item in the contract. Materials or workmanship not in reasonable conformance with the provisions of the specification shall be rejected at any time during the progress of the work.
b) The dimensions, forms, weights and tolerances of all rolled shapes bolts, nuts, studs, washers etc. and other members used in the fabrication shall, wherever applicable, conform to the requirements of the latest relevant BIS.

1203 MATERIALS

General requirements relating to the supply of material shall conform to the specifications of IS: 1387 and IS: 8910. The inspection documents of steel and steel products shall be as per IS: 10474.

1203.1 Structural members

a) Standard structural steel sections shall be used instead of fabricated steel sections as far as possible.

b) All steel materials required for the work shall be supplied by the Contractor. The geometric dimensions of various structural steel sections shall be as per the BIS codes listed in table 1200-1.

Table 1200-1: *Dimension requirements for structural members*

Sl. No.	*Code*	*Item*
1	IS: 808 and IS: SP 6 (1)	Dimensions of hot rolled sections.
2	IS: 1161	Dimensions of hollow circular sections.
3	IS: 4923	Dimensions of rectangular hollow sections
4	IS: 1730	Dimensions of plates, sheets, strips and flats.
5	IS: 1732	Dimensions of bars, rounds and squares.
6	IS: 3954	Dimensions of channel sections.
7	IS: 12778	Dimensions of Parallel beams and column sections.
8	IS: 1852	Rolling and cutting tolerance for hot rolled steel sections.
9	IS: 12779	Rolling and cutting tolerance for parallel flange beams.
10	IS: 811	Dimensions of light gauge steel members.

c) The mechanical and chemical properties of steel materials shall comply with the BIS codes listed in table 1200-2.

Table 1200-2: *Mechanical and chemical properties of structural members*

Sl. No.	*Code*	*Item*
1	IS: 1079	Cold formed light gauge steel structural member.
2	IS: 2062	Grade A - Structural steel for plate thickness up to 20 mm.
3	IS: 2062	Grade B (Killed) - Structural steel for plate thickness above 20 mm.
4	IS: 2062	Grade C - For crane gantry girders.
5	IS: 15911	Low tensile structural steel (For gates, door frames etc.).
6	IS: 15962	High tensile structural steel for improved seismic resistance.
7	IS: 806	Steel tubes in general building construction.
8	IS: 6603	Stainless steel bars and flats.

d) Standard tests are to be conducted on sample specimen for evaluating the mechanical and chemical properties of the steel supplied. Relevant BIS codes for conducting the tests are listed in table 1200-3.

Table 1200-3: *Tests for structural steel sections*

Sl. No.	*Code*	*Tests*
1	IS: SP 71	Compendium of method of chemical analysis of steels.
2	IS: 1599	Bend test.
3	IS: 1608	Tensile test.
4	IS: 1757	Method for Charpy impact test.
5	IS: 10842	Evaluation procedure for Y grove weld crackability test.

e) The sampling of specimen shall be done as per the BIS codes listed in table 1200-4.

Table 1200-4: *Sampling of specimen for structural steel sections*

Sl. No.	*Code*	*Sampling*
1	IS: 3711	Location and preparation of samples for mechanical testing.
2	IS: 14284	Preparation of samples for determination of chemical composition.

1203.2 Structural fasteners

a) The connections in steel structures are done either by bolting or welding. The selection of method of connection shall be based on the nature of connection and the convenience and suitability of fabrication and erection.

b) Various quality requirements for both welded connection as well as the bolted connection are described below:

1203.2.1 Bolted connection

a) All bolts and nuts shall conform to the requirements of IS: 1367. Mild steel for bolts and nuts tested as per relevant BIS codes and shall have a tensile strength of not less than 44 kg/mm^2 and minimum elongation of 23% on a gauge length of $5.6\sqrt{A}$, where 'A' is the cross sectional area of the test specimen.

b) Materials for bolts and nuts shall comply with the BIS codes listed in table 1200-5.

Table 1200-5: *Requirements of materials for bolts and nuts*

Sl. No.	*Code*	*Item*
1	IS: 1367 Part 1	General requirements for bolts, screws and studs.
2	IS: 1608	Method for tensile testing of steel other than sheet, strip, wire and tube.
3	IS: 1367 Part 3	High tensile steel material for fasteners.
4	IS: 6623	High strength structural nuts.

c) Washers shall be made of steel conforming to the BIS codes listed in table 1200-6.

Table 1200-6: *Requirements of materials for washers*

Sl. No.	*Code*	*Item*
1	IS:1977	Structural steel (Ordinary quality).
2	IS: 2062	Steel for general structural purpose.
3	IS: 6649	Hardened and tempered washers for high strength structural bolts and nuts.

d) Codes to be followed for the dimension requirements of various bolts are listed in table 1200-7.

Table 1200-7: *Dimension requirements of bolts and washers*

Sl. No.	*Code*	*Item*
1	IS: 1363 (Part 1 to 3)	Unfinished bolts/black bolts/ C grade bolts.
2	IS: 1363 (Part 1 to 3)	A grade bolts and B grade bolts.
3	IS: 3757 and IS 4000	High strength bolts.
4	IS: 730	Hook bolting for corrugated roofing sheets.
5	IS: 5624	Foundation bolts.
6	IS: 6623	High strength structural nuts.
7	IS: 6649	Hardened washers for high strength bolts.
8	IS: 8412	Specification for slotted countersunk head bolts
9	IS: 10238	Threaded steel fasteners- step bolts for steel construction

e) The technical requirements regarding material and other quality control aspects of threaded fasteners are elaborated in IS: 1367 (Part 1 to 20).

1203.2.2 Welded connection

a) Welding shall be in accordance with relevant IS. It shall be done by experienced and good welders, qualified by tests in accordance with BIS. The relevant welding procedure shall be adopted based on the BIS codes as recommended by the Engineer.

b) Welders shall undergo relevant test conforming to BIS and follow the safety practices recommended by BIS. Various BIS codes relating to the selection of welders, welding procedures and safety aspects in welding are listed in table 1200-8.

Table 1200-8: *Requirements for welding*

Sl. No.	*Code*	*Item*
1	IS: 817	Code of practice for training and testing of metal arc welders.
2	IS: 1393	Code of practice for training and testing of oxy acetylene welders.
3	IS: 818	Code of practice for safety and health requirements in electric and gas welding and cutting operations.
4	IS: 1179	Equipment for eye and face protection during welding.
5	IS: 3016	Code of practice for fire precautions in welding and cutting operations.
6	IS: 817 (Part 1)	Manual metal arc welding.
7	IS: 817 (Part 2)	Oxy fuel welding.
8	IS: 7307 (Part 1)	Approval tests for welding procedures: fusion welding of steel.
9	IS: 7310 (Part 1)	Approval tests for welders working to approved welding procedures: fusion welding of steel.
10	IS: 7318 (Part 1)	Approval tests for welders when welding procedure approval is not required IS: 7318 (Part 2)-TIG or MIG welding of aluminium and its alloys.
11	-	ISI Handbook of manual metal-arc welding for welders.

Table 1200-8: *Requirements for welding (contd.……..)*

Sl. No.	*Code*	*Item*
12	SP: 12	ISI Handbook for gas welders.
13	SP: 6 (Part 7)	Handbook for Structural Engineers - simple welded girders.
14	IS: 816	Code of practice for use of metal arc welding for General construction in mild steel.
15	IS: 819	Code of practice for resistance spot welding for light assemblies in mild steel.
16	IS: 1024	Code of practice for use of welding in bridges and structures subject to dynamic loading.
17	IS: 1261	Code of practice for seam welding in mild steel.
18	IS: 1323	Code of practice for oxy-acetylene welding for work in mild steels .
19	IS: 2751	Recommended practice for welding of mild steel plain and deformed bars for reinforced construction.
20	IS: 2811	Recommendations for manual tungsten inert gas arc welding of stainless steel.
21	IS: 2812	Recommendations for manual tungsten inert gas arc welding of aluminium and aluminium alloys.
22	IS: 4353	Submerged arc welding of mild steel and low alloy steels-recommendations.
23	IS: 10234	Recommendations for general pipeline welding
24	IS: 11991	Recommended practice for flash butt welding of tubes, rods and other sections in carbon and alloy steel.
25	IS:15326 (Part1)/ ISO 3834 (Part 1)	Quality requirement for welding -fusion welding of metallic material - guidelines for selection and use.
26	IS:15326 (Part3)/ ISO 3834	Quality requirement for welding -fusion welding of metallic material Part 3: Standard quality requirements.
27	IS:15326 (Part 4)/ ISO 3834 (Part 4)	Quality requirement for welding -fusion welding of metallic material- elementary quality requirements.
28	IS: 15327/ISO 14731	Welding coordination - tasks and responsibility.

c) The welding electrodes and allied materials shall conform to the IS as listed in table 1200-9.

1203.3 Non-structural member

1203.3.1 Anchor bolts

a) Materials for anchor bolts, nuts, locknuts, washers, pipe sleeves and anchor plates shall conform to their respective specification

b) Fabrication of anchor bolts and their complete assemblies shall be strictly in compliance with the specifications and drawings/standards. Anchor bolts shall have coarse type threads conforming to IS: 4218.

c) Tolerances allowed for anchor bolts positioning shall be:

   i) For sleeved bolts: one-tenth of the bolt nominal diameter.

   ii) For bolts without sleeves: one-twentieth of the bolt nominal diameter.

Table 1200-9: *Requirements for welding electrodes*

Sl. No.	*Code*	*Item*
1	IS: 1278	Filler rods and wires for gas welding.
2	IS: 1395	Low and medium alloy steel covered electrodes for manual metal arc welding.
3	IS: 4972	Resistance spot welding electrodes.
4	IS: 5206	Covered electrodes for manual metal arc welding of stainless steel and other similar high alloy steels.
5	IS: 5511	Covered electrodes for manual metal arc welding of cast iron.
6	IS: 5856	Corrosion and heat resisting chromium-nickel steel solid welding rods, bare electrodes.
7	IS: 5857	Nickel and nickel alloy bare solid welding rods and electrodes.
8	IS: 5897	Aluminium and aluminium alloy welding rods and wires and magnesium alloy welding rods.
9	IS: 5898	Copper and copper alloy bare solid welding rods and electrodes.
10	IS: 6016	Hose connection for welding and cutting equipment.
11	IS: 6419	Welding rods and bare electrodes for gas shielded arc welding of structural steel.
12	IS: 7280	Bare wire electrodes for submerged arc welding of structural steels.
13	IS: 7303	Covered electrodes for surfacing of metal by manual arc welding.
14	IS: 8363	Bare wire electrodes for electro slag welding of steels.
15	IS: 8484	Metal powders welding electrodes.
16	IS: 8666	Copper and copper alloy covered electrodes for manual metal arc welding.
17	IS: 8736	Nickel and nickel alloy covered electrodes for metal arc welding.
18	IS: 13043	Covered manual metal arc welding electrodes.
19	IS:13851	Storage and re-drying of covered electrodes before use – recommendations.
20	IS: 15387/ ISO 5830	Resistance spot welding - male electrode caps.

1203.3.2 Metal inserts

a) Materials required for fabricating metal inserts shall conform to their respective specification.

b) Fabrication of inserts shall be done strictly as per Drawings/Standards and in compliance with the requirements given in IS.

1203.3.3 Chequered plates

a) Chequered plates shall be of mild steel and conforming to IS: 3502. Chequering shall be closed or open-ended or of any other pattern as shown in the Drawings.

b) Chequered plates shall be fabricated as per the fabrication Drawings prepared by the Contractor based on design Drawings. These shall be perfectly flat and

without any dents/deformations and shall be cut to the required size and shape.

1203.3.4 Gratings

a) The gratings shall be of two categories:
   Category A- Fabricated by the Contractor as per design Drawings/Standards.
   Category B- Readymade bought out from an approved manufacturer.
b) Materials for fabrication and fixing of gratings shall conform to their respective specification.
c) *Category A Gratings*: These shall be fabricated strictly as per the fabrication drawings prepared by the Contractor based on design Drawings and Standards.
d) *Category B Gratings*: These shall be as per manufacturer's details designed to carry loads as specified on the design Drawing supplied to the contractor. The deflection shall not exceed span/200 or 6 mm whichever is minimum. The maximum clear size of voids in the grating shall be limited to 30 mm x 55 mm. Thickness of grating shall be 25 mm.

1203.3.5 Tubular hand railing

a) Materials for fabrication and fixing of tubular hand railing shall conform to their respective specification for the item in the contract.
b) Handrails shall be fabricated strictly as per the fabrication Drawings prepared by the Contractor based on design Drawings and Standards. All tubes shall be straight and without any dents/deformations.

1203.3.6 Expansion fasteners

a) Expansion fasteners (medium and heavy duty) shall be of mild steel/high tensile steel with rust proof coating including both mechanical and chemical fasteners.
b) The Contractor shall submit to the Engineer manufacturer's catalogues along with the specifications of expansion fasteners (proposed to be used for the job) for his selection and approval. Selected fasteners shall be capable to carry the specified loads.
c) If so desired by the Engineer, the Contractor shall carry out all the requisite tests (pull out test, torque test etc.) of specimen expansion fasteners (representative of those to be used) from approved laboratory/test house and submit the report to him for approval. The decision of the Engineer regarding the adequacy of strength and load carrying capacity of the expansion fastener shall be final and binding to all. The cost of all such tests shall be borne by the Contractor.

1203.4 Paint

a) All materials for paints and enamels shall conform to the requirements specified on the Drawings or other special provisions laid down by the Engineer.
b) The type of paints which can be used shall be as follows:
   i) Ordinary paint: Paints based on drying oils, alkyd resin, modified alkyd resin, phenolic varnish epoxy.
   ii) Chemical resistant paint: One pack type (Ready for use) or two pack type (Mixed before use).

iii) Vinyl paint.
iv) Chlorinated rubber paint.
v) Bituminous paint as per IS: 9862.
vi) Epoxy paint as per IS: 14925.
vii) Polyurethane paint as per IS: 13759.
viii) Zinc rich paint as per IS: 14589.

c) Unless otherwise specified, paints shall conform to the relevant BIS. Paints shall be tested for the following quality as per specifications given in the relevant BIS codes:
   i) Weight (For 10 litres of paint, thoroughly mixed).
   ii) Drying time.
   iii) Consistency.
   iv) Dry film thickness and rate of consumption.

1204 WORKMANSHIP

1204.1 Fabrication

a) Fabrication of structures shall be done strictly as per fabrication Drawings prepared by the Contractor based on the latest design Drawings and in accordance with IS: 800, IS: 9595 and other relevant BIS codes and BIS hand book SP: 6 (Part 1).
b) Prior to commencement of structural fabrication, undulations in the fabrication yard, if any, shall be removed and area levelled and paved by the Contractor.
c) Any defective material used in the work shall be replaced by the Contractor at his own expense. Necessary care and precautions shall be taken so as not to cause any damage to the structure during any such removal and replacement.
d) Any faulty fabrication pointed out at any stage of work by the Engineer, shall be made good or replaced by the Contractor at his own cost.
e) Tolerances for fabrication of steel structures shall be as per IS: 7215.
f) Tolerances in dimensions of components of fabricated structural steel work shall be specified in the Drawings and shall be subjected to the approval of the Engineer before fabrication.
g) Unless otherwise specified, all parts of an assembly shall fit together accurately within tolerances specified in IS: 7215 as given in table 1200-10.

1204.1.1 Stages of fabrication

The stages of fabrication shall be done in accordance with the procedure specified in the technical specification for the work. The stages which require proper attention of the Engineer are the following:

i) Straightening and bending.
ii) Cutting.
iii) Holing.
iv) Assembly.
v) Welding.
vi) Bolting.
vii) Splicing.
viii) Machining and grinding.

For quality control aspects regarding various stages of fabrication, Engineer shall refer guide book on fabrication and erection of steel structures (INS/072) by INSDAG (Institute of Steel Development and Growth – Kolkata).

Table 1200-10: *Tolerances for structural steel sections*

Sl. No.	*Dimension specified*	*Tolerances*
1	Length:	
	a) Member with both ends finished for contact bearing.	±1 mm
	b) Individual components of members with end plate connection.	+0 mm/-2 mm
	c) Other members of length: i) Upto and including 12 m. ii) Over 12 m.	 ±2 mm ±3.5 mm
2	Width:	
	a) Width of built-up girders.	±3 mm
	b) Deviation in the width of members required to be inserted in other members.	+0 mm/-3 mm
3	Depth:	
	Deviation in the depths of solid web and open web girders.	+3 mm/-2 mm
4	Straightness:	
	Deviation from straightness of columns. i) In elevation	L/3000 subject to maximum of 15 mm (Where L is length of member) +5mm/-0mm.
	ii) In plan	L/1000 subject to a maximum of 10 mm.
5	Deviation of center line of web from centerline of flanges inbuilt-up members at contact surface.	3 mm.
6	Deviation from flatness of plate of webs of built-up members in a length equal to the depth of the members.	0.005d subject to a maximum of 2 mm where'd' is depth of the member.
7	Tilt of flange of plate girders.	
	a) At splices and stiffeners, at supports, at the top flanges of plate girders and at bearings.	0.005 b to a minimum of 2 mm where 'b' is width of the member.
	b) At other places	0.015 b to a maximum of 4 mm where 'b' is width.
8	Deviation from squareness of flange to web of columns and box girders.	L/1000 where L is nominal length of the diagonal.
9	Deviation from squareness of fixed base plate (not machined) to axis of columns. This dimension shall be measured parallel to the longitudinal axis of the column at points where, the outer surfaces of the column sections make contact with the base plate.	D/500, where D is the distance from the column axis to the point under consideration on the base plate.
10	Deviation from squareness of machined ends to axes of columns.	D/1000, where D is as defined in 9 above.
11	Deviation from squareness of machined ends to axes of beams.	D/1000, where D is as defined in 9 above.
12	Ends of members abutting at joints through cleats or end plates, permissible deviation from squareness of ends.	1/600 of depth of member subject to a maximum of 1.5 mm.

1204.1.2 Quality control in welding

The quality control procedures specific to the process of welding is very important considering the overall strength and stability of structure. The quality control aspects of welding are elaborated below.

a) All joints shall be welded unless noted otherwise on the design drawings.
b) Welding shall be in accordance with IS: 816, IS: 819, IS: 1024, IS: 1261, IS: 1323 and IS: 9595 as appropriate.
c) The Contractor shall make necessary arrangement for providing sufficient number of welding sets of the required capacity, all consumables, cutting and grinding equipment with requisite accessories/auxiliaries, equipment and materials required for carrying out various tests such as dye penetration, magnetic particle, ultrasonic etc.
d) Adequate protection against rain, dust, snow and strong winds shall be provided to the welding personnel and the structural members during welding operation. In the absence of such a protection no welding shall be carried out.
e) It shall be the responsibility of the Contractor to ensure that all welding is carried out in accordance with the terms of this specification and relevant BIS codes. The Contractor shall provide all the supervision to fulfil this requirement.
f) Preparation of member for welding shall be given due importance. The procedure for member preparation shall be as per IS: 9595 and the technical specification.
g) The stages of member preparation are:
    i) Edge preparation.
    ii) Cleaning.
    iii) Preheating.
    iv) Grinding.

1204.1.3 Selection of welding process

a) Welding of various materials shall be carried out using one or more of the following processes.
    i) Manual Metal Arc Welding Process (MMAW).
    ii) Submerge Arc Welding Process (SAW).
    iii) Gas Metal Arc Welding Process (GMAW).
    iv) Flux Cored Arc Welding Process (FCAW).
b) The welding procedure adopted and consumables used shall be specifically approved by the Engineer. A combination of different welding processes or a combination of electrodes of different classes/makes may be employed for a particular joint only after selecting the welding procedures to be adopted and obtaining the written approval of the Engineer.

1204.1.4 Approval of welders

a) The Contractor shall satisfy the Engineer that the welders are suitable for the work upon which they will be employed. For this purpose the welders shall have satisfied the relevant requirements of IS: 7318.
b) Adequate means of identification shall be provided to enable each weld to be traced to the welder by whom it was made.
c) The Contractor shall intimate the Engineer sufficiently in advance, the commencement of tests, to enable him to be present to witness the same.

1204.1.5 Approval of welding procedures

a) The Contractor, in accordance with IS:7307, shall carry out procedure tests by means of a specimen weld of adequate length on steel, representative of that to be used, to demonstrate that he can make welds with the welding procedure to be used for the work to the complete satisfaction of the Engineer.
b) The test weld shall include weld details from the actual construction and it shall be welded in a manner simulating the most unfavourable instances of fit-up, electrode condition etc., which are anticipated to occur on the particular fabrication.
c) Where material analyses are available, the welding procedure shall be carried out on material with the highest carbon equivalent value.

1204.1.6 Inspection and testing of welds

a) The method of inspection shall be according to IS: 822 and extent of inspection and testing shall be in accordance with the relevant applicable standard or, in the absence of such a standard, as specified by the Engineer.
b) Welds shall not be painted or otherwise obscured until they have been inspected, approved and accepted.
c) The various tests to be performed on welds are listed below:
   i) Visual inspection.
   ii) Mechanical tests.
   iii) Magnetic particle/dye penetration/ultrasonic examination.
   iv) Radiographic examination.

1204.1.7 Repair of faulty welds

a) No repair of defective welds shall be carried out without proper permission of the Engineer and his approval for the corrective procedure.
b) Welds not complying with the acceptance requirements (As specified by BIS Codes and the Engineer), as revealed during inspection and testing of welds or erection or in-situ condition shall be corrected either by removing and replacing or rectified as specified in table 1200-11.

Table 1200-11: *Remedial measures for defective welds*

Sl. No.	*Defect*	*Remedy*
1	Excessive convexity.	Reduced to size by removal of excess weld metal.
2	Shrinkage cracks, cracks in parent plates and craters.	Defective portions removed down to sound metal and re-welded.
3	Under cutting	Additional weld metal deposited.
4	Improperly fitted/ misaligned parts.	Welding cut and edges suitably prepared.
5	Members distorted by heat of welding.	Member straightened by mechanical means or careful application of limited amount of heat, temperature of such area not to exceed 650°C dull red heat.

1204.2 Shop erection

The steel work shall be temporarily shop erected complete or as directed by the Engineer, so that the accuracy of fit can be checked.

1204.3 Packing

a) All items shall be suitably packed in case these are to be transported from the fabrication shop to the actual site of erection so as to protect them from any damage/distortion or falling during transit.

b) Where necessary, slender projecting parts shall be temporarily braced to avoid warping during transportation. Small parts such as gussets, cleats etc., shall be securely wired on to their respective main members. Bolts, nuts washers etc. shall be packed in crates.

1204.4 Transportation

a) Loading and transportation shall be done in compliance with the rules and procedures for transporting materials.

b) In case, certain parts cannot be transported in the lengths stipulated on the Drawings, the position details of such additional splice joints shall be got approved by the Engineer.

1204.5 Tolerances of field erection

The tolerances for field erection shall be as per IS: 12843 which are shown in tables 1200-12 and 1200-13.

Table 1200-12: *Tolerance for erection of structural steel sections for columns*

Sl. No.	*Member*	*Tolerance*
1	Deviation of column axes at foundation top level with respect to true axes.	
	i) In longitudinal direction.	±5 mm
	ii) In lateral direction.	±5 mm
2	Deviation in the level of bearing surface of columns at foundation top with respect to true level.	±5 mm
3	Out of plumb (Verticality) of column axis from true vertical axis, as measured at top:	
	i) Up to and including 30m height	±H/1000 or ±25 mm whichever is less
	ii) Over 30m height	±H/1200 or ±35 mm whichever is less
4	Deviation in straightness in longitudinal and transverse planes of column at any point along the height.	±H/1000 or ±10 mm whichever is less
5	Difference in the erected positions of adjacent pairs of columns along length or across width of building prior to connecting trusses/beams with respect to true distance.	±5 mm
6	Deviation in any bearing or seating level with respect to true level.	±5 mm
7	Deviation in difference in bearing levels of a member on adjacent pair of columns both across and along the building.	±5 mm

NOTE: 1. Tolerance specified under 3 should be read in conjunction with 4 and 5.
2. 'H' is the column height in mm.

Table 1200-13: *Tolerance for erection of structural steel sections for truss*

Sl. No.	*Member*	*Tolerance*
1	Shift at the centre of span of top chord member with respect to the vertical plane passing through the centre of bottom chord.	±1/250 of height of truss in mm at centre of span or ±15mm, whichever is less.
2	Lateral shift of top chord of truss at the centre of span from the vertical plane passing through the centre of supports of the truss.	±1/1500 of span of truss in mm or ±10mm, whichever is less.
3	Lateral shift in location of truss from its true position.	±10 mm.
4	Lateral shift in location of purlin from true position.	±5 mm.
5	Deviation in difference of bearing levels of truss from the true level.	±1/1200 of span of truss in mm or 20 mm, whichever is less.

1204.6 Safety and security during erection

The Contractor shall comply with IS: 7205 for necessary safety, adhere to safe erection practices and guard against hazardous as well as unsafe working conditions during all stages of erection.

1204.7 Grouting

a) Grouting (Under the base plates/shoe plates including grouting of sleeves and pockets) shall be done with non-shrink grout having compressive strength (28 days) not less than 40 MPa.
b) Non shrink grout shall be of free flow premix type and of approved quality and make. It shall be mixed with water in proportion as specified by the manufacturer.
c) The thickness of grout shall be as shown on the Drawings but not less than 25 mm or more than 40 mm in any case.

1204.8 Surface preparation and painting

1204.8.1 Surface preparation

a) The surface preparation before painting shall be done in accordance with IS: 1477/Swedish Standards Institute SIS 05 5900.
b) The grade of surface preparation (St2, St3, Sa1, Sa2, Sa2½, and Sa3) shall be as per the specification for the item in the contract.

1204.8.2 Painting

a) The painting operation to be performed depends on the type of painting adopted. The painting done on metal surface can be broadly classified as ordinary paints and chemical resistant paint.
b) Ordinary paints: These include paints based on drying oils, alkyd resin, modified alkyd resin, phenolic varnish epoxy, etc. Ordinary painting can generally be sub-divided into two types:
    i) *Primary coats*: This shall be applied immediately after the surface preparation and should have the properties of adhesion, corrosion inhibition and imperviousness to water and air.

ii) *Finishing coats*: This shall be applied over the primary coat and should have the properties of durability, abrasion resistance, aesthetic appearance and smooth finish.

c) Chemical resistant paints: The two pack paints shall be mixed together just before use since they remain workable thereafter only for a restricted period of time.

d) All fabricated steel shall be painted in the shop after inspection and acceptance with at least one priming coat, unless the exposed surfaces are subsequently to be cleaned at site or are metal coated. No primer shall be applied to galvanised surfaces.

e) Surfaces which will be inaccessible after site assembly shall receive the full specified protective treatment before assembly.

f) Damaged or deteriorated paint surfaces shall be first made good with the same type of coat as the shop coat.

1204.8.3 Protective coating for different environment

Since the severity of corrosion depends upon atmospheric conditions and these vary enormously, there is no single protective system or method of application that is suitable for every situation. The guidelines for various types of coatings to be used in various environmental conditions are given in table 1200-14.

Table 1200-14: *Protective coatings for different exposure conditions*

Sl. No.	*Type of coating*	*Exposure condition*
1	Wire brush to remove all loose rust and scale, 2 coats drying oil type primer, 1 under coat alkyd type paint, 1 finishing coat alkyd type. Total dry thickness: 150 µm.	Moderate.
2	Wire brush to remove all loose rust and scale; 2 coats drying oil type primer; 2 under coats micaceous iron oxide (MXO) pigmented phenolic modified drying oil. Total dry film thickness: 170 µm (Life up to 5 years).	Polluted in land environment.
3	Blast clean the surface, 2 coats of quick drying primer, under coat alkyd type paint, 1 finishing coat alkyd type. Total dry film thickness:130-150 µm.	Moderate.
4	Blast clean the surface, 2 coats of drying type oil primer; 1 under coat micaceous iron oxide pigmented drying oil type paint. Total dry film thickness: 165-190 µm.	Polluted inland environments.
5	Blast clean the surface, 2 coats of metallic lead pigmented chlorinated rubber primer, 1 under coat of high build chlorinated rubber primer, 1under coat of high build chlorinated rubber and 1 finishing coat of chlorinated rubber. Total dry film thickness: 200 µm.	Severe coastal and non-coastal interior situations.
6	Blast clean the surface, 350-450 µm thickness coal tar epoxy.	Severe.
7	Pickle; hot dip galvanized (Zinc). Total thickness: 85 µm (Life up to 15-20 years).	Moderate.
8	Grit blast, hot dip galvanized (Zinc). Total thickness: 140 µm (Life more than 20 years).	Moderate.
9	Grit blast, 1 coat of sprayed zinc/aluminum followed by suitable sealer Total thickness: 150 µm (Life up to 15-20 years).	Severe.

1204.8.4 Inspection and testing of painting works

a) All painting materials including primers and thinners brought to site by the Contractor for application shall be procured directly from reputed and approved manufacturers and shall be accompanied by manufacturer's test certificates.

b) Paint formulations without certificates shall not be accepted. The Engineer at his discretion may call for additional tests for paint formulations. The Contractor shall arrange to have such tests performance including batch wise test of wet paints for physical and chemical analysis.

c) The painting work shall be subject to inspection by the Engineer at all times. In particular, the stage inspection will be performed and Contractor shall offer the work for inspection and approval at every stage before proceeding with the next stage. The record of inspection shall be maintained.

d) Stages of inspection are as follows:
   i) Surface preparation.
   ii) Primer application.
   iii) Each coat of paint.

e) Any defect noticed during the various stages of inspection shall be rectified by the Contractor and got accepted by the Engineer before proceeding further.

f) Irrespective of the inspection, repair and approval at intermediate stages of work, the Contractor shall be responsible for making good any defects found during final inspection/guarantee period/defects liability period, as defined in General Conditions of Contract.

g) Dry Film Thickness (DFT) shall be checked and recorded after application of each coat. The thickness shall be measured at as many locations as decided by the Engineer. The Contractor shall provide standard thickness measuring instrument such as Elkometer (With appropriate range for measuring dry film thickness of each coat) free of cost to the Engineer whenever asked for.

1205 REFERENCES

1.	IS: SP6 (1)	Handbook for structural engineers – structural steel sections.
2.	IS: SP-6 (7)	ISI Handbook for Structural Engineers: simple welded girders.
3.	IS: SP-12	ISI Handbook for gas welders.
4.	IS: SP-71	Compendium of method of chemical analysis of steels.
5.	IS: 117	Ready mixed paint, brushing, finishing exterior, semi-gloss for general purposes to Indian Standard colours.
6.	IS: 128	Ready mixed paint, brushing, finishing, semi-gloss, for general purposes, black.
7.	IS: 730	Hook bolts for corrugated sheet roofing.
8.	IS: 800	General construction in steel - code of practice.
9.	IS: 806	Code of practice for use of steel tubes in general building construction.
10.	IS: 808	Dimensions for hot rolled steel beam, column, channel and angle sections.
11.	IS: 811	Cold formed light gauge structural steel sections.
12.	IS: 813	Scheme of symbols for welding.
13.	IS: 816	Code of practice for use of metal arc welding for general construction in mild steel.

14.	IS: 817	Code of practice for training and testing of metal arc welders:
	(Part 1)	Training of welders - manual metal arc welding.
	(Part 2)	Training of welders - oxyfuel welding.
15.	IS: 818	Code of practice for safety and health requirements in electric and gas welding and cutting operations.
16.	IS: 819	Code of practice for resistance spot welding for light assemblies in mild steel.
17.	IS: 822	Code of procedure for inspection of welds.
18.	IS: 1024	Code of practice for use of welding in bridges and structures subject to dynamic loading.
19.	IS: 1079	Hot rolled carbon steel sheet and strip.
20.	IS: 1161	Steel tubes for structural purposes.
21.	IS: 1179	Equipment for eye and face protection during welding.
22.	IS: 1261	Code of practice for seam welding in mild steel.
23.	IS: 1278	Filler rods and wires for gas welding.
24.	IS: 1323	Code of practice for oxy-acetylene welding for structural work in mild steels.
25.	IS: 1363 (Parts 1 to 3)	Hexagon head bolts, screws and nuts of product.
26.	IS: 1367 (Parts 1 to 20)	Technical supply conditions for threaded steel fasteners.
27.	IS: 1387	General requirements for the supply of metallurgical materials.
28.	IS: 1393	Code of practice for training and testing of oxy acetylene welders.
29.	IS: 1395	Low and medium alloy steel covered electrodes for manual metal arc welding.
30.	IS: 1477	Code of practice for painting of ferrous metals in buildings.
31.	IS: 1599	Metallic materials - bend test.
32.	IS: 1608	Mechanical testing of metals - tensile testing.
33.	IS: 1730	Dimensions for steel plates, sheets strips and flats for general engineering purposes.
34.	IS: 1732	Steel bars round and square for structural and general engineering purposes.
35.	IS: 1757	Method for charpy impact test (V notch) for metallic material.
36.	IS: 1852	Rolling and cutting tolerances for hot rolled steel products.
37.	IS: 1977	Low tensile structural steels.
38.	IS: 2062	Hot rolled medium and high tensile structural steel.
39.	IS: 2074	Ready mixed paint, air drying, red oxide zinc chrome, priming.
40.	IS: 2751	Code of practice for welding of mild steel plain and deformed bars for reinforced concrete construction.
41.	IS: 2811	Recommendations for manual tungsten inert-gas arc welding of austenitic stainless steel.
42.	IS: 2812	Recommendations for manual tungsten inert gas arc welding of aluminium and aluminium alloys.
43.	IS: 2932	Enamel, synthetic, exterior: (a) undercoating (b) finishing.
44.	IS: 2933	Enamel exterior (a) undercoating, (b) finishing.
45.	IS: 3016	Code of practice for fire precautions in welding and cutting operations.
46.	IS: 3502	Steel chequered plates.

47.	IS: 3711	Steel and steel products- location and preparation of samples and test pieces for mechanical testing.
48.	IS: 3757	High strength structural bolts.
49.	IS: 3954	Hot rolled steel channel sections for general engineering purposes - dimensions.
50.	IS: 4000	Code of practice for high strength bolts in steel structures.
51.	IS: 4218	ISO General purpose metric screw threads.
52.	IS: 4353	Submerged arc welding of mild steel and low alloy steels – Recommendations.
53.	IS: 4923	Hollow steel sections for structural use – specification.
54.	IS: 4972	Resistance spot welding electrodes
55.	IS: 5206	Covered electrodes for manual metal arc welding of stainless steel and other similar high alloy steels.
56.	IS: 5511	Covered electrodes for manual metal arc welding of cast iron.
57.	IS: 5624	Foundation bolts.
58.	IS: 5856	Corrosion and heat resisting chromium-nickel steel solid welding rods, bare electrodes.
59.	IS: 5857	Nickel and nickel alloy bare solid welding rods and electrodes.
60.	IS: 5897	Aluminium and aluminium alloy welding rods and wires and magnesium alloy welding rods.
61.	IS: 5898	Copper and copper alloy bare solid welding rods and electrodes.
62.	IS: 6016	Gas welding equipment - hose connections for equipment for welding, cutting and allied processes.
63.	IS: 6419	Welding rods and bare electrodes for gas shielded arc welding of structural steel.
64.	IS: 6603	Stainless steel bars and flats.
65.	IS: 6623	High strength structural nuts.
66.	IS: 6649	Hardened and tempered washers for high strength structural bolts and nuts.
67.	IS: 7205	Safety code for erection of structural steelwork.
68.	IS: 7215	Tolerances for fabrication of steel structures.
69.	IS: 7280	Bare wire electrodes for submerged arc welding of structural Steels.
70.	IS: 7303	Covered electrodes for surfacing of metal by manual arc welding
71.	IS: 7307	Approval tests for welding procedures:
	(Part 1)	*Fusion welding of steel.*
72.	IS 7310	Approval tests for welders working to approved welding procedures:
	(Part 1)	*Fusion welding of steel.*
73.	IS 7318	Approval test for welders when welding procedure approval is not required:
	(Part 1)	*Fusion welding of steel.*
	(Part 2)	*Tig or Mig welding of aluminium and its alloys.*
74.	IS: 8363	Bare wire electrodes for electroslag welding of steels.
75.	IS: 8412	Slotted countersunk head bolts for steel structures.
76.	IS: 8484	Metal powders welding electrodes.
77.	IS: 8666	Copper and copper alloy covered electrodes for manual metal arc welding.

78.	IS: 8736	Nickel and nickel alloy covered electrodes for metal arc welding.
79.	IS: 8910	General technical delivery requirements for steel and steel products.
80.	IS: 9595	Metal arc welding of carbon and carbon manganese steels - Recommendations.
81.	IS: 9862	Ready mixed paint, brushing, bituminous, black, lead-free, acid, alkali, water and chlorine resisting.
82.	IS: 10234	Recommendation for general pipeline welding.
83.	IS: 10238	Fasteners - threaded steel fastener - step bolts for steel structures.
84.	IS/ISO: 10474	Steel and steel products- inspection documents.
85.	IS: 10842	Evaluation procedure for Y-groove weld crackability test in structural steel.
86.	IS: 11991	Recommended practice for flash butt welding of tubes, rods and other sections in carbon and alloy steel.
87.	IS: 12778	Hot rolled parallel flange steel sections for beams, columns and bearing piles - dimensions and section properties.
88.	IS: 12779	Rolling and cutting tolerances for hot rolled parallel flange beam and column sections.
89.	IS: 13043	Covered manual metal arc welding electrodes - determination of efficiency, metal recovery and deposition co-efficient.
90.	IS: 13759	Polyurethane primer zinc phosphate (two pack) for exterior painting of railway coaches.
91.	IS: 13851	Storage and redrying of covered electrodes before use recommendations.
92.	IS: 14284	Steel and iron - sampling and preparation of samples for the determination of chemical composition.
93.	IS: 14589	Zinc priming paint, epoxy based, two pack – specification.
94.	IS: 14925	Epoxy resin for paints.
95.	IS: 15326/ ISO 3834	Quality requirements for welding - fusion welding of metallic materials:
	(Part 1)	*Guidelines for selection and use*.
	(Part 3)	Standards quality requirements.
	(Part 4)	*Elementary quality requirements*.
96.	IS: 15327/ ISO 14731	Welding coordination - tasks and responsibilities.
97.	IS: 15387/ ISO 5830	Resistance spot welding - male electrode caps.
98.	IS: 15862	Structural steel for buildings and structures with improved seismic resistance.
99.	IS: 15911	Structural steel (Ordinary quality).
100.	INS/072	Guide book on fabrication and erection of steel structures.
101.	SIS 05 5900	Pictorial surface preparation standards for painting steel surface

+++++++

1301 REQUIREMENTS FOR DRAINAGE

In designing a drainage system for building(s), the aim shall be to provide a self cleansing conduit for the conveyance of soil, waste, surface or sub-surface waters and for the removal of such wastes speedily and efficiently to a sewer or other outlet, without risk of nuisance and hazard to health.

The discharge of water through a domestic drain is intermittent and limited in quantity. Therefore, small accumulations of solid matter are liable to form in the drains between the building and the public sewer. Gradients shall be sufficient to prevent these temporary accumulations building up and blocking the drains.

The approximate gradients to give a velocity of 2.4 m/sec for the various sizes of pipes and the corresponding discharge when flowing half-full are given in table 1300-1.

Table 1300-1: *Gradients for sewers*

Diameter mm	*Minimum gradient*		*Maximum gradient*	
	Gradient	*Discharge m^3/minute*	*Gradient*	*Discharge m^3/minute*
100	1 in 57	0.18	1 in 5.6	0.59
150	1 in 100	0.42	1 in 9.7	1.32
200	1 in 145	0.73	1 in 14	2.40
230	1 in 175	0.93	1 in 17	2.98
250	1 in 195	1.10	1 in 19	3.60
300	1 in 250	1.70	1 in 24.5	5.30

1302 GLAZED STONEWARE PIPES AND FITTINGS

The practice of using glazed stoneware pipes and fittings are obsolete now. For the details of SW pipes, fittings, laying, jointing and testing, IS: 651 and IS: 4127 shall be referred.

1303 CEMENT CONCRETE PIPES (LIGHT DUTY, NON-PRESSURE)

For the details of cement concrete pipes, laying, jointing and testing, IS: 458 and IS: 783 shall be referred.

1304 CAST IRON PIPES AND SPECIALS

Cast iron/ductile iron drainage pipes and specials shall conform to IS: 1729. Laying and jointing of cast iron pipes and fittings shall be in accordance with IS: 3114.

1304.1 Gully grating

a) *Horizontal gully grating:* The casting of the grating and frames shall be the same as that of manhole covers. The gully grating cover shall be hinged to the frame to facilitate its opening for cleaning and repairs. The weight of grating shall be minimum 75 kg. In case of RCC horizontal gully grating it shall be in cement concrete 1:1:2 (1 cement: 1 coarse sand: 2 graded stone aggregate 20 mm nominal size)

b) *Vertical gully grating:* The chamber shall be of brick masonry, 12 mm dia round

bar shall be fixed in cement concrete block at the bottom. The bars at the top shall be welded or riveted to MS flat 40 mm x 6 mm.

1304.2 Manhole covers and frames

a) Manhole covers and frame shall be manufactured from appropriate grade of grey cast iron not inferior than FG150 grade of IS: 210.
b) Cast iron covers and frames shall conform to IS: 1726.
c) Pre-cast reinforced cement concrete manhole covers intended for use in sewerage and water works shall generally conform to IS: 12592.
d) Pre-cast concrete covers shall be of the grades and types given in table 1300-2.

Table 1300-2: *Grades and types of pre-cast concrete covers.*

Grades	*Grade designation*	*Type/shape of cover*
Light duty	LD-2.5	Rectangular, Square, Circular.
Medium duty	MD-10	Rectangular, Circular and Square (for pre-cast concrete manhole covers)
Heavy duty	HD-20	Circular-Square, Rectangular, (Scrapper Manhole)
Extra heavy duty	EHD-35	Circular, Square, Rectangular, (Scrapper Manhole)

1305 PVC/UPVC PIPE

Polyvinyl chloride (PVC) is a polymer of vinyl chloride. The Vinyl Chloride is polymerized, to form long chains of polyvinyl chloride. PVC pipes are manufactured by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These are rigid PVC pipes.

Unplasticised polyvinyl chloride (UPVC) pipe is an extruded product from a blend of polymer resin and various additives, but plasticisers are not added during manufacture. The standard specifies that the material for manufacturing the pipes should consist substantially of unplasticised polyvinyl chloride to which may be added only those additives needed to facilitate manufacture of pipe and the production of sound and durable pipe of good surface finish, mechanical strength and opacity under conditions of use. The type and quantities of additives used individually or together should ensure that the pipes are sound and meet the health and strength requirements of the standard.

1305.1 Requirements

a) The pipes shall conform to IS: l5328. Pipes of nominal outside diameters ranging from 110 mm up to and including 630 mm are covered in this standard.
b) Standards for pipes of nominal diameter less than 110 mm shall be governed by IS: 4985.
c) The mean outside diameter, outside diameter at any point and tolerances shall be as given in table 1 of IS: 12235 (Part 1).
d) The nominal wall thickness shall be in accordance with table 2 of IS: l5328.
e) Tolerances in outside diameter shall be those given in IS: 4985.
f) When viewed without magnification, the internal and external surfaces of the pipe shall be smooth, clean and free from grooving, blistering and any other surface irregularity, which is likely to prevent conformance of the pipe with this standard. Slight shallow longitudinal grooves or irregularities in the pipe shall be

permissible, provided the wall thickness remains within permissible limits. The pipe wall shall not contain impurities or pores.

g) The pipe ends shall be cleanly cut and reasonably square to the axis of the pipe.

h) The colour of the pipes shall be dark (any shade of brown). The pipe shall be uniformly coloured throughout the entire wall. Slight variations in the appearance of the colour are permitted.

i) Marking - Each pipe shall have Standard BIS certification marking

j) Each pipe shall be clearly and indelibly marked in ink/paint or hot embossed on white base at intervals of not more than 3 m, but at least once per pipe, in a colour which shall be different from that of the basic colour of the pipe. The marking shall be legible without magnification. The marking shall not initiate cracks or other types of defects which adversely influence the performance of the pipe. The marking shall show the following:
   i) Identification of the source of manufacture.
   ii) Outside diameter.
   iii) Stiffness class.
   iv) Batch or Lot number.

k) The colour of the marking shall be as follows:

Class of pipe	*Colour*
SN2	Blue
SN4	Green
SN8	Brown

1305.2 Quality control tests

a) *Vicat softening temperature*: The Vicat softening temperature, when determined according to Annex A of IS: l5328, shall not be less than 79°C.

b) *Longitudinal reversion*: The longitudinal reversion, when tested according to the method prescribed in IS: 12235 (Part *5*), shall not exceed ±5%.

c) *Resistance to external blows at 0^0C*: When tested according to the method prescribed in Annex 8 of IS: l5328, the pipe shall have a true impact rate of not more than 10 percent.

d) *Ring stiffness*: When tested according to the method described in Annex C of IS: l5328, the ring stiffness of the pipe shall be as stated in table 5 of the above code.

e) *Resistance to internal hydrostatic pressure (Type test)*: When tested according to the method described in IS: 12235 (Part 8), the pipe shall not fail (Seep, crack, bulge or burst) during the prescribed duration of the test and shall meet the requirements given in table 6 of IS: l5328.

1305.3 Sampling and criteria for conformity

The sampling procedure and criteria for conformity shall be as given in Annex F of IS: l5328.

1305.4 Test certificate

Manufacturer's test certificate shall be produced by the Contractor, if the total length of pipe used for drainage and sanitary works including all sizes is more than 200 meters.

1306 MANHOLES

a) At every change of alignment, gradient or diameter of a drain, there shall be a manhole or inspection chamber. Bends and junctions in the drains shall be

grouped together in manhole as far as possible. The maximum distance between manholes shall be 30 m.

b) Manholes of different types and sizes as specified shall be constructed in the sewer line at such places and to such levels and dimensions as shown in the Drawings or as directed by the Engineer. The size specified shall indicate the inside dimensions between brick faces of the manholes.

c) Sewers of unequal sectional area shall not be jointed at the same invert in a manhole.

d) No drain from house fittings such as gully trap, soil pipe etc. to manhole shall normally exceed a length of 6 m unless it is unavoidable.

e) Manholes 90 cm x 80 cm are generally constructed within compound for house drainage only and near the buildings for house drainage. Manholes 1.2 m x 90 cm are generally constructed for main drainage work for depths less than 1.5 m.

f) Manhole 1.4 m x 90 cm is of the arched type and is generally constructed for main drainage works where depth is 1.50 m or more. The width of manholes shall be increased more than 90 cm on bends or junctions or pipes with diameter greater than 450 mm and that the benching width on either side of the channel is minimum 20 cm.

g) Manholes 1.4 m internal diameter are generally constructed for main drainage works where depth is 2.45 m or more as an alternative to manholes of arch type. The diameter shall be increased suitably, for pipes with diameter greater than 450 mm in the same manner as in the case of rectangular manholes.

h) All manholes deeper than 0.8 m shall be provided with MS or SS foot rests. These shall be embedded 20 cm deep in 20 cm x 20 cm x 10 cm blocks of cement concrete 1:3:6 (1 cement: 3 coarse sand 6 graded stone aggregate 20 mm nominal size). The concrete block with MS foot rest placed in its centre shall be cast in-situ along with the masonry and plastered with 12 mm thick cement mortar 1:3 (1 cement: 3 coarse sand), finished smooth.

i) In cases where branch pipe sewer enters the manhole of main pipe sewer at a higher level than the main sewer, a drop connection shall be provided.

1307 OPEN SURFACE DRAIN

a) The open drains shall be of the size, as specified in the item and laid to such gradients and in such locations as may be shown in the relevant Drawing or as directed by the Engineer.

b) The average depths of the various sizes of drains shall be as per table 1300-3.

Table 1300-3: *Recommended sizes of open drains*

Drain size	*Depth*
10 cm	20 cm
15 cm	20 cm
25 cm	30 cm

1308 GULLY CHAMBER WITH GRATING

a) The chamber shall be of brick masonry of specified class.

b) The horizontal grating shall have a CI grating with frame fixed in 15 cm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate 20 mm nominal size) at the top. The chamber shall be built at the location fixed

by the Engineer.

c) Generally the spacing of the chambers shall be 18 m to 36 m depending upon the grading of the road channel and the area of the drainage.

d) The vertical grating shall be 12 mm dia round bar fixed in cement concrete block at the bottom. The bars at the top shall be welded or riveted to MS flat 40 mm x 6 mm.

1309 BRICK MASONRY GULLY TRAP

The internal size of the trap shall be 80 cm x 40 cm x 46 cm. The height shall be measured from the top of the floor to the top of the cover. Stone baffles 40 mm thick shall be fixed 50 mm deep in masonry with cement mortar 1:4 (1 cement: 4 fine sand). The connection of open surface, drain with a soak pit shall be invariably through a grease trap.

1310 SEPTIC TANK

a) In areas where public drainage system do not exist, every house shall have arrangements for its sewage being treated in septic tank, effluent from which should be given secondary treatment either in a biological filter or on the land, or in a sub-surface disposal system.

b) Surface and sub-soil water should be excluded from finding way into the septic tank.

c) Waste water may be passed into the septic tank provided the tank and the means for effluent disposal are designed to cope up with this extra liquid. Depending on the location of the water table and the nature of the strata, the type of disposal for the effluent from the septic tank shall be decided.

d) IS: 2470 Part 1 and 2 shall be referred for the details, regarding design and installation of septic tanks.

e) Before the tank is commissioned for use, it shall be tested for water-tightness by filling it with water and allowing it to stand for 24 hours. It shall then be topped up, if necessary, and allowed to stand for a further period of 24 hours during which time the fall in the level of the water shall not be more than 1.5 cm.

f) Construction of soak pits shall be carried out as per IS: 2470 Part 1 and 2.

1311 SANITARY INSTALLATIONS

All vitreous sanitary appliances (Vitreous china) shall conform to IS: 2556 (Part 1) general requirements.

1312 APPLIANCES AND FITTINGS

1312.1 Water closet

a) Indian type WC: Indian type pans shall be of white vitreous china conforming to IS: 2556 (Part 1) for general requirements and relevant IS codes for each pattern as given below:
   i) Long pattern-conforming to IS: 2556 (Part 3).
   ii) Orissa pattern-conforming to IS: 2556 (Part 3).
   iii) Integrated type conforming to IS: 2556 (Part 14).

b) Preferably Orissa type pan shall be used in public buildings. In all cases, a pan shall be provided with a 100 mm trap 'P' or 'S' type with approximately 50

mm water seal.

c) European type WC: Water closets shall be of white vitreous china conforming to IS: 2556 (Part 1) and IS: 2556 (Part 2) and relevant IS codes for each pattern as given below:
   i) Wash down type - conforming to IS: 2556 (Part 2.)
   ii) Wash down wall mounted type - conforming to IS: 2556 (Part 16).
   iii) Dual purpose Anglo-Indian type.

d) *Foot rests:* Foot rests shall be of vitreous china conforming to IS: 2556 (Part 10). Foot rests of different shapes and sizes shall also be allowed subject to approval of Engineer.

e) *Installation:* Installation of water closet and accessories shall be done as detailed in the Specification. For making good the damage to the under mentioned items of work, the procedures given below shall be followed, unless directed otherwise.
   i) *Masonry work:* The masonry work shall be made good by using the same class of bricks, tiles or stones as was damaged during the execution of the work. The mortar used shall be cement mortar 1:5 or as directed by the Engineer.
   ii) *Plain concrete work:* Concrete work for sub-grade of the flooring, foundations and other plain concrete works shall be with grade M10 concrete. A coat of neat cement slurry shall be applied at the junction with old work, before laying fresh concrete.
   iii) *Cement concrete flooring and RCC work:* Cement concrete with grade not less than M20 shall be used after applying a coat of neat cement slurry at the junction with old work, and the surface finished to match with the surrounding surface.
   iv) *Plastering:* Cement plaster 1:4 shall be used. The sand shall be fine or coarse, as used in the original work. The surface shall be finished with two or more coats of white wash, colour wash, distemper or painting as required, but where the surface is not to be white washed, colour washed, distempered or painted, it shall be finished as required to match with the surrounding surface.

1312.2 Flushing cisterns

a) The flushing cisterns shall be automatic or manually operated high level or low level as specified, for water closets and urinals. A high level cistern is intended to operate with minimum height of 125 cm and a low level cistern with a maximum height of 30 cm between the top of the pan and the underside of the cistern.

b) The following types of flushing cistern are normally used:
   i) Vitreous china flushing cistern conforming to IS: 774.
   ii) Automatic flushing cistern conforming to IS: 2326.
   iii) Plastic cisterns conforming to IS: 7231.
   iv) Concealed flushing cistern with single/dual type.

c) The materials for manufacturing various components of the flushing cisterns shall conform to the requirements given in table 1300-4.

Table 1300-4: *Materials for various components of flushing cisterns*

Sl. No.	*Component*	*Material*	*Code*
1.	Cisterns	High density polyethylene (HDPE) or Polystryene, high impact or Polypropylene or Acrylonitrile-butadiene-styrene (ABS) or Glass Fibre reinforced plastic (GRP)	IS: 7328 IS: 2267 - - -
2.	Flush pipe	Steel tube, seamless or welded, medium or light, completely protected inside and outside by hot-dip galvanizing, electroplating or vitreous enamelling or Lead pipe or Copper alloy tube or High density polyethylene pipe or Unplasticised PVC plumbing pipe	IS: 1239 ((Part 1) IS: 404 (Part 1) IS: 407 IS: 2501
3.	Cover	Same material as that of the body	
4.	Chain	Hot-dip galvanized steel wires or Inter-locked non-ferrous metal or any other corrosion resistant material	-
5.	Overflow pipe	High density polyethylene/unplasticised PVC or any other corrosion-resistant material	IS: 4984/ IS: 4985
6.	Siphon/valve	High density polyethylene Or Polystyrene, high impact Or Polypropylene Or Acrylonitrile- butadiene-styrene Or Glass fibre reinforced plastic (GRP)	IS: 7328 IS: 2267 - - -
7.	Operating Mechanism/ Lever	Non-ferrous metal or any other corrosion- resistant material	-
8.	Float valve	As specified in IS: 1703/IS: 12234/IS: 13049	-
9.	Polyethylene float for float valve	As specified in IS: 9762	-
10.	Coupling nut and lock-nut	Non-ferrous metal or Hot-dip galvanised steel or Hot-dip galvanised malleable iron or any other non-corrosive metal or Injection-moulded HDPE/polyacetal	-

NOTE: Where the requirements for the material of any component or the relevant Indian Standard designation for any material are not specified, these shall be as directed by the Engineer.

1312.3 Requirements of flushing cistern

a) The cistern under working conditions and with the float valve in closed position shall operate on a single operation of the operating mechanism/lever without calling for a sudden jerk in pulling.
b) If a valve is used instead of siphon for flushing purposes, the valve shall be completely leak proof. The float valve shall be 15 mm nominal size and shall conform to IS: 1703, IS: 12234 or IS: 13049.
c) The working water-level shall be a minimum of 6.5 cm below the effective top edge of the cistern and shall be legibly and permanently marked on the inside of the cistern.
d) The siphonic system shall be capable of being rapidly brought into action when the water is at the working water level, but shall not self siphon or leak into the flush pipe when the water is up to 1 cm above the invert of the overflow pipe.
e) The discharge shall operate satisfactorily when the cistern is filled to a level up to 1 cm below the working water level.

1312.4 Quality control tests for flushing cistern

a) When tested in accordance with IS: 7231, the discharge rate shall be 10±0.5 litres within 6 seconds for cistern of 10 litres capacity, 5±0.5 litres within 3 seconds for 5 litres capacity, 6±0.5 litres within 6 seconds for 6 litres capacity and 3±0.5 litres within 3 seconds for 3 litres capacity.
b) The cistern shall be so designed that there is no appreciable variation in the force of the flush during the discharge of the required quantity of water. For coupled cisterns, this test shall not be applicable.
c) Flushing cistern shall satisfy the following tests:
    i) *Distortion resistance test:* The cisterns, complete with its fittings, shall be installed and filled with water to the marked water line and observed for any distortion. The cistern shall not budge more than 6 mm and the cover shall not be dislodged.
    ii) *Dead load test:* When the flushing mechanism incorporates chain pull or hand operated lever, the cistern, complete with its fittings, when installed and filled with water to the marked water line and tested by the application of a dead load of 230 N applied 6 mm from the end of the operating lever arm for 30 seconds, shall not distort to such an extent that any part becomes detached. In the case of other operating mechanism, the dead load applied shall be a mass equivalent to the operating force required to overcome the normal hydrostatic head. The function and appearance of the cistern shall not be impaired thirty seconds after the load is removed.
    iii) *Front thrust test:* The front thrust test shall be applied only to cisterns intended for low level use. The cistern complete with its fittings, when installed and filled with water to the marked water line and tested by the method described in IS: 7231, shall not distort to such an extent as to be inoperable or unsightly when the load is removed.
    iv) *Impact test:* The cistern, complete with its fittings, when installed and filled as described in IS: 7231 shall show no defect after one impact. Repeat the

test but with the cistern empty. The cistern shall show no defect after further impact.

d) The seat and cover shall be of thermosetting or thermoplastic conforming to IS: 2548 as specified. Unless otherwise specified these shall be of closed pattern.
e) Seats shall have a smooth finish and shall be non absorptive and free from cracks and crevices. They shall be capable of being easily cleaned and shall not be adversely affected by common solvents or household cleanser.
f) The seats shall withstand without permanent distortion of the seat or hinge fittings or damage to any finish, a load of 1150 N for 30 minutes applied in the manner prescribed in IS: 2548.

1312.5 Flush valve

a) Flush valves are used for flushing of water closets, squatting pans and urinals by directly connecting to pressure water pipes. The performance requirements and testing of flush valves are detailed in IS: 9758.
b) Flush valves connected to pressure water pipes when operated, shall allow a limited quantity of water to flow through, in order to flush water closets and urinals and should slowly close automatically.
c) The nominal sizes of the flush valves are 15, 25 and 32 mm.
d) The outside of the body shall be polished bright and chromium plated which shall be of quality not less than service grade 3 of IS: 4827.
e) Each flush valve and its component parts shall be clearly and permanently marked with the manufacturer's name or trademark and nominal size.
f) Each flush valve may be marked with the ISI certification mark.

1312.6 Wash basins/Sinks

a) Wash basins shall be of white vitreous china conforming to IS: 2556 (Part 1) and IS: 2556 (Part 4).
b) Where oval shape or round shape wash basins are required to be fixed these shall be fixed preferably in RCC platform or available stone slabs as directed by Engineer.
c) Laboratory sinks and kitchen sinks shall be of white glazed fire clay conforming to IS: 771 (Part 2).
d) The kitchen sink shall be of one piece construction with or without rim but without overflow. Stainless steel kitchen sink shall be of sizes as specified and shall be conforming to IS: 13983.
e) The waste fittings shall be of nickel chromium plated brass, with thickness of plating not less than service grade 2 of IS: 4827 which is capable of receiving polish and will not easily scale off.
f) The fittings shall conform in all respect to IS: 2963 and shall be sound, free from laps, blow holes and other manufacturing defects.

1312.7 Mirror

The mirror shall be of superior glass with edges rounded off or bevelled, as specified. It shall be free from flaws, specks or bubbles.

1312.8 Floor trap or Nahani trap

Nahani trap shall conform to IS: 1729.

1312.9 Urinals

The following types of urinals are normally used:

i) *Bowl type urinals:* Urinal basins shall be of flat back or corner wall type lipped in front. These shall be of white vitreous china conforming to IS: 2556 (Part 6).

ii) *Half stall urinals**:*** They shall be of white vitreous China conforming to IS: 2556 (Part 6).

iii) *Urinal partition slabs:* Urinal partition slabs shall be provided, as specified in the item of work.

iv) *Squatting plate urinal:* The plates shall be of white vitreous china conforming to IS: 2556 (Part 1) and IS: 2556 (Part 6) with internal flushing rim with front or side inlet.

1313 FIXING AND JOINTING OF PIPES AND FITTINGS

1313.1 Jointing

a) The jointed pipe line shall be at required levels and alignment.

b) The leading of pipes shall be made by means of ropes covered with clay or by using special leading rings.

c) The lead shall be melted so as to be thoroughly fluid and each joint shall be filled in one pouring.

d) The joints shall not be covered till the pipe line has been tested under pressure.

e) Use of collars for jointing is not permitted in any concealed or embedded location.

1313.2 Testing

In order to ensure that adequate lead is poured properly into the joints and to control waste in use of lead, at the beginning of work three or four sample joints shall be made and the quantum of lead per joint approved by the Engineer. All sand cast iron/cast iron (Spun) pipes and fittings including joint shall be tested by smoke test to the satisfaction of the Engineer and left in working order after completion. The smoke test shall be carried out as under:

i) Smoke shall be pumped into the pipes at the lowest end from a smoke machine which consists of a bellow and burner.

ii) The material usually burnt is greasy cotton waste which gives out a clear pungent smoke which is easily detectable by sight as well as by smell, if there is leak at any point of the drain.

1313.3 Painting

All sand cast iron/cast iron (Spun) pipes and fittings shall be painted with shade to match the colour of the background as directed by the Engineer.

1314 WATER SUPPLY

Buildings in which plumbing fixtures are installed shall be provided with ample supply of potable water by connection to a public water supply system. Water from the street main is supplied to the individual building through a service connection. Within the building, water is distributed to different fixtures through pipes.

1314.1 Requirements

a) No piping shall be laid or fixed so as to pass into, through or adjoining any

sewer, scour outlet or drain or any manhole connected therewith nor through any ash pit or manure-pit or any material of such nature that can cause undue deterioration of the pipe.

b) Where the laying of any pipe through fouled soil or previous material is unavoidable, the piping shall be properly protected from contact with such soil or material by being carried through an exterior cast iron tube or by some other suitable means.

c) The design of the pipe work shall be such that there is no possibility of backflow towards the source of supply from any cistern or appliance whether by siphonage or otherwise, and reflux or non-return valves shall not be relied upon to prevent such back flow.

d) All pipe work shall be so designed, laid or fixed, and maintained so that it remains completely watertight, thereby avoiding wastage of water, damage to property and the risk of contamination of the water conveyed.

e) To reduce frictional losses, piping shall be as smooth as possible inside. Methods of jointing shall be such as to avoid internal roughness and projection at the joints, whether of the jointing materials or otherwise.

f) Underground piping shall be laid at such a depth that it is unlikely to be damaged by frost or traffic loads and vibrations.

g) In flats and tenements, supplied by a common service pipe, a stop valve shall be fixed to control each branch separately. In large buildings sufficient number of stop valves shall be fixed on branch pipes to control groups of ball valves and draw off taps, so as to minimise interruption of the water supply.

h) Water for drinking or for culinary purposes as far as possible shall be on branch pipes connected directly to the service pipe.

i) Pumps shall not be allowed on the service pipe as they cause a drop of pressure on the suction side thereby affecting the supply to the adjoining properties. In cases where pumping is required, a properly protected storage tank of adequate capacity shall be provided to feed the pump.

j) Service pipes shall be so designed and constructed as to avoid air-locks, so that all piping and fittings above ground can be completely emptied of water to facilitate repairs. Service pipes shall be designed so as to reduce the production and transmission of noise as much as possible.

k) The rising pipe to the storage cistern, if any, or to any feed cistern shall be taken as directly as possible to the cistern and shall be fixed away from windows or ventilators.

l) All pipe work shall be planned so that the piping is accessible for inspection, replacement and repair.

m) When it is necessary for a pipe to pass through a wall or floor, a sleeve shall be fixed therein for insertion of the pipe and to allow freedom for expansion, contraction and other movement.

n) No service pipe shall be connected to any water closet or urinal. All such supplies shall be from flushing cisterns which shall have supply from storage tank. No service or supply pipe shall be connected directly to any hot-water system or to any apparatus used for heating other than through a feed cistern thereof.

1314.2 Components of water supply system

The prescribed standards for important components of water supply system are as follows:

a) The ball valve shall be of brass or gunmetal as specified conforming to IS: 1703.
b) Polyethylene floats shall conform to IS: 9762.
c) Bib taps and stop valve shall be of specified size and shall be of screw down type and shall conform to IS: 781. In case these are required to be nickel plated, the plating shall be of the first quality with a good thick deposit of silvery whiteness capable of taking high polish which will not easily tarnish or scale.
d) The ferrules for connection with CI main shall generally conform to IS: 2692.
e) Fire hydrants shall conform to IS: 909. The body, bonnet, gland, outlet cap and spindle cap shall be of good quality cast iron grade FG200 of IS: 210. Outlet, seat for valve, valve, spindle nut and check nut shall be made of copper alloy as per IS: 909.
f) Gun metal gate valve shall generally conform to IS: 778.
g) Pig lead shall conform to IS: 782.
h) Lead wool shall conform to IS: 782 in all respects.
i) Gun metal non-return valve shall be of quality approved by the Engineer and shall generally conform to IS: 778.

1315 PIPES AND SPECIALS

Pipes and specials may be of any of the following types as specified:

a) Cast iron centrifugally cast (spun) – IS: 1536.
b) Galvanised steel - IS: 1239 & IS: 4736.
c) PVC/UPVC Pipes – IS: 4985.
d) HDPE Pipes – IS: 4984.
e) PP-R Pipes – IS: 15801.
f) CPVC pipes – IS: 15778.
g) PE-AL-PE Pipes – IS: 15450.

1315.1 Centrifugally cast (Spun) iron pipes

The spun iron pipes shall conform to IS: 1536.

1315.2 Galvanised iron (GI) pipes

a) The pipes (tubes) shall be galvanised mild steel hot finished seamless (HFS) or welded (ERW) HRIW or HFW screwed and socketed conforming to the requirements of IS: 1239 Part 1 for medium grade.
b) Galvanising shall conform to IS: 4736.
c) The dimensions and weights of pipes and sockets are given in table 1300-5.
d) The tolerances shall be as prescribed in table 1300-6.
e) All screwed tubes and sockets shall have pipe threads conforming to the requirements of IS: 554.
f) All tubes shall withstand a test pressure of 50 kg/m^2 without showing defects of any kind.
g) The fittings shall be of mild steel tubular or wrought steel fittings conforming to IS: 1239 (Part 2) or as specified.

Table 1300-5: *Particulars of medium grade GI pipes*

Nominal bore (mm)	*Dimensions of pipes*			*Weight of pipe*	
	Outside diameter		*Thickness*	*Plain end*	*Screwed end socket*
	Max (mm)	Min (mm)	mm	kg/m	kg/m
6	10.6	9.8	2.0	0.404	0.407
8	14.0	13.2	2.3	0.641	0.645
10	17.5	16.7	2.3	0.839	0.845
15	21.8	21.0	2.6	1.21	1.22
20	27.3	26.5	2.6	1.56	1.57
25	34.2	33.3	3.2	2.41	2.43
32	42.9	42.0	3.2	3.10	3.13
40	48.8	47.9	3.2	3.56	3.60
50	60.8	59.7	3.6	5.03	5.10
65	76.6	75.3	3.6	6.42	6.54
80	89.5	88.0	4.0	8.36	8.53
100	115.0	113.1	4.5	12.2	12.50
125	140.8	138.5	4.8	15.90	16.40
150	166.5	163.9	4.8	18.90	19.50

Table 1300-6:*Tolerance in thickness and weight*

Dimension	*Nature*	*Tolerance*
Thickness	Butt welded medium tubes	+ not limited – 10%
	Seamless tubes	+ not limited – 12.5%
Weight	Single tube (Light series)	+10% – 8%
	Single tube (Medium and heavy series)	±10%
	For quantities per load of 10 tonnes minimum (Light series)	±5% – 8%
	For quantities per load of 10 tonnes minimum (Medium and heavy series)	±7.5%

1315.3 PVC/UPVC Pipes

The method of manufacture of UPVC pipes are detailed under clause 1305 under Section 1300. Being made of a tasteless and odourless material, UPVC pipes remain neutral to all transported fluids. UPVC is completely inert and is widely used for transporting liquids made for human consumption. The specifications and tests of UPVC pipes for potable water supplies are detailed in IS: 4985.

1315.3.1 Requirements

a) The pipes shall confirm to the standards specified in IS: 4985.
b) Laying and jointing of UPVC pipes for supply of potable water shall be as detailed under IS: 7634(Part 3).
c) PVC pipes are available from 40 mm dia to 600 mm dia and up to 6 m length.
d) Pressure rating ranges from 2.5 kg/cm^2 to 12 kg/cm^2.
e) PVC pipes are not suitable for high pressure applications.

f) Backfilling of pipes shall be carried out with appropriate pipe zone back fill material.

g) PVC pipes with minimum of 6 kg/cm^2 pressure rating shall be used for pipes up to 63 mm dia.

h) The additives to be used shall be selected from IS: 10148 and shall be uniformly dispersed.

i) Each pipe shall have Standard BIS certification mark.

j) The following details shall also be clearly and indelibly marked on each pipe in colour using ink/paint at intervals of not more than 3 meters. Alternatively, inkjet printing in any contrasting colour can also be used for marking at intervals of not more than 3 m.
   i) Manufacturer's name or trade mark.
   ii) Outside diameter.
   iii) Class of pipe and pressure rating.
   iv) Batch or lot number.
   v) The word plumbing in the case of plumbing pipes.

k) The information shall be marked in colour as indicated in table 1300-7 for different classes of pipes (In the case of indelible marking by ink/paint). In the case of inkjet printing, the pipes shall also be provided near the end with a circumferential colour band as indicated below for different classes of pipes to identify the class of pipe.

Table 1300-7: *Marking on UPVC pipes*

Class of Pipe	*Colour*
Class 1	Red
Class 2	Blue
Class 3	Green
Class 4	Brown
Class 5	Yellow
Class 6	Black
Plumbing pipes	Pink

l) The mean outside diameter, outside diameter at any point, and wall thickness of plumbing pipes shall be as given in table 1300-8 (Table 2 of IS: 4985).

Table 1300-8: *Dimensions of UPVC plain end pipe for plumbing in buildings*

Nominal outside diameter (mm)	*Mean outside diameter (mm)*		*Outside diameter at any point(mm)*		*Wall thickness (mm)*	
	Min	Max	Min	Max	Min	Max
20	20.0	20.3	19.5	20.5	2.8	3.3
25	25.0	25.3	24.5	25.5	2.9	3.4
32	32.0	32.3	31.5	32.5	3.4	3.9
40	40.0	40.3	39.5	40.5	3.6	4.2
50	50.0	50.3	49.4	50.6	3.7	4.3

1315.3.2 Classification

The pipes shall be classified by pressure ratings (working pressures) at 27°C as follows:

Table 1300-9: *Classification of pipes*

Class of pipe	*Working pressure (PN)*
Class 1	0.25 MPa (2.5 kg/cm^2)
Class 2	0.4 MPa (4.0 kg/cm^2)
Class 3	0.6 MPa (6.0 kg/cm^2)
Class 4	0.8 MPa (8.0 kg/cm^2)
Class 5	1.0 MPa (10.0 kg/cm^2)
Class 6	1.25 MPa (12.5 kg/cm^2)

1315.3.3 Quality control tests

a) *Visual appearance:* The colour of the pipes shall be light grey. Slight variations in the appearance of the colour are permitted. The internal and external surfaces of the pipe shall be smooth, clean and free from grooving and other defects. Slight shallow longitudinal grooves or irregularities in the pipe shall be permissible provided the wall thickness remains within the permissible limits.

b) *Opacity:* The wall of the plain pipe shall not transmit more than 0.2% of the visible light falling on it when tested in accordance with IS: 12235 (Part 3).

c) *Reversion test:* When tested by the immersion method prescribed in IS: 12235 (Part 5), a length of pipe 200±20 mm long shall not alter in length by more than 5%. In the case of socket end pipes, this test shall be carried out on the plain portion of the pipe taken at least 100 mm away from the root of the socket.

d) *Vicat softening temperature:* When tested by the method prescribed in IS: 6307, the Vicat softening temperature of the specimen shall not be less than 80°C.

e) *Density:* When determined in accordance with IS: 13360 (Part 3/Sec 1), the density of the pipe shall be between 1.40 and 1.46 gm/cm^3.

f) *Test for hydrostatic characteristics:* When subjected to internal hydrostatic pressure test in accordance with the procedure given in IS: 12235 (Part 8), the pipe shall not fail during the prescribed test duration.

g) *Resistance to external blows at 0°C:* When tested by the method prescribed in Annex C of IS: 4985, the pipe shall have a true impact rate of not more than 10%.

1315.3.4 Sampling and criteria for conformity

Sampling and criteria for conformity shall be as given in Annexure D of IS: 4985.

1315.3.5 Test Certificate

Manufacturer's test certificate shall be produced by the contractor if the total length of pipe used for plumbing including all sizes is more than 500 m.

1315.4 Medium density polyethylene (PE) pipes

a) MDPE pipes are manufactured from medium density polyethylene pipes grade materials for smaller diameter pipes as per IS: 4987. The pipes are flexible and available in coil form for long lengths.

b) The use of MDPE pipes shall be considered for house connections.

1315.5 High density polyethylene (HDPE) pipes

General guidance regarding laying and jointing including storage and handling for polyethylene pipes has been provided in IS: 7634 (Part 2) 'Code of practice for plastic

pipe work for potable water supplies - Laying and jointing of polyethylene pipes'. However, some additional requirements for these pipes have been given in Annex A. There is no Indian Standard for the laying and jointing of Polypropylene (PP) pipes at present. PE and PP pipes belong to the same polyolefin's family. As such, IS: 7634 (Part 2) may be used for PP pipes also.

a) HDPE pipes are manufactured from High Density Polyethylene pipe material PE 63, PE 80 or PE 100, a most versatile material suitable for pipes.
b) Pipes are manufactured as per IS: 4984 and IS: 14151 and are available in coil form or straight lengths depending on sizes and customer's requirements.
c) HDPE pipes are available from 50 mm to 800 mm diameter, 6m and above length.
d) Pressure rating of HDPE pipe is available in the range from 2.5 kg/cm^2 to 16 kg/cm^2.
e) HPDE pipes are not recommended in ground contaminated with organic chemicals.
f) The use of HDPE pipes is more economical and to be considered for smaller diameter pipes up to 110 mm where they are available on coils thereby avoiding joints.

1315.5.1 Requirements

a) The pipes shall conform to IS: 4984.
b) The colour of the pipe shall be black.
c) Each pipe shall contain minimum three equispaced longitudinal stripes of width 3mm (min) in blue colour. This is for identification.
d) UPVC pipes are recommended for water temperature ranging from 1 to 45^{0}C. Strength of pipe reduces at higher temperatures.
e) Nominal diameter of pipes available are 16, 20, 25, 32, 40, 50, 63, 75, 90, 110, 125, 140, 160, 180, 200, 225, 250, 280, 315, 355, 400, 450, 500, 560, 630, 710, 800, 900 and 1000 mm.
f) The percentage of anti-oxidant used shall not be more than 0.3 percent by mass of finished resin.
g) The minimum and maximum wall thickness of pipes shall be as specified in table 3, 4 and 5 of IS: 4984.
h) Each pipe shall have Standard BIS certification mark.
i) Each straight length of pipe shall be clearly marked in indelible ink/paint on either end and for coil at both ends or hot embossed on white base every metre throughout the length of pipe/coil with the following information.
    i) Manufacturer's name/trade mark.
    ii) Designation of pipe.
    iii) Lot number/batch number.

1315.5.2 Classification

j) Pipes shall be classified by pressure rating (PN) corresponding to the maximum permissible working pressure at 30°C, as follows (Clause 3.3 of IS: 4984)

Table 1300-10 *Pressure rating of HDPE pipes*

Pressure rating of pipe	*Maximum permissible working pressure*
PN 2.5	0.25 MPa
PN 4	0.40 MPa
PN 6	0.60 MPa
PN 10	1.00 MPa
PN 12.5	1.25 MPa
PN 16	1.60 MPa

1315.5.3 Quality control tests

a) *Visual appearance:* The internal and external surfaces of the pipe shall be smooth, clean and free from grooving and other defects. Slight shallow longitudinal grooves or irregularities in the pipe shall be permissible provided the wall thickness remains within the permissible limits.

b) *Test for hydraulic characteristics:* When subjected to internal pressure creep rupture test in accordance with procedure given in Annex B, the pipes shall show no signs of localized swelling, leakage or weeping and shall not burst during the test procedure.

c) *Reversion test:* When tested according to the procedure given at Annex C, the value of the longitudinal reversion shall not be greater than 3%.

d) *Overall migration test:* When tested from a composite sample of minimum 3 pipes as per IS: 9845, the overall migration of constituents shall be within the limits stipulated in IS: 10146.

e) *Density:* When tested from a composite sample of minimum three pipes as per Annex A of IS: 7328, it shall meet the requirement as given in 5.2.1 of IS: 4984

f) *Melt flow rate (MFR):* When tested from a composite sample of minimum three pipes as per IS: 2530, at 190°C with nominal load of 5 kgf, MFR shall be between 0.4 to 1.1 g/10 minutes and also shall not differ by more than 30% of the MFR of the material used in manufacturing pipes.

g) *Carbon black content and dispersion:* When tested from a composite sample of minimum three pipes, in accordance with IS: 2530, the carbon black content shall be within 2.5±0.5 percent and the dispersion of carbon black shall be satisfactory.

1315.5.4 Sampling and criteria for conformity

Sampling and criteria for conformity shall be as given in Annexure D of IS: 4984.

1315.6 Polypropylene random co-polymer (PP-R) pipes

a) The PP-R is a bonded, multilayer pipe consisting of different layers of the pipe. The pipes should in general be conforming to the requirements of IS: 15801 or as specified in the item.

b) The Polypropylene used for manufacturing the pipe shall conform to the requirements of IS: 10951 and IS: 10910.

c) The marking on pipe shall carry the following information:
   i) Manufacturer's name/trade mark.
   ii) PPR pipe.
   iii) SDR.
   iv) Outside diameter and minimum wall thickness.
   v) Lot/batch number containing date of manufacturing and machine number.

1315.7 Chlorinated polyvinyl chloride (CPVC) pipes

CPVC piping systems are considered cost effective and environmentally friendly. CPVC can be easily shaped, bent and welded. In addition, CPVC provides a long service life. It is highly corrosion resistant and is recognized by all model-plumbing codes for potable (Drinkable) hot and cold water distribution systems.

1315.7.1 Requirements

a) CPVC pipes and fittings used in hot and cold potable water distribution system shall conform to requirement of IS: 15778.

b) Diameter and wall thickness of CPVC pipes are as per given in table 1300-11.

Table 1300-11: *Diameter and wall thickness of CPVC pipes*

Nominal size	*Nominal outside diameter*	*Mean outside diameter*		*Outside diameter at any point*		*Wall thickness*					
						Class 1, SDR 11			*Class 3, SDR 17*		
		Min	*Max*	*Min*	*Max*	*Avg. Max*	*Min*	*Max*	*Avg. Max*	*Min*	*Max*
15	15.9	15.8	16.0	15.8	16.0	2.2	1.7	2.2	-	-	-
20	22.2	22.1	22.3	22.0	22.4	2.5	2.0	2.5	-	-	-
25	28.6	28.5	28.7	28.4	28.8	3.1	2.6	3.1	-	-	-
32	34.9	34.8	35.0	34.7	35.1	3.7	3.2	3.7	-	-	-
40	41.3	41.2	41.4	41.1	41.5	4.3	3.8	4.3	-	-	-
50	54.0	53.9	54.1	53.7	54.3	5.5	4.9	5.5	-	-	-
65	73.0	72.8	73.2	72.2	73.8	-	-	-	4.8	4.3	4.8
80	88.9	88.7	89.1	88.1	89.7	-	-	-	5.9	5.2	5.9
100	114.3	114.	114.5	113.5	115.1	-	-	-	7.5	6.7	7.5
150	168.3	168.	168.6	166.5	170.1	-	-	-	11.1	9.9	11.1

NOTE: For CPVC pipes SDR is calculated by dividing the average outer diameter of the pipe in mm by the minimum wall thickness in mm. If the wall thickness calculated by this formula is less than 1.52 mm, it shall be increased to 1.52 mm. The SDR values shall be rounded to the nearest 0.5.

c) The difference between the measured maximum outside diameter and measured minimum outside diameter in the same cross-section of pipe (also called tolerance on ovality) shall not exceed the greater of the following two values:
   (i) 0.5 mm and
   (ii) 0.012 d_n rounded off to the next higher 0.1 mm.

d) Wall thickness shall be measured by any of the three methods given in IS: 12235 (Part 1).

1315.7.2 Physical and chemical characteristics

a) *Visual appearance:* The colour of the pipes shall be off-white. Slight variations in the appearance of the colour are permitted.

b) *Opacity:* The wall of the plain pipe shall not transmit more than 0.1% of the visible light falling on it when tested in accordance with IS: 12235 (Part 3).

c) *Effect on water:* The pipes shall not have any determinate effect on the composition of the water flowing through them, when tested as per 10.3 of IS 4985.

d) *Reversion test:* When tested by the method prescribed in IS: 12235 (Part 5/ Section 1 and 2), a length of pipe 200±20 mm long shall not alter in length by more than 5%.

e) *Vicat softening temperature:* When tested by the method prescribed in IS: 12235 (Part 2), the Vicat softening temperature of the specimen shall not be less than 110°C.

f) *Density:* When tested in accordance with IS: 12235 (Part 14), the density of the pipes shall be between 1450 kg/m^3 and 1650 kg/m^3.

1315.7.3 Mechanical properties

a) *Hydrostatic characteristics:* When subject to internal hydrostatic pressure test in accordance with the procedure given in IS: 12235 (Part 8/Sec 1), the pipe shall not fail during the prescribed test duration. The temperatures, duration and hydrostatic (hoop) stress for the test shall conform to the requirements given in table 1300-12. The test shall be carried out not earlier than 24 hours after the pipes have been manufactured.

Table 1300- 12: *Requirements of pipes for internal hydrostatic pressure test*

Sl. No.	*Test*	*Test temperature Min*	*Test period*	*Hydrostatic (Hoop) stress*
		°C	*hours*	*MPa*
1	Acceptance test	20	1	43.0
2	Type test	95	165	5.6
3	Type test	95	1000	4.6
4	Type test	95	8760	3.6 (Test for thermal stability)

b) *Thermal stability by hydrostatic pressure testing:* When subject to internal hydrostatic pressure test in accordance with the procedure given in IS: 12235 (Part 8/Section 1), the pipe shall not burst or leak during the prescribed test duration.

c) *Resistance to external blow at 0°C*: When tested by the method prescribed in IS: 4985, with classified striker mass and drop height as given in table 1300-13, the pipe shall have a true impact rate of not more than 10%.

Table 1300-13: *Classified striker mass and drop height conditions for the falling weight impact test*

Sl. No.	*Nominal pipe size*	*Mass of falling Weight*	*Falling height*
	mm	*kg*	*mm*
1	15	0.5±0.5%	300±10
2	20	0.5±0.5%	400±10
3	25	0.5±0.5%	500±10
4	32	0.5±0.5%	600±10
5	40	0.5±0.5%	800±10
6	50	0.5±0.5%	1000±10
7	65	0.8±0.5%	1000±10
8	80	0.8±0.5%	1200±10
9	100	1.0±0.5%	1600±10
10	150	1.6±0.5%	2000±10

d) When tested by the method prescribed in IS: 12235 (Part 19), pipe shall show no signs of cracking, splitting and breaking.

e) When tested by the method prescribed in IS: 12235 (Part 19), the tensile

strength at yield shall not be less than 50 MPa at 27±2°C.

1315.7.4 Storage of CPVC pipes

a) CPVC pipes of all sizes are packed in polyethylene packing rolls and both the ends of the packed roll are sealed with air bubble film cap in order to provide protection during handling and transportation.
b) After packing, the whole bunch of pipes is tightened with polypropylene/ HDPE strapping. Each roll is then marked with size/type of the pipe, lot number and quantity.
c) The packed pipe rolls are stored in their respective racks in properly covered storage area.
d) Apart from providing protection during handling and transportation, the packing rolls also protect the pipe from ultra violet rays.

1315.7.5 Installation of CPVC pipes

a) Visually inspect pipe ends before making the joint. Use of a chamfering tool will help identify any cracks, as it will catch on to any crack.
b) Pipe may be cut quickly and efficiently by wheel type plastic tubing cutter, ratchet type cutter or fine tooth saw are another options. Cutting tubing as squarely as possible provides optimal bonding area within a joint.
c) Burrs and filings can prevent proper contact between the tube and fittings during the assembly, and should be removed from the outside and inside of the tube.
d) Use only CPVC cement jointing. Use CPVC cement, which is fully recommended by the manufacturer.
e) Ensure proper ventilation when using adhesive solution/solvent cement.
f) When making a joint, apply a heavy, even coat of cement to the pipe end. Use the same applicator without additional cement to apply a thin coat inside the fitting socket. Too much could result in a weakening of the pipe wall and possible pipe failure when the system is pressurized.
g) Rotate pipe one-quarter to one-half turn while inserting it into the fitting socket and remove the excess adhesive solution/solvent cement from the joint with clean rag.
h) When making a transition connection to metal threads, use a special transition fitting or CPVC male threaded adapter whenever possible. Do not over-torque plastic threaded connections. Hand tight plus one-half turn should be adequate.
i) Hang or strap CPVC systems loosely to allow for thermal expansion. Do not use metal straps with sharp edges that might damage the tubing.
j) CPVC stub-outs for lavatories, closets and sinks are appropriate. However, on areas where there is a likelihood that movement or impact abuse will occur, metal pipe nipples may be more appropriate stub-out material.

1315.8 PE-AL-PE pipes

a) The PE-AL-PE pipes are bonded, multilayer pipes consisting of metal aluminium and polyethylene i.e. metallic pipe bonded with adhesive both internally and externally by polyethylene coating.
b) These pipes are used for conveyance of hot and cold water supply for domestic and industrial purposes including internal and external plumbing, air conditioning and heating installations within buildings.
c) Polyethylene composite pressure pipes have welded aluminium tube

reinforcement between inner and outer polyethylene layers, inner and outer polyethylene layer being bonded to aluminium tube by melt adhesive and are manufactured as per IS: 15450.

d) Polyethylene compounds shall conform to IS: 7328 as follows:
   i) PEEWA 45 T006 for black pipes.
   ii) PEELA 45 T006 for coloured pipes.

1316 PLUMBING FIXTURES

1316.1 General requirements

The purpose of any water supply system is to supply water for drinking, cooking, washing, bathing, gardening and other uses at the required places in a building. Terminal fittings such as bib tap, pillar tap, mixers of various types, shower rose etc fulfill this purpose. All fixtures shall be designed, fixed and maintained to remain watertight to avoid waste of water, damage to property and the risk of contamination of the water conveyed. All washers and bushings shall be periodically examined and changed to avoid wastage of water by dripping or leaks from the fitting. All water supply fixtures must fulfill the following design requirements.

a) Mixing of hot and cold water for human comfort in winter.
b) As the plumbing lines are concealed and installed ahead of plastering and tile fixing in the bathroom and the kitchen, the design of the plumbing fixtures shall cater for the possible construction inaccuracies to facilitate their proper installation with ease.
c) The fixtures shall be watertight during operation and permit repairs conveniently.
d) As there is considerable drop of pressure in the fixtures, the internal valve passages shall be designed to ensure specified rate of flow from a faucet. To ensure adequate rate of flow from the fixtures installed in the top floor of a building due to inadequate water pressure in the pipe line, high flow mixers shall be provided in preference to normal flow mixer diverters; the former have internal water passage in the valve of 20mm, while the later have 15mm diameter water passage.
e) All fixtures shall have long maintenance free service life.

1316.2 Pillar taps

Pillar taps shall be chromium plated brass and shall conform to IS: 1795. Pillar taps shall be nickel chromium plated and thickness of coating shall not be less than service grade No. 2 of IS: 4827 and plating shall be capable of taking high polish which shall not easily tarnish or scale. Every pillar tap, complete with its component parts shall withstand an internally applied hydraulic pressure of 20 kg/cm^2 maintained for a period of 2 minutes during which period, it shall neither leak nor sweat.

1316.3 Shower rose

The shower rose shall be of chromium plated brass of specified diameter. It shall have uniform perforations. The inlet size shall be 15 mm or 20 mm as required.

1316.4 Bidet

a) It is a sanitary fitting on which persons sit for washing the lower parts of the body and in appearance resembles a pedestal WC but is shaped differently to suit its special purpose.

b) Bidet shall be of vitreous china conforming to IS: 2556 (Part 9).
c) Wall mounted bidet shall be of vitreous china conforming to IS:2556 (Part 17)
d) Pedestal bidets shall be one of the following patterns and sizes:
   i) Pattern 1 - Pedestal bidets with flushing rim and spray hole.
   ii) Pattern 2 - Pedestal bidets without flushing rim and over rim supply.
e) Pedestal bidets shall be of one piece construction.
f) Pedestal bidet with flushing rim has three tap hole and a spray hole. The pop up hole shall be optional. The central hole shall have the provision to supply water to the rim.
g) Pedestal bidet without flushing rim shall be provided with one or three tap holes and without any spray holes.
h) Each bidet shall be provided with a tap fitting hole with or without overflow arrangement.
i) Suitable provision shall be made for fixing the bidet to the floor.

1316.5 Bath tubs, whirlpools (jacuzzi), sauna and steam baths

1316.5.1 Tub

Soaking tub is a place where people like to relax without the noise and the motion. It is usually large enough that one person is comfortable, but in some designs two people can fit in. If a person needs a hydro massage, then a whirlpool tub can provide the oxygenation of the water to get into muscles.

1316.5.1.1 Gel coated glass fibre reinforced polyester resin bath tubs

a) Gel coated glass fibre reinforced polyester resin bath tub shall conform to IS: 6411.
b) The fibre glass used in the manufacture of bath tubs shall be non-alkaline conforming to 'E' type or 'A' type grade.
c) The proportion of the glass fibre shall not be less than 25% of the glass fibre reinforced polyester layer including gel coated layer.
d) Unsaturated polyester resin used in the manufacture of bath tubs shall be resistant to not water and weathering.
e) The bath tub shall possess a uniform gel coat on the working surface. The resin used in the gel coat shall be isopthalic grade of polyester or epoxy resin or any equally suitable chemical resistant grade of resin.
f) The gel coat shall not be less than 0.25 mm thickness or more than 1.0 mm thickness.
g) The thickness of glass fibre reinforced polyester laminate including the gel coat shall not be less than the following:

Apron	- 2 mm
Inner wall and bottom	- 3 mm
Bottom bend	- 4 mm

1316.5.1.2 Whirlpool

Whirlpool tubs come under the category of jetted tubs. Whirlpool tubs were invented by Roy Jacuzzi and Jacuzzi has become a generic name of this type of jetted tub. The whirl comes from the jets that mix air and water to create massaging bubbles that are targeted to different parts of the body creating a pulsating effect on the body where they strike.

1316.5.1.3 Air bath

Air bath tub is another type of jetted tub. It creates fizzy all round bubbles because the air outlets that move the water are tiny and the air encircles the bottom of the

tub.

1316.5.2 Steam bath

It is a free standing glass shower enclosure also termed as steam cabin or steam shower, which has arrangement for supply of wet steam. It differs from the sauna by virtue of its higher humidity, but they have a common purpose - fostering relaxation.

1316.5.3 Sauna

Sauna is a small wood lined room that heats up to around 90°C. Sauna walls, ceilings, floor slats, doors and benches are built from softwoods as they deflect heat as opposed to hardwoods, which retain heat. About 1.6 m^3 of space is recommended for a bather and by this standard a 1.2 m x 1.2 m x 2.1 m cubicle in a home would be just sufficient for two bathers. The essential component of any sauna is a gas or electric stove.

1316.6 Valves

1316.6.1 Gate valve

Gate valve is an on/off valve and is chosen in situations where it is fully open or closed, where the valve is operated infrequently. These shall in all respects comply with IS: 778 and IS: 13114. If it is kept partially open, there is turbulence and the pressure of water moving across the gate/disc wears down its surface, resulting in an imperfect seal or leaking valve.

1316.6.2 Sluice valve

These are gate valves having non-rising stem and double flanged ends for connection. They come in 50 mm to 1200 mm sizes for use in waterworks. It shall be placed on at least three sides of every cross section and at every kilometer on long mains. The size of sluice valve shall be the same as the size of the main up to 300 mm diameter and at least two-thirds the size of the main for longer diameter. These shall in all respects comply with IS: 14846.

1316.6.3 Ball valve

a) Ball valve is a quarter turn valve that opens by turning a handle attached to a ball inside the valve. These shall in all respects comply with IS: 9890. This type of valve creates little water turbulence owing to its straight through flow design.
b) Ball valves are not used for throttling; they are usually open or closed. It has internal threads only and is often used for garden hose connection and other places where gate valve is used.
c) Ball valves made of cast iron and carbon steel used in waterworks come in sizes up to 600 mm. Brass ball valves in size range 10, 15, 20, 25, 32, 40 and 50 mm are used in domestic services.

1316.6.4 Stop valve or Globe valve

a) Stop valve shall in all respects comply with IS: 778 and 13114.
b) Nominal size of stop valve is designated by the nominal bore of the pipe to which valve is fitted. The body and the bonnet are made of forged brass, which shall be sound and free from blowholes, pitting etc.
c) All surfaces shall be smoothly finished. The stop valve in larger diameters has an unpolished cast finish.
d) Stop valves come with both internal threads and external threads. Overall length (End to end dimension) and weight of internally threaded and externally threaded stop valve for the commonly used sizes in water services

in indicated in table 1300–14.

Table 1300–14: *Length and weight of screwed–down stop valves*

Nominal size (mm)	*Internally threaded*		*Externally threaded*	
	Length (mm)	*Weight (kg)*	*Length (mm)*	*Weight (kg)*
15	60	0.330	85	0.400
20	70	0.675	100	0.750
25	85	1.180	125	1.300
32	100	1.680	135	1.800
40	110	2.090	145	2.250
50	135	3.700	175	3.850

1316.6.4.1 Fancy stop valve/Concealed stop valve

a) These are made of brass having chrome trim and are available in regular (Commercial) and heavy body.
b) These are available in nominal sizes of 15 mm and 20 mm. It is also called open stopcock as opposed to concealed stopcock used in bath mixers, diverters etc.
c) These shall in all respects comply with IS: 8931.

1316.6.4.2 Angle stop valve

a) It is a valve having generally a spherical body in which the body ends are at right angles to each other. It eliminates one 90° turn of the water flow.
b) It is intended to facilitate servicing of water fittings or appliances (geyser, flushing cistern and the wash basin mixer) without having to shut off water supply to other plumbing fixtures in a bathroom or kitchen.
c) These are available in nominal sizes of 15 mm and 20 mm. These shall in all respects comply with IS: 8931.

1316.6.5 Float valve

a) A float valve (Also called ball cock/valve) regulates the fluid level by using a float to drive an inlet valve so that a higher fluid level will force the valve closed while a lower fluid level will force the valve open.
b) These shall in all respects comply with IS: 1703 and 9762.

1316.6.6 Check or Non- return valve

a) They are used to prevent reversal of flow in a pipe. Reflux valves are valves through which flow can proceed in one direction only, they are of larger diameter (50 mm to 600 mm) and are used in waterworks.
b) Check valve is generally restricted to small size mains. These shall in all respects comply with IS: 13114 and 5312 (Part1).

1316.6.7 Foot valve

a) A foot valve is generally placed at the lower end of the suction pipe of a centrifugal pump to prevent suction pipe from emptying while the pump is at rest.
b) Screwed end foot valves are available in sizes from 25 to 150 mm and flanged end valves from 50 mm to 450 mm nominal sizes (Nominal bore of the pipe).
c) Foot valves shall in all respects comply with IS: 4038.

1316.6.8 Bib tap/Cock

Bib tap/cock shall be conforming to specifications as per IS: 781.

1316.6.9 Fancy bib tap/Cock

Fancy bib tap/cock shall be conforming to specifications as per IS: 8931.

1316.6.10 Plastic bib tap

They are available in sizes 15 and 20 mm and shall be tested under an internal hydraulic pressure of 2MPa for duration of 5 minutes. These shall be conforming to IS: 9763.

1316.6.11 Table mounted mixers

a) In the case of basin/sink mixer, the inlet holes for hot and cold water supplies are vertical and the mixer is installed a little distance away from the wall where the concealed pipeline has been laid.
b) The connection is therefore made to the mixer through two angle valves with flexible copper or plastic pipe connectors. These shall be conforming to IS: 8931.

1316.6.12 Wall mounted mixers

a) In the case of wall mixers (Sink and bath mixers) the location of the concealed elbows bringing in hot and cold water supplies is fixed at the time of laying the distribution pipes.
b) Manufacturer's instruction sheets shall be consulted for allowable maximum construction tolerances in the location of the inlet elbows. These shall be conforming to IS: 8931.

1316.6.13 Single lever basin mixer

Instead of two separate knobs or levers for controlling hot and cold water supplies, single lever mixers are also now commercially available in numerous models and styles. They are generally preferred in all up market buildings.

1316.6.14 Exposed diverter-mixers

a) These mixer assemblies are commercially available in both compression faucet as well as quarter turn faucet models. The assembly consists of two faucets and a spout cast integrally.
b) The mixer has provision for 11.5 mm diameter long bend above the spout for directing the flow of mixed water to the overhead shower by turning the diverter handle.
c) IS code requires that minimum inside valve passage shall not be less than 15 mm. All compression faucet mixer diverters are designed with 20 mm inside valve passage to improve the flow from spout in low rise buildings where water supply pressure may not be adequate.
d) In quarter turn faucets, the mixer is available in both 15 mm and 20 mm inside valve passages.
e) The spout has a provision for optional button assembly, which when pulled up, directs the mixed supply of hot and cold water to the hand shower hung from a wall hook. The mixer assembly has a crutch for supporting the hand shower (Telephone shower). It is thus a 3-in-1 system with provision for both telephone shower and overhead shower.

1316.6.15 Single lever concealed diverter

a) Concealed diverter is a valve that has four inlets, two for entry of hot and cold water and two for diverting the mixed water either to the spout or to the overhead shower. It is also called a 4-way diverter.
b) The main function of the diverter is to mix the hot and cold water to suit the requirement of the user and to direct the mixed water flow to either the spout or the shower, directing the flow of mixed water to the shower is effected by pulling the button assembly, which is housed below the cartridge body.

c) Diverters 5 way (3 inlet) are also now available. They have two inlets for cold water – one for fresh water supply from bore well or municipal supply and the other from overhead tank placed on the roof of the building plus an inlet for hot supply from geyser.
d) There are two outlets for diverting the flow to either the spout or the shower. As the supply from the overhead tank may become uncomfortably hot in summer this design allows the cold water supply to be received from bore well/municipal mains through the same diverter assembly.

1316.6.15.1 Pressure requirement

a) The single lever mixers require an extra water pressure than the normal taps/mixers.
b) It is recommended that a minimum 83 to 103 kPa pressure on 20 mm diameter pipeline shall be provided to overcome the drop in pressure in single lever diverters.
c) There are two model diverters available, one is 'High flow diverter' having 47 mm diameter cartridge and the other is normal flow diverter which is having 40 mm diameter cartridge. 'High flow diverters' are used for low rise houses and normal flow diverters are recommended for use in apartments and houses where there is sufficient water pressure in the supply line.

1316.6.15.2 Installation

a) Reputed manufacturers undertake the responsibility for the installation of the diverter mixer. Before installing the diverter body, flush the pipeline properly so that it is free from dirt.
b) The body of the diverter shall be installed in a recess cut in the masonry wall. The water pipeline for the hot and cold water inlets and for the spout and the shower outlets shall be 12.5 mm.
c) Diverter body shall be installed at the stage of laying the concealed pipelines in the bathroom. Diverter body shall be fixed carefully with respect to the finished surface of the tile (Plaster + tile thickness).
d) Permissible variation is 25 mm to 50 mm. The finished surface after tiling shall be within 25 mm adjustment range indicated in the manufacturer's instruction sheet for the diverter assembly.

1316.6.16 Spout

Spout facilitates the functions of long body bib cock and shall be of chromium plated brass.

1316.6.17 Hand shower

It shall be easily removed from its fixing to allow a greater flexibility of use. The flexible tube shall be 1.50 m minimum in length. Swinging wall hook allows direction of spray to be changed.

1316.6.18 Shower panel

a) These are luxurious expensive fixtures which allow you vertical hydro massage. Typically 6 to 8 water jets are installed in a vertical panel which can be directed manually to different parts of the body to stimulate and relax muscles.
b) A thermostatic mixer diverter valve controls the temperature of the water and regulates the flow to the overhead shower and the hand shower. The overhead shower can provide three types of sprays which are rain, whirl and balance spray.

1316.6.19 Health faucet

a) It shall be attached to an angle valve or 2 way bib cock near the European water closet for washing purposes. It has a 8 mm diameter flexible pipe is either of PVC tube or chrome plated flexible tube having 1 m long with a wall hook. The hand shower body shall be of chrome brass or plastic.

b) The wall hook shall be installed at 550 mm above floor level and 400 mm from center line of water closet on the right side while sitting on the seat. The position of the angle valve or 2 way bib cock shall be so fixed that the flexible tube is clear of the floor by about 150 mm when the spray head is kept in the wall hook.

1316.6.20 Home pressure booster pump

a) Wherever the static water pressure in the bathrooms is inadequate, low water pressure booster pumps can be installed in the plumbing system to augment the flow particularly in single lever operated overhead showers. Generally 0.72 to 1 kW pump is adequate for 2 to 4 bathrooms. For a single bathroom 0.55 kW pump is suitable.

b) These pumps are equipped with a pressure switch which senses the pressure in the water tank and as soon as it drops below a pressure value, it starts the pump. If there are no taps in operation in the plumbing system, it stores the water in the tank and when the pressure reaches the present value the pump is cut off.

c) Pumps are equipped with plastic, brass or stainless steel impeller and dry run protection in the pump must be insisted upon.

1316.7 Surface box

a) This shall be of cast iron, well made and free from casting and other defects.

b) The CI surface boxes shall be coated with a black bituminous composition except in case of fire hydrants where the cover of the surface box shall be painted with two coats of rust resisting bright luminous yellow paint for clear visibility during night.

1316.8 Water meter (Domestic type)

Special care is necessary in selecting the most suitable meter where large rates of flow may exist for short periods.

a) The normal working flow shall be well within the continuous running capacity specified in IS: 779, as high rates of flow over short period may cause excessive wear if the meter chosen is too small for the duty.

b) Overall dimension of water meters shall be as specified in table 1300-15.

c) Tolerance on the overall length shall be ±5 mm for meter with nipples and +0/-2 mm for meters without nipples.

d) Screws and studs shall be of brass or other corrosion resistant material.

Table 1300-15: *Overall dimensions of water meters*

Nominal size of meter	*Overall length including nipples*	*Overall width (Max)*	*Overall height (Max)*
15	250	100	180
20	290	130	240
25	380	170	260
40	430	210	300
50	470	270	300

1317 POLYETHYLENE WATER STORAGE TANKS

a) Polyethylene water tanks shall confirm to IS: 12701.
b) Polyethylene used for manufacture of tanks and manhole lids may be high density (HDPE), low density (LDPE) or linear low density (LLDPE) and shall conform to IS: 10146.
c) Polyethylene shall be compounded with carbon black so as to make the tank resistant to ultraviolet rays from the sun.
d) The percentage of carbon black content in polyethylene shall be 2.5±0.5 percent and it shall be uniformly distributed.
e) The materials used for the manufacture of tank, manhole lid and fittings shall be such that they neither contaminate the water nor impart any taste, colour, odour or toxicity to water.
f) Minimum weight of the empty tank (Exclusive of manhole lid fittings) and the minimum wall thickness of top, bottom and sides shall be specified in table 1300-16.

Table 1300-16: *Standards specified for water tanks*

Sl. No.	*Capacity litres*	*Minimum wall thickness mm*	*Minimum weight of empty tank kg*
1	200	4.4	7.8
2	300	4.4	9.0
3	400	5.5	15.0
4	500	6.0	18.0
5	700	6.6	23.5
6	1000	7.0	33.0
7	1250	7.0	40.0
8	1500	7.0	47.0
9	1700	7.0	54.0
10	2000	8.2	64.0
11	2500	8.2	81.0
12	3000	8.8	96.0
13	4000	10.4	138.0
14	5000	10.7	191.0
15	6000	10.7	209.0
16	7500	10.7	250.0
17	10000	11.5	363.0
18	15000	11.5	550.0
19	20000	13.2	814.0

1318 TUBE WELLS WITH HAND PUMPS

a) The casing pipe shall be of GI of 140 mm dia and strong enough to stand hammering and vibrations to which it is subjects.
b) The filter shall consist of a GI pipe of the required diameter with 15 mm diameter holes covered with brass strainer both inside and outside. It shall have a driving point riveted or welded to it.
c) Hand Pump shall be of approved quality. It shall be complete with necessary bolt and nuts for joining to the masonry or concrete base.
d) Square holes of size as specified or as directed by the Engineer shall be cut in the masonry. Any damage to the adjoining portion or to any other item shall be made good as directed by the Engineer.
e) All dismantled material shall be removed from the site.

1319 BORE WELL WITH SUBMERSIBLE PUMP

Selection criteria, installation, operation and maintenance of submersible pump set are detailed in IS: 14536.

1320 REFERENCES

Drainage:

1.	IS:458	Pre-cast concrete pipes (With and without reinforcement).
2.	IS:651	Specification for salt glazed stoneware pipes and fittings.
3.	IS:783	Code of practice for laying concrete pipes.
4.	IS:1726	Specification for cast iron manhole covers and frames.
5.	IS:1729	Cast iron/ductile iron drainage pipes and pipe fittings socket and spigot series for over-ground non-pressure pipe line.
6.	IS:4127	Code of practice for laying of glazed stone ware pipes.
7.	IS:4885	Specifications for sewer bricks.
8.	IS:12592	Pre-cast concrete manhole covers and frames – specifications.

Sanitary installations:

1.	IS: 771	Specification for glazed fire clay sanitary appliances:
	(Part 2)	*Specific requirements of kitchen and laboratory sink.*
2.	IS: 772	Specific action for general requirements for enamelled cast iron sanitary appliances.
3.	IS: 774	Flushing cisterns for water closets and urinals (Other than plastic cistern)-specifications.
4.	IS: 1300	Phenolic moulding materials- specifications.
5.	IS: 1703	Water fittings- copper alloy float valves (Horizontal plunger type) - specification.
6.	IS: 1729	Cast iron/ductile iron drainage pipes and pipe fittings for over ground non-pressure pipe line socket and spigot series.
7.	IS: 1795	Specification for pillar taps for water supply purposes.
8.	IS: 2267	Polystyrene moulding and extrusion materials – specifications.
9.	IS: 2326	Specification for automatic flushing cisterns for urinals (Other than plastic cisterns).
10.	IS: 2548	Plastic seats and covers for water closets:
	(Part 1)	*Thermo set seats and covers – specifications.*
	(Part 2)	*Thermoplastic seats and covers - specifications.*
11.	IS: 2556	Vitreous sanitary appliances (Vitreous china) –specifications:
	(Parts 1to15)	
12.	IS: 2963	Specification for copper alloy waste fittings for wash basins and sinks.
13.	IS: 3076	Specification for low density polyethylene pipes for potable water supplies.
14.	IS: 3989	Specification for centrifugally cast (Spun) iron spigot and socket soil, waste and ventilating pipes fittings and accessories.
15.	IS: 4827	Specification for electroplated coating of nickel and chromium on copper and copper alloys.
16.	IS: 4984	Specification for high density polyethylene pipes for potable water supplies.

17.	IS: 4985	Unplasticised PVC pipes for potable water supply – specifications.
18.	IS: 7231	Plastic flushing cisterns for water closets and urinals – specifications.
19.	IS: 13983	Stainless steel sinks for domestic purposes –specifications.

Water supply:

1.	IS: 554	Pipe threads where pressure tight joints are required on the threads - dimensions, tolerances and designation.
2.	IS: 778	Specification for copper alloy gate, and check valves for water works purposes.
3.	IS: 779	Water meters (Domestic type) –specification.
4.	IS: 780	Specification for sluice valves for water works purposes (50 to 300 mm size).
5.	IS: 781	Specification for cast copper alloy screw-down bib taps and stop valves for water services.
6.	IS: 909	Underground fire hydrant, sluice valve type -specification.
7.	IS: 1239 (Part 1)	Steel tubes tubular and other wrought steel fittings: *Steel tubes- specification.*
8.	IS: 1239 (Part 2)	Specification for mild steel tubes tubular and other wrought steel fittings: *Mild street tubular and other wrought steel pipe fittings.*
9.	IS: 1538	Cast iron fittings for pressure pipes for water, gas and sewage – specification.
10.	IS: 1703	Water fittings - copper alloy float valves (Horizontal plunger type) - specification.
11.	IS: 2065	Code of practice for water supply in buildings.
12.	IS: 2692	Ferrules for water services - specification.
13.	IS: 3950	Specification for surface boxes for sluice valves.
14.	IS: 4736	Specification for hot-dip zinc coatings on mild steel tubes.
15.	IS: 9762	Specification for polyethylene floats (Spherical) for float valves.
16.	IS: 9763	Plastic bib taps and stop valves (Rising spindle) for cold water services - specifications.
17.	IS:15450	PE-AL-PE Pipes for hot and cold water supplies - specifications.
18.	IS:15778	Chlorinated polyvinyl chloride (CPVC) pipes for potable hot and cold water distribution supplies - specifications.
19.	IS: 15801	Polypropylene - Random copolymer pipes for hot and cold water supplies - specifications.
20.	IS: 16098 (Part 2)	Structured wall plastics piping systems for non-pressure drainage and sewerage specification: *Pipes and fittings with non-smooth external surface, type B.*

+++++++

Part - B
Roads

SECTION 2000 QUALITY CONTROL IN ROAD CONSTRUCTION

2001 GENERAL

The part B of the Quality Control Manual has been prepared to provide a base document to carry out construction quality control in road works. This is intended to enable the supervisory staff to check the different activities of road construction and ensure quality. The documents referred to in preparing the sections are given at the end of the section.

2002 TECHNICAL SPECIFICATIONS FOR ROAD CONSTRUCTION IN INDIA

2002.1 General

In India, the road agencies in various States carry out the road works following the standards and codes adapted by organizations such as Bureau of Indian Standards (BIS), Indian Roads Congress (IRC), Central Public Works Department (CPWD), Ministry of Road Transport and Highways (MoRTH) etc. It is a common practice to follow International Specifications like BS, ASTM, AASHTO etc where Indian Standards are not available. The Government of Kerala as per GO (P) No. 36/2013/PWD dated 17-04-2013 have implemented MoRTH Specifications in the Kerala Public Works Department.

2002.2 Bureau of Indian Standards (BIS)

BIS is the national Standards body of India. BIS is a founder member of International Organisation for Standardization (ISO). It represents India in the International Organisation for Standards (ISO), the International Electrotechnical Commission (IEC) and the World Standards Service Network (WSSN).

One of the major functions of the Bureau is the formulation, recognition and promotion of the Indian Standards. More than 19000 codes have been published by BIS (Formerly Indian Standards Institution). The National Building Code was first published by BIS in 1970 at the instance of the Planning Commission of India.

2002.3 Indian Roads Congress (IRC)

Indian Roads Congress (IRC) was set up by the Government of India in 1934 with the objective of promoting and encouraging the science for building and maintenance of roads. In the past several years IRC has published several standards, specifications and codes of practice, related to road and bridge works. IRC also publishes plans and specifications for the Ministry of Road Transport and Highways (MoRTH). The most important among those is the Specifications for Road and Bridge Works (5th revision 2013).

2002.4 Ministry of Road Transport and Highways (MoRTH) Specifications

Ministry of Road Transport and Highways (MoRTH) is an apex body under the Government of India. It is responsible for the planning, development and maintenance of National Highways in India. The standard specifications for road and bridge works in the country are evolved by MoRTH.

2002.5 Central Public Works Department (CPWD)

The Central Public Works Department of India, commonly referred to as CPWD, is a Government of India owned authority in charge of public sector works. The CPWD, which came into existence in 1854, builds and maintains public buildings. CPWD also

has developed many codes, manuals, schedules, technical specifications, design manuals and other necessary technical publications for effective working.

2002.6 British Standards (BS)

British Standards are produced by the British Standards Institute (BSI) group established in 1901 under the National Standards Body (NSB) for the UK. More than 27000 standards of the BSI are now under circulation.

2002.7 American Society for Testing and Materials (ASTM)

ASTM was formed in 1898 by Chemists and Engineers from the Pennsylvania Railroad, USA. In 2001, the Society became known as ASTM International. Currently about 12,000 ASTM standards are used around the world.

2002.8 American Association of State Highway and Transportation Officials (AASHTO)

AASHTO, founded in 1914, is a standards setting body which publishes specifications, test protocols and guidelines used in highway design and construction. The association represents not only highways but air, rail, water, and public transportation as well.

2003 INTERNATIONAL ORGANISATION FOR STANDARDS

The International Organization for Standardization (ISO) is an independent, non-governmental organization, the members of which are the standards organisation of the 163 member countries. ISO's main products are international standards. ISO also publishes technical reports, specifications, and guides.

Some ISO standards are mentioned below for reference:

a) ISO 14001: This is the internationally recognized standard for Environmental Management Systems (EMS). ISO 14001 specifies a process for controlling and improving a company's environmental performance.
b) ISO 9001: This specifies requirements for a quality management system where an organization need to demonstrate its ability to consistently provide product that meets customer and applicable statutory and regulatory requirements.

2004 HIGHWAY CLASSIFICATION

Roads are generally classified into non-urban and urban roads.

2004.1 Non-urban roads

The six categories of non-urban roads in India are as below:

a) *Expressways*: This is intended to carry traffic at high speeds. No slow moving traffic, parking, loading/unloading of goods or passengers cross-traffic are features of expressways.
b) *National Highways* (NH): NH connects State capitals, port cities, places of industrial and tourist importance and neighbouring countries.
c) *State Highway* (SH): This connects district head quarters and cities within the State.
d) *Major District Roads* (MDR): These are roads within the district connecting markets, industrial towns and linking highways.
e) *Other District Roads* (ODR): These roads serve the rural areas of production, taluk and block development headquarters.
f) *Village Roads*: These are the primary roads connecting villages to other roads nearby.

2004.2 Urban roads

There are five categories of urban roads as below:

a) *Expressways*: These serve the same purpose as non-urban expressways.

b) *Arterial streets*: This system along with the expressways or highways forms the principal network for traffic flow. These are spaced at less than 1.5 km in developed business areas and 8 km or more in sparsely developed urban outskirts.

c) *Sub-arterial streets*: This also serves the similar purpose as arterial streets but with lesser level of traffic intensity. These are spaced at about 0.5 km in developed business areas and at 3 km to 5 km in sparsely developed sub-urban fringes.

d) *Collector streets*: The traffic from arterial and sub-arterial streets is carried to local streets by collector streets and vice-versa. Parking restrictions are less in collector streets except during peak hours.

e) *Local streets*: These provide access to properties and normally do not carry large volume of traffic. Local streets may be residential, commercial or industrial, depending on the property adjacent to it. Majority of the trips in urban areas originate or terminate in local streets. Normally parking restrictions are not imposed in local streets.

2005 ROAD CROSS SECTION

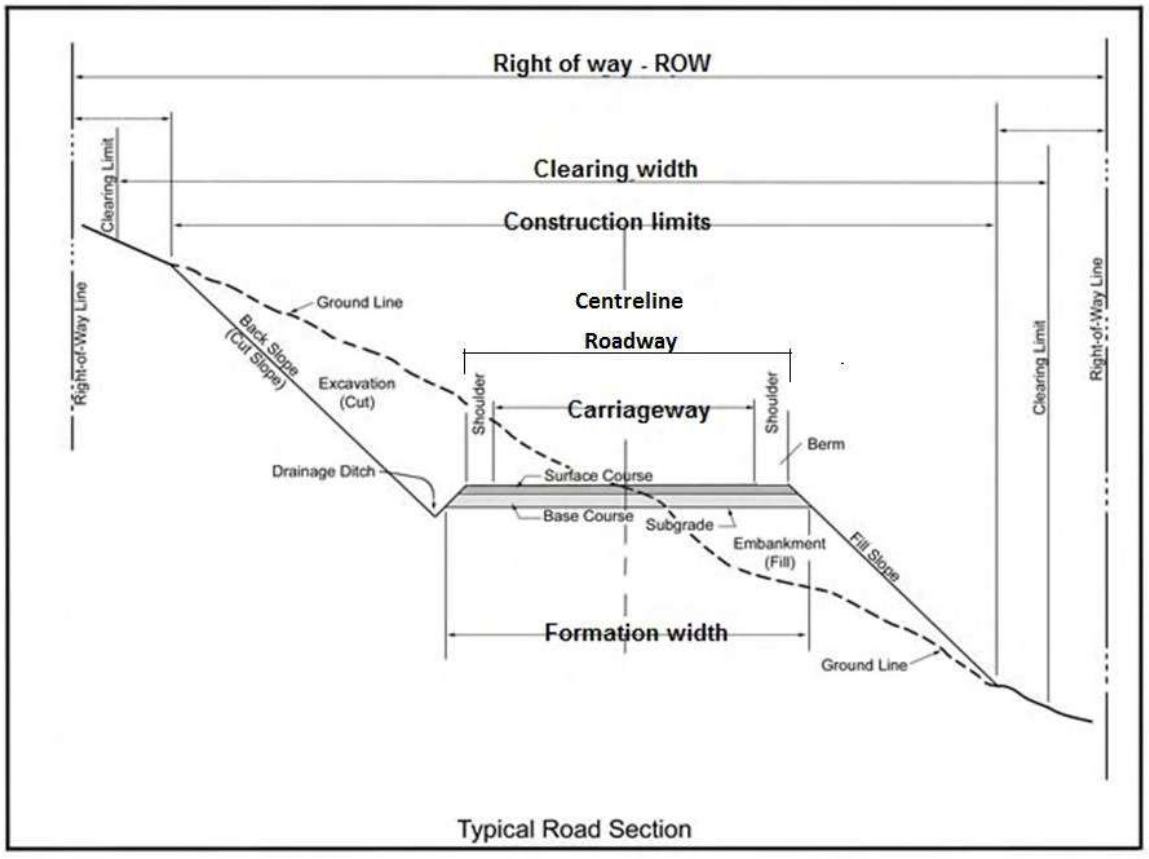


Figure 2000-1: A typical road cross section.

A typical road cross section is given in figure 2000-1. The terms associated with the cross section of a road are:

a) *Right-of-way*: Right-of-way (ROW) is the total width of land available for road construction. These are normally marked by planting boundary stones on both sides.
b) *Construction limits*: The limits within which the road work carried out is called construction limits. The earthwork for the road is carried within this. The land between the ROW and the construction limits is the land left for future development.
c) *Clearing width*: During road work, the site clearance is carried out 2 or 3 metres beyond the construction limits. This is called the clearing width.
d) *Formation width*: The top width of the completed embankment is termed formation width. The top 500 mm of the embankment is called subgrade. The subbase/base layer of the pavement is placed over the subgrade.
e) *Roadway*: Roadway or simply road is the portion of carriageway and shoulders combined together. Footpath is also part of roadway.
f) *Carriageway*: A carriageway is the portion of the road constructed to carry the vehicular traffic.
g) *Shoulder*: Shoulders are portion of the roadway on either side of the carriageway. Shoulders (Normally earthen) are sometimes known as berm.

2006 CLASSIFICATION OF PAVEMENTS

For the purpose of design, pavements are broadly classified into 4 categories.

a) *Flexible*: Flexible pavement has low flexural strength. The external load is transmitted to the soil through so many layers, the stronger ones at higher levels. The upper layers are made with bitumen as binder and lower layers are granular materials.
b) *Rigid*: Rigid pavements have high flexural strength. The load is carried by the beam action of the pavement slab constructed with high strength cement concrete.
c) *Semi-rigid*: This is intermediate between flexible and rigid pavements. The materials used are soil-cement, lean concrete and lime-fly ash stabilised soil.
d) *Composite*: In composite type, some layers are rigid and some are flexible. A pavement with rolled cement concrete base and a bituminous wearing course is a good example for composite pavement.

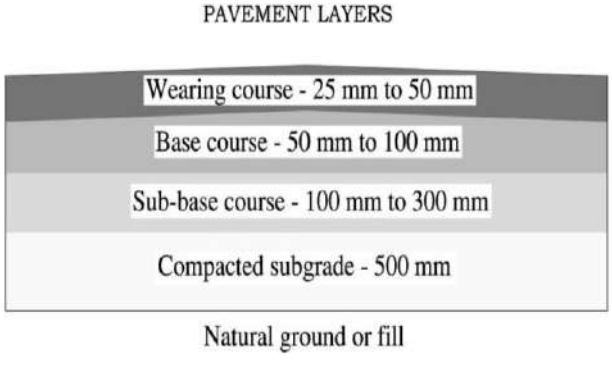
Specifications stipulated in the MoRTH Specifications for Road & Bridge works (Fifth edition 2013) related to construction of road are discussed in this Part of the Manual.

2007 PAVEMENT COMPONENTS

A pavement should be designed and constructed to support the loads imposed on it, by the wheels of the vehicles moving over it, and to transfer the loads safely to the underlying ground.

Pavement is built up of several layers as shown in the figure:

i) Subgrade.
ii) Subbase.



iii) Base.
iv) Wearing or surface course.

2007.1 Subgrade

Subgrade is the foundation layer which finally carries all the loads coming on the top of the pavement. The top 500 mm of the compacted embankment is called subgrade. In some cases, the existing ground itself serve as a subgrade, provided, the soil properties meet the requirements for subgrade material. The desirable properties of a subgrade are strength, drainage characteristics and ease of compaction.

2007.2 Subbase

If the subgrade material available is not capable of supporting the pavement layers, an interim layer called subbase is provided. Subbase also helps to construct relatively cheaper pavement. The functions of the subbase are given below:

i) Structural support to the base and surface courses is increased.
ii) Drainage improvement.
iii) Mitigation of frost heave and salt heave.
iv) Prevent damages to the base and surface layers due to inadequate subgrade.

As far as possible, locally available material shall be used for constructing subbase. Natural gravel not suitable for base layer is a good choice for subbase. Compacted stone or stabilised soil are considered to be good subbase materials. The thickness of the subbase course varies from 100 mm to 300 mm.

2007.3 Base course

The layer immediately under the wearing course of the pavement structure is called base course which should essentially have the following requirements.

i) Sufficient thickness to evenly distribute the heavy wheel load from the wearing course layer to the subbase or subgrade.
ii) Sufficient structural capacity to resist the vertical pressure and horizontal shear stresses caused by standing or moving vehicle wheels.
iii) Sufficient density to withstand consolidation due to heavy load which may cause distortion of the wearing surface.
iv) Sufficient resistance to weathering so that its stability is not affected by moisture or frost.

The base course layer is normally extended, to some distance beyond the edge of the wearing course, to support the load coming at the edge of the wearing course layer. Base course layer can be bituminous or non-bituminous. Non-bituminous base course material should have a CBR of 80% minimum.

The thickness of the base designed shall be sufficient to prevent overstressing of the subgrade. If a bituminous base like bituminous macadam is provided, the thickness of a single layer is 50 mm to 100 mm.

Under a rigid pavement, the base course is provided for the following reasons:

i) To prevent pumping of fine grained soils (Mud-pumping).
ii) Protect against frost action, on frost-susceptible soils.
iii) To prevent volume changes of the subgrade on highly active soils.
iv) To form a working surface on the subgrade to provide a working platform for machineries.
v) To expedite construction especially during wet weather.
vi) To provide a levelling course on a roughly shaped platform.
vii) For increased structural stability where it is more practical and economical than providing smaller extra thickness slab.

2007.4 Wearing course

This is the component of the pavement with which the wheels are rolling over. The wearing course should provide a smooth riding surface as well as prevent penetration of surface water into layers beneath. The thickness of the wearing course depends on the traffic it has to carry and the structural capacity of the base layer. A single layer of wearing course normally varies from 25 mm to 50 mm.

Depending on the intensity of traffic, the type of wearing course varies from thin premix surfacing or surface dressing to thick bituminous concrete or Portland cement concrete.

2008 OVERVIEW OF CONTENTS

This part of the Quality Control Manual contains the main components of road construction viz., earthwork, non-bituminous and bituminous base and subbase, concrete pavement, geosynthetics, road drainage, maintenance of road etc under 9 sections as given below:

a) *Earthwork*: Earthwork is an integral part of any construction. Classification of excavated material, road excavation, construction of embankment, rock fill embankment, natural and artificial turfing of embankment slopes and improvement of weak embankment foundations are included under Section 2100.

b) *Non-bituminous base and subbases*: Bases and subbases are major components of pavement layers. Non-bituminous bases and subbases are covered under Section 2200. Materials, requirement, construction procedure, quality control and rectification of surface irregularities, as applicable, are given in detail for water bound macadam, stabilised soil, granular subbase, wet mix macadam, crusher rum macadam and dry lean concrete.

c) *Bituminous bases and wearing courses*: Wearing courses form top portion of the pavement. Bituminous wearing courses are dealt with in Section 2300 along with bituminous base courses. Prime coat, tack coat, surface dressing, premix surfacing, seal coat, the popular base course bituminous macadam, dense bituminous macadam etc are given in this section. Some items not commonly used in PWD like sand bitumen, slurry seal and semi-dense bituminous concrete are included for reference purpose. In addition to bituminous concrete, stone matrix asphalt (SMA) which is an advanced wearing course mix has been included.

d) *Cement concrete pavement*: Concrete pavement is getting prominence now a days. The Section 2400 gives an outline of concrete pavement construction and quality control. Materials, mix design, joints, forms, mixing and placing, curing and quality control in concrete pavement construction are given in this section.

e) *Maintenance of road*: Life of a road can be extended by regular and proper maintenance. Section 2500 covers the reasons for deterioration of a pavement, classification of maintenance, evaluation of need for maintenance etc. Different types of surface defects and their rectification are discussed in this section. Restoration of rain cuts in the embankment slopes and repairs to earthen shoulders are also included. Repairs to concrete pavement are mentioned.

f) *Geosynthetics*: Various types of geosynthetic materials and its quality requirements, application of geosynthetic materials in drainage, separation layer, erosion control, pavement strengthening, ground improvement etc are included under Section 2600.

g) *Road drainage*: A good drainage system is required for preventing damages to the pavement and for reducing the maintenance cost of the road. Section 2700 covers the types of road drainages, investigation for drainage system etc. Features of surface and subsurface drains are given separately.

h) *Traffic signs and road markings*: It is needless to mention the importance of traffic signs and road markings. Classification, materials, installation and maintenance of traffic signs are included under Section 2800. The requirements for different retro-reflective sheeting used for making signs are explained. This section covers overhead signs also. Materials for road markings, its requirements, sampling and testing are added. Types of road studs, its requirements, warranty etc are also included in this section.

i) *Miscellaneous*: Section 2900 is intended to include topics of special nature. Presently one item, use of shredded plastic in bituminous mix is included.

+++++++

SECTION 2100 EARTHWORK

2101 GENERAL

Earthwork includes excavation and fill. Excavation is carried out for the construction of roads, buildings and other structures. Road excavation is required where a hill is to be cut to get the design profile of the road, widening the existing road etc. Excavation for structures shall consist of:

a) Removal of material for the construction of foundations for buildings, bridges, culverts, retaining walls, headwalls, cut off walls, pipe culverts and other similar structures, in accordance with the requirements of contract specifications and to lines and dimensions shown in the Drawings or as indicated by the Engineer.
b) Construction of the necessary cofferdams and cribs and their subsequent removal.
c) All necessary sheeting, shoring, bracing, draining and/or pumping for dewatering.
d) Removal of all logs, stumps, grubs and other deleterious matter and obstructions, necessary for placing the foundations.
e) Trimming bottom and sides of excavations.
f) Backfilling and clearing up the site and the disposal of all surplus material.

Fill includes earthwork operations for backfilling the space between the structure and excavation, yard filling at construction sites, construction of embankment etc.

The details of earthwork construction for building works are given in Section 200 and for bridges and culverts in Section 3100 of this Manual. Earthwork related to road construction is included in this section.

2102 CLASSIFICATION OF EXCAVATED MATERIALS

All materials involved in excavation are classified under Clause 301.2.1 of the MoRTH Specifications for Road and Bridge works (5th revision) published by the Indian Roads Congress, New Delhi. The excavated materials are basically classified as soil, ordinary rock, hard rock and marshy soil.

a) Soil: This includes topsoil, sand, silt, clay, black cotton soil, soft shale which yields to the ordinary application of pick, spade/shovel or any other ordinary digging equipment. Gravel not exceeding 75 mm size shall also be included under soil.
b) Ordinary rock (Not requiring blasting):
    i) Rocky laterites, shales, limestone, sandstone etc.
    ii) WBM, bituminous bound macadam, soling of roads, stabilized soil, gravel, cobble etc. of 75 mm to 300 mm size.
    iii) Lime concrete, stone masonry in lime mortar, brickwork in lime/cement mortar below ground level, RCC which may be broken up with crow bars or picks and stone masonry in cement mortar below ground level.
    iv) Boulders of size more than 300 mm lying loose on the surface/embedded in soil.
c) Hard rock (Requiring blasting):

i) Any rock/cement concrete which require the use of mechanical plant/blasting.
ii) RCC below ground level.
iii) Big boulders requiring blasting.

d) Hard rock (Blasting prohibited):
As above but chiseling or wedging is required.

e) Marshy soil.
Soft clays, peat excavated below the original ground level of marshes and swamps and soil excavated from other areas requiring continuous pumping or bailing out of water is included under this.

NOTE: Mere use of explosives does not entitle the contractor to make claim for higher classification. Requirement of blasting should be affirmed by the Engineer.

2103 EXCAVATION FOR ROAD

2103.1 General

a) After site clearance, the limits of excavation should be set out true to lines, curves, slopes, grades and cross-sections as shown in the Drawings by constructing reference pillars, back cutting lines, reference lines (1.5 m away from formation lines on hill and valley sides).
b) If directed, the top soil shall be stripped to specified depths and stockpiled for reuse.
c) Excavation shall be done manually or mechanically using dozers.
d) After excavation, the sides of excavated area should be trimmed and the area contoured to minimise erosion and ponding, allowing natural drainage to take place.
e) Cross drainage works like scuppers or small culverts 1.0 m to 2.0 m span and side drains, shall be so constructed along with the formation cutting work, as to have least interference with the existing drainage.
f) The cut formation, which will serve as subgrade, should be checked for its field density and if the density at the top is less than 97% of the maximum dry density (MDD), the material shall be removed to a depth of 500 mm and compacted in layers of 210 mm maximum compacted thickness to achieve the required density (IS: 2720 - Part 8).
g) In hilly areas, cutting should be done from top to bottom. Special attention should also be paid to side slopes and side drains in cutting.
h) Rock when encountered in road excavation shall be removed up to the formation level.
i) Where unstable shale or other unsuitable materials are encountered at the formation level, these shall be excavated to the extent of 500 mm below the formation level.
j) In rocky formation, the surface irregularities shall be corrected with granular base material to achieve the specified profile and levels.
k) Where blasting is involved for rock cutting, guidelines given in Clause 302 of MoRTH Specifications shall be followed.
l) Excavation in marshes shall begin at one end and proceed in one direction across the entire marsh immediately ahead of filling work to ensure complete removal or displacement of muck.

m) For widening of existing pavement, the existing shoulders shall be removed to their full width and up to subgrade level to enable proper compaction in the widened portions.
n) Excavated material, if suitable shall be used when required for works. The excavated materials can be temporarily stockpiled, but must cause no damage to services or property.
o) Any excess suitable material, which is not required for the construction of the works or any material classified as unsuitable shall be stockpiled separately, as directed, or placed in an approved location on the site.
p) The Contractor shall take adequate protective measures to see that the excavation operations are fenced, provided with proper caution signs and marked with red lights at night to avoid accidents.
q) The Contractor shall take adequate protective measures to see that the excavation operations do not affect or damage adjoining structures. For safety precautions, guidance may be taken from IS: 3764.

2103.2 Quality Control

a) The horizontal alignment should be reckoned with respect to the centre line of the carriageway as shown in the Drawings.
b) The edges of the roadway as constructed should be correct within a tolerance limit of ±40 mm in plain and rolling terrains and ±50 mm in hilly terrain.
c) No point on the slopes shall vary from the designated slopes by more than 150 mm measured at right angles to the slope (300 mm in case of rock excavation).

2104 EMBANKMENT CONSTRUCTION

2104.1 General

a) All embankments, subgrades, earthen shoulders and miscellaneous backfills shall be constructed in accordance with the requirements of Clause 305 of MoRTH Specifications and in conformity with the lines, grades and cross sections shown in the Drawings or as directed by the Engineer.
b) The field engineer shall ensure that only suitable material is used in the construction of fill and that the required density is achieved at the expected moisture content.
c) The samples of soil brought to site shall be tested to determine the laboratory maximum dry density (MDD) and optimum moisture content (OMC) in accordance with IS: 2720 (Part 8).
d) Field tests for moisture and field density shall be carried out and appropriate corrective measures taken, as necessary.
e) If the fill is to be deposited against the face of a slope steeper than 1:4, such faces shall be benched in advance as per Clause 305.4.1 of MoRTH Specifications, before the material is placed.
f) Embankment construction in waterlogged and marshy areas shall be in accordance with IRC: 34.
g) If settlement period is specified in the contact, the embankment shall remain in place for the period specified. The settlement shall be monitored by driving nails or plates into the fill and taking levels at frequencies approved by the Engineer.

2104.2 Materials

a) The material used in embankment, subgrade, shoulders etc. shall conform to the requirement of Clause 305.2 of MoRTH Specifications.

b) The following types of material shall be considered unsuitable for embankment:
   i) Materials from swamps, marshes and bogs.
   ii) Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Pt in accordance with IS: 1498-Classification and identification of soils for general engineering.
   iii) Materials susceptible to spontaneous combustion.
   iv) Materials in a frozen condition.
   v) Clay having liquid limit (LL) exceeding 50 and plasticity index (PI) exceeding 25.
   vi) Materials with salts resulting in leaching in the embankment.

c) Expansive clays with free swelling index more than 50% (IS: 2720-Part 40) shall not be incorporated in the fill. Where expansive clay (With free swelling index less than 50) is used in the fill, the subgrade and 500 mm immediately below the subgrade shall be constructed with non-expansive material.

d) Only materials satisfying the density requirements given in table 2100-1 shall be employed for the construction of the embankment and the sub grade.

Table 2100-1: *Density requirements of embankment and subgrade material.*

Sl. No.	*Type of work*	*Maximum laboratory dry density when tested as per IS: 2720 (Part 8)*
1	Embankments up to 3.0 m height, not subjected to extensive flooding.	Not less than 15.2 kN/m^3.
2	Embankments exceeding 3.0 m height or embankments of any height subjected to long periods of inundation.	Not less than 16.0 kN/m^3.
3	Subgrade, earthen shoulders, verges/backfill.	Not less than 17.5 kN/m^3.

NOTE: *The above table is not applicable to light weight materials like fly ash, cinder etc. The Engineer may relax these requirements taking into account of the availability of the materials and other relevant factors, if not detrimental to the stability of the embankment or durability of the road structure. The material to be used in subgrade layer shall satisfy the CBR requirements specified in the design or Contract document.*

e) The selection of materials for the construction of the embankment shall be made after conducting necessary soil surveys and laboratory investigations as set out in IRC: 36. The tests to be carried out on borrow material are given in table 2100-2.

f) When the fill is to be placed under water, non-plastic granular material consisting of graded hard durable particles with maximum particle size 75 mm and uniformity coefficient not less than 10 shall be used.

g) The fill material placed in open water shall be deposited by end tipping with out compaction.

h) The embankment construction using fly-ash shall be in accordance with IRC: SP 38 – Guidelines for use of fly-ash in road construction.

Table 2100-2: *Control tests on borrow material.*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Gradation*/Sand content	IS: 2720 Part 4	1-2 tests per 8000 m^3 of soil.
2	Plasticity index	IS: 2720 Part 5	1-2 tests per 8000 m^3 of soil.
3	Standard Proctor test	IS: 2720 Part 7	1-2 tests per 8000 m^3 of soil.
4	CBR test on a set of 3 specimens**	IS: 2720 Part 16	One test per 3000 m^3 of soil.
5	Deleterious constituents	IS: 2720 Part 27	As required.
6	Natural moisture content	IS: 2720 Part 2	One test per 250 m^3 of soil.

***To be done if specification requires it.*

***For the purpose of design, unless specified in the Contract.*

2104.3 Construction

a) The construction operations of embankment shall be in accordance with the requirements of Clause 305.3 of MoRTH Specifications.

b) The embankment/subgrade shall be constructed sufficiently wider than the design dimension and surplus material trimmed so that the compacted embankment has the desired density and the specified slope.

c) The original ground over which the fill/subgrade is placed shall be scarified and compacted to the required density.

d) Any unsuitable material occurring in the embankment (500 mm below the subgrade) shall be removed and replaced with suitable material.

e) Any foundation treatment specified in the contract shall be carried out as directed by the Engineer.

f) To obtain adequate compaction, the embankment shall be constructed in uniform layers. Due care shall be exercised to ensure that compacted thickness of each layer does not exceed 250 mm when vibratory roller is used and 210 mm when 80-100 kN static roller is used or the limit specified in the contract.

g) Successive layers of embankment shall not be placed until the layer constructed has been compacted to the required density and necessary control tests carried out to ensure that the specified requirements are satisfied.

h) After adjusting the moisture content whether at the road side or at borrow area (Making due allowance for evaporation losses), the soil shall be processed by means of graders, harrows, rotary mixers or other suitable equipment or even manually if no equipment is available, until the moisture distribution is reasonably uniform.

i) Clods or hard lumps of earth if present shall be broken down to sizes preferably of the order of 50 mm but under no circumstances shall the maximum size of clods exceed 75 mm when soil is being placed in the body of the embankment and 50 mm when it is being placed in the top 500 mm of the embankment.

j) It is desirable to conduct field trials on compaction so as to obtain data which would serve as an aid to in planning of compaction operations.

k) Compaction trial is carried out as follows:

i) A test area about 20 m long and 5 m wide is prepared after removing the top soil.
ii) The fill material to be used is spread over this area, the depth of the loose layer being 250 mm.
iii) The moisture content of the soil should be as specified, subject to the tolerance limits indicated.
iv) The test layer is then compacted with the type of compaction plant decided upon, and the mean dry density to the full depth determined over the range of about 4 to 16 passes. The number of passes required depends upon the weight and type of rollers employed.
v) The field dry density shall be determined in accordance with IS: 2720 (Part 28) and the mean of 5 determinations obtained for each compaction condition.
vi) The mean dry densities are then plotted against the number of roller passes. From this graph, the approximate number of passes required for the compaction equipment to obtain the specified dry density is determined.

l) The moisture content of the material shall be checked in accordance with IS: 2720 (Part 2), before the commencement of compaction. If water is to be added, a water tanker fitted with sprinkler arrangement shall be used.
m) The field moisture content during compaction shall be within 1% above to 2% below the optimum moisture content (OMC) determined in accordance with IS: 2720 (Part 8).
n) It the material delivered at site is too wet, it shall be dried by aeration and exposure to sun.
o) Compaction shall be suspended, if the material cannot be dried due to poor weather conditions.
p) The compaction of the layer spread shall be made with a vibratory roller of 80-100 kN static weight or pneumatic tyred roller as approved by the Engineer.
q) Use of a lighter category plant to provide any preliminary compaction is not allowed.
r) The surface of the embankment/subgrade at all times during construction shall be maintained at a cross fall sufficient to allow the drainage of surface water and prevent ponding.
s) The finished layer shall be subjected to field density tests as per IS: 2720 (Part 28) and accepted by the Engineer.
t) If approved by the Engineer, a properly calibrated nuclear density gauge may be used for checking the field densities if the gauge is capable of providing identical test results to that obtained from tests in accordance with IS: 2720 (Part 28).
u) Where nuclear or other type density gauges are used for compaction checks, proper records to establish this shall be maintained.

2104.4 Quality control

a) The horizontal alignment shall be reckoned with respect to the centre line of the carriageway as shown on the drawings.
b) The edges of the roadway as constructed shall be within the following tolerances indicated in table 2100-3.

Table 2100-3: *Permitted tolerances for edges of carriageway and roadway.*

Description	*Plain and rolling terrains*	*Hilly terrain*
Edges of carriageway	±25 mm.	±30 mm.
Edges of roadway and lower layers of pavement	±40 mm.	±50 mm.

c) The permitted tolerance in surface level for subgrade will be +20 mm and -25 mm.

d) The maximum allowable difference between the road surface and underside of a 3.0 m straight edge shall be 20 mm for the longitudinal profile and 15 mm for the cross profile.

e) The undulations in excess of the specified magnitude shall be marked on the surface and necessary rectification carried out.

f) The embankment layers shall be compacted to satisfy the density requirements given in table 2100-4.

Table 2100-4: *Compaction requirements for embankment and subgrade.*

Sl. No.	*Type of work/ material*	*Relative compaction as % of max laboratory dry density as per IS: 2720 (Part 8)*
1	Subgrade and earthen shoulders	Not less than 97%.
2	Embankment	Not less than 95%.
3(a)	*Expansive clays*: Subgrade and 500 mm just below subgrade	Not permitted to use such materials.
3(b)	*Expansive clays*: Remaining portion of the embankment	90 to 95%.

g) The moisture content of soil just before compaction and dry density of the compacted layer are the two tests designated for the control of compaction. The frequency of these tests and unevenness control for subgrade layer shall be as given in table 2100-5.

Table 2100-5: *Field tests for compaction control.*

Sl. No.	*Type of test*	*Frequency*
1	Field moisture content as per IS: 2720 Part 2 (Any of the rapid methods for the determination of the moisture content can also be used)	2-3 tests per 250 m^3 of loose material.
2	In-situ density (IS: 2720 Part 28) measurement for each layer	One test per 1000 m^2 of compacted area. For the top 500 mm of the embankment (Subgrade), this shall be increased to one test per 500-1000 m^2 area.
3	Control of surface evenness of earthen subgrade layer	Measured for every 300 m length using a 3 m straight edge. Permitted undulations 30 nos. of 24 mm or above.

2105 ROCKFILL EMBANKMENT

2105.1 General

Construction of rockfill embankment is suitable when the foundation conditions are poor. Rockfill construction is particularly suitable when satisfactory earth material is

not available or if rock is available in abundant quantities. Rockfill is adapted in conditions where wet and cold weather prevails, limiting the use of earth for construction. Special rock equipment and procedures are to be followed for rock borrowing, hauling, placing and compaction.

2105.2 Materials

The rockfill embankment shall be constructed with be hard, durable, inert material, preferably maximum size not exceeding 300 mm and fraction finer than 125 mm shall not exceed 10%. The rock fragments and blinding material to fill the voids shall also meet the above requirement.

2105.3 Construction

a) The material for each layer is tipped, spread and leveled to the full width of the embankment.
b) Suitable equipment like a bull dozer or crawler tractor shall be used for the spreading of the material.
c) Fragments of rock are then spread on the top to the required extent and layer compacted using at least 5 passes of a vibratory roller.
d) The compacted thickness of each layer shall not exceed 500 mm.
e) After compaction of the layer, the voids on the surfaces are filled with broken fragments.
f) The succeeding layers are placed in the above manner.
g) The top layer of rockfill on which the normal earth fill is placed shall be blended with suitable granular material to seal the voids completely.
h) A layer of geo-textile may be placed before normal fill is commenced.

2106 TURFING WITH SODS

2106.1 General

Sod or turf consists of grass and the part of the soil beneath it held together by the roots, or a piece of thin material. This work consists of providing and laying of the live sod of perennial turf forming grass on the embankment slopes, verges or in landscaping. The work shall be carried out immediately following the construction of the embankment subject to the weather conditions. The details of materials and construction are given under Clause 307 of MoRTH Specifications.

2106.2 Material

a) Dense, well-rooted growth of permanent and desirable grasses shall be used as sod for turfing.
b) Sods shall be selected from the locality where it should be used and shall be free from weeds or any undesirable matter.
c) At the time when sod is cut, the grass shall have approximately 50 mm length and free from debris.
d) The sods shall be of uniform thickness with 50 to 80 mm thick soil covering the glass roots such that all the dense roots of the grass are retained with the sod.
e) The sods shall be cut in rectangular shape not less than 250 mm x 300 mm size.
f) During wet weather, the sods shall be sufficiently dried to prevent tearing during handling.
g) In dry weather, the sods shall be properly moistened before lifting to prevent dropping of soil during handling.

2106.3 Construction

a) The area where turfing is to be done is constructed to the required slope and cross-section.
b) The area to receive the sod shall be scarified, freed of all stones larger than 50 mm size, sticks, stumps and any undesirable matter and brought to a granular texture, for 25 mm depth.
c) If required, topsoil shall be placed before turfing, after scarifying the surface.
d) Topsoil shall not be spread if ground is excessively wet.
e) Fertilizer and if specified, ground limestone are spread at a uniform rate as specified in the contract.
f) After spreading of manure, mixing is carried out using disc harrow or other means to the required depth.
g) The sod bed prepared is moistened and the sods are placed within 24 hours after it has been cut.
h) Each strip is laid to the edge such that the joints are staggered. The sod strips are slightly tamped with metal or wooden tampers to eliminate air pockets and press it to the soil.
i) On slopes greater than 2:1, the laying shall start from the bottom.
j) At points where water is likely to flow over the sods, the upper edge of the sod is folded in to the soil and a layer of soil placed over it and thoroughly compacted.
k) Sod shall be staked with pegs or nails spaced at 500 mm to 1000 mm along its longitudinal axis, if the slope is greater than 2:1. The stakes shall be driven plumb and flush with the surface.
l) After laying is finished, the surface of the sods shall be cleaned by removing any loose material, excess soil or other foreign matters.
m) Thereafter a thin layer of topsoil is scattered over the surface and moistened by sprinkling water.
n) Watering of the turf shall be done for a minimum period of four weeks after laying. This shall be carried out without causing erosion or any damage to the turf caused by wheels of water tanks.
o) Necessary warning boards, barriers etc shall be erected to protect the turf from intrusion and damage by external interferences.
p) Any areas damaged during the maintenance period shall be rectified. Areas failing to show uniform growth shall be replaced.

2107 TURFING BY SEEDING AND MULCHING

2107.1 General

This clause describes the requirements for preparing slopes, placing top soil, furnishing and installing seed, mulching material, fertilizer, and netting. The requirements include the type of materials to be used, methods and requirements for installation. The details of materials and construction are given under Clause 308 of MoRTH Specifications.

2107.2 Material

a) The seeds shall be of approved quality and suitable for the soil on which these are to be applied.
b) Fertilizers shall be standard commercial type conforming to the specified grade. Organic manure like cow dung can also be used.

c) Mulching materials shall be stray, hay, wood shavings or saw dust suitable for placing with mulch blower.
d) The mulching materials shall be free from weed seed or any such foreign materials, non-conducive to the plant growth.
e) Topsoil should not be obtained from an area with noxious weeds growing. The topsoil shall not contain organic matter less than 2% or more than 12%. The topsoil shall be tested for residue, if treated with herbicide or sterilents.
f) A suitable grade of bitumen emulsion, not containing any diluting agent or solvent toxic to plant life is used as a tie down for mulch.
g) Jute netting shall be of un-dyed jute yarn woven into a uniform open weave with approximately 25 mm square openings.
h) Black or green geo-netting with 20 mm x 20 mm mesh opening, weighing 3.8 kg/1000 m^2 shall be used.
i) A layer of biodegradable mulching material sandwiched between two layers of polymer or non-woven coconut fibre coir netting can also be used.

2107.3 Construction

a) The area where seeding is to be done is constructed to the required slope and cross-section.
b) All live plants and stones larger than 50 mm in the seed bed area shall be removed.
c) The seed bed area is excavated to 100 mm depth using suitable agricultural implements.
d) Topsoil is evenly spread over the seed bed area to the specified depth and compacted by minimum 4 passes of a roller or any approved equipment.
e) Fertilizer at the required quantities shall be spread and thoroughly incorporated into the seed bed soil.
f) All seeds shall be sowed uniformly at the approved rate.
g) After sowing, the seeds shall be raked or dragged to cover the seeds with 6 mm thick soil.
h) Sowing shall not be done on muddy ground or during rain. However enough moisture shall exist from 25 mm to 125 mm depth from the surface at the time of planting.
i) Jute netting/geo-netting or coir netting shall be placed on the slope, parallel to the flow of water, immediately following the preparation of the area or after placing seed and fertilizer.
j) The netting provided shall be held in position by vertically driven stakes, pins, spikes or wire staples.
k) A minimum overlap of 100 mm is to be provided if more than one strip is required to cover the area.
l) Within 24 hours of seeding, mulching material mixed with manure shall be spread uniformly for 25 mm depth using an approved mechanical blower.
m) If provided in the contract, bitumen emulsion is applied at the rate of 2300 litres per hectare for anchoring the mulch material.
n) The seeded and mulched areas shall be protected by providing necessary warning signs and barricades, till final acceptance.
o) If any mulched area is damaged during the maintenance period the same shall be seeded and mulched again.

2108 GROUND IMPRROVEMENT USING PVD WITH SURCHARGE

2108.1 General

Using geosynthetic drains viz., prefabricated vertical drains (PVD) with surcharge, weak embankment foundations having problematic sub-soil conditions can be improved to carry the design load of the embankment. The design and construction of PVD with surcharge is carried out as per IS: 15284 (Part 2). The details of materials and installation are given in Clause 314.2 of MoRTH Specifications for Road and Bridge works. The requirements for geotextiles used in PVD are given under Section 2600 of this Manual.

2108.2 Materials

a) *Geosynthetic drain*: Geosynthetic strip or band drain shall be minimum 100 mm wide and 5 mm thick. Band drain consists of corrugated, studded or 3-D mesh with inner core of thick polyester wrapped in non-woven geotextile filter fabric. The core serves as the drainage medium to convey the core water from the soft soil subsoil to the drainage layer at the top. The band drain shall meet the properties specified in table 700-3 of MoRTH Specifications.

b) *Granular sand blanket*: After vertical band drains are installed in the subsoil, a blanket of well draining natural or coarse sand conforming to class I grading given in table 300-4 of MoRTH Specifications is provided. The sand blanket of the specified thickness shall be compacted to a density of 75% to 80% of the MDD obtained as per IS: 2720 (Part 8).

c) *Geotextile fabric for separation and drainage*: The synthetic geotextile shall meet the requirements given in table 700-1 of MoRTH Specifications (5th revision). Under any circumstance, the paving fabric shall not be subjected to ultraviolet light more than 14 days.

2108.3 Construction

a) The geosynthetic band drain shall be dry and wrapped with water proof cover such that it is protected from the exposure to ultraviolet light during shipping and storage.

b) The geosynthetic band drain shall be installed using an installation rig/sticher mounted on a base machine.

c) After the installation of band drains are completed, a blanket of approved granular material is spread over the entire area and compacted.

d) The selected geotextile fabric is spread over and under the granular sand blanket.

e) The geotextile shall be laid smooth in the direction of traffic without any wrinkles or folds. Adjacent fabrics shall be overlapped, sewn or jointed. The overlaps shall be held in position with pins or staples of piles of fill or rock.

f) The surcharge shall be placed over the geotextile in stages ensuring the minimum initial lift thickness to prevent damage of the geotextile by tyres of the construction vehicles.

g) For seaming of the geotextiles, a sewn seam shall be used with high strength, ultraviolet radiation resistant, polypropylene or polyester thread.

h) The surcharge shall be placed with approved embankment material with adequate side slopes.

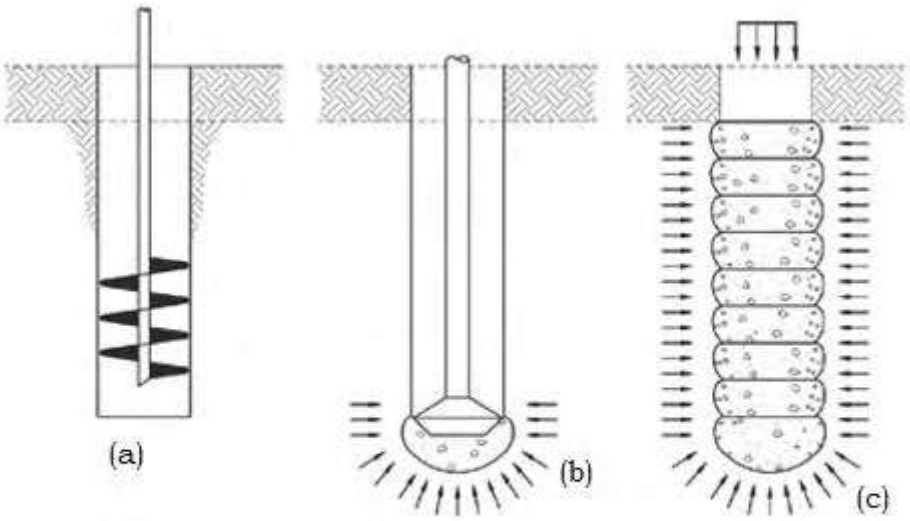
i) After the desired level of consolidation is obtained, the surcharge material which is not part of permanent work/embankment is removed.

j) Casagrande open type piezometers shall be used for the pore pressure measurement. Suitable sensors shall be used to record the water level.
k) The rate of vertical settlement shall be measured by installing platform type settlement gauges.
l) The unconfined compressive strength of the subsoil at each stage of surcharge loading shall be measured at locations specified by the Engineer.
m) During addition of surcharge and compaction, the monitoring devices shall not be disturbed.
n) Daily readings are taken in stretches where filling is in progress. In other locations, weekly readings shall be taken.
o) Readings are taken during construction and for three months thereafter.
p) The water from subsoil coming out through the PVDs shall be dewatered regularly.
q) During supply, the Contractor shall furnish the manufacturers certificate with all information to describe the material, compliance to specification including minimum average roll values (MARV).

2109 RAMMED STONE COLUMNS FOR GROUND IMPROVEMENT

2109.1 General

a) Rammed stone columns using non-displacement method of construction is provided for strengthening weak embankment foundations. Due to the high angle of internal friction and stiffness of stone column when compared with that of in-situ weak soil, the majority of the applied load is transferred to the stone column. As a result, lesser load is transferred to surrounding weak soil which leads to reduction in settlement.



a. Drilling column of specified size.
b. Ramming stones at the bottom bulb.
c. Filling the column with graded aggregates.

b) The design and construction of this is carried out in accordance with IS: 15284 (Part 2).
c) The details of materials and installation are given in Clause 314.3 of MoRTH Specifications for Road and Bridge works.

2109.2 Materials

a) Stone columns are formed with well graded crushed stone and gravel compacted to a dense state. The grading requirements are given in table 2100-6.

Table 2100-6: *Grading for crushed stone in stone columns.*

IS sieve designation	% passing
75	90-100
50	80-90
38	55-75
20	10-20
12	5-13
2	0-5

b) A compacted blanket of well draining gravel or coarse sand is to be provided. The sand blanket of the specified thickness shall be compacted to a density of 75% to 80% of the MDD obtained as per IS: 2720 (Part 8).

2109.3 Construction

a) The rammed stone columns shall be constructed by non-displacement technique of 'Bailer and Casing Method' as given in IS: 15284 (Part 1).
b) The field controls, initial and routine tests, data recording etc shall be carried out as given in IS: 15284 (Part 1).
c) The ultimate load capacity of single column shall be determined from load tests.

2110 REFERENCES

1. MoRTH Specifications for Road and Bridge Works, 5th Edition 2013 – published by IRC, New Delhi.
2. MoRTH Specifications for Road and Bridge Works, 4th Edition 2001 – published by IRC, New Delhi.
3. IRC SP: 11 Quality control for the construction of roads and runways.
4. IRC: 34 Recommendations for road construction in water logged areas.
5. IS: 3764 Code of safety for excavation work.
6. IS: 15284 Design and construction of ground improvement – guidelines.
   Part -1: *Stone columns.*
   Part -2: *Preconsolidation using vertical drains.*

+++++++

SECTION 2200 NON-BITUMINOUS BASE AND SUBBASE COURSES

2201 GENERAL

The following non-bituminous subbase courses are adopted in pavement layers.

a) Water bound macadam.
b) Mechanically stabilized soil.
c) Lime stabilized soil.
d) Cement modified soil.
e) Granular subbase.
f) Wet mix macadam.
g) Crusher-run macadam.
h) Dry lean concrete.

2202 CONTROL OF ALIGNMENT, LEVEL AND SURFACE REGULARITY

All works shall be completed to the specified lines, grades and levels, within the permissible tolerance limits stipulated in Clause 902 of MoRTH Specifications (5th revision).

2202.1 Horizontal alignment

The horizontal alignment is checked with respect to the design centre line. The edges of the carriageway, as constructed, shall be correct within the tolerance of ±10 mm. For roadway and lower layers of pavement a tolerance of ±25 mm is permitted.

2202.2 Surface levels

a) The levels of subgrade and different pavement courses when constructed shall not exceed the tolerances indicated in table 2200-1 (Ref: Table 900-1 of MoRTH Specifications) from the approved longitudinal and cross profiles.

Table 2200-1*: Permitted tolerances in surface levels*

1	Subgrade	±20 mm.
2	Subbase for flexible pavement	±10 mm.
3	Subbase for concrete pavement	±6 mm.
4	Bituminous base/binder course for flexible pavement	±6 mm.
5	Granular –do- (Machine laid)	±10 mm.
6	Granular –do- (Manually laid)	±15 mm.
7	Wearing course for flexible pavement (Machine laid)	±6 mm.
8	Wearing course for flexible pavement (Machine laid)	±10 mm.
9	Cement concrete pavement	±5 mm.

b) Even though a higher positive tolerance is permitted for subbase/base of flexible pavements, the thickness of the wearing course shall not be reduced by more than 4 mm for wearing courses of thickness 40 mm or more and 3 mm for wearing courses less than 40 mm thickness. In case of concrete pavement slab, the thickness shall not be reduced more than 5 mm.
c) For checking the surface level requirements of subgrade, subbase and base layers, levels shall be taken at grid points placed at 6.25 m longitudinally and 3.5 m transversely.
d) For 10 consecutive levels taken either longitudinally or transversely only one level is permitted to vary from the tolerance limits, but not exceeding 5 mm above the permitted tolerance limit.

e) For bituminous wearing courses and concrete pavements, levels shall be taken at grid points placed at 6.25 m along the centre line and at 0.5 m from the edges are considered.

f) Compliance to level requirements is approved only if the levels at all grid points are within the tolerance limits in the case of bituminous wearing courses and concrete pavements.

2202.3 Surface regularity of pavement layers

The longitudinal profile shall be checked with a 3 m long straight edge moved along the middle of each traffic lane parallel to the centre line.

a) The maximum number of surface irregularities shall be as given in table 2200-2 (Ref: Table 900-2 of MoRTH Specifications).

Table 2200-2*: Maximum permitted number of surface irregularities*

	Surface of carriageway and paved shoulders				*Surface of laybys, service areas and all bituminous base courses*			
Irregularity	*4 mm*		*7 mm*		*4 mm*		*7 mm*	
Length (m)	*300*	*75*	*300*	*75*	*300*	*75*	*300*	*75*
Maximum allowed in NH and expressways	15	9	2	1	40	18	4	2
Maximum in lower category roads	40	18	4	2	60	27	6	3

b) The maximum allowable difference between the road surface and under side of a 3 m straight edge when placed parallel to or at right angles to the centre line of the road at points decided by the Engineer shall be as given in table 2200-3.

Table 2200-3*: Permitted difference between surface and straight edge*

Sl. No.	*Type of surface*	*Allowable difference (Max)*
1	Bituminous/cement concrete pavement	3 mm
2	Bituminous base course	6 mm
3	Granular subbase/base	8 mm
4	Subbase under concrete pavement	10 mm
5	Subgrade	15 mm

2203 WATER BOUND MACADAM

a) Water bound macadam (WBM) is constructed with clean crushed aggregates, mechanically interlocked by rolling and bonded together, by screening and/or binding material and water.

b) WBM subbase is made with larger sized aggregates viz., 40 mm to 75 mm size.

c) Construction is generally carried out in accordance with IRC: 19. The specifications for materials and construction procedures for WBM subbase/base are given under Clause 404 of MoRTH Specifications for Road and Bridge works (5th revision 2013).

2203.1 Materials

a) The materials for WBM shall be crushed or broken stones, crushed slag, over burnt brick aggregates etc.

b) Materials other than stone aggregates shall be used only for subbase layer.

c) The physical properties of aggregates for WBM shall be as given in table 2200-4 (Ref: Table 400-8 of MoRTH Specifications).

Table 2200-4*: Physical properties required for coarse aggregate for WBM*

Sl. No.	*Test*	*Code*	*Requirement*
1	Flakiness and elongation indices (Combined)**	IS: 2386 (Part 1)	35% (Max)
2	Los Angeles*** Abrasion value	IS: 2386 (Part 4)	40% (Max)
	Aggregate Impact value***	IS: 2386 (Part 4) or IS: 5640*	30% (Max)
3	Water absorption†	IS: 2386 (Part 3)	2% (Max)

**Aggregates which get softened by the presence of water shall be tested for impact value under wet conditions as per IS: 5640.*

***Requirement of Flakiness/elongation indices is applicable for crushed aggregates/slag.*

****If WBM is used as a subbase, the LAAV and AIV may be increased to 50 and 40 respectively.*

†*If the water absorption of the aggregate is more than 2%, soundness test shall be carried out on the aggregate supplied*.

d) The coarse aggregate for WBM shall conform to the grading requirement given in table 2200-5 (Ref: Table 400-9 of MoRTH Specifications).

Table 2200-5*: Grading requirement of coarse aggregate for WBM*

Type of grading	*Grading 1*	*Grading 2*
Aggregate size range	63 mm to 45 mm	53 mm to 22.4 mm
Compacted layer thickness	75 mm	75 mm
IS Sieve (mm)	Cumulative % by wt of total aggregate	
75 mm	100	-
63 mm	90-100	100
53 mm	25-75	95-100
45 mm	0-15	65-90
22.4 mm	0-5	0-10
11.2 mm	-	0-5

e) Screenings to fill the voids in the coarse aggregates shall be of the same material as the coarse aggregates. If gravel or moorum is used the Liquid Limit and Plasticity Index of the material shall be less than 20 and 6 respectively. Besides, the fraction passing 75 micron sieve shall not be more than 10%.

f) The screenings shall conform to the grading requirements (Cumulative percentage passing by weight of total aggregate) set forth in table 2200-6 (Ref: Table 400-10 of MoRTH Specifications).

Table 2200-6*: Grading requirement of screenings for WBM*

Grading classification	*A*	*B*
Size of screenings	13.2 mm	11.2 mm
IS Sieve (mm)	Cumulative % by wt of total aggregate	
13.2 mm	100	-
11.2 mm	95-100	100
9.5 mm	-	80-100
5.6 mm	15-35	50-70
180 mic	0-10	5-25

g) The quantity of screenings for WBM is estimated as given in table 2200-7 (Ref: Table 400-11 of MoRTH Specifications).

Table 2200-7*: Quantity of screening material required for WBM*

Grading classification	*Type A screening*	*Type B screening*	*Moorum or gravel screenings*
Size of screenings	13.2 mm	11.2 mm	Not uniform
Quantity for WBM grading 1 (63 mm to 45 mm)	0.12 m^3 to 0.15 m^3	-	0.22 m^3 to 0.24 m^3
Quantity for WBM grading 1 (63 mm to 45 mm)	-	0.20 m^3 to 0.22 m^3	0.22 m^3 to 0.24 m^3
Quantity for WBM grading 2 (53 mm to 22.4 mm)	-	0.18 m^3 to 0.21 m^3	0.22 m^3 to 0.24 m^3

h) Application of binding materials may not be necessary if the screenings used are of crushable type, like moorum or gravel.

2203.2 Requirements

a) The subgrade shall be checked for line, grade and compaction.
b) Any vegetation or extraneous matter on the finished subgrade shall be removed, sprinkled with water, if necessary, and rolled with two passes of 80-100 kN smooth wheeled roller before the WBM is placed.
c) The surface shall be scarified and reshaped, if required. In such cases, necessary density checks shall be followed and the layer got approved by the Engineer.
d) Where WBM is placed directly over the subgrade, a layer of Type B screenings 25 mm thick shall be spread first. If the subgrade is sand, silt or clayey, 100 mm thick insulating layer of screenings or coarse sand shall be placed.
e) If WBM is to be placed on an existing metalled road, the surface shall be cleaned after ruts and soft or yielding places are rectified.
f) Laying WBM on an existing bituminous layer may be avoided as it may create drainage problems at the interface of the two layers. It is desirable to pick out the existing thin bituminous surface where WBM layer is to be placed. Alternately appropriate geosynthetics may be used as a separation/drainage layer.
g) Lateral confinement of aggregates in WBM construction shall be made by constructing the adjacent shoulder along with the carriageway.
h) The coarse aggregate shall not be spread more than 3 days ahead of subsequent construction operations.

2203.3 Construction

The following points shall be given attention during execution of WBM work.

a) The aggregates from stockpiles shall be spread uniformly and evenly on the prepared subgrade/subbase to get a compacted layer of 75 mm thickness. Templates shall be placed at 6 m intervals to check the profile.
b) No segregation of aggregates or pockets of fine material shall be allowed.
c) Rolling shall commence following the spreading of aggregates. 80 kN to 100 kN weight three wheeled power roller/tandem/vibratory roller shall be used for rolling.
d) Rolling shall proceed with the driving wheel in the front. Rolling shall start from the edges to centre. In curves, the rolling shall start from the inner edge to centre. The rolling shall continue with the offset of half rear wheel till the layer fully compacted.
e) Where stone aggregates are used for constructing WBM, after initial rolling, screenings and binder material are applied.

f) Rolling shall not be carried out if the subgrade is soft or yielding or when the subgrade/subbase causes a wave-like motion ahead of the roller wheel.
g) The surface regularity shall be checked with a 3 m straight edge longitudinally and transversely.
h) Depressions exceeding 12 mm shall be rectified by loosening the surface and adding/removing the material and re-compacting. Use of screenings to make up depressions is not allowed.
i) The screenings shall be spread gradually in three or four applications such that the interstices in the partially compacted coarse aggregate layer are filled up completely.
j) Dry rolling is done while screening is applied so that the vibrations assist the filling of interstices. Rolling is continued along with brooming the screenings with a mechanical or hand broom.
k) After all the voids are filled with screenings, the surface is copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet screenings, additional screenings added, if required.
l) Excessive quantity of water shall not be used to cause moisture damage to the subgrade/subbase.
m) The binding material, if required, is then applied at a uniform rate in two or three thin layers. After each application, the surface is copiously sprinkled with water, the resulting slurry swept with mechanical or hand brooms and rolled. Water shall be applied on the wheels of the roller if necessary to wash down binding material sticking on it.
n) After final compaction, the WBM layer is allowed to dry overnight. The layer shall be inspected the next day morning for any short comings.
o) Any hungry spots shall be filled with screenings or binding material, lightly sprinkled with water and rolled if necessary.
p) The completed WBM layer shall be allowed to dry and set before next pavement course is laid over it.

2203.4 Quality Control

The control tests for WBM and their frequencies are as given in table 2200-8 (Ref: Table 900-3 of MoRTH Specifications).

Table 2200-8: *QC tests for water bound macadam*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Aggregate impact value†	IS: 2386 (Part 4)/ IS:5640*	One test per 1000 m^3.
2	Grading of aggregates	IS: 2386 (Part 1)	One test per 250 m^3.
3	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	One test per 500 m^3.
4	Plasticity index of screenings (Fraction passing 425 mic)	IS: 2720 (Part 5)	One test per 100 m^3.
5	Atterberg limits of binding material	IS: 2720 (Part 5)	One test per 50 m^3.
6	Control of grade, camber thickness and surface finish	Ref: Clause 2202 (Clause 902 of MoRTH Spec)	Regularly.

**Aggregates which get softened by the presence of water shall be tested for impact value under wet conditions as per IS: 5640.*

NOTE: The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing.

2204 MECHANICALLY STABILISED SOIL SUBBASE

Mechanical stabilisation is carried out in three different ways:

i) Stabilisation of sandy soils with admixture of clay.
ii) Stabilisation of clayey soils with admixture of sand.
iii) Stabilisation with soft aggregates.

The blending/grafting materials used for mechanical stabilisation shall be checked for compliance with specification.

2204.1 Construction

The following points shall be kept in mind during execution of the work:

a) Stabilisation shall be carried out preferably by mechanical means.
b) It shall be ensured that the plant used and the method of processing shall be capable of pulverising the soil to the required degree and achieving uniform mixing.
c) Wherever manual mixing is adopted, it shall be ensured that mixing of the ingredients is uniform to the full depth of the layer processed.
d) The degree of pulverisation shall be specified.
e) The CBR grading and plasticity index of the mixed material shall be checked.
f) Before compaction, moisture content of the mixed material shall be brought to the desired level, which is normally optimum moisture content.
g) In case of stabilisation with aggregates, it shall be ensured that the aggregates are evenly dispersed in the stabilised layer.
h) Rolling shall begin from edge towards centre. In horizontal curves, rolling shall proceed from the inner edge to the outer edge.
i) The surface after rolling shall be free from movement, ridges, cracks or loose materials.
j) After rolling, the compacted layer shall be checked for density. The laboratory density of the mixed material is determined before, on samples taken from the field.
k) The control on levels and shape shall be verified regularly for compliance given under Clause 2202.
l) The layer shall be subjected to curing as specified.

2204.2 Quality Control

The control tests and their frequencies are as given in table 2200-9 (Ref: Table 900-3 of MoRTH Specifications).

Table 2200-9: *QC tests for mechanically stabilized soil subbase*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Grading of mixed material	IS: 2386 (Part 1)	One test per 250 m^3.
2	Aggregate Impact value*	IS: 2386 (Part 4)	One test per 1000 m^3.
3	Moisture content prior to compaction	IS: 2720 (Part 2)	One set of two tests per 500 m^2.
4	Dry density of compacted layer	IS: 2720 (Part 28)	One set of two tests per 500 m^2.
5	CBR test on materials ** mixed at site (On a set of 3 specimens)	IS: 2720 (Part 16)	As required.
6	Deleterious constituents	IS: 2720 (Part 27)	As required.

**Wherever applicable. Aggregates which get softened by the presence of water shall be tested for impact value under wet conditions as per IS: 5640.*

***This test is only for the purpose of design unless otherwise specified.*

NOTE: The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing. Accepted engineering practice shall be followed where procedure of testing is not indicated.

2204.3 Rectification of surface irregularities

a) Surface irregularities falling outside tolerance levels shall be rectified.
b) If the surface is too high, it shall be trimmed and suitably compacted.
c) If it is too low, the deficiency shall be corrected by adding fresh materials.

2205 LIME STABILIZED SOIL

In this method, a pre-determined quality of lime is added to soil, mixed thoroughly and compacted at the required moisture content to get the desired subbase. The specifications for materials and construction procedures are given under Clause 402 of MoRTH Specifications for Road and Bridge works (5th revision 2013).

2205.1 Materials

a) The soil for stabilisation shall be locally available material with plasticity index (PI) greater than 8.
b) Lime shall be checked for purity and calcium oxide content as specified.
c) The lime content is pre-determined on the basis of laboratory tests.
d) The laboratory CBR/UCS value shall be 1.5 times the value required in the field.

2205.2 Construction

The following points shall be kept in mind while executing the work.

a) The subgrade shall be checked for line, grade and compaction.
b) The surface shall be scarified and reshaped if required. In such cases, necessary density checks shall be followed and the layer got approved by the Engineer.
c) Stabilisation shall be carried out preferably by mechanical means.
d) Rotavators or agricultural machineries like ploughs or disc harrows shall be used for in-situ mixing the lime with soil.
e) It shall be ensured by trial runs that the plant used and method of processing shall be capable of pulverising the soil to the required degree and achieving uniform mixing.
f) Wherever manual mixing is adopted, it shall be ensured that mixing of the ingredients is uniform to the full depth of the layer processed.
g) The degree of pulverisation shall be as specified (100% passing 26.5 mm sieve and 80% passing 5.6 mm sieve as per Clause 402.3.2 of MoRTH Specifications).
h) Mixing shall be uniform so that no streaks of free lime are visible.
i) After mixing, the lime content of the mix shall be determined.
j) Before compaction, the moisture content of the mixed material shall be brought to the desired level, normally optimum moisture content.
k) The time interval between mixing of lime with soil and compaction shall not exceed 3 hours.
l) Rolling shall commence from edge and progress towards the centre. In curves, the rolling shall proceed from the inner edge to the outer edge.

m) Compaction equipments shall not be allowed to stay on the partially hardened material previously laid.
n) The surface after rolling shall be free from movement, compaction planes, ridges, cracks or loose materials.
o) After rolling, the compacted layer shall be checked for compaction control, levels and shape.
p) The layer shall be subjected to curing for 7 days and the subsequent pavement courses shall be laid immediately to prevent further drying out of the layer.
q) No traffic shall be allowed over the stabilised layer.

2205.3 Quality Control

The QC tests on materials and work shall be as indicated in 2200-10 (Ref: Table 900-3 of MoRTH Specifications) given below. The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing.

Table 2200-10: *QC tests for lime stabilised soil subbase*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Purity of lime and available calcium oxide	IS:1514	One test for each consignment subject to minimum of one test per 5 tonnes of lime.
2	Lime content immediately after mixing	IS:1514*	One test per 500 m^2.
3	Degree of pulverisation	-	Regularly.
4	Moisture content prior to compaction	IS: 2720 (Part 2)	One test per 500 m^2.
5	Dry density of compacted layer	IS:2720 (Part 28)	One test per 500 m^2.
6	Control of grade, camber thickness and surface finish	Ref: Clause 2202 (Clause 902 of MoRTH Spec)	Regularly.
7	CBR test on materials** mixed at site (On a set of 3 specimens)	IS: 2720 (Part 16)	As required.
8	Deleterious constituents of soil	IS: 2720 (Part 27)	As required.

***This test method is inconvenient for wide application in the field. As such, it will be desirable to exercise close control over material quantities and their processing.*
****Unless otherwise specified, this test is only for the purpose of design.*

2205.4 Rectification of surface irregularities

a) Surface irregularities falling outside the tolerance levels shall be rectified.
b) If the surface is too high, the same shall be suitably trimmed without disturbing the material below.
c) If the surface is too low, the affected area is scarified to 50 mm depth, fresh material is added and re-compacted, provided, the time interval is within 3 hours from mixing the lime and soil.
d) The layer is removed for the full depth and replaced, if the repairs are to be done after 3 hours of mixing.

2206 CEMENT MODIFIED SOIL

Soil is modified with lower cement content to improve the material to get the required subbase properties. The specifications for materials and construction procedures are given under Clause 403 of MoRTH Specifications for Road and Bridge works (5th revision 2013).

2206.1 Materials

a) The soil selected for cement stabilization shall not have a sulphate content of more than 0.2%.
b) The cement used for mixing with soil shall conform to IS: 269, IS: 455 or IS: 1489. The percentage of cement to be added to the dry weight of soil is determined after laboratory tests.

2206.2 Construction

The procedure to be followed in the processing and control of the cement stabilised layer are the same for lime stabilization.

2206.3 Quality Control

The control tests and frequencies shall be as given in 2200-11 (Ref: Table 900-3 of MoRTH Specifications). The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing.

Table 2200-11: *QC tests for cement stabilised soil subbase*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Deleterious constituents of soil	IS: 2720 (Part 27)	As required.
2	Quality of cement	IS: 269/455/1489	As required.
3	Cement content immediately after mixing*	-	One test per 500 m^2.
4	Degree of pulverisation	-	Regularly.
5	Moisture content prior to compaction	IS: 2720 (Part 2)	One test per 500 m^2.
6	Dry density of compacted layer	IS: 2720 (Part 28)	One test per 500 m^2.
7	CBR test on materials** mixed at site (On a set of 3 specimens)	IS: 2720 (Part 16)	As required.
8	Control of grade, camber thickness and surface finish	Ref: Clause 2202 (Clause 902 of MoRTH Spec)	Regularly.

**This test method is inconvenient for wide application in the field. As such, it will be desirable to exercise close control over material quantities and their processing.*
***This test unless, otherwise specified, is for the purpose of design only.*

2206.4 Rectification of surface irregularities

The rectification of surface irregularities is carried out as in the case for lime stabilization except that the time criteria specified shall be 2 hours in the case of cement stabilised layers.

2207 GRANULAR SUBBASE

Granular subbase is made with well graded aggregates, spread and properly compacted on a previously prepared subgrade. The specifications for materials and construction procedures are given under Clause 401 of MoRTH Specifications for Road and Bridge works (5th revision 2013).

2207.1 Materials

The material for granular subbase shall be natural sand, crushed gravel or rock free from organic or other deleterious substances conforming to the specified grading requirement.

2207.2 Construction

The following points shall be given attention during execution of the work.

a) The subgrade shall be checked for line, grade and compaction.
b) Any vegetation or extraneous matter on the finished subgrade shall be removed, sprinkled with water, if necessary and rolled with two passes of 80-100 kN smooth wheeled roller before the subbase is placed.
c) The subbase material of the specified grading shall be mixed with a suitable mixer with provision to add the required amount of water.
d) Moisture content before compaction shall be checked in accordance with IS: 2720 (Part 2) and shall be from 1% to 2% below optimum moisture content (OMC).
e) Immediately after spreading, the rolling shall be carried out with a 80-100 kN smooth wheeled roller for compacted thickness of 100 mm. For compacted thickness above 100 mm but upto 200 mm, 80-100 kN vibratory roller shall be used.
f) Rolling shall commence from edge and progress towards the centre. In curves, the rolling shall proceed from the inner edge to the outer edge.
g) Rolling shall continue till the density achieved is at least 98% of the maximum dry density (MDD) determined as per IS: 2720 (Part 8).
h) The surface after rolling shall be free from movement, compaction planes, ridges, cracks or loose materials.
i) After rolling, the compacted layer shall be checked for compaction control, levels and shape.

2207.3 Quality Control

The control testes and their minimum frequencies are given in 2200-12 (Ref: Table 900-3 of MoRTH Specifications). The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing.

Table 2200-12: *QC tests for granular subbase*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Gradation	IS: 2386 (Part 1)	One test per 400 m^3.
2	Atterberg limits	IS: 2720 (Part 5)	One test per 400 m^3.
3	Moisture content prior to compaction	IS: 2720 (Part 2)	One test per 400 m^3.
4	Dry density of compacted layer	IS: 2720 (Part 28)	One test per 1000 m^2.
5	Deleterious constituents	IS: 2386 (Part 2)	As required.
6	CBR	IS: 2720 (Part 16)	As required.

2207.4 Rectification of surface irregularities

a) The surface irregularities beyond the permitted tolerance levels (Ref: Clause 2202) shall be rectified.

b) Such areas are scarified to the full depth, excess material added, as found necessary and recomputed to the required density.
c) In no case the depressions shall be filled up with unmixed or ungraded materials or fines.

2208 WET MIX MACADAM

Wet mix Macadam (WMM) is constructed as a subbase or base and in accordance with IRC: 109. The detailed specification and construction procedures for the work are given under Clause 406 of MoRTH Specification for Road and Bridge works (5th revision 2013).

2208.1 Materials

a) The coarse aggregates shall be crushed stone.
b) The physical requirements of coarse aggregates for WMM subbase/base layer is give in table 2200-13 (Ref: Table 400-12 of MoRTH Specifications).

Table 2200-13: *Physical requirements of coarse aggregate for WMM*

Sl. No.	*Test*	*Code*	*Minimum requirement*
1	Los Angeles Abrasion value*	IS: 2386 (Part 4)	40% (Max)
2	Aggregate Impact value*	IS: 2386 (Part 4) or IS: 5640**	30% (Max)
3	Flakiness and Elongation indices (Combined)***	IS: 2386 (Part 1)	35% (Max)

**Either one of the test shall pass.*

***Aggregate which gets softened in the presence of water shall be tested under wet conditions as per IS: 5640.*

****The flaky aggregates are separated first. The flakiness index is then weight of flaky stones divided by the total weight of the sample. The elongated aggregates are then separated from the non-flaky portion and elongation index is given the weight of flaky stones divided by the total weight of non-flaky sample. The combined flakiness and elongation index is obtained by adding the both values.*

c) The aggregates for WMM shall conform to the grading requirements given in table 2200-14 (Ref: Table 400-13 of MoRTH Specifications).

Table 2200-14: *Grading requirements of aggregates for WMM*

IS sieve designation	% by weight passing
53 mm	100
45 mm	95-100
22.4 mm	60-80
11.2 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 mic	8-22
75 mic	0-5

2208.2 Construction

The following points shall be carefully observed while executing the work.

a) All material used for WMM construction shall be tested in advance to ensure compliance with quality requirement.

b) The subgrade/subbase shall be checked for density requirement, line, grade and cross section. If required, the surface shall be scarified and reshaped followed by density check and approval by the Engineer.
c) Adequacy of the lateral confinement of the WMM mix shall be checked before the commencement of the work.
d) WMM shall be prepared in an approved mixing plant of suitable capacity.
e) For small quantity of wet mix preparation, mixing in a concrete mixer may be permitted.
f) The mixing shall be uniform and there should be no segregation of coarse and fine aggregates.
g) The optimum moisture content for WMM mix is determined in accordance with IS: 2720 (Part 8).
h) While adding water in the plant, due allowance shall be given for loss of moisture due to evaporation during transporting to site.
i) At the time of compaction, the moisture content shall not vary more than the agreed limit.
j) The wet mix shall be spread by the paver finisher or motor grader.
k) After spreading, the surface of the aggregate shall be carefully checked with a template. Any high or low spots noticed shall be removed or filled up, as required.
l) The thickness of the layer shall be checked using depth blocks.
m) Rolling of the spread material shall begin immediately from edge to the centre.
n) In curve portions, rolling shall proceed from inner edge to the outer.
o) Rolling shall continue till the required density is achieved. By site trials number of passes required by each roller to achieve the specified level of compaction can be determined.
p) After final compaction, the layer is allowed to dry for 24 hours.
q) No traffic shall be allowed over the WMM layer till the wearing course is laid.

2208.3 Quality Control

The control tests and their minimum frequencies for WMM are given in table 2200-15 (Ref: Table 900-3 of MoRTH Specifications). The QC tests shall be carried out even if the quantity of materials or work done is less than that specified in the frequency for testing.

Table 2200-15: *QC tests for WMM*

Sl. No.	*Test*	*Code*	*Minimum desirable frequency*
1	Gradation	IS: 2386(Part 1)	One test per 200 m^3.
2	Aggregate Impact value	IS: 2386 (Part 4) or IS: 5640	One test per 1000 m^3.
3	Los Angeles Abrasion value*	IS: 2386 (Part 4)	One test per 1000 m^3.
4	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	One test per 500 m^3.
5	Atterberg limits	IS: 2720 (Part 5)	One test per 200 m^3.
6	Moisture content prior to compaction	IS: 2720 (Part 2)	One test per 400 m^3.
7	Dry density of compacted layer	IS: 2720 (Part 28)	A set of three tests per 1000 m^2.

**Either one of the test shall pass.*

2208.4 Rectification of surface irregularities

a) If the surface irregularity of the WMM layer exceeds the permissible tolerance, the same shall be rectified.
b) Such areas shall be scarified to the full depth, excess material removed or fresh material added, as found necessary and recompacted to the required density.
c) In no case, the depression shall be filled up with unmixed or ungraded materials or fines.

2209 CRUSHER-RUN MACADAM

Crusher stone aggregate subbase/base courses are constructed in accordance with Clause 407 of MoRTH Specifications (5th revision 2013).

2209.1 Materials

a) The material used for the crusher run macadam (CRM) work shall be crushed rock, free from any organic impurities and other deleterious substances.
b) The aggregate grading required for CRM is given in table 2200-16 (Ref: Table 400-14 of MoRTH Specifications).

Table 2200-16: *Grading requirement of aggregate for CRM*

Sieve size	*Percentage passing by weight*	
	53 mm maximum size	*37.5 mm maximum size*
63 mm	100	-
45 mm	87-100	100
22.4 mm	50-85	90-100
5.6 mm	25-45	35-55
710 mic	10-25	10-30
90 mic	2-5	2-5

c) The physical properties specified for aggregates for CRM work is given in table 2200-17 (Ref: Table 400-15 of MoRTH Specifications).

Table 2200-17: *Physical properties required for aggregate for CRM*

Sl. No.	*Test*	*Code*	*Minimum requirement*
1	Los Angeles Abrasion value*	IS: 2386 (Part 4)	40% (Max)
2	Aggregate Impact value	IS: 2386 (Part 4) or IS: 5640	30% (Max)
3	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	35% (Max)
4	Water absorption	IS: 2386 (Part 3)	2% (Max)
5	Liquid limit of fraction passing 425 mic	IS: 2720 (Part 5)	25% (Max)
6	PI of material passing 425 mic	IS: 2720 (Part 5)	6 (Max)

**Either one of the test shall pass.*

d) The grading and quality of the aggregates shall be checked before the work is commenced.

2209.2 Construction

The following points shall be given attention while the work is executed.

a) The subgrade/subbase shall be prepared as in the case of WMM course.

b) The subgrade/subbase shall be checked for density requirement, line, grade and cross section.
c) If required, the surface shall be scarified and reshaped followed by density checking and approval by the Engineer.
d) The aggregate shall be uniformly deposited on the approved subgrade/subbase by means of hauling vehicles with or without spreading devices.
e) The aggregate shall be spread on the surface to the specified thickness which may be checked using depth blocks.
f) After the material has been deposited on the base, it shall be thoroughly blade-mixed to the full depth of the layer.
g) The mix is then spread and finished to the required cross section by means of a motor grader.
h) The material shall be moistened sufficiently to prevent segregation during the mixing and spreading operations.
i) Water shall be applied in sufficient amount to assist compaction.
j) Alternately, the mixing of the crusher run material and water may be done in a mixing plant.
k) The compaction of the material shall commence immediately after spreading.
l) Vibratory rollers shall be used for compaction for layer thickness above 100 mm up to 200 mm.

2209.3 Quality Control

a) The density of the layer shall not be less than 98% of the maximum dry density (MDD) as determined in the laboratory by IS: 2720 (Part 8).
b) The finished surface shall be checked for line, level and grade before accepting for payment.
c) The control on the quality of materials and work shall be carried out as given in table 2200-18 (Ref: Table 900-3 of MoRTH Specifications).

Table 2200-18: *QC tests for crusher run macadam*

Sl. No.	*Test*	*Code*	*Minimum requirement*
1	Los Angeles Abrasion value	IS: 2386 (Part 4)	40% (Max)
2	Aggregate Impact value	IS: 2386 (Part 4) or IS: 5640	30% (Max)
3	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	35% (Max)
4	Water absorption	IS: 2386 (Part 3)	2% (Max)
5	Liquid limit of fraction passing 425 mic	IS: 2720 (Part 5)	25% (Max)
6	PI of material passing 425 mic	IS: 2720 (Part 5)	6 (Max)

2210 DRY LEAN CEMENT CONCRETE SUBBASE

Dry Lean Concrete (DLC) subbase is normally provided for concrete pavement construction. The detailed specification and construction procedure for DLC work is given under Section 601 of MoRTH Specification (5th Revision 2013).

2210.1 Materials

2210.1.1 Cement

The following types of cement may be used for DLC work with prior approval of the Engineer.

OPC 43 grade – IS: 8112
Portland slag cement – IS: 455
Portland pozzolana cement – IS: 1489 (Part 1)

If the subgrade soil contains soluble sulphates more than 0.5%, sulphate resistant cement conforming to IS: 6909 shall be used.

2210.1.2 Fly-ash

If batch mixing plant with automated process control is available, fly-ash conforming to IS: 3812 (Part I) may be used to replace OPC cement grade 43 up to 30%.

2210.1.3 Coarse aggregates

a) Aggregates shall comply to IS: 383 with Los Angeles Abrasion Value not exceeding 35%.
b) The maximum size of coarse aggregates shall be 26.5 mm.
c) The limits of deleterious materials shall not exceed the requirements set forth in table 2200-19 (Ref: Table 600-2 of MoRTH Specifications).

Table 2200-19: *Permissible limits of deleterious substances in aggregates*

Sl. No.	*Deleterious substance*	*Fine aggregate percentage by weight (Max)*		*Coarse aggregate percentage by weight (Max)*	
		Uncrushed	*Crushed**	*Uncrushed*	*Crushed**
1	Coal and lignite (IS: 2386 Part 2)	1.0	1.0	1.0	1.0
2	Clay lumps (IS: 2386 Part 2)	1.0	1.0	1.0	1.0
3	Materials finer than 75 micron IS sieve (IS: 2386 Part 1)	3.0	8.0	3.0	3.0
4	Soft fragments (IS: 2386 Part 2)	-	-	3.0	-
5	Shale (IS: 2386 Part 2)	1.0	-	-	-
6	Total of percentages of all deleterious materials (Except mica)	5.0 [All from (i) to (v)]	2.0 [(i) & (ii) alone]	5.0 [All from (i) to (v)]	5.0 [All from (i) to (v)]

**Crushed aggregate with at least one face fractured.*

NOTE: The presence of mica in the fine aggregate has been found to reduce considerably the durability and compressive strength of concrete and further investigations are underway to determine the extent of the deleterious effect of mica. It is advisable, therefore, to investigate the mica content of fine aggregate and make suitable allowances for the possible reduction in the strength of concrete or mortar, in cases where the stretch of the project road passes through micacious belt.

d) Aggregates with water absorption more than 2% shall not be used in the DLC mix.
e) The combined elongation and flakiness indices shall not exceed 35%.
f) Aggregates shall be tested for soundness in accordance with IS: 2386 (Part 5).
g) The grading of aggregates for DLC mix shall be according to table 2200-20 (Ref: Table 600-1 of MoRTH Specifications).

Table 2200-20: *Aggregate grading for DLC*

Sieve designation	*Percentage by weight passing the sieve*
26.50 mm	100
19.0 mm	75-95
9.50 mm	50-70
4.75 mm	30-55
2.36 mm	17-42
600 micron	8-22
300 micron	7-17
150 micron	2-12
75 micron	0-10

2210.1.4 Water

The water for DLC mix shall be free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete and meeting the requirement stipulated in IS: 456.

2210.2 Proportions of material for DLC mix

a) The maximum aggregate to cementitious material ratio shall be 15:1.
b) The water content shall be adjusted to the optimum by rolling during trial length construction.
c) The DLC mix shall have an average compressive strength, for a group of 5 consecutive cubes, not less than 10 MPa when tested after 7 days curing. Further, the minimum compressive strength of an individual cube shall not be less than 7.5 MPa at 7 days.
d) The minimum cement content shall be 150 kg/m^3 of concrete.
e) If fly-ash is incorporated in the DLC mix design, the quantity of fly ash shall not be more than 20% of the cementitious material. However, the content of OPC shall not be less than 120 kg/m^3.
f) If this cement content in the DLC mix is not sufficient to produce the mix of the specified strength, the cement content shall be increased at Contractor's own cost.

2210.3 Preparation of subgrade

a) The finished subgrade shall conform to the grade and cross section specified in the Drawings.
b) The subgrade construction shall be carried out in accordance with Clause 305 of MoRTH Specifications.
c) Construction traffic shall be avoided on the prepared subgrade.
d) A granular subbase (GSB) drainage layer conforming to Clause 401 of MoRTH Specifications shall be provided over the subgrade, before laying DLC subbase.
e) The paving of DLC mix shall be properly planned in such a way that cement concrete pavement layer is overlaid only after 7 days.

2210.4 DLC mix preparation

a) Batching and mixing of DLC mix shall be done at a central batching and mixing plant with automatic controls capable of weighting materials separately. Details of plant and equipments required for DLC work are given under Clause 602, 9.3 of MoRTH Specifications.
b) The prepared DLC mix shall be discharged immediately from the mixer, transported to the point of paving in tipper trucks, protected from weather with water proof tarpaulin covers.

c) The number of tipper trucks to be engaged shall be selected to ensure continuous paving of the DLC mix by the paving equipment.
d) Each tipper truck shall be thoroughly washed with water jet before next batch of mix is loaded.

2210.5 Placing and compaction

a) Dry lean concrete mix shall be placed by a paver with electronic sensor. The paver shall be provided with high amplitude damping bars to give good initial compaction to the mix spread.
b) The GSB/drainage layer shall be given a fine spray of water and rolled with a smooth wheeled roller on the previous day of DLC paving.
c) DLC shall be placed minimum 750 mm wider on each side than the proposed width, including paved shoulders of the concrete pavement, to facilitate the crawler to move over the DLC layer. The cost of extra width shall be borne by the Contractor.
d) As far as possible, DLC shall be placed for the full width of the pavement and compacted. In roads with more than 2 lanes, a longitudinal joint shall be provided. Transverse butt joint shall be provided at the end of the construction in a day. Transverse joints in DLC shall not coincide with the joints in the pavement concrete.
e) Compaction shall be carried out immediately after the material is spread and levelled. Rolling shall continue till there is no visible movement under the wheels and the surface is well closed.
f) The minimum dry density shall be 98% of the density obtained for the trial length. The densities within 0.50 m from the edges may be 96% minimum.
g) The final finishing of the DLC layer shall be completed within 90 minutes of the commencement of batching. If the temperature of concrete is less than 25°C, the working time can be increased up to 120 minutes. Work shall not proceed if the temperature of concrete is more than 30°C. Chilled water may be used for mixing, to regulate concrete temperature. If the ambient temperature is more than 35°C concreting shall be stopped.
h) Roller shall not be allowed to stand on the compacted surface during the curing period except for the next day's work.
i) Double drum smooth-wheeled vibratory roller of 80 to 100 kN static weight are suitable for rolling DLC. The type and number of roller, number of passes etc. are determined during trial run by measuring in-situ density and the quantity of work done.
j) Rolling shall be carried out from the edge to the centre. The edge shall be compacted first, roller then gradually moved towards the centre and compaction done with an overlap of half wheel width. An initial pass without vibration to bed the DLC mix down shall be provided, followed by the decided number of passes in vibration to achieve the prescribed density. A final pass without vibration shall be given to remove the roller marks and smoothen the surface.
k) In case of any difficulty in effecting compaction near joints, kerbs, drains, around man holes etc., plate vibrator shall be used to achieve the stipulated density.
l) Paving operation shall be controlled to avoid segregation of the DLC mix.

m) The final surface shall be inspected immediately and all loose, segregated or defective areas corrected using fresh mix. Concrete mix using 10 mm aggregates shall be used to repair the depressions, honey-combing etc.

n) The joints shall be cut to vertical face after the concrete is laid.

2210.6 Curing

After the DLC layer is compacted, curing is done by one of the following methods:

a) Curing may be done by covering the surface by gunny bags /hessian, kept wet continuously by 7 days by sprinkling water.

b) Curing compound conforming to ASTM C 309-81 shall be sprayed with a mechanical sprayer which forms into an impervious film or membrane. The curing compound shall be sprayed in 2 applications to ensure uniform coating as recommended by the supplier. As soon as the curing compound looses its tackiness, the surface shall be covered with wet hessian for 3 days.

c) Wax based white pigmented curing compound with water retention index not less than 90% conforming to BS: 7542 also can be used for curing DLC. The compound shall be applied using a mechanical sprayer. The rate of application shall be 0.2 litre/m^2 or as prescribed by the supplier. The first application is carried out immediately after the final rolling is completed. As soon as the tackiness of the compound is lost, the surface shall be covered with wet hessian for 3 days. The second application of curing compound is carried out within 24 to 48 hours prior to the placement of concrete pavement.

2210.7 Mix design

a) The contractor shall prepare laboratory trial mixes of DLC with moisture content from 5% to 7% with specified cement content, aggregate grading and aggregate cement ratio. The optimum moisture and dry density shall be established from cubes prepared and tested after 7 days curing. Compaction of the mix shall be done in three layers with a vibratory hammer. After establishing optimum moisture content, a set of 6 cubes are prepared and tested for compressive strength at 3 and 7 days. Trial mixes shall be repeated with increased cement content, if the strength is not satisfactory.

b) The mix design shall be approved by the Engineer after the mix parameter are finalised.

c) The field trial is then carried out at the locations approved by the Engineer. If the moisture content determined in the laboratory is found to be not satisfactory, suitable changes may be made during field trial. The cubes made during field trial shall be checked for compressive strength. During mix production, the aggregate moisture content shall be determined daily and quantity of free water modified accordingly.

d) The mix should not be either wet to stick to the roller wheel or dry, causing raveling of the surface.

e) The trial length shall be constructed 14 days in advance of the date of commencement of paving operations.

f) The 'Method Statement' for DLC mix production, transporting, placing, compaction, curing, protection of the layer, traffic arrangement during and after construction etc and including all other relevant details shall be submitted to the Engineer for approval.

g) The trial length shall not be less than 100 m, outside the main work area. The trial length shall include at least one transverse joint to check the efficiency in

making the joints on the hard concrete. The construction of trial length may be repeated, if all elements of constructing DLC are not found satisfactory in the previous trial.

h) After the trial section is completed, the in-situ density shall be determined by sand replacement method. Three equally spaced density holes are made, along a diagonal that bisects the trial area. Average of the three densities is taken to check the compaction which shall be 98% of the laboratory density.

i) A three meter wide strip of the hardened concrete shall be cut and reversed, to inspect the bottom side of the layer for any segregation. The bottom side shall be free of any combing and the aggregates on the edge shall not be loose. If not satisfactory, the trial is repeated after varying mix parameter and construction procedure.

j) Paving of DLC mix shall not commence until the trial length is approved by the Engineer.

2210.8 Quality Control

a) Samples of un-compacted DLC mix shall be taken from different location before compaction at the rate of 3 samples per 1000 m^2 area or part thereof, for each day's work. The sampling shall be done from paving site.

b) The frequency of quality control tests on materials shall be as given in table 2200-21 (Ref: Table 900-6 of MoRTH Specifications).

Table 2200-21: *Quality control tests on materials and concrete mix for DLC*

Sl. No.	*Test*	*Code*	*Desired frequency*
1. Cement:			
i)	Physical and chemical properties	IS: 269 IS: 455 IS: 1489 IS: 8112 IS: 12269	One test for each source and after long/improper storage. Daily report from cement manufacturer should be submitted by the Contractor.
2. Coarse and fine aggregates:			
i)	Gradation	IS: 2386	One test for each fraction for every day's work (May be relaxed if production is consistent).
ii)	Deleterious constituents	IS: 2386 (Part 2)	
iii)	Water absorption	IS: 2386 (Part 3)	Minimum one test per day for coarse aggregates and two tests for fine aggregates.
3. Coarse aggregates:			
i)	Los Angeles Abrasion/ Aggregate Impact value	IS: 2386 (Part 4)	Once for each source of supply and subsequently on monthly basis.
ii)	Soundness	IS: 2386 (Part 5)	Before approving the aggregates for the work and subsequently on monthly basis.
iii)	Alkali-aggregate reactivity	IS: 2386 (Part 7) IS: 456	Before approving the aggregates for the work and subsequently on monthly basis.
4. Water:			
i)	Chemical tests	IS: 2386	One test for approval of source. Subsequently in case of doubt.

c) 150 mm test cubes are prepared from the samples collected for 3 days and 7 days testing.

d) The cubes are prepared and cured in accordance with IS: 516 except that vibrating hammer shall be used for compacting the mix in the mould.

e) The dry density of the compacted layer shall be determined from three density holes along a diagonal for each 2000 m^2 area or part thereof for each day's work. The rate of testing may be increased by the Engineer, if found necessary.

f) The edge strip of 500 mm shall be checked with holes selected randomly.

g) The extent of deficient area shall be decided based on the holes. Additional holes may be taken to mark the limits of defective work clearly.

h) The frequency of quality control tests on concrete shall be as given in table 2200-22 (Ref: Table 900-6 of MoRTH Specifications).

Table 2200-22: *Quality control tests on concrete for DLC*

Sl. No.	*Test*	*Code*	*Desired frequency*
1	Strength of concrete	IS: 516	2 cubes and 2 beams per 150 m^3 or part thereof (One for 7-days and one for 28-days strength). Minimum 6 cubes and 6 beams per day's work.
2	Core strength on hardened concrete	IS: 516	If required, as directed by the Engineer.
3	Slump test	IS: 1199	One tests each at plant and at paving site for each truck initially. Subsequently from alternate trucks.
4	Thickness of completed layer	-	From level data of subbase and surface layers at 5/6.5 m x 3.5 m grid points.
5	Thickness of trial layer	-	From 3 cores per each trial length.
6	Verification of string level/steel forms	-	Level checks at 5.0 or 6.5 m intervals. The tolerance shall be within ±2 mm. Shall be approved 1- 2 hours before the concreting activity starts.

i) The checking of level, alignment and texture shall be as mentioned in table 2200-23 (Ref: Table 900-6 of MoRTH Specifications).

Table 2200-23: *Checking of levels and surface regularity for DLC*

Sl. No.	*Item*	*Frequency*
1	Tolerance in levels	±5 mm.
2	Pavement width and position of paving edges	±10 mm with respect to centre line.
3	Thickness of pavement	-5 mm to +10 mm. Deficiency more than 5 mm may be paid at the reduced rate. Deficiency more than 10 mm is not allowed.
4	Alignment of joints, width, depth of dowel grooves	Check one joint per each 400 m of paved length.
5	Surface regularity – Transverse & longitudinal	Once in a day's work without disturbing the curing process.
6	Alignment of dowel bars and their accuracy/tie bars	To be checked in the trial section and once in every 2 km paving.
7	Texture depth	Sand patch method or using tyre depth gauge.

2211 REFERENCES

1. MoRTH Specifications for Road and Bridge works, 5th revision 2013 –

published by IRC, New Delhi.

2. IRC SP: 11 Quality control for the construction of roads and runways.
3. IS: 383 Specification for coarse and fine aggregates from natural sources for concrete.

+++++++

SECTION 2300 BITUMINOUS BASE AND SURFACE COURSES

2301 GENERAL

The bituminous base courses included in the MoRTH Specifications for Road and Bridge works (5th revision 2013) and which are normally used in pavement construction are:

a) Bituminous macadam
b) Dense bituminous macadam
c) Sand bitumen

The bituminous surface courses include:

a) Surface dressing
b) Open-graded premix surfacing
c) Close-graded premix surfacing/Mixed seal surfacing
d) Seal coat
e) Slurry seal
f) Micro-surfacing
g) Bituminous concrete
h) Stone Matrix Asphalt (SMA)
i) Semi-dense bituminous concrete

Some bituminous pavement layers commonly used in PWD road works are discussed in this section. The general requirements of bituminous construction regarding materials, production, transporting, spreading, compacting etc are included under the respective clauses of various items. For more details, Clause 501 of MoRTH Specifications shall be referred.

2302 PRIME COAT AND TACK COAT

2302.1 Prime coat over granular base

Prime coat is the application of a single coat low viscosity bituminous material over a granular base or subbase to prevent entry of water into the subgrade. The main function of the prime coat in bituminous pavement is to protect the subgrade from moisture and weathering. The specifications and procedure for applying prime coat is giver under Clause 502 of MoRTH Specifications (5th revision).

2302.1.1 Materials

a) The primer shall be cationic bitumen emulsion SS1 grade conforming to IS: 8887 or medium curing (MC) cutback bitumen conforming to IS: 217 or as specified in the contract.
b) For WMM/WBM surfaces, SS1 grade bitumen emulsion shall be used at the rate of 0.7 to 1.0 lit/m^2. For stabilised soil bases/crusher run macadam layers, 0.9 to 1.2 lit/m^2 shall be used for priming.
c) Cut back bitumen MC 30 is recommended for WMM/WBM surfaces at the rate of 0.6 to 0.9 lit/m^2. For stabilised soil bases/crusher run macadam layers, MC 70 cut back at the rate of 0.9 to 1.2 lit/m^2 is recommended for priming.
d) Cut back for primer shall not be prepared at site.
e) The quantity of primer shall be selected based on site trials so as to achieve a penetration of 8 mm to 10 mm into the primed layer and there is no run-off of excessive primer.

2302.1.2 Construction

a) Primer shall not be applied if the weather is foggy, rainy, windy or if the temperature in the shade is less than 10°C. Cutback bitumen shall be applied only to dry surfaces. However if emulsion is used, the surface may be made damp by very light sprinkling of water.
b) The surface to be primed shall be made clean by power brooms or mechanical sweepers. Soil or moorum used in the WBM layer shall be removed using a brush, to a depth of about 2 mm, so as to achieve good penetration.
c) The primer shall be applied at a uniform rate using a bitumen pressure sprayer at the rate specified.
d) The Contractor shall establish the capacity of the equipment to be used in the project for priming by a field trial.
e) The temperature of cutback bitumen shall be high enough to achieve a uniform and specified rate of prime on the surface.
f) No heating or dilution of SS1 bitumen emulsion is permitted at site.
g) A primed surface shall be allowed to cure for at least 24 hours so as to allow for the moisture/volatiles to evaporate before the bituminous mix is placed.
h) Any excess primer shall be blotted with a light application of sand.
i) A primed surface shall not be allowed to traffic.

2302.1.3 Quality control

The tests on materials for prime coat and work shall be carried as mentioned in the table 2300-1 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-1: *Control tests on prime coat/tack coat*

Property	*Code*	*Frequency*
Quality of binder	IS: 73, IS: 217 or IS: 8887 as applicable	As per relevant code.
Binder temperature	-	At regular close intervals.
Rate of spread of binder	Tray test	3 tests per day.

2302.2 Tack coat

A tack coat is a very light spray application of a bitumen emulsion to create a bond between the new bituminous layer and the existing surface.

a) The application of a tack coat is an integral part of any bituminous construction, whether the mix is placed over a compacted granular base, existing bituminous surface, or over cement concrete pavement.
b) Tack coat applications ensure a proper bond and enhance the shear strength between the bituminous layers, as well as aiding in overall mix compaction.
c) Adjacent vertical surfaces, such as bituminous cold joints and where the bituminous mix meets concrete pavement, should also be tacked to help mitigate cracking and de-bonding.
d) It is observed that a tack coat provides the following benefits:
   i) Prevents de-bonding of the bituminous layers.
   ii) Prevents mat-slippage and reduces top-down cracking.
   iii) Enables super-imposed lifts to act as a monolithic layer, thus, increasing the overall structural capacity of the roadway.
   iv) Aids in increasing layer density during rolling operations, due to decreased slippage/forward movement of the bituminous layer being rolled.
   v) Increased pavement life and decreased life cycle costing.

vi) Small cost for higher return.

The specifications and procedure for applying tack coat is given under Clause 503 of MoRTH Specifications (5th revision).

2302.2.1 Materials

a) The binder for tack coat is either cationic bitumen emulsion (RS1) complying with IS: 8887 or suitable low viscosity paving bitumen VG 10 grade conforming to IS: 73.
b) Cut back bitumen RC: 70 as per IS: 217 is recommended only for sites at sub-zero temperatures.

2302.2.2 Construction

a) Tack coat shall not be applied if the weather is foggy, rainy, windy or if the temperature in the shade is less than 10°C. However, if emulsion is used, the surface may be slightly damp. If cutback bitumen is used for tack coat, the surface shall be dry.
b) The tack coat shall be applied at a uniform rate using a bitumen pressure sprayer at the rate specified. Hand spraying may be permitted in small areas or narrow strips where the sprayer cannot be used.
c) The surface on which the tack coat is to be applied shall be clean, free of dust, dirt and any other extraneous matter.
d) The granular or stabilised surfaces shall be primed before the application of tack coat.
e) Immediately before the tack coat is applied, the surface shall be swept clean with a mechanical broom and high pressure air jet.
f) The rate of application of tack coat shall be as given in table 2300-2 (Ref: Table 500-5 of MoRTH Specifications).

Table 2300-2: *Rate of application of tack coat*

Type of surface	*Rate of spray in kg/m²*
Bituminous surface	0.20-0.30
Primer granular surface	0.25-0.30
Cement concrete pavement	0.30-0.35

g) No heating or dilution of RS1 bitumen emulsion is permitted at site.
h) If paving bitumen is used for tack coat, it shall be heated in boilers to appropriate temperature to achieve a viscosity less than 2 poise.
i) The spraying temperature for bitumen emulsion is 20°C to 70°C and for cut back is 50°C to 80°C.
j) The Contractor, by a field trial, shall establish the capacity of the equipment to be used for applying the tack coat.
k) The tack coat shall be allowed to cure till all the volatiles are evaporated before any subsequent layer is placed. No plant or vehicles other than those required for the subsequent layer work shall be allowed over the tack coat.

2303 BITUMINOUS MACADAM (BM)

Constructing bituminous macadam base shall generally be done as per IRC: 27-1967. The specifications and construction procedure of bituminous macadam is given under Clause 504 of MoRTH Specifications (5th revision).

2303.1 Materials

a) The bitumen shall be viscosity grade paving bitumen complying with IS: 73 or as specified in the contract.

b) The coarse aggregate shall be crushed rock retaining on 2.36 mm sieve.

c) The physical properties of coarse aggregate shall be as given in table 2300-3 (Ref: Table 500-6 of MoRTH Specifications).

Table 2300-3: *Physical requirements for coarse aggregates for BM*

Property	*Test*	*Code*	*Requirement*
Cleanliness	Grain size analysis	IS: 2386 (Part 1)	Max 5% passing 75 micron sieve
Particle shape	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	Max 35%
Strength*	Los Angeles Abrasion value	IS: 2386 (Part 4)	Max 40%
	Aggregate Impact value	IS: 2386 (Part 4)	Max 30%
Durability	Soundness – *Sodium Sulphate* (5 cycles)	IS: 2386 (Part 5)	Max 12%
	Soundness – *Magnesium Sulphate* (5 cycles)	IS: 2386 (Part 5)	Max 18%
Porosity	Water absorption	IS: 2386 (Part 3)	Max 2%
Bitumen adhesion	Coating and stripping of bitumen aggregate mixtures	IS: 6241	Minimum 95% coating retained
Water sensitivity	Retained tensile strength** AASHTO 283	IS: 6241	Min 80%

**Any one of these shall need to be satisfied.*

***Anti-stripping agent shall be added if the value falls below 80%.*

d) Before commencement of the work the aggregate and binder shall be checked to ensure quality.

e) Only materials from approved sources shall be allowed to be used in the construction.

f) The fine aggregate shall be crushed rock or naturally occurring material passing 2.36 mm sieve and retaining on 0.075 mm sieve.

2303.2 Combined grading and binder content

a) The combined grading of the coarse and fine aggregates and binder content shall be as per table 2300-4 (Ref: Table 500-7 of MoRTH Specifications).

Table 2300-4: *Aggregate grading and binder content for BM*

Mix designation	*Grading 1*	*Grading 2*
Nominal maximum aggregate size*	40 mm	19 mm
IS Sieve (mm)	Cumulative % by wt of total aggregate	
45	100	--
37.5	90-100	--
26.5	75-100	100
19	-	90-100
13.2	35-61	56-88
4.75	13-22	16-36
2.36	4-19	4-19
0.3	2-10	2-10
0.075	0-8	0-8
Bitumen content, percentage by weight of total mixture	3.3	3.4

**Nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate material is retained.*

b) 40 mm nominal size aggregate shall be used for grading 1 (80 mm to 100 mm thickness) and 19 mm for grading 2 (50 mm to 75 mm thickness).

2303.3 Preparation of the surface

a) The surface on which the bituminous macadam to be placed shall be cleaned after ruts and soft or yielding places are rectified.
b) The surface shall be checked for line, grade and section. If required, the surface shall be scarified and reshaped to the required grade. In such cases, necessary density checks shall be carried out and the layer got approved by the Engineer.
c) The surface shall be thoroughly cleaned first with wire brush followed by dusting using compressed air.

2303.4 Construction

The following points shall be given attention while bitumen macadam work is carried out.

a) Bituminous macadam work shall not be carried out when the atmospheric temperature in shade is less than 16°C or when the underlying course is damp or wet.
b) The plant and other machineries shall be checked for their efficiency of functioning before the work is commenced.
c) A tack coat is applied on the base/subbase and the rate of spray controlled by tests. If the prime coat applied on the subbase layer is still wet, tack coat can be avoided.

2303.5 Mix preparation

a) The job mix formula for the bituminous macadam mix shall be specified and subjected to control tests at the prescribed frequencies.
b) The binder content shall not vary more than ±0.3% by weight of the total mix.
c) The preparation of the bituminous macadam mix shall be carried out in an approved hot mix plant of the required capacity.
d) The temperature of the binder and aggregates shall be consistent and within the permissible limit.
e) For shorter distance of haul, the mix temperature shall be controlled to avoid waiting at sight for the mix to cool to reach the initial rolling temperature.
f) Mix heated over the maximum allowable temperature shall not be used for paving under any circumstances.

2303.6 Spreading and rolling of the mix

a) Spreading of the hot bituminous mix shall be done preferably using a paver finisher to the correct thickness, grade and camber.
b) The temperature of the mix at the time of laying and rolling shall be within the specified limit.
c) Rolling shall proceed with the driving wheel in the front. Rolling shall start from the edges to centre. In curves, the rolling shall start from the inner edge to centre. The rolling shall continue with the offset of half rear wheel till the layer is fully compacted.

d) The wheels of the roller shall be kept moist to prevent sticking of mix. In no case, fuel/lubricant oil shall be applied on the wheel for this purpose.
e) Longitudinal joints shall be constructed parallel to the centre line of the road.
f) All joints shall be cut vertical to the full thickness of the layer previously laid and the cut face painted with hot bitumen before placing mix.
g) The traffic shall not be allowed on the completed layer till it has cooled down to the surrounding temperature.

2303.7 Quality control

a) The finished surface shall be checked for line, level and regularity before acceptance for payment (Ref: Clause 2202).
b) If the surface irregularities of the bitumen macadam layer are outside the tolerance limits specified, the same shall be rectified by removing the affected areas to full depth and relaid with fresh mix.
c) In no case the depressions shall be filled with screening or binder materials.
d) The QC tests on the material and work shall be as given in table 2300-5 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-5: *Control tests for bituminous macadam*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 350 m^3.
7	Los Angeles Abrasion	IS: 2386 Part 4	One test per 200 m^3.
8	Aggregate Impact value	IS: 2386 Part 4	One test per 200 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Plasticity index	IS: 2720 Part 5	One test for each source.
13	Temperature check	-	At regular intervals.
15	Binder content	ASTM D 2172	Two tests per day.
16	Mix grading	IS: 2386 Part 1	Two tests per day.
17	Layer density		One test per 700 m^2 area.

2304 DENSE BITUMINOUS MACADAM (DBM)

The specifications for the design and construction of Dense Bituminous Macadam are giver under Clause 505 of MoRTH Specifications (5^{th} revision 2013).

2304.1 Materials

a) The bitumen shall be viscosity graded paving bitumen complying with IS: 73 or as specified in the contract.
b) The coarse aggregate shall be crushed rock retaining on 2.36 mm sieve.
c) The physical properties of coarse aggregate shall be as given in table 2300-6 (Ref: Table 500-8 of MoRTH Specifications).

Table 2300-6: *Physical requirements for coarse aggregates for DBM*

Property	*Test*	*Code*	*Specification*
Cleanliness	Grain size analysis	IS: 2386 (Part 1)	Max 5% passing 75 micron sieve
Particle shape	Flakiness and Elongation Indices (Combined)	IS: 2386 (Part 1)	Max 35%
Strength*	Los Angeles Abrasion value	IS: 2386 (Part 4)	Max 35%
	Aggregate Impact value	IS: 2386 (Part 4)	Max 27%
Durability	Soundness – *Sodium Sulphate* (5 cycles)	IS: 2386 (Part 5)	Max 12%
	Soundness – *Magnesium Sulphate* (5 cycles)	IS: 2386 (Part 5)	Max 18%
Porosity	Water absorption	IS: 2386 (Part 3)	Max 2%
Bitumen adhesion	Coating and stripping of bitumen aggregate mixtures	IS: 6241	Minimum 95% coating retained
Water sensitivity	Retained tensile strength**	AASHTO 283	Min 80%

**Any one of these shall need to be satisfied.*

***Anti-stripping agent shall be added if the value falls below 80%.*

d) The filler shall be finely divided mineral matter such as rock dust, hydrated lime or cement. The grading limits of filler shall be as given in table 2300-7 (Ref: Table 500-9 of MoRTH Specifications).

Table 2300-7: *Grading requirements for mineral filler*

IS sieve mm	*Cumulative percentage passing by total weight of aggregate*
0.600	100
0.300	95-100
0.075	85-100

2304.2 Combined aggregate grading and binder content

The combined grading of the coarse and fine aggregates and binder content for Dense Bituminous Macadam shall be as per table 2300-8 (Ref: Table 500-10 of MoRTH Specifications).

Table 2300-8: *Aggregate grading and binder content for DBM*

Mix designation	*Grading 1*	*Grading 2*
Nominal aggregate size	37.5 mm	26.5 mm
Layer thickness	75 mm-100 mm	50 mm-75 mm
IS Sieve (mm)	Cumulative % by wt of total aggregate	
45	100	-
37.5	90-100	100
26.5	63-93	90-100

Table 2300-8: *Aggregate grading and binder content for DBM (Contd..)*

Mix designation	*Grading 1*	*Grading 2*
19	-	71-95
13.2	55-75	56-80
4.75	38-54	38-54
2.36	28-42	28-42
0.300	7-21	7-21
0.075	2-8	2-8
Bitumen content, % by weight of total mixture	Min 4.0**	Min 4.5**

***The bitumen content shall be determined as per the Marshall mix design procedure.*

2304.3 Mix design

a) The DBM mix shall be designed in accordance with the procedure laid out in Asphalt Institute Manual MS-2.

b) The fines to bitumen ratio (F/B) by weight of total mix shall be in the range 0.6 to 1.2.

c) The mix requirements for DBM are given in table 2300-9 (Ref: Table 500-11 of MoRTH Specifications).

Table 2300-9: *Mix requirements for DBM*

Properties	*Viscosity grade paving bitumen*	*Modified bitumen*		*Code*
		Hot climate	*Cold climate*	
Compaction level	75 blows on each face of the specimen			
Minimum stability (kN at 60°C)	9.0	12.0	10.0	AASHTO T 245
Marshall flow (mm)	2 - 4	2.5 - 4	3.5 - 5	AASHTO T 245
Marshall quotient (Stability/Flow)	2 - 5	2.5 - 5		MS-2 and ASTM D 2041
Air voids %	3 - 5			
Voids filled with bitumen (VFB) %	65 - 75			
Coating of aggregate particle	95% (Min)			IS: 6241
Tensile strength ratio	80% (Min)			AASHTO T 283
Voids in mineral aggregate(VMA) %	Minimum percent voids in mineral aggregate (VMA) are set out in table 500-13 of MoRTH			

d) The binder content shall be selected to achieve the requirements for mix set out in table 2300-9.

e) The minimum percentage air voids in the mineral aggregates (VMA) shall be as prescribed in table 2300-10 (Ref: 500-12 of MoRTH Specifications).

Table 2300-10: *Minimum percentage voids in mineral aggregate (VMA)*

Nominal maximum particles size (mm)*	*Minimum VMA percent related to design percentage air voids*		
	3.0	*4.0*	*5.0*
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

** Interpolate minimum voids in the mineral aggregate (VMA) for designed percentage air voids values between those listed.*

f) The binder content shall be optimized to meet the requirements of mix. The binder content shall be selected from the Marshall design curves to obtain 4% air voids in the design mix. Marshall Method of mix design procedures as given in Asphalt Institute Manual MS-2 shall be followed to get the optimum binder content.

g) Where the maximum size of aggregate in the mix is more than 26.5 mm, the modified Marshall method using 150 mm diameter specimens as given in MS-2 and ASTM D 5581 shall be used.

2304.4 Job mix formula

The job mix formula to be used in the work shall be proposed by the Contractor 21 days before the start of the work. The following details shall be included in the report accompanying the job mix formula.

a) Source and location of all materials.
b) Binder type and percentage by weight of total mix.
c) Proportion of various coarse and fine aggregates including filler by weight of total aggregate mix.
d) A single definite percentage passing each sieve for the aggregate mix.
e) Grading of the individual aggregates including filler.
f) Where batch mixing is adopted, the weight of each fraction of aggregate and binder per batch.
g) Test results of the physical properties of the aggregates to be used in the work.
h) Test results of the volumetric analysis of the mix such as maximum specific gravity of the loose mix (G_{mm}), densities of the compacted specimens for various binder contents, voids in mineral aggregates (VMA), air voids in the compacted mix (Va), voids filled with bitumen (VFB).
i) Reports on the Marshall test viz., stability & flow.
j) Mixing temperature and compacting temperature.
k) Marshall design curves showing stability, flow, density, air voids, VMA and VFB plotted against different binder contents.

2304.5 Approval of the job mix formula

a) Approval of the job mix formula shall be given by the Engineer after conducting necessary acceptance tests using the samples of materials proposed to be used in the work.
b) A revised mix design shall be carried out and a new job mix formula approved once a change in source of the material is required.

2304.6 Plant and field trials

a) After approval of the job mix formula, plant trials must be carried out to establish that a uniform mix is produced and the variations of individual fractions are within the permitted tolerance specified in table 2300-11 (Ref: Table 500-13 of MoRTH Specifications).
b) After the successful completion of plant trials, field trials are carried out.
c) The field trials will establish if the paving machineries and procedures are sufficient to produce a satisfactory pavement layer.
d) Density of the finished paving shall be determined by taking cores no sooner than 24 hours after finishing the layer.

Table 2300-11: *Permissible variations in the actual mix from the job mix formula*

Description	*Base/binder course*
Aggregate passing 19 mm sieve or larger	± 8%
Aggregate passing 13.2 mm,9.5 mm	± 7%
Aggregate passing 4.75 mm	± 6%
Aggregate passing 2.36 mm, 1.18 mm, 0.600 mm	± 5%
Aggregate passing 0.300 mm, 0.150 mm	± 4%
Aggregate passing 0.075 mm	± 2%
Binder content	± 0.3%
Mixing temperature	± 10°C

e) The minimum field density required is 92% or more than the theoretical maximum specific gravity (G_{mm}) obtained on the day of compaction in accordance with ASTM D 2041. This means not more than 8% air voids is allowed in the compacted layer of DBM.

2304.7 Construction

a) The layer on which the DBM is to be placed shall be prepared in accordance with Clause 502 or 902 of MoRTH Specifications.
b) If any geosynthetic material is to be provided as per design, this shall be done in accordance with the Clause 703 of MoRTH Specifications.
c) If the design requires stress absorbing layer, it shall be provided in accordance with the requirements of Clause 517 of MoRTH Specifications.
d) Tack coat shall be provided on the cleaned surface as per Clause 503 of MoRTH Specifications.
e) If the surface on which the DBM is to be placed is not a bitumen bound surface, a prime coat shall be provided as per Clause 502 of MoRTH Specifications.
f) Transportation of the mix shall be carried out as prescribed in Clause 501.4 of MoRTH Specifications.
g) The Clause 501.5.1 of MoRTH Specifications shall be followed for weather and seasonal limitations.

2304.8 Spreading and compaction

a) The spreading of DBM mix shall be carried out in accordance with Clause 501.5.3 of MoRTH Specifications.
b) Compaction of the mix spread shall be carried as per Clause 501.6 and 501.7 of MoRTH Specifications and on the basis of the site trials.
c) Joints shall be prepared as per Clause 501.7 of MoRTH Specifications.
d) No traffic shall be allowed over the DBM layer till the mat cools down to the ambient temperature.

2304.9 Quality control

a) The surface finish shall conform to the requirements of Clause 900 of MoRTH Specifications.
b) The levels and regularities shall be checked in accordance with Clause 2202 (Clause 902 of MoRTH Specifications).
c) The QC tests on material and work shall be as given in table 2300-12 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-12: *Quality control tests on DBM*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 350 m^3.
7	Los Angeles abrasion	IS: 2386 Part 4	One test per 350 m^3.
8	Aggregate impact	IS: 2386 Part 4	One test per 350 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Sand equivalent	IS: 2720 Part 37	One test for each source.
13	Plasticity index	IS: 2720 Part 5	One test for each source.
14	Temperature check	-	At regular intervals.
15	Binder content	ASTM D 2172	Two tests per day.
16	Aggregate mix grading	IS: 2386 Part 1	Two tests per day.
17	Marshall test	AASHTO T 245	Three tests per 400 tonnes.
18	Max sp. gravity of mix	AASHTO T 209	Three tests per 400 tonnes.
19	Volumetric analysis	MS-2	Three tests per 400 tonnes.
20	Moisture susceptibility	AASHTO T 283	One test for each mix.
21	Layer density		One test per 700 m^2 area.

2305 SAND BITUMEN MIX

The sand bitumen mix can be used both as subbase and base.

2305.1 Materials

a) The sand used shall be non-plastic and the percentage fines passing 75 micron shall be 5% to 10%.

b) The requirements for sand are prescribed in table 2300-13 (Ref: Table 500-14 of MoRTH Specifications).

Table 2300-13: *Grading and physical requirements of sand for sand bitumen mix*

Sieve size mm	*Cumulative percentage passing by weight of aggregate*
9.5	100
2.75	85-100
2.36	80-100
1.18	70-98
0.600	55-95
0.300	30-75
0.150	10-40
0.075	4-10
Plasticity index (PI)	6 (Max)
Sand equivalent (IS: 2720 Part 37)	30 (Min)
Los Angeles abrasion (IS: 2386 Part 4)	40 (Max)

c) The mix requirements are prescribed in table 2300-14 (Ref: Table 500-15 of MoRTH Specifications).

Table 2300-14: *Requirements for sand bitumen base course*

Mix parameter	*Requirement*
Minimum stability (kN at 60°C)	2.0
Minimum flow (mm)	2
Compaction level (Blows)	75 on each face
Air voids in the mix (%)	3 - 5
Voids in the mineral aggregate (VMA) %	16 (Min)
Percentage voids filled with bitumen (VFB) %	65 - 75

d) The binder content of the mix shall be determined in the laboratory by Marshall method given in the Asphalt Institute Manual MS-2.

2305.2 Construction

The following points shall be given attention while executing work with sand bitumen mix:

a) The preparation of subgrade/subbase shall be carried out as in the case of BM base (Clause 2303.3).
b) The mix constituents and their proportions shall be determined after proper laboratory tests.
c) Sand shall be dried before mixing with binder.
d) The mixing of sand and binder shall be done mechanically and uniform coating of the particle shall be ensured.
e) If the binder used is cut back, the mix is spread and aerated for 24 hours, regraded and compacted thereafter.
f) The edge confinement shall be provided for this type of construction.
g) The thickness of the layer shall be as specified.
h) Rolling shall proceed with the driving wheel in the front. Rolling shall start from the edges to centre. In curves, the rolling shall start from the inner edge to centre. The rolling shall continue with the offset of half rear wheel till the layer is fully compacted.
i) The wheels of the roller shall be kept moist to prevent sticking of mix. No fuel/lubricant oil shall be applied on the wheels for this purpose.
j) The binder content is checked by extraction test on the mix sample at the specified frequencies.
k) After rolling, the compacted layer is checked for the density requirements.
l) The finished surface is checked for line, level and regularities (Ref: Clause 2202).

2305.3 Quality control

The QC tests for sand bitumen subbase/base course are carried out as given in table 2300-15 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-15: *Control tests for sand bitumen base/subbase*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Water absorption	IS: 2386 Part 3	One test for each source.
7	Sand equivalent	IS: 2720 Part 37	One test for each source.
8	Plasticity index	IS: 2720 Part 5	One test for each source.

Table 2300-15: *Control tests for sand bitumen base/ subbase (Contd...)*

9	Temperature check	-	At regular intervals.
10	Binder content	ASTM D 2172	Two tests per day.
11	Mix grading	IS: 2386 Part 1	Two tests per day.
12	Marshall test	AASHTO T 245	Three tests per 400 tonnes.
13	Max sp. gravity of mix	AASHTO T 209	Three tests per 400 tonnes.
14	Volumetric analysis	MS-2	Three tests per 400 tonnes.
15	Layer density		One test per 700 m^2 area.

2305.4 Rectification of surface irregularities

a) If surface irregularities are noted, the same shall be rectified.
b) The rectification is done while the mix is still workable.
c) If the surface is too high, the same shall be trimmed off without disturbance to the underlying layer.
d) If the surface is too low, the depression shall be filled up with sand-bitumen mix and rolled according to specification.

2306 SINGLE COAT SURFACE DRESSING

a) The work of the single coat surface dressing shall generally follow the specifications laid down in IRC: 17. The specifications and construction procedures are given under Clause 509 of MoRTH Specifications.
b) The quality of the aggregate and bitumen shall be checked as required in the specification.
c) The base on which the surface dressing to be done shall be properly prepared. The depressions and potholes shall be filled and compacted to line, grade and section. The surface shall be thoroughly cleaned and any caked earth removed before the binder is applied.
d) If prime coat is specified on the base layer, the same shall be applied and cured before surface dressing is done.
e) All irregularities beyond tolerance on the base shall be rectified before the surface dressing work is commenced.

2306.1 Construction

The following points shall be given attention while executing the surface dressing work:

a) No surface dressing shall be carried out if atmospheric temperature in shade is less than 16°C, the base layer or aggregate is damp or the weather foggy, rainy or dusty.
b) The cleaned surface shall be kept free of traffic and dust.
c) The binder shall be sprayed using mechanical sprayers at the correct temperature. The rate of spray shall be checked by tray test and shall be within 2.5% of the specified application rate. Excessive deposits shall be removed immediately.
d) Immediately after application of the binder, cover aggregates of the approved quality shall be spread over the sprayed area.
e) The cover aggregate are rolled immediately with the roller of approved weight. The rolling is continued till all the aggregate is embedded into the binder. Excessive rolling resulting in the crushing of the aggregates shall be avoided.
f) Generally no traffic shall be allowed on the finished surface for 24 hours. If the binder used is cutback, no traffic is allowed till the binder is adequately cured.

2307 TWO COAT SURFACE DRESSING

a) The work of two coat dressing is done as per IRC: 23-1966. The specifications and construction procedures are given under Clause 509 of MoRTH Specifications.
b) The procedure for work is same as for single coat surface dressing except that the second coat should not be applied until the first coat has been opened to traffic for two weeks.
c) The binder for second layer is sprayed at the specified rate. The second layer aggregate is then spread and rolled as in the case of single coat surface dressing (Clause 2306).

2307.1 Quality control

QC test on materials and work for surface dressing shall be as indicated in table 2300-16 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-16: *Control tests for surface dressing and seal*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 100 m^3.
7	Los Angeles abrasion	IS: 2386 Part 4	One test per 200 m^3.
8	Aggregate impact	IS: 2386 Part 4	One test per 200 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Temperature check	-	At regular intervals.
13	Binder content	ASTM D 2172	Two tests per day.
14	Moisture susceptibility	AASHTO T 283	One test for each mix type.

2307.2 Surface regularity

Irregularities in surface dressing cannot be rectified. Hence it is essential that the base on which surface dressing is placed must be prepared to the true shape, line and levels.

2308 SURFACE DRESSING WITH PRE-COATED AGGREGATE

a) Construction of surface dressing with pre-coated stone chips is carried out as per IRC: 48. The specifications and construction procedures are given under Clause 509 of MoRTH Specifications.
b) This work is similar to conventional surface dressing except that cover aggregates are lightly pre-coated with binder.

2308.1 Construction

The procedure for construction and quality control checks are same as for surface dressing work.

The following additional checks or also made:

a) The binder and aggregate shall be at the specified temperature while mixing.
b) Binder on the aggregate shall be uniformly coated.
c) The aggregate shall be aerated and cooled properly before using them in the work.

d) During cooling, the coated aggregate shall not be placed in big heaps and care shall be exercised to protect from dust.

2309 OPEN-GRADED PREMIX SURFACING

a) The premix surfacing (Often referred to as premix carpet) may be either open-graded or closely graded depending on the type of mix used.

b) Open-graded premix surfacing shall be in accordance with IRC: 14. The specifications and construction procedure are given under Clause 510 of MoRTH Specifications.

2309.1 Materials

a) The binder shall be viscosity grade bitumen of the specified grade. For selection of grade of bitumen table 2300-17 (Ref: Table 500-1 of MoRTH Specifications) may be used for guidance.

Table 2300-17: *Selection of VG graded paving bitumen based on climatic conditions*

Lowest daily mean air temperature °C	Lowest daily mean air temperature °C		
	Less than 20°C	20°C to 30°C	More than 30°C
More than -10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

b) The coarse aggregates shall satisfy all the physical requirements set for BM (Table 2300-3) except that the water absorption shall be 1% maximum. The Polished stone value (PSV) shall not be less than 55% when tested in accordance with BS: 812-114.

c) The fine aggregates shall be crushed or naturally occurring material or a combination of the two, passing 2.36 mm sieve and retained on 75 mic sieve.

d) The quantities of materials to be proportioned for open graded premix surfacing are given in table 2300-18 (Ref: Table 500-23 of MoRTH Specifications).

Table 2300-18: *Quantities of materials required 20 mm thick open-graded premix surfacing per 10 m^2 area*

	Materials	*Quantity*
AGGREGATES		
i)	Nominal stone size 13.2 mm (Passing 22.4 mm sieve and retained on 11.2 mm sieve)	0.18 m^3
ii)	Nominal stone size 11.2 mm (Passing 13.2 mm sieve and retained on 5.6 mm sieve)	0.09 m^3
	TOTAL	0.27 m^3
BINDER		
i)	For 0.18 m^3 of 13.2 mm nominal size stone @ 52 kg bitumen per m^3	9.5 kg
ii)	For 0.09 m^3 of 11.2 mm nominal size stone @ 56 kg bitumen per m^3	5.1 kg
	TOTAL	14.6 kg

2309.2 Construction

The following points shall be given attention while executing the work.

a) The binder and aggregates shall be checked for quality compliance before work is done.

b) The base over which the premix carpet is placed shall be prepared properly.

c) Mix proportion of the constituent materials shall be specified. The binder content shall be checked by extraction and regulated to be within 2.5% of the prescribed quantity.
d) Tack coat shall be applied uniformly over the previously prepared base.
e) The rate of spray shall be checked by tray test.
f) Mixing of the aggregates and binder shall be done in a suitable plant provided with pugmill.
g) The mixing shall be done only after heating the aggregates and bitumen to the specified temperatures.
h) The mixed material shall be spread evenly with raker or spreader to the specified thickness or camber.
i) Rolling shall commence immediately after spreading of the mix. The wheels of the roller shall be kept moist to prevent the mix from sticking to the wheels. No fuel/lubricant shall be permitted to be used for this purpose.
j) Where specified, the seal coat shall be applied immediately over the base carpet.
k) If liquid seal coat is applied, the points to be attended are same as for surface dressing.
l) If premixed sand coat is applied, the same shall be done as in the case of premix carpet.
m) When bitumen is used as binder, traffic can be allowed after the carpet is cooled to the surrounding temperature. If cutback is used, traffic shall not be permitted till the binder is cured.
n) The finished surface shall be checked for line, level and regularities as per specification.

2309.3 Quality control

The QC tests on material and work shall be as given in table 2300-19 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-19: *Quality control tests for open/close graded premix surfacing*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 100 m^3.
7	Los Angeles abrasion	IS: 2386 Part 4	One test per 200 m^3.
8	Aggregate impact	IS: 2386 Part 4	One test per 200 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Temperature check	-	At regular intervals.
13	Binder content	ASTM D 2172	Two tests per day.
14	Moisture susceptibility	AASHTO T 283	One test for each mix type.

2309.4 Rectification of surface irregularities

a) Premix carpet can improve the evenness of an existing surface only to a limited extend. So before the premix carpet is laid, large irregularities on the base layer shall be rectified.

b) When surface irregularities in premix carpet are outside the tolerance level (Ref: Clause 2202) these are to be rectified as in the case of surface dressing work.

2310 CLOSE-GRADED PREMIX SURFACING/MIX SEAL SURFACING

The specifications and construction procedures for close-graded premix surfacing are given under Clause 508 of MoRTH Specifications. Close-graded premix surfacing/mix seal surfacing shall be either Type A or Type B and is laid to a thickness of 20 mm. Type A surfacing is recommended for areas where average annual rainfall is more than 1500 mm.

2310.1 Materials

a) The binder shall be viscosity grade bitumen of the grade specified in the contract conforming to the requirements of IS: 73. For the selection of the grade of binder, table 2300-17 shall be referred.

b) The coarse aggregates shall satisfy all the physical requirements set for BM (Table 2300-3) except that the water absorption shall be 1% maximum. The polished stone value (PSV) shall not be less than 55% when tested in accordance with BS: 812-114.

c) Fine aggregates shall be crushed rock, natural sand or a mixture of both which shall be clean, hard, durable, dry and free from soft, friable, flaky particles and organic and deleterious substances.

d) The coarse and fine aggregates shall be combined to get a grading as stipulated in table 2300-20 (Ref: Table 500-19 of MoRTH Specifications).

Table 2300-20: *Aggregate grading for close-graded premix surfacing/ mixed seal surfacing*

IS sieve designation	*Cumulative percentage by weight passing total aggregate*	
	Type A	*Type B*
13.2 mm	-	100
11.2 mm	100	88-100
5.6 mm	52-88	31-52
2.8 mm	14-38	5-25
0.090 mm	0-5	0-5

e) The total quantity of graded aggregates for Type A and Type B premix surfacing shall be 0.27 m^3 per 10 m^2 area.

f) For Type A premix /mix seal surfacing, bitumen @ 22 kg/10 m^2 area and for Type B surfacing, 19 kg/10 m^2 shall be used.

2310.2 Construction

a) The procedure for close-graded premix surfacing is similar to that of open-graded surfacing.

b) Traffic may be allowed after the layer has cooled down to the surrounding temperature. Speed restrictions may be imposed at initial stages.

2311 SEAL COAT

Clause 511 of MoRTH Specification provides the details for the application of a seal coat for sealing the voids in the bituminous surface laid to the specified levels, grade and cross fall (Camber). The seal coat shall be either type A (Liquid seal coat) or type B (Premixed seal coat).

2311.1 Materials

a) The quantity of bitumen shall be 9.8 kg/10 m^2 for Type A and 6.8 kg/10 m^2 for Type B seal coat. If emulsion is used this shall be 15 kg for Type A and 10.5 kg for Type B.

b) For Type A seal coat, clean, hard, durable stone chips 6.7 mm size passing 11.2 mm sieve and retaining on 2.36 mm IS sieve at the rate of 0.09 m^3 per 10 m^2 area shall be used.

c) The physical requirements of stone chips shall be as per table 2300-21 (Ref: Table 500-8 of MoRTH Specifications - except that water absorption shall be 1% maximum).

Table 2300-21: *Physical requirements for stone chips for Type A seal coat*

Test	*Code*	*Requirement*
Grain size analysis	IS: 2386 (Part 1)	Max 5% passing 75 micron sieve
Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	Max 35%
Los Angeles abrasion value	IS: 2386 (Part 4)	Max 35%
Aggregate impact value	IS: 2386 (Part 4)	Max 27%
Soundness – *Sodium sulphate*	IS: 2386 (Part 5)	Max 12%
Soundness – *Magnesium sulphate*	IS: 2386 (Part 5)	Max 18%
Water absorption	IS: 2386 (Part 3)	Max 1%
Coating and stripping of bitumen aggregate mixtures	IS: 6241	Minimum 95% coating retained
Retained tensile strength	AASHTO T 283	Min 80%

d) The aggregate for Type B seal coat shall be sand or grit consisting of clean, hard, durable material passing 2.36 mm sieve and retaining on 180 micron sieve at the rate of 0.06 m^3 per 10 m^2 area.

2311.2 Construction

The following points shall be given attention while executing the work.

a) Weather and seasonal limitations shall be as for premix surfacing.

b) The seal coat shall be applied immediately after laying the base carpet.

c) The surface shall be cleaned free from any dust or extraneous matter.

d) The construction operations for Type A seal coat shall be as for single coat surface dressing described under Clause 2306 (Clause 509.3.3 to 509.3.5 of MoRTH Specifications).

e) The construction operations for Type B seal coat using paving bitumen shall be as for premix surfacing described under Clause 2309 (Clause 510.1.3 of MoRTH Specifications). If bitumen emulsion is used, construction shall be carried out as per Clause 510.2.4.

f) For Type B surfacing, traffic may be allowed immediately after the premixed seal coat cools down.

g) In the case of type A seal coat, traffic shall be permitted in the following day only. Under unavoidable situations, slow traffic at the speed less than 20 km per hour shall be permitted.

2312 SLURRY SEAL

Slurry seal is a mixture of mineral aggregate, slow setting cationic bitumen emulsion, water, additives if required, proportioned, mixed and uniformly spread over a

previously prepared surface. The detailed specification and construction procedure for slurry seal is given under Clause 512 of MoRTH Specifications.

The three different types of slurry seal and their applications are given in table 2300-22 (Ref: Table 500-25 of MoRTH Specifications).

2312.1 Materials

2312.1.1 Bitumen

Cationic slow setting emulsion SS2, conforming to IS: 8887 shall be used.

Table 2300-22: *Different types of slurry seals*

Items	*Type I (2-3 mm)*	*Type II (4-6 mm)*	*Type III (6-8 mm)***
Application	Filling of hair cracks	Filling of surface cracks 1-3 mm and preventive/renewal treatment (Up to 450 CVPD)***	Filling of surface cracks 3-6mm and preventive/ renewal treatment (Up to 1500 CVPD)***
Quantity* of slurry (kg/m^2)	4.3 to 6.5	8.4 to 9.8	10.1 to 12
Residual binder (% by weight of dry aggregate)	10 to 16	7.5 to 13.5	6.5 to 12

**In terms by weight of dry aggr*egate. ** *Indicative only.*

*** *CVPD-Commercial vehicles per day.*

2312.1.2 Aggregate

a) Crushed stone dust, clean, sharp, hard, durable, free from soft pieces and organic impurities shall be used for preparing slurry seal mix.

b) The physical properties required for the aggregates are given in table 2300-23 (Ref: Table 500-26 of MoRTH Specifications).

Table 2300-23: *Properties of aggregates for slurry seal*

Properties	*Code*	*Requirement*
Sand equivalent value	IS: 2720 (Part 37)	50% (Max)
Water absorption*	IS: 2386 (Part 3)	2% (Max)
Soundness with: (i) Sodium Sulphate (ii) Magnesium Sulphate	IS: 2386 (Part 5)	 12% (Max) 18% (Max)

***In case water absorption exceeds 2% but is less than 4%, same may be permitted subject to conformity of soundness test and wet stripping test.*

c) The aggregate grading stipulated for various types of slurry seal are given in table 2300-24 (Ref. table 500-27 of MoRTH Specifications).

Table 2300-24: *Aggregate grading for slurry seal*

IS sieve (mm)	*Cumulative % by weight of total aggregate passing*		
	Type I (2-3 mm)	*Type II (4-6 mm)*	*Type III (6-8 mm)*
9.5	-	-	100
6.3	-	100	90-100
4.75	100	90-100	65-90
2.36	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.600	40-65	30-50	19-34
0.300	25-42	18-30	12-25
0.150	15-30	10-21	7-18
0.075	10-20	5-15	5-15

d) The tolerance of various fractions of aggregates from the selected grading shall be as given in table 2300-25 (Ref: Table 500-28 of MoRTH Specifications).

Table 2300-25: *Tolerances for slurry seal*

Description	*Tolerance prescribed*
Aggregate passing 4.75 mm	±*5%*
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±*5%*
Aggregate passing 0.300 mm	±*4%*
Aggregate passing 0.150 mm	±*3%*
Aggregate passing 0.075 mm	±*2%*

2312.1.3 Filler

Ordinary Portland Cement (OPC) in the range of 0.5% to 2% by weight of total aggregates shall be incorporated as filler.

2312.1.4 Water

Portable water with pH value in the range 6 to 7, free from harmful salt and impurities, shall be used for mixing.

2312.1.5 Additives

Chemical additives may be used to accelerate or retard the break-set time of the slurry or to improve the resulting surface finish. The additive, if used, shall be compatible with the type of emulsion used.

2312.2 Mix Design

a) The mix design criteria for slurry seal mix is given in IRC: SP-81.

b) The requirements for the slurry seal mix is given in table 2300-26 (Ref: Table 500-29 of MoRTH Specifications).

Table 2300-26: *Mix design criteria for slurry seal*

Property	*Code*	*Requirement*
Mix time	IRC:SP-81, Appendix 1	180 sec (Min)
Consistency	IRC:SP-81, Appendix 3	3 cm (Max)
Wet cohesion	IRC:SP-81, Appendix 4	20 kgcm (Min)
Wet stripping	IRC:SP-81, Appendix 5	90% (Min)
Wet track abrasion loss (1 hour soak)	IRC:SP-81, Appendix 6	800 gm/m^2 (Max)

c) The design report shall indicate the proportion of aggregate, filler, water and residual bitumen content based on dry weight of aggregate, additives to be used etc.

d) The quantity of ingredients in the mix and their limits are given in table 2300-27 (Ref: Table 500-30 of MoRTH Specifications).

Table 2300-27: *Quantity of ingredients for slurry seal mix*

Ingredients	*Limits (% by weight of dry aggregates)*
Bitumen emulsion (Cationic)	10 to 16 for type I
	7.5 to 13.5 for type II
	6.5 to 12 for type III
Water	6 to 12
Filler	1.0 to 2.0
Additive	0.5 to 2.0

2312.3 Construction

a) Laying of slurry shall not be undertaken if either the pavement or air temperature is below 10°C.

b) Placing slurry seal on a wet surface without stagnant water can be allowed.
c) The underlying surface on which the slurry seal is to be applied shall be cleaned properly and prepared to the required shape.
d) Any caked earth on the surface shall be removed with wire brushes, then swept with mechanical brooms and finally dusted with air jet or any other approved means.
e) Cracks on the pavement surface shall be sealed with approved crack sealing material prior to application of slurry seal.
f) Tack coat is not required for slurry seal application on flexible pavements. If specified, the same shall be provided as per Clause 503 of MoRTH Specifications.
g) The machine for laying slurry seal shall be self-propelled, truck mounted, with the following units, designed to prepare and spread the mix simultaneously on the surface.
   i) Aggregate bin.
   ii) Filler bin.
   iii) Water and emulsion tanks.
   iv) Additive tanks.
   v) Conveyor to fill aggregates and filler to the mixer box.
   vi) Pump to supply emulsion/water.
   vii) Mixer box.
   viii) Spreader box to place the mix on the surface.
h) The calibration of the slurry seal machine shall be carried out in the presence of the Engineer.
i) The proportion of the constituents and mix consistency shall be verified by taking 2 kg of sample of the slurry seal mix.
j) The procedure for calibration and verification shall be done as given in Appendix 7 of IRC: SP-81.
k) The surface shall be pre-wetted by fogging ahead of the spreader box, if required during hot weather.
l) The rate of application of the mix shall be adjusted to during the day to suit the temperature, surface texture and humidity.
m) The mixer shall be continuously agitated by means of twin shafted paddles or spiral augers fixed in the spreader box.
n) Overloading of the spreader box shall be avoided.
o) Streaking, caused by oversize of particles, shall be corrected immediately with fresh mix.
p) Longitudinal joints shall correspond with the edges of existing traffic lanes.
q) Longitudinal joints common to two traffic lanes shall be butt joints with overlap not exceeding 60 to 100 mm.
r) Rate of application of slurry seal shall be as per table 2300-22 above (Ref: Table 500-25 of MoRTH Specification).
s) Rolling is not required for slurry seal. If required, it shall be done with a pneumatic tyred roller (PTR) as soon as the slurry is set.
t) The normal setting time of slurry seal is 4 hours. Traffic shall be allowed only thereafter. Speed shall be restricted to 20 km per hour for the initial 12 hours.

2312.4 Quality Control

a) The surface finish of construction shall meet the requirements of Clause 2202 (Clause 902 of MoRTH Specifications).

b) Control on the materials and paving shall be done as given in table 2300-28 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-28: *Quality control tests for slurry seal/micro-surfacing.*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Quality of emulsion	IS: 8887	One test per lot of 20 tonnes.
2	Aggregate moisture	IS: 2386 Part 3	Two tests at site per day.
3	Water absorption	IS: 2386 Part 3	One test for each source/site.
4	Soundness	IS: 2386 Part 5	One test for each source/site.
5	Sand equivalent	IS: 2720 Part 37	One test for each source/site.
6	Binder content	ASTM D 2172	Two tests per lane/km.
7	Aggregate grading	IS: 2386 Part 1	Two tests at site per day.
8	Calibration of machine	-	Once per project.
9	Quantity of slurry (By weight of aggregate)	-	Daily (Travel time of machine).

2313 MICRO-SURFACING

Micro-surfacing is provided for surface treatment of pavements in accordance with the procedure given in Clause 514 of MoRTH Specifications.

The micro-surfacing is applied to an existing pavement surface which is structurally sound but the surface showing signs of premature ageing, aggregate loss, cracking, higher degree of polishing. The types of micro-surfacing and rates of application are given in table 2300-29 (Ref: Table 500-31 of MoRTH Specification).

Table 2300-29: *Types of micro-surfacing and rate of application*

Items	*Type II (4 to 6 mm) ***	*Type III (6 to 8 mm) ***
Application	Preventive and Renewal Treatment for roads carrying <1500 CVPD	Preventive and Renewal Treatment for roads carrying 1500 to 4500 CVPD
Quantity of mix* (kg/m^2)	8.4 to 10.8	11.1 to 16.3
Residual binder (Percentage by weight of dry aggregate)	6.5 to 10.5	5.5 to 10.5

** By weight of dry aggregate. ** Indicative only.*

2313.1 Material

2313.1.1 Bitumen

The bitumen emulsion shall be a modified bitumen emulsion conforming to requirements specified in table 2300-30 (Ref: Table 500-32 of MoRTH Specifications).

Table 2300-30: *Requirement for modified bitumen emulsion for micro-surfacing*

Property	*Code*	*Requirement*
Residue on 600 mic sieve (% by mass)	IS: 8887	0.05 (Max)
Saybolt Furol viscosity at 25°C	IS: 8887	20-100 sec
Coagulation of emulsion at low temperature	IS: 8887	Nil.
Storage stability after 24 hrs (168 hrs)	IS: 8887	2 (4) % (Max)
Particle charge	IS: 8887	+ve

Table 2300-30: *Requirement for modified bitumen emulsion for micro-surfacing (Cont…)*

Tests on residue:		
a) Residue by evaporation %	IS: 8887	60
b) Penetration at 25°C	IS: 1203	40-100
c) Ductility at 27°C	IS: 1208	50
d) Softening point in °C	IS: 1205	57
e) Elastic recovery* %	IS: 15462	50
f) Solubility in tri-chloroethylene %	IS: 1216	97

**In case the elastic recovery is tested for torsional elastic recovery as per appendix 8 of IRC: SP-81, the minimum value shall be 20%.*

2313.1.2 Aggregates

The aggregate grading similar to type II and type III slurry seal given in table 2300-24 (Ref: Table 500-27 of MoRTH Specifications) shall be used.

2313.1.3 Filler

Ordinary Portland cement (OPC) in the range of 0.5% to 2% by weight of total aggregates shall be incorporated as filler.

2313.1.4 Water

Potable water with pH value in the range 6 to 7, free from harmful salts and impurities, shall be used for mixing.

2313.1.5 Additives

Chemical additives may be used to accelerate or retard the break-set time of the mixture or to improve the resulting surface finish. The additive, if used, shall be compatible with the type of emulsion used.

2313.2 Mix requirements and design

a) The design criteria for micro surfacing mix are given in IRC: SP-81.
b) The requirements of the mix are given in table 2300-31 (Ref: Table 500-33 of MoRTH Specifications).

Table 2300-31: *Mix design criteria for micro-surfacing mix*

Property	*Method of test as given IRC: SP-81*	*Requirement*
Mix time	Appendix -1	120 sec (Min)
Consistency	Appendix - 3	3 cm (Max)
Wet cohesion, within 30 minutes	Appendix - 4	12 kg cm (Min)
Wet cohesion, within 60 minutes	Appendix - 4	20 kg cm (Min)
Wet stripping, pass %	Appendix - 5	90 (Min)
Wet track abrasion loss (One hour soak)	Appendix - 6	538 gm/m^2 (Max)

c) The set time of micro-surfacing mix shall be determined in accordance with IRC: SP-81 appendix 2.
d) The quantity of various ingredients of micro-surfacing mix shall be as given in table 2300-32 (Ref: Table 500-34 of MoRTH Specifications).

Table 2300-32: *Indicative ingredients in mix*

Ingredients	*Limits (% by weight of aggregates)*
Residual bitumen	(i) 6.5 to 10.5 for type II (ii) 5.5 to 10.5 for type III
Mineral filler	0.5 to 3.0
Additive	As needed.
Water	As needed.

2313.3 Construction

The construction procedures are similar to that of slurry seal paving explained under Clause 2312.3. The micro- surfacing requires about 2 hours to set. Traffic over the completed layer shall be allowed after this period, restricting the speed to 20 km per hour for the next 12 hours.

2313.4 Quality Control

The control on the quality of material, work and surface finish are carried out as in the case of slurry seal given under Clause 2312.4 above.

2314 BITUMINOUS CONCRETE (BC) SURFACING

Bituminous concrete surfacing is done in accordance with requirement of IRC: 29-1968. The construction of BC wearing and profile corrective courses is given in Clause 507 of MoRTH Specifications for Road and Bridge works (5th edition 2013).

2314.1 Materials

a) Paving bitumen complying with IS: 73 shall be used for designing BC mix.

b) Coarse aggregates shall be crushed rock retained on 2.36 mm sieve. The source of aggregate shall be approved only after testing for stripping. The physical requirements for coarse aggregates specified in table 2300-33 (Ref: Table 500.16 of MoRTH Specifications) shall be achieved.

Table 2300-33: *Physical requirements for coarse aggregate for BC*

Property	*Test*	*Code*	*Specification*
Cleanliness (Dust)	Grain size analysis	IS:2386 Part 1	Max.5% passing 0.075 mm sieve
Particle shape	Flakiness and elongation indices (Combined)	IS:2386 Part 1	Max 35%
Strength	Los Angeles abrasion value or aggregate impact value	IS:2386 Part 4	Max 30% Max 24%
Durability	Soundness - *Sodium sulphate*	IS:2386 Part 5	Max 12%
	Soundness - *Magnesium sulphate*	IS:2386 Part 5	Max 18%
Polishing	Polished stone value	BS: 812-114	Min 55
Porosity	Water absorption	IS: 2386 Part 3	Max 2%
Stripping	Coating and stripping of bitumen aggregate mix	IS: 6241	Retained coating 95% Min
Water sensitivity	Retained tensile strength*	AASHTO T 283	Min 80%

**If the minimum retained tensile test strength falls below 80%, use of anti-stripping agent is recommended to meet the requirement.*

c) Fine aggregates shall consist of crushed or naturally occurring mineral material or a combination of the two passing IS 2.36 mm sieve and retained on 75 micron. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious impurities.

d) The fine aggregate shall have a sand equivalent value of not less than 50 when tested as per IS: 2720 (Part 37). The plasticity index of the fraction passing

0.425 mm sieve shall not exceed 4, when tested in accordance with IS: 2720 (Part 5).

e) Filler shall be finely divided mineral matter such as rock dust, hydrated lime or cement as approved by the Engineer. When the aggregates fail to meet the water sensitively test, then 2% hydrated lime by weight of aggregate shall be added without any additional payment.

f) The combined aggregate grading shall be tested by wet sieving method as per IS: 2386 Part I. The combined grading shall be within the limits specified in table 2300-34 (Ref: Table 500-17 of MoRTH Specifications).

Table 2300-34: *Composition of bituminous concrete mix*

Grading	*1*	*2*
Nominal maximum aggregate size*	19 mm	13.2 mm
Layer thickness	50 mm	30-40 mm
IS Sieve[1](mm)	Cumulative % by weight of total aggregate passing	
45	-	-
37.5	-	-
26.5	100	-
19	90-100	100
13.2	59-79	90-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-3	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	Min 5.2**	Min 5.4**

**The nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate is retained.*

***Corresponds to specific gravity of the aggregate being 2.7. In case aggregates have specific gravity more than 2.7, the minimum bitumen content can be reduced proportionately. Further, for regions where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is -10°C or lower, the bitumen content may be increased by 0.5%.*

2314.2 Bituminous concrete mix requirement

a) The BC mix shall meet the requirements stipulated for dense graded bituminous macadam (DBM) in table 2300-9 (Ref: Table 500-11 of MoRTH Specifications).

b) The minimum percentage of air voids in mineral aggregate (VMA) conditions shall be satisfied for the selected nominal maximum size of aggregates (Table 2300-10).

c) Binder content shall be optimised to achieve the requirements specified for the bituminous mix, and the traffic volume of the road.

2314.3 Job mix formula

a) The job mix formula proposed for the work shall be given in writing at least 30 days before the start of the work and got approved by the Engineer.

b) The job mix shall be approved only after independent testing by the Engineer using the same materials proposed for the work.
c) The job mix formula shall be changed by repeat tests, if the source of the material or the properties changes.

2314.4 Plant and field trials

a) After the job mix formula is approved, the Contractor shall carry out plant trials to set the plant for producing a uniform mix conforming to the specification requirements.
b) The variations in quantities of the ingredients shall not exceed the prescribed limits given in table 2300-35 (Ref: Table 500-18 of MoRTH Specifications).

Table 2300-35: *Permissible variations in plant mix from the job mix formula*

Description	*Permissible variation*
Aggregate passing 19 mm sieve or larger	± 7%
Aggregate passing 13.2 mm, 9.5 mm	± 6%
Aggregate passing 4.75 mm	± 5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	± 4%
Aggregate passing 0.3 mm, 0.15 mm	± 3%
Aggregate passing 0.075 mm	±1.5%
Binder content	±0.3%
Mixing temperature	±10°C

c) Once the plant trials are successful, field trials shall be carried out, to demonstrate that the mix can be properly laid and compacted to satisfy the requirements stipulated.
d) Fielding trials shall be preferably done on an area outside the project road.
e) Once the plant and field trials are approved, the same methodology shall be followed for laying the mix in the project road.

2314.5 Construction

a) Laying shall be suspended during rain, fog and dust storms or if free standing water is present on the surface.
b) Bituminous work shall not be carried out if the temperature of the surface to be laid is below 10°C.
c) The surface on which the mix to be placed shall be cleaned by means of a mechanical broom. Then a high pressure air compressor shall be used to remove any dust or loose matters.
d) If a crack prevention layer is specified, it shall be provided in accordance with the requirement of Clause 522 of MoRTH Specification.
e) Tack coat shall be provided as specified. If the layer to receive the mix is a freshly laid bituminous layer not contaminated by dust, tack coat is not mandatory when overlay is done within two days.
f) All bituminous premixes shall be prepared in a properly calibrated hot mix plant of adequate capacity and capable of delivering a uniform mix with thoroughly coated aggregates.
g) The temperature requirement for bituminous mixes shall be as given in table 2300-36 (Table 500-2 of MoRTH Specifications).
h) The difference in temperature between the binder and the aggregate should at no time exceed 14°C.
i) If the plant used is continuous type, the combined grading of the cold feed aggregate mix shall be within the grading limits approved for the mix.

Table 2300-36: *Temperature requirements for bituminous mixes in °C*

Bitumen Grade	*Bitumen*	*Aggregate*	*Mix*	*Laying*	**Rolling*
VG -40	160-170	160-150	160-170	150 Min	100 Min
VG -30	150-165	150-170	150-165	140 Min	90 Min
VG -20	145-165	145-170	145-165	135 Min	85 Min
VG -10	140-160	140-165	140-160	130 Min	80 Min

**Rolling must be completed before the mat cools to these minimum temperatures.*

j) The binder content shall be based on the combined grading including filler.

k) The mix from the hot mix plant shall be transported to the site in clean insulated trucks. The trucks shall be covered with water proof covers during transport and waiting for tipping.

l) A thin coating of diesel or lubricating oil may be allowed to be applied to the interior of the truck to prevent sticking of the bituminous mix.

2314.6 Spreading and compaction

a) Spreading of the bituminous mix shall be carried out using a self-propelled sensor paver.

b) In restricted areas where mechanical paver cannot find access, manual spreading using experienced persons can be allowed.

c) The rate of travel of paver shall be adjusted by site trials to yield a uniform layer to the full width of the screed, free from dragging, tearing and segregation of the mix.

d) Paving shall be stopped 300 mm before expansion joints of structures and resume 300 mm after the joint. The 600 mm left unpaved shall be kept clean free of any paving materials and other matters.

e) Bituminous mix with temperature more than 145°C shall not be placed over a bridge deck unless approved heat damage measures are taken.

f) Hand placing of bituminous mix is allowed for laying courses of varying thickness or shape, in confined spaces or footways, approaches to expansion joints of structures, filling potholes etc as directed by the Engineer.

g) The bituminous mix shall be kept clean and uncontaminated. If the mix gets contaminated due to some reason, the same shall be made good.

h) The base or binder course layer shall not be left uncovered for more than 3 days or as specified in the contract. If not covered in 3 days time due to valid reasons, a tack coat shall be provided before placing the wearing course.

i) The compaction of the bituminous mix shall commence immediately after laying.

j) The process of compaction should be completed before the rolling temperature falls below the stipulated value. Rolling of longitudinal joints shall be done first. After this, rolling shall start from the edge towards the centre. In super elevated portion, the rolling should proceed from the inner edge to the outer. Before the initial rolling is commenced, all deficiencies on the surface spread shall be made good by the workers assisting paving.

k) The initial or breakdown rolling is done with 8-10 tonnes dead weight smooth wheeled rollers. The intermediate rolling shall be done with 8-10 tonnes vibrating rollers or pneumatic tyre roller (PTR) of 12-15 tonnes weight with nine wheels with a minimum tyre pressure of 5.6 kg/cm^2.

l) Final or finish rolling shall be done with 6 to 8 tonnes smooth wheeled tandem rollers.

m) The number of pass required for each roller to achieve the designed density is determined by site trials, the speed of the roller shall not exceed 5 km per hour.

n) The roller shall not be permitted to stand on pavement not fully compacted or freshly completed. The wheels of the roller shall be kept moist with water by a spray system attached to the roller. Use of excess water for this shall be prevented.

o) Necessary precaution shall be taken to prevent dropping of oil, grease, fuel oil or other foreign matters on the pavement layer while the rollers are operating or standing.

p) The longitudinal joints in the bituminous premix layers shall be fully compacted in one the following ways:

i) By heating the joint for a minimum of 75 mm width with an approved joint heater but without cutting back or coating with binder.

ii) By using two or more pavers simultaneously for paving the adjacent lanes.

iii) By cutting back the loose material in a vertical face for a distance equal to the specified thickness clearing all loose materials painting the verticals cut face with an approved hot binder before paving the adjacent layer.

q) The newly laid bituminous surface shall not be open to traffic for at least 24 hours after laying and completion of compaction.

2314.7 Quality control

a) The control of alignment, level and surface regularity shall be as given in Clause 2202 (Clause 902 of MoRTH Specifications).

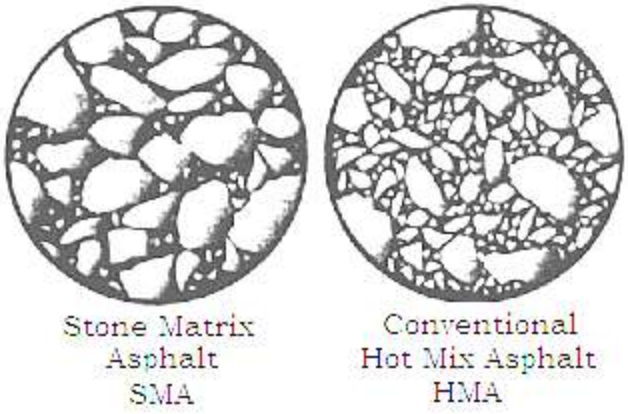
b) The control tests and their minimum frequencies for BC work shall be as given in table 2300-37 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-37: *Quality control tests for bituminous concrete (BC)*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 350 m^3.
7	Los Angeles Abrasion	IS: 2386 Part 4	One test per 350 m^3.
8	Aggregate impact	IS: 2386 Part 4	One test per 350 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Sand equivalent	IS: 2720 Part 37	One test for each source.
13	Plasticity index	IS: 2720 Part 5	One test for each source.
14	Temperature check	-	At regular intervals.
15	Binder content	ASTM D 2172	Two tests per day.
16	Mix grading	IS: 2386 Part 1	Two tests per day.
17	Marshall test	AASHTO T 245	Three tests per 400 tonnes.
18	Max sp. gravity of mix	AASHTO T 209	Three tests per 400 tonnes.
19	Volumetric analysis	MS-2	Three tests per 400 tonnes.
20	Moisture susceptibility	AASHTO T 283	One test for each mix type.
21	Layer density	-	One test per 700 m^2 area.

2315 STONE MATRIX ASPHALT

Stone Matrix Asphalt (SMA) is a tough, stable, rut-resistant mixture that relies on stone-on-stone contact to provide strength and a rich mortar binder to provide durability.



The primary advantage of SMA is the extended life compared to the conventional dense graded mixes. Other potential advantages include resistance to rutting and raveling, reduction in tyre splash and traffic noise reduction.

The cost of SMA mix has been reported to be 20-25% higher than conventional dense-graded mixes. However up to 40% additional life term is obtained and the services of a premium pavement offered to the public.

The specification for the design and construction of SMA are given under Clause 515 of MoRTH Specifications.

2315.1 Materials

2315.1.1 Coarse aggregate

The coarse aggregates shall consist of crushed rock retained on 2.36 mm sieve. The physical requirements shall be as set forth in table 2300-38 (Ref: Table 500-35 of MoRTH Specifications).

2315.1.2 Fine aggregates

a) Non-plastic, fine aggregates passing 2.36 mm sieve and retained on 75 micron sieve, of 100% crushed/manufactured sand shall be used.
b) The sand equivalent test (IS: 2720 Part 37) value shall not be less than 50.

2315.1.3 Mineral filler

a) Filler shall consist of finely divided matter such as stone dust and/or hydrated lime. Fly ash shall not be permitted for use as filler for SMA mix.
b) Grading requirements of filler shall be as stipulated in table 2300-39 (Ref: Table 500-36 of MoRTH Specifications).

Table 2300-38: *Physical requirements of aggregates for SMA*

Property	*Test*	*Code*	*Specification*
Cleanliness	Grain size analysis	IS: 2386 (Part 1)	<2% passing 0.075 mm sieve
Particle shape	Flakiness and elongation indices (Combined)	IS: 2386 (Part 1)	<30%
Strength	Los Angeles abrasion value	IS: 2386 (Part 4)	<25%
	Aggregate impact value	IS: 2386 (Part 4)	<18%
Polishing*	Polished stone value	BS: 812-114	>55%
Durability	Soundness	Either sodium or magnesium (5 Cycles)	
	Sodium sulphate	IS: 2386 (Part 5)	<12%
	Magnesium sulphate	IS: 2386 (Part 5)	<18%
Water absorption	Water absorption	IS: 2386 (Part 3)	<2%

**Polishing requirement does not apply when the coarse aggregate is used for intermediate (binder) course.*

Table 2300-39: *Grading requirements of filler for SMA*

IS sieve (mm)	*Cumulative % passing by weight of total aggregate*
0.600	100
0.300	95-100
0.075	85-100

2315.1.4 Stabiliser additive

a) Only palletized cellulose fibre shall be utilised.
b) The dosage rate for celluloses fibres is 0.3% minimum by weight of the total mix.
c) The dosage shall be confirmed so that the bitumen drain down does not exceed 0.3% when the designed mix is tested in accordance with ASTM D 6390.
d) The cellulose fibre shall meet the requirements indicated in table 2300-40.

Table 2300-40: *Requirements for cellulose fibre for SMA.*

Maximum fibre length	8 mm
Ash content	Max. of 20% non-volatile
Oil absorption	More than 4 times of fibre weight
Moisture content	Less than 5% by weight

2315.2 Aggregate grading

The combined grading of the coarse aggregate, fine aggregate and mineral filler shall be within the limits specified in table 2300-41 (Ref: Table 500-37 of MoRTH Specifications).

Table 2300-41: *Grading requirements of stone matrix asphalt*

SMA designation	*13 mm SMA*	*19 mm SMA*
Course where used:	Wearing course	Binder (Intermediate) course
Nominal aggregate size:	13 mm	19 mm
IS sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
26.5	-	100
19	100	90-100
13.2	90-100	45-70
9.5	50-75	25-60
4.75	20-28	20-28
2.36	16-24	16-24
1.18	13-21	13-21
0.600	12-18	12-18
0.300	10-20	10-20
0.075	8-12	8-12

2315.3 Mix requirements

a) The SMA mix shall be designed using AASHTO MP8 - Standard Specification for designing Stone Matrix Asphalt and AASHTO PP41 - Standard Practice for designing SMA.
b) Compaction of the mix shall be carried with 50 blows on each side using Marshall Method given in Asphalt Institute Manual MS-2.

c) The design mix shall meet the requirements given in table 2300-42 (Ref: Table 500-38 of MoRTH Specifications).

Table 2300-42: *SMA mix requirements*

Mix design parameters	*Requirement*
Air void content %	4.0
Bitumen content %	5.8
Celluloid fibres	0.3% minimum by weight of total mix.
Voids in mineral aggregate (VMA) %	17 min.
Voids in coarse aggregates (VCA) mix %	Less than VCA (Dry rodded)
Bitumen drain down % ASTM D 6390 (Annexure C of IRC: SP: 79)	0.3% (Max)
Tensile strength ratio (TSR) % AASHTO T 283 (Annexure E of IRC: SP: 79)	85% (Min)

2315.4 Mix Design

The five steps required to obtain a satisfactory SMA mix are given below.

a) Select proper aggregate materials.
b) Determine an aggregate grading which will yield stone-on-stone contact.
c) Ensure that the selected grading meets the minimum VMA requirement and allows the use of minimum binder content.
d) Select bitumen content which will provide the desired air voids in the mix.
e) Evaluate the moisture susceptibility and bitumen drain down sensitivity.

2315.5 SMA mix production

a) SMA mix shall be prepared in a hot mix plant of adequate capacity capable of producing a mix of uniform quality with thoroughly coated aggregate.
b) The mix temperature shall be as recommended by the manufacturer where modified bitumen is used. If viscosity grade bitumen is used, the mix temperature shall be from 150°C to 165°C.
c) Mineral filler shall be incorporated properly. Provisions to incorporate the mineral filler at a uniform rate shall be made.
d) In batch plants, the fibre additive shall be directly weighed into the hopper above the pug mill.
e) Adequate mixing time is required to disperse the fibre uniformly though out the hot aggregate.
f) In drum mix plant, fibre addition is carried out through separate feeding system. The rate of addition shall be controlled to meet the requirement for a normal production of the mix. However, no wastage of fibre into the bag house should occur.

2315.6 Construction

a) The existing bituminous surface shall be cleaned of all loose extraneous matter by means of mechanical broom and high pressure air jet.
b) All pot holes and cracks shall be repaired and sealed.
c) Tack shall be provided on the cleaned surface as per Clause 503 of MoRTH Specifications.
d) Transportation of the mix shall be carried out as prescribed in Clause 501.4 of MoRTH Specifications.
e) Regarding weather and seasonal limitations, the Clause 501.5.1 of MoRTH specifications shall be followed in carrying out bituminous paving.

f) The spreading of SMA mix shall be carried out in accordance with Clause 501.5.3 of MoRTH Specifications.
g) Compaction shall be as per Clause 501.6 except that pneumatic roller shall not be used for compacting SMA layer.
h) Joints shall be prepared as per Clause 501.7 of MoRTH Specifications.
i) No traffic shall be allowed over the SMA layer till the mat cools down to the ambient temperature.

2315.7 Density and levels of the compacted layer

a) Cores of 150 mm dia shall be taken from the compacted mat for determining the percentage compaction.
b) The density of the finished layer shall not be less than 94% of the theoretical maximum specific gravity (G_{mm}) of the loose mix obtained on that day tested in accordance with ASTM D 2041. That means not more than 6% air voids shall be allowed in the compacted SMA layer.

2315.8 Quality control

a) The control of alignment, level and surface regularity shall be as given in Clause 902 of MoRTH Specifications.
b) The control tests and the minimum frequencies for bituminous concrete work shall be as given in table 2300-43 (Ref: Table 900-4 of MoRTH Specifications).

Table 2300-43: *Quality control tests for SMA*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 100 m^3.
7	Los Angeles Abrasion	IS: 2386 Part 4	One test per 100 m^3.
8	Aggregate Impact	IS: 2386 Part 4	One test per 100 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Sand equivalent	IS: 2720 Part 37	One test for each source.
13	Plasticity index	IS: 2720 Part 5	One test for each source.
14	Temperature check	-	At regular intervals.
15	Binder content	ASTM D 2172	Two tests per day.
16	Mix grading	IS: 2386 Part 1	Two tests per day.
17	Marshall test	AASHTO T 245	Three tests per 400 tonnes.
18	Max sp. gravity of mix	AASHTO T 209	Three tests per 400 tonnes.
19	Volumetric analysis	MS-2	Three tests per 400 tonnes.
20	Moisture susceptibility	AASHTO T 283	One test for each mix.
21	Layer density		One test per 250 m^2 area.

2316 SEMI-DENSE BITUMINOUS CONCRETE

The specifications for SDBC are more or less similar to dense bituminous macadam (DBM). This item is not included in the 5th revision published in 2013. Hence for the detailed specifications and construction procedures of Semi-dense Bituminous Concrete (SDBC) wearing and profile corrective courses (PCC) Clause 508 of MoRTH Specifications for Road and Bridge works (4th revision 2001) shall be referred.

2316.1 Materials

a) Paving bitumen complying with IS: 73 shall be used for designing SDBC mix.

b) Coarse aggregates shall be crushed rock retained on 2.36 mm sieve. The source of aggregate shall be approved only after testing for stripping. The physical requirements for coarse aggregates are specified in table 2300-44 (Ref: Table 500-14 of MoRTH Specifications - 4th revision).

Table 2300-44: *Physical requirements for coarse aggregate for SDBC*

Property	*Test*	*Code*	*Specification*
Cleanliness (dust)	Grain size analysis	IS:2386 Part 1	Max.5% passing 0.075 mm sieve
Particle shape	Combined flakiness and elongation indices	IS:2386 Part 1	Max 30%
Strength	Los Angeles abrasion value† or Aggregate impact value†	IS:2386 Part 4	Max 30% Max 27%
Durability	Soundness - *Sodium sulphate*	IS:2386 Part 5	Max 12%
	Soundness - *Magnesium sulphate*	IS:2386 Part 5	Max 18%
Polishing	Polished stone value	BS: 812-114	Min 55
Porosity	Water absorption	IS: 2386 Part 3	Max 2%
Stripping	Coating and stripping of bitumen aggregate mix*	IS: 6241	Retained coating 95% Min
Water sensitivity	Retained tensile strength**	AASHTO T 283	Min 80%

†*The aggregate may satisfy one of the requirements.*

**If the minimum coating retained is ≥95%, the water sensitivity test need not be carried out.*

***If the minimum retained tensile strength falls below 80%, use of anti-stripping agent is recommended to meet the requirement.*

c) The requirement of minimum % air voids in the mineral aggregate mix (VMA) shall be as stipulated in table 2300-45 (Ref: Table 500-12 of MoRTH Specifications – 4th revision).

Table 2300-45: *Minimum percentage voids in mineral aggregate (VMA)*

Nominal maximum particles size (mm)*	***Minimum VMA % related to design % air voids of the mix*		
	3.0	*4.0*	*5.0*
9.5	14.0	15.0	16.0
12.5	13.0	14.0	15.0
19.0	12.0	13.0	14.0
25.0	11.0	12.0	13.0
37.5	10.0	11.0	12.0

**The nominal maximum particle size is one size larger than the first sieve to retain more than 10%.*

***For intermediate values air voids in the design mix, interpolate the value of VMA given in the table.*

d) Fine aggregates shall consist of crushed or naturally occurring mineral material or a combination of the two, passing IS 2.36 mm sieve and retained on 75

micron. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious impurities.

e) The fine aggregate shall have a sand equivalent value of not less than 50 when tested as per IS: 2720 (Part 37). The plasticity index of the fraction passing 0.425 mm sieve shall not exceed 4, when tested in accordance with IS: 2720 (Part 5).

f) Filler shall be finely divided mineral matter such as rock dust, hydrated lime or cement as approved by the Engineer.

g) The combined aggregate grading shall be tested by wet sieving method as per IS: 2386 (Part 1). The combined grading, with filler added, shall be within the limits specified in table 2300-46 (Ref: Table 500-15 of MoRTH Specifications - 4th revision).

Table 2300-46: *Composition of SDBC mix*

**Grading*	*1*	*2*
Nominal maximum aggregate size:	13 mm	10 mm
Layer thickness:	35-40 mm	25-30 mm
IS sieve (mm)	Cumulative % by weight of total aggregate passing	
19.0	100	-
13.2	90-100	100
9.5	70-90	90-100
4.75	35-51	35-51
2.36	24-39	24-39
1.18	15-30	15-30
0.300	9-19	9-19
0.075	3-8	4-10
Bitumen content % by mass of total mix	Min 4.5**	Min 5.0**

**The combined aggregate grading shall not vary from the low limit on one sieve to the high limit on the adjacent side.*

***Determined by Marshall method.*

h) When the aggregates fail to meet the water sensitivity test, then 2% hydrated lime by weight of aggregate shall be added without any additional payment.

2316.2 Mix requirements

a) The semi-dense bituminous concrete mix shall meet the requirements stipulated in table 2300-47 (Ref: Table 500-16 of MoRTH Specifications-4th revision).

Table 2300-47: *Mix requirements for SDBC*

Mix parameter	*Requirement*
Marshall Stability (kN at 60°C)	2.0 (Min)
Marshall Flow (mm)	2-4
Compaction level (Blows)	75 on each face
Air voids in the mix (%)	3-5
Voids in the mineral aggregate (VMA)	Table 2300-45
Percentage voids filled with bitumen (VFB)	65-75

b) The minimum percentage of air voids in mineral aggregate (VMA) conditions shall be satisfied for the selected nominal maximum size of aggregates.

c) Binder content shall be optimised to achieve the requirements specified for the bituminous mix, and the traffic volume of the road.

2316.3 Job mix formula

a) The job mix formula proposed for the work, satisfying the mix requirements given in table 2300-47 above, shall be given in writing atleast 30 days before the start of the work and got approved by the Engineer.
b) The job mix shall be approved only after independent testing by the Engineer using the same materials proposed for the work.
c) The job mix formula shall be changed by repeat tests, if the source of the material or the properties of the mix constituents change.

2316.4 Plant and field trials

a) After the job mix formula is approved, the contractor shall carry out plant trials to set the plant for producing a uniform mix conforming to the specification requirements.
b) The variations in quantities of the ingredients from the approved job mix formula shall not exceed the prescribed limits given in table 2300-48 (Ref: Table 500-13 of MoRTH Specifications-4th revision).

Table 2300-48: *Permissible variations in plant mix from the job mix formula*

Description	*Permissible variation*	
	Base/ binder course	*Wearing course*
Aggregate passing 19 mm sieve or larger	±8%	±7%
Aggregate passing 13.2 mm, 9.5 mm	±7%	±6%
Aggregate passing 4.75 mm	±6%	±5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	±5%	±4%
Aggregate passing 0.3 mm, 0.15 mm	±4%	±3%
Aggregate passing 0.075 mm	±2%	±1.5%
Binder content	±0.3%	±0.3%
Mixing temperature	±10°C	±10°C

c) Once the plant trials are successful, field trials shall be carried out, to demonstrate that the mix can be properly laid and compacted to satisfy the requirements stipulated. The trial section area shall be 100 m^2 minimum, in conditions similar to the project road.
d) Field trials shall be preferably done on an area outside the project road.
e) Once the plant and field trials are approved, the same methodology shall be followed for laying the mix in the project road.

2316.5 Construction

a) Laying shall be suspended during rain, fog and dust storms or if free standing water is present on the surface.
b) Bituminous work shall not be carried out if the temperature of the surface to be laid is below 10°C.
c) The surface on which the mix to be placed shall be cleaned by means of a mechanical broom. Then a high pressure air compressor shall be used to remove any dust or loose matters.
d) If a crack prevention layer is specified, it shall be provided in accordance with the requirement of Clause 517 of MoRTH Specifications.
e) Tack coat shall be provided as specified. If the layer to receive the mix is a freshly laid bituminous layer not contaminated by dust, tack coat is not mandatory when overlay is done within two days.

f) All bituminous premixes shall be prepared in a properly calibrated hot mix plant of adequate capacity and capable of delivering a uniform mix with thoroughly coated aggregates.
g) The temperature requirement for bituminous mixes shall be as given in table 2300-36 (Ref: Table 500-2 of MoRTH Specifications – 5th revision).
h) The difference in temperature between the binder and the aggregate should at no time exceed 14°C.
i) If the plant used is continuous type, the combined grading of the cold feed aggregate mix shall be within the grading limits approved for the mix.
j) The binder content shall be based on the combined grading including filler.
k) The mix from the hot mix plant shall be transported to the site in clean insulated trucks. The trucks shall be covered with water proof covers during transport and waiting for tipping.
l) A thin coating of diesel or lubricating oil may be allowed to be applied to the interior of the truck to prevent sticking of the bituminous mix.

2316.6 Spreading and compaction

a) Spreading of the bituminous mix shall be carried out using a self-propelled sensor paver.
b) In restricted areas where mechanical paver cannot find access, manual spreading using experienced persons can be allowed.
c) The rate of travel of paver shall be adjusted by site trials to yield a uniform layer to the full width of the screed, free from dragging, tearing and segregation of the mix.
d) Paving shall be stopped 300 mm before expansion joints of structures and resume 300 mm after the joint. The 600 mm left unpaved shall be kept clean free of any paving materials and other matters.
e) Bituminous mix with temperature more than 145°C shall not be placed over a bridge deck unless approved heat damage measures are taken.
f) Hand placing of bituminous mix is allowed for laying courses of varying thickness or shape, in confined spaces or footways and approaches to expansion joints of structures, filling potholes etc as directed by the Engineer.
g) The bituminous mix shall be kept clean and uncontaminated. If the mix gets contaminated due to some reason, the same shall be made good.
h) The base or binder course layer shall not be left uncovered for more than 3 days or as specified in the contract. If not covered in 3 days time due to valid reasons, a tack coat shall be provided before placing the wearing course.
i) The compaction of the bituminous mix shall commence immediately after laying.
j) The process of compaction should be completed before the rolling temperature falls below the stipulated value. Rolling of longitudinal joints shall be done first. After this, rolling shall start from the edge towards the centre. In super elevated portion, the rolling should proceed from the inner edge to the outer.
k) The initial or breakdown rolling is done with 8-10 tonnes dead weight smooth wheeled rollers. The intermediate rolling shall be done with 8-10 tonnes vibrating rollers or pneumatic tyre roller (PTR) of 12-15 tonnes weight with nine wheels with a minimum tyre pressure of 5.6 kg/cm^2.
l) Final or finish rolling shall be done with 6 to 8 tonnes smooth wheeled tandem rollers.

m) The number of pass required for each roller to achieve the designed density is determined by site trials, the speed of the roller shall not exceed 5 km per hour.

n) The roller shall not be permitted to stand on pavement not fully compacted or freshly completed. The wheels of the roller shall be kept moist with water by a spray system attached to the roller. Use of excess water for this shall be prevented.

o) Necessary precaution shall be taken to prevent dropping of oil, grease, fuel oil or other foreign matters on the pavement layer while the rollers are operating or standing.

p) The longitudinal joints in the bituminous premix layers shall be fully compacted in one the following ways:

  i) By heating the joint for a minimum of 75 mm width with an approved joint heater but without cutting back or coating with binder.

  ii) By using two or more pavers simultaneously for paving the adjacent lanes.

  iii) By cutting back the loose material in a vertical face for a distance equal to the specified thickness, clearing all loose materials and painting the vertical cut face with an approved hot binder, before paving the adjacent layer.

q) The newly laid bituminous surface shall not be open to traffic for at least 24 hours after laying and completion of compaction.

2316.7 Quality control

a) The control of alignment, level and surface regularity shall be as given in Clause 2202 (Clause 902 of MoRTH Specifications).

b) The QC tests and their minimum frequencies for SDBC work shall be carried out as given in table 2300-49.

Table 2300-49: *Control tests for SDBC*

Sl. No.	*Test prescribed*	*Code*	*Minimum test frequency*
1	Viscosity of binder	IS: 73, IS: 15462	One test for each supply.
2	Ductility	IS: 73, IS: 15462	One test for each supply.
3	Penetration	IS: 73, IS: 15462	One test for each supply.
4	Softening point	IS: 73, IS: 15462	One test for each supply.
5	Grain size analysis	IS: 2386 Part 1	Two tests per day.
6	Flakiness & elongation	IS: 2386 Part 1	One test per 350 m^3
7	Los Angeles abrasion	IS: 2386 Part 4	One test per 350 m^3.
8	Aggregate impact	IS: 2386 Part 4	One test per 350 m^3.
9	Water absorption	IS: 2386 Part 3	One test for each source.
10	Stripping	IS: 6241	One test for each source.
11	Soundness	IS: 2386 Part 5	One test for each source.
12	Sand equivalent	IS: 2720 Part 37	One test for each source.
13	Plasticity index	IS: 2720 Part 5	One test for each source.
14	Temperature check	-	At regular intervals.
15	Binder content	ASTM D 2172	Two tests per day.
16	Mix grading	IS: 2386 Part 1	Two tests per day.
17	Marshall test	AASHTO T 245	Three tests per 400 tonnes.
18	Max sp. gravity of mix	AASHTO T 209	Three tests per 400 tonnes.
19	Volumetric analysis	MS-2	Three tests per 400 tonnes.
20	Moisture susceptibility	AASHTO T 283	One test for each mix.
21	Layer density		One test per 700 m^2 area.

2317 REFERENCES

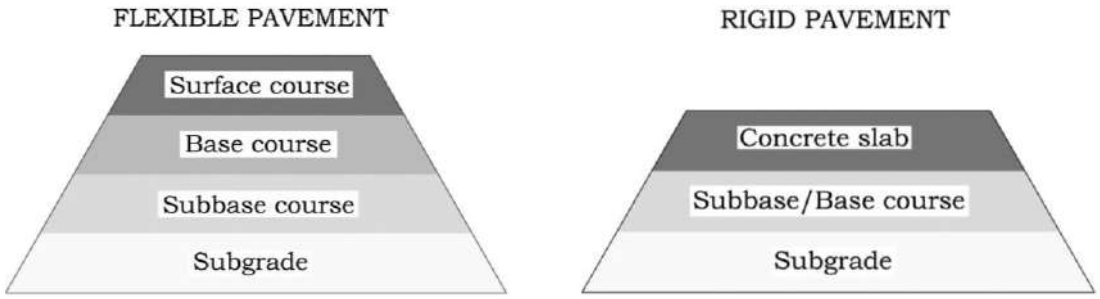
1. MoRTH Specifications for Road and Bridge Works, 5th Edition 2013 - Published by IRC, New Delhi.
2. MoRTH Specifications for Road and Bridge Works, 4th Edition 2001 - Published by IRC, New Delhi.
3. MoRTH Manual for construction and supervision of bituminous works, Edition 2001 - Published by IRC, New Delhi.
4. IRC SP: 11 Quality Control for the Construction of Roads and Runways - Published by IRC, New Delhi.
5. MS-2 Marshall method of mix design for asphalt concrete and other hot mix types – Asphalt Institute Manual Series No. 2 (MS-2) - Published by Asphalt Institute (USA).

+++++++

SECTION 2400 CEMENT CONCRETE PAVEMENT

2401 GENERAL

Concrete pavement comes under the classification of rigid pavement. The life of a rigid pavement is much higher than that of a flexible pavement.



Even though the cost of rigid pavement is very high, owing to its longer service life, better riding surface and low maintenance cost, rigid pavements are widely used in the present road construction. The details and construction procedure for un-reinforced, dowel jointed plain cement concrete pavement are given under Section 600 of MoRTH Specifications for Road and Bridge works (5th revision).

2402 MATERIALS

a) Only materials from approved sources shall be allowed to be used in the construction.
b) Cement used shall be preferably 43 grade or higher.
c) Admixtures, if used, shall be checked for its performance through laboratory and field trials.
d) Aggregates shall conform to IS: 383 with maximum Los Angeles Abrasion value of 35%.
e) The maximum size of coarse aggregate shall be 25 mm for pavement concrete. The water absorption shall not exceed 2%.
f) The fine aggregate shall conform to IS: 383 with fraction passing 75 micron sieve not exceeding 4%.
g) Water for mixing shall meet the requirement stipulated in IS: 456.
h) The dowel bars shall conform to IS: 432 Grade I and tie bars to IS: 1786 and of Fe500 Grade or plain bars conforming to IS: 432 Grade I.

2402.1 Joint materials

a) Joint filler board to be provided at expansion joints shall comply with the requirement of IS: 1838.
b) The joint sealing compound shall be of hot poured elastomeric type or cold polysulphide/polyurethane/silicone type as per IRC: 57.

2402.2 Storage of materials

a) The materials for concrete shall be stored properly.
b) Aggregates of different sizes shall be stored in partitioned grade yards.
c) The stacking platform shall be prepared with compacted GSB material 150 mm thick, with sufficient slope for draining rain water.

2403 MIX DESIGN

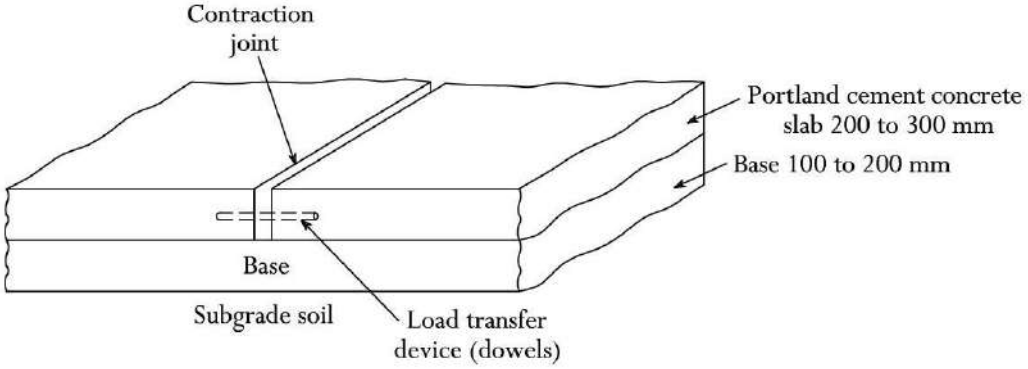
a) The mix design for pavement concrete shall be prepared as per IS: 10262 - Recommended guidelines for concrete mix design. Guidance in this can also be obtained from IS: SP: 23- Hand book on concrete mixes. The mix design shall be based on flexural strength of the concrete.
b) The cement content shall not be less than 350 kg per m^3 of concrete, but in no case shall exceed 425 kg.
c) The maximum free water cement ratio shall be 0.50.
d) The control of workability in the field shall be exercised by slump test as per IS: 1199. A slump of 30 mm to 15 mm is reasonable for paving.

2404 PREPARATION OF SUBBASE

a) The pavement quality concrete shall be placed over a subbase prepared with dry lean concrete.
b) Cracks exceeding 10 mm if found on the subbase concrete layer shall be repaired with fine cement concrete or bituminous concrete.
c) Separation membrane of 125 micron impermeable plastic sheets shall be nailed to the lower layer with concrete nails.

2405 CONSTRUCTION JOINTS

a) Joints shall be cut to full depth using sawing machine after the concrete has hardened.
b) Longitudinal and transverse joints in the subbase shall be staggered so that they are at least 1 m and 0.30 m apart.
c) Contraction joints are mechanical sawn joints grooves 3 mm to 5 mm wide extending to one-fourth to one-third depth of the slab.
d) The expansion joints shall consist of joint filler board and dowel bars.
e) Transverse construction joints are made wherever concreting is completed after a day's work or work suspended for more than 30 minutes.



f) Longitudinal joints shall be saw cut at least one-third depth of the slab.
g) The tie bars at longitudinal joints shall be placed correctly.
h) The dowel bars shall be positioned at mid-depth of the slab, aligned parallel to the surface of the slab and to the centre line of the carriage way, unless otherwise specified in the Drawing.
i) The dowel bars supported on cradles in assemblies shall be checked for deflection and shall be within limits given under Clause 602.6.5.2 of MoRTH Specifications mentioned below:
    i) All bars in joint shall be within ±2 mm per 300 mm length.

ii) Two-third of the total bars shall be within ±3 mm per 500 mm length.
iii) No bar shall differ in alignment from an adjoining bar by more than 300 mm length of bar in either the horizontal or vertical plane.
iv) Cradles supporting the dowel bar shall not extend across the line of joint.

j) For bars inserted using a dowel bar inserter, the tolerance for alignment may be twice as indicated above.
k) The dowel bars shall be covered by a thin plastic sheath to the specified length.
l) Transverse joints at curves shall be radial in the direction of the radius.

2406 WEATHER

a) When concreting is done in rainy season, sufficient supply of tarpaulin or water proof cloth shall be kept along the line of work.
b) Any concrete damaged by rain shall be removed and replaced.
c) No concreting shall be done if the concrete temperature is above 30°C.

2407 FORMS

a) All side forms shall be of mild steel of depth equal to the thickness of the pavement layer. The form shall not be removed for at least 12 hours after the paving is completed.
b) Sufficient length of forms shall be set in advance to ensure uninterrupted paving for 2 days.
c) When slip form paving is used, a guide wire shall be provided along both sides of the slab.
d) The stakes supporting the guidewires, through connectors shall be spaced 5 m to 6 m apart. On curves, stakes shall be spaced at not more than 3 m centre-to centre.
e) The line and levels of the stakes and connectors shall be made available on the previous day of paving for checking and effecting any corrections required.

2408 MIXING AND PLACING OF CONCRETE

a) The concrete mixing shall be carried out in a central batching plant provided with automatic controls.
b) The speed of mixing and placing of concrete shall be controlled to ensure proper finishing, protection and curing of the concrete placed.
c) The surface of the slab shall be brush-textured in a direction at right angles to the longitudinal axis of the carriage way.

2409 CURING

a) Immediately after texturing, the surface and sides of the slab shall be cured by applying approved curing compound by mechanical sprayers.
b) After 3 hours, the surface shall be covered with moist hessian and kept damp for 14 days.

2410 METHOD STATEMENT

a) A method statement for carrying out the concrete paving shall be prepared and got approved by the Engineer before commencement of the work.

b) A trial length of at least 60 m shall be constructed one month in advance of the proposed start of concrete paving work.
c) The trial section shall be prepared away from the carriage way but with at least a subbase layer below it.

2411 QUALITY CONTROL

a) The surface levels and regularities shall be checked for compliance with respect to Clause 902.3 and 902.4 of MoRTH Specifications (5th revision).
b) Density of the paved layer shall be assessed from at least 3 cores from each part of the trial section.
c) No vehicular traffic is allowed to run on the finished surface of a concrete pavement within a period of 28 days of its construction and until the joints are permanently sealed.

2411.1 Rectification of deficiencies

a) Appropriate deduction in the rate shall be effected for deficiencies in thickness of the layer.
b) If the deficiency is of average thickness more than 10 mm, the areas deficient by more than 10 mm is identified by coring, removed and reconstructed by the contractor at his cost.
c) Deficient slab identified shall be removed and reconstructed to the full depth.

2412 REFERENCES

1. MoRTH Specifications for Road and Bridge works, 5th Edition 2013 - published by IRC, New Delhi.
2. IRC-SP: 11 Quality control for the construction of roads and runways - published by IRC, New Delhi.
3. IS-SP: 23 Hand book on concrete mixes – published by Bureau of Indian Standards.

+++++++

SECTION 2500 MAINTENANCE OF ROAD

2501 GENERAL

Life of a pavement system can be improved by timely and proper maintenance. Reconstruction of the pavement becomes inevitable, if timely maintenance is not carried out. This section covers the different types of surface and layer failures noticed on bituminous surfaces and the commonly followed remedial measures. The section also covers restoration of the eroded embankment and shoulders, repairing of concrete pavement etc.

2502 DETERIORATION OF BITUMINOUS SURFACES

A bituminous surface deteriorates with passage of time due to the following reasons:

a) Action of wheel load from vehicles on the pavement layer.
b) Ingress of water, oxidation of the binder, loss of volatiles etc.
c) Inadequate design and improper specifications and lack of quality in construction.
d) Insufficient capacity of lower pavement layers.
e) Poor drainage conditions.
f) Lack of maintenance of shoulders.

2503 CLASSIFICATION OF MAINTENANCE OF BITUMINOUS PAVEMENTS

a) *Routine maintenance*: This includes activities such as pothole patching, crack sealing, shoulder repairing etc.
b) *Periodic maintenance*: This work is carried out in every few years of time to prevent deterioration. It covers works such as applying a seal or thin resurfacing course.
c) *Rehabilitation and strengthening*: These are mostly major works to restore or upgrade the pavement. The work covers thick overlays like Bituminous Macadam (BM) or/and Bituminous Concrete (BC).

2504 EVALUATING THE NEED FOR MAINTENANCE

The need for maintenance is assessed on the basis of condition surveys carried out in the following ways:

a) *Visual rating*: The pavement surface is inspected and the severity of damages is visually assessed. The types of distress checked are rutting, raveling, pothole, amount of patching done already, cracks, edge failures etc.
b) *Roughness measurements*: The riding quality of pavement can be measured by a Bump Integrator. The roughness value in mm/km for different types of pavement surface recommended by MoRTH is indicated in table 2500-1.
c) *Deflection measurements*: Benkelman Beam Deflection (BBD) measurements are used in India for designing thickness of overlay, although the method is not precise.

   Falling Weight Deflectometer (FWD) is used to measure residual life of pavement. This is a quick and accurate test but requires some capital

investment. The trailer size equipment is attached to a wheel drive vehicle and the test results are directly entered into a computer and analysed later.

Table 2500-1: *Roughness values in mm per km recommended by MoRTH*

Type of surface	*Good*	*Average*	*Poor*	*Very poor*
Bituminous Concrete/SDBC	2000-5000	2500-3500	3500-4000	Over 4000
Premix surfacing/MSS	2500-4500	4500-5500	5500-6500	Over 6500
Surface dressing	5000-6000	5000-6500	6500-7500	Over 7500

d) *Skid resistance*: Due to continuous traffic or by bleeding of bitumen, the pavement looses its anti-skid properties. The skid resistance can be periodically measured and section which lost the anti-skid properties may be treated with a fresh bituminous surface layer.

2505 SURFACE DEFECTS AND THEIR RECTIFICATION

2505.1 Fatty surface

A fatty surface occurs when the binder in the bituminous layer moves up and collects as a film on the surface. On an asphaltic concrete surface, this indicates that air voids are reduced close to zero and possibility of rutting/corrugation is likely to happen.

The causes for a fatty surface are:

a) Poor mix design or mix production.
b) Loss of cover aggregates in surface dressing.
c) Non-uniform spreading of cover aggregates in surface dressing.
d) Excessive application of binder.
e) Poor quality of aggregates resulting to its breaking down and loss.
f) Smaller particles in aggregates getting covered by the binder.
g) Too heavy prime or tack coat.
h) Excessive compaction of the layer.

2505.1.1 Treatment of fatty surface

a) If the bleeding is uniform, an application of cover aggregates (9 mm and down) or sand-blotting (Sand blinding) can be tried.
b) Surfacing with a thin layer of premix surfacing with lesser binder may absorb the excess binder from the layers.
c) A liquid seal coat with appropriate binder application and aggregate can be effective.
d) If bleeding occurs on an asphaltic concrete or pre-mix surface, removal and replacement is necessary.

2505.2 Smooth surface

A smooth surface has a low skid resistance value and becomes skidding when wet. Polishing of aggregates under traffic leads to this.

2505 2.1 Treatment of smooth surface

Rectification of a smooth surface is carried out by providing a surface dressing with type A seal coat or an open graded pre-mix surfacing.

2505.3 Streaking

This is appearance of alternate lean and fatty lines of bitumen usually in a longitudinal form. Streaking in surface dressing is caused by non-uniform application

of bitumen from distributors, temperature of binder being low at the time of spraying etc.

2505.3.1 Treatment of streakiness

This defect cannot be rectified by any treatments. Hence proper care shall be enforced while using mechanical sprayers or distributors for applying tack or prime coat.

2505.4 Hungry or lean surface

A hungry surface is created when the fine aggregate and bitumen between the coarse aggregates is lost. Hungry surface is prone to "raveling" where the aggregates are picked by traffic, which leads to formation of pot holes.

The hungry surface may be caused by the following reasons:

a) Use of insufficient binder in the mix.
b) Aggregates with higher value of absorption used in the layer.
c) Oxidisation bitumen on an old surface which takes off the aggregate by the action of traffic.
d) Error in mixing procedure.

2505.4.1 Treatment of hungry surfaces

Surface dressing/pre-mix surfacing is the remedial measure for a hungry surface. A slurry seal of 2 mm to 5 mm thickness is an alternative.

2506 CRACKS ON THE PAVEMENT SURFACE

2506.1 Hair-line Cracks

Hair-line cracks appear as short and fine cracks at close intervals on the surface. Cracks can be observed by inspection on foot. Hair-line cracks are caused by:

a) Insufficient bitumen content.
b) Excessive fines on the surfaces.
c) Compaction when the mix is too hot.
d) Over compaction when the supporting layer is unstable.

2506.1.1 Prevention of cracks

If the steel drums or wheels of the rollers are cold, hair-line cracking can be noticed on a newly laid surface during initial rolling. These cracks normally closed when pneumatic tyred roller (PTR) is used for intermediate rolling. If cracks are visible after paving is completed, the design of the mix and paving techniques needs to be reviewed.

2506.2 Alligator cracks

These appear as interconnected cracks forming a series of regular small blocks up to 100 mm size. Alligator cracks are caused due to following reasons:

a) Excessive deflection of the pavement layer due to week sub grade or subbase layer below.
b) Excessive and overloading of the layer or inadequate pavement thickness.
c) Ageing of the binder may lead to fine cracks of the alligator pattern. Initial over heating of the binder may also cause alligator cracks. Such cracks are also called as 'Crazing'.

Alligator cracks can be taken as a sign of base failure. The remedial measures are based on the level of failure or distress. Detailed investigations are necessary.

2506.3 Longitudinal cracks

These cracks appear mostly in a straight line either at the joint between pavement and shoulder or between adjoining lanes. Longitudinal cracks are caused if:

a) The joint between the adjoining lanes is weak.

b) The joints in the layer beneath are not staggered.
c) The joint between shoulder and pavement allow water to penetrate.
d) Poor drainage conditions exist below shoulder.
e) There is settlement of shoulder due to passing of truck over the joint.

2506.4 Edge cracks

These are formed parallel to the outer edge of the pavement within a distance of 0.3 m to 0.5 m from the edge. Some transverse cracks also appear towards the shoulder. If not sealed early, excavation and complete replacement of the area will be required.
Edge cracks are caused due to the following reasons:

a) Lack of lateral support from the shoulder.
b) Settlement or yielding of the underlying material.
c) Inadequate surface drainage.
d) Shrinkage due to drying of one of the underlying earth. The roots of trees close to the pavement edge contribute to this.
e) Presence of highly expansive soil below pavement layer.
f) Inadequate pavement width forcing vehicle to use edge of pavement often.
g) When extra widening is not provided on curves.

2506.5 Block cracking

The cracks appear in the form of blocks. Block cracks are resulting from widely spaced longitudinal cracks when associated with transverse cracking. Brittleness of binder is a major factor contributing block cracking.

2506.6 Reflection cracks

Reflection cracks are resulting from cracks and joints of the pavement layer underneath. This is mostly seen in overlays placed over cement concrete pavements or cement-soil bases. If the overlay is placed without treatment of the cracks in the existing pavement, reflection cracks can occur. When a pavement is widened and the entire pavement is resurfaced, reflection cracks occur at the joint of the old pavement and the newly constructed strip. These cracks can allow water to enter the underlying pavement and the subgrade, causing further deterioration. Reflection cracks can result from the vertical or horizontal movements at joints and cracks in the pavement layer underneath.

2507 TREATMENT OF CRACKS

2507.1 Crack sealing

Areas having cracks with less than 3 mm width treatment by fog spraying conforming to Clause 3004.3.2 of MoRTH Specifications shall be carried out. If wider cracks are present, they shall be sealed and a surface dressing/pre-mix surfacing shall be provided.

2507.2 Crack filling

a) Crack filling is normally carried out with a slow setting bitumen emulsion.
b) For cracks exceeding 8 mm width, application of crusher dust passing 4.75 mm sieve and not more than 10% passing 0.075 mm sieve shall be carried out before emulsion is applied.
c) The dust is filled to a level 5 mm below the surface.
d) After cleaning the surface emulsion is carefully filled into the gap.
e) Any spillage of bitumen shall be properly removed by blotting.
f) For wider cracks say 12 mm or more, sand-bitumen mix prepared by hand mixing is good crack filler.

2507.3 Crack prevention course

Stress Absorbing Membranes (SAM) or Stress Absorbing Membranes Interlaying (SAMI) are used for prevention of cracks. The details are given in Clause 517 of MoRTH Specifications.

2508 LAYER DEFORMATION AND THEIR RECTIFICATION

2508.1 General

Any change in the shape of the pavement from its original shape is a deformation which may be associated with slippage, rutting etc.

2508.2 Slippage

The relative movement of the surface layer with respect to the layer below is called slippage. This normally occurs when there is a low strength surface layer or poor bonding exists between the surface and the next layer of the pavement structure. Slippage is characterized by crescent shape cracks, mostly formed by breaking or turning vehicles. Slippage is caused by:

a) Unusual thrust by wheels on the surface in a particular direction.
b) Inadequacy of tack or prime coat.
c) Poor bonding between layers caused by dust, moisture etc.
d) Failure of bond between the layers caused due to excessive deflection under wheel load.

2508.2.1 Treatment of slippage

The surface layer showing poor bonding is removed and patching to be done after applying necessary tack coat.

2508.3 Rutting

Longitudinal groove or depression along the wheel track is called rutting. Rutting is caused by:

a) Heavy, channeled traffic.
b) Inadequate compaction of the pavement layer.
c) Improper mix design - mix of low stability and high flow is used.
d) Weak pavement- not designed to the actual traffic conditions.
e) High contact stress caused by heavy bullock-cart traffic.
f) Mud pumping from subgrade into the subbase layer.
g) Aggregate of surface dressing being pressed into the lower layer.

2508.3.1 Treatment of rutting

a) The rectification consists of filling up with bituminous premix - open or dense graded - and compacting to the desired level.
b) The limits of the rutting are measured using a string line and marked on the surface. After applying a tack coat, the premix is spread and compacted.

If shear failure or movement of sub grade is noticed, reconstruction is required.

2508.4 Corrugations

Formation of fairly regular undulation or ripples across a bituminous surface is called corrugation. They are normally shallow, about 25 mm depth, located at a spacing of around 3 m. Large depressions caused by the weak pavement layer or subgrade do not come under this category.

Corrugations are caused due to:

a) Lack of stability of the mix due to excess or soft binder, high proportion of fines, smooth textured aggregates in the mix etc.
b) Oscillations by the vehicle spring causing alternate valley and ridges.

c) Faulty laying of surface course.

2508.4.1 Treatment of corrugated layer

a) If the surface is thin, it is scarified and recomputed and a new surfacing layer is then placed.
b) Cutting of the high spots with or without heating and adding of leveling course material also can be adopted.
c) Sand-bitumen mix spread, using a drop spreader with its blade adjusted to clear off the high spots, can be effective to make up the corrugations. The area is then rolled thoroughly.

2508.5 Shoving

Shoving is caused by the plastic movement within the layer resulting in localised bulging of the pavement surface. Shoving is generally exhibited at the intersections, hills or grades and on sharp curves. Shoving can be caused due to:

a) Lack of stability of the mix due to excess or soft binder, high proportion of fines, smooth textured aggregates in the mix etc.
b) Lack of bonding between the surface and the layer below.
c) Heavy traffic movement of a start and stop type or involving negotiation of curves and gradients.
d) Use of non-volatile oil on roller wheels.

2508.6 Shallow depressions

Localised shallow depression below 25 mm are filled up with premix material and compacted to the desired profile. The following steps shall be followed in filling shallow depressions:

a) Mark the area of the depression using a straight edge. The outline may be marked with chalk.
b) The edge shall be cut using a saw or jack hammer or pick, to a depth of 25 mm.
c) Apply tack coat, after cleaning, using a sprayer or by any other convenient means.
d) Fill the depressions with the bituminous mix. An excess material of about one-third the depth of the depressions shall be placed to allow for compaction.
e) Compact the mix using a small vibratory roller or rammer till the surface is level.

2508.7 Potholes

These bowl shaped holes of varying size are a common type of pavement distress.
The filling of potholes and patching shall be carried out as below:

a) All loose materials shall be removed from the area to be repaired.
b) The area is cut/trimmed to get a regular shape without round corners, preferably rectangular. The edge shall be cut vertically without disturbing any tightly held particles.
c) The area is again cleaned preferably using a compressed air jet to remove all dust and loose materials.
d) Layers below the bituminous layer shall be replaced with the same/equivalent materials.
e) The area is then primed with suitable bituminous material. The sides shall be primed using a brush.
f) Bitumen mix for patching may be either hot or cold mix.
g) The mixture shall be spread in layers not more than 100 mm thick.

h) Compaction of the layer shall be carried out to the required level using rollers/plate compactor/hand roller or rammer.
i) The last layer shall be placed slightly above the final level to be achieved, to allow for the compaction of the mix.
j) For large areas, wooden straight edge shall be used for levelling the mix.
k) During the process of compaction, the surface should be frequently checked using a 3 m straight edge.

2508.8 Settlement and upheaval

These are characterized by large deformations of the pavement. This reduces speed of the vehicle and can cause accidents. They are generally followed by extensive cracks on the pavement surface.

The following are the causes for settlement and upheavals in the pavement:

a) Inadequate compaction of the fill, especially behind bridge abutments, over utility trenches etc.
b) Excess moisture in subgrade/subbase/base layer due to poor drainage conditions.
c) Pavement thickness insufficient to carry the wheel load.
d) Frost heave conditions.

2508.8.1 Treating of the settlement and upheavals

a) If caused due to subgrade failure, it may be necessary to excavate and replace the subgrade material.
b) If pavement thickness is inadequate, a properly designed pavement should be provided.
c) Under drains may be provided where the drainage condition is poor.
d) In frost affected regions, complete reconstruction of the pavement is required.

2508.9 Stripping

This defect is characterized by the separation of bitumen adhering to the surface of the aggregate particle in the presence of moisture. This may lead to loss of strength of the layer and material from the surface.

Stripping is caused due to following reasons:

a) Use of hydrophilic aggregates.
b) Inadequate mix composition.
c) Continuous contact of the layer with moisture.
d) Initial over heating of the binder or aggregates during mixing.
e) Dusty particles on the aggregates, preventing proper coating of binder.
f) Poor bonding of the aggregates with the surface below, delay in spreading of cover aggregates on the sprayed bitumen or less compaction in the case of surface dressing.
g) Rain or dust storm immediately after compaction.
h) Opening the road to fast traffic before the mix is set.
i) Use of improper grade of bitumen.
j) Ageing of binder leading to brittleness of the binder film.

2508.9.1 Treatment for stripping

a) The lost aggregates may be replaced using hot coarse sand heated to 150°C and spread over the affected areas in the case of surface dressing.
b) After spreading, the aggregates should be rolled immediately so that it will be seated into the bitumen.
c) If aggregates are only partially lost, a liquid seal coat may be sufficient.

d) In other cases, the bituminous mix should be removed and a fresh one laid.

As a precautionary measure, a suitable anti-stripping agent should be added to the bitumen during constructions.

2508.10 Loss of aggregates

This is associated with surface dressing wearing course. The surface will look rough, with aggregates intact in some portions and lost in some areas.

The loss of aggregates occurs due to the following reasons:

a) Ageing or hardening of the binder which affects its adhesive property.
b) Stripping of binder due to wet or cold weather.
c) Using dusty aggregates which interfere with the adhesion of binder to it.
d) Binder used is not sufficient to ensure full coating of the aggregates.
e) Poor affinity of the aggregates to the binder.
f) Sufficient rolling not given before opening the traffic.
g) Fast traffic over new work whipping the aggregates off.
h) Cold spraying of bitumen or delay spraying of aggregates over spread bitumen.

2508.10.1 Treatment for loss of aggregates

a) If ageing of the binder is the reason for stripping a new seal coat shall be applied.
b) If loss of aggregates is present for a large area, a new surface dressing shall be provided after cleaning the area.
c) For small isolated areas, a liquid seal coat patching will be sufficient.

2508.11 Raveling

Raveling is generally associated with premixed bituminous layers. Raveling starts from the surface downwards or from edge inwards. Due to failure of the binder to hold the aggregates, loss of fine aggregate begin exposing large aggregates. Gradually breaking of large aggregates makes surface look like eroded.

The causes of raveling are:

a) Inadequate compaction during paving.
b) Paving in cold weather resulting in non-uniform or incomplete coat of the binder.
c) Using of weaker aggregates, causing breaking under the traffic and opening new faces.
d) Deficiency of binder content in the mix.
e) Ageing of binder.
f) Excessively open bituminous mix.
g) Poor workability of the mix paved.
h) Overheating of the mix or binder.
i) Improper coating of the binder on the aggregates in the mix.

2508.11.1 Treatment for raveling

a) Raveling is corrected by adding binder.
b) If raveling has not developed too far, simple application of cutback bitumen covered with coarse sand or a slurry seal can be tried.
c) If raveling has reached an advanced stage, a double surface dressing or an overlay is preferred to extend the life of the pavement.

2509 RESTORATION OF RAIN CUT

The eroded portions of the embankment and shoulders due to storm water flow shall be rectified using appropriate material and compacted to the required density. The

specification of materials and construction procedures are given under Clause 3002 of MoRTH Specifications.

The following points shall be given attention while this work is done:

a) Materials for restoration of rain cuts shall satisfy the requirement specified in Clause 305.2 of MoRTH Specifications.
b) The area affected shall be cleared of all loose soil and benched. The benches shall extend for sufficient length to allow compaction.
c) The height of benches shall be in the range of 150 mm to 300 mm.
d) Fresh material is deposited in layers not exceeding 250 mm loose thickness.
e) The layers shall be compacted using appropriate equipment, at or near optimum moisture content, to a density of not less than 95% of the laboratory MDD for fill.
f) The finished work shall be checked for the required level, slope and alignment.

2510 MAINTENANCE OF EARTHEN SHOULDER

The irregularities or loss of material from the shoulder due to movement of traffic shall be rectified using suitable approved material.

The specification of materials and construction procedures are given under Clause 3003 of MoRTH Specifications.

The following points shall be given attention while this work is carried out.

a) The materials for use in shoulders shall be of subgrade quality possessing the required MDD and CBR.
b) If extra earth is to be added, the existing surface shall be scarified to receive fresh materials.
c) The deficiency in thickness shall be made up in layers not exceeding 250 mm thickness.
d) Compaction shall be done at OMC using appropriate equipment like smooth wheel roller, vibratory roller, hand roller, plate compactor, or hand rammer.
e) The density of the compacted layer shall not be less than 97% of laboratory density tested as per IS: 2720 (Part 8).
f) The finished surface shall have the specified slope and line.
g) Excess material on the shoulder shall be cut using a grader or by manual means.
h) The cut surface shall have a uniform density of at least 97% of MDD obtained as per IS: 2720 (Part 8).
i) If the surface is not uniformly compacted, it shall be excavated to a depth of 150 mm, the soil mixed with water and compacted at OMC to get the required density of 97%.

2511 JOINT REPAIRS OF CONCRETE ROAD

The repairing of spalled joint grooves of contraction joints, longitudinal joints and expansion joints in concrete pavement is done using epoxy mortar or epoxy concrete. The specification of materials and construction procedures are given under Clause 3005 of MoRTH Specifications.

The following points shall be considered while joint repairs are carried out.

a) The type/grade of epoxy shall be compatible with the coefficient of thermal expansion of concrete.

b) The epoxy material shall be mixed with fine aggregates or fine stone chips to repair the spalled or damaged edges.
c) The spalled/damaged edges shall be cut vertically with chisel to rectangular shapes.
d) Pneumatic chisel may be used with proper care to control the depth of cutting to the minimum.
e) The epoxy mortar/concrete is then applied using hand tools like trowel, straight edge, brush etc.
f) The repaired edge shall be in line with the joint groove and shall be flush with the concrete slab surface.
g) If the joint sealant is damaged, the same shall be raked out and the affected portion repaired by resealing.

2512 REFERENCES

1. MoRTH Specifications for Road and Bridge works, 5th Edition 2013 - published by IRC, New Delhi.
2. IRC SP: 11 Quality control for the construction of roads and runways - published by IRC, New Delhi.

+++++++

SECTION 2600 GEOSYNTHETICS

2601 GENERAL

Geosynthetics includes geotextile, geogrid, geomembrane, geonet, geocomposite, geocell, geomat, paving fabric, glass grid etc. Geofabrics made of natural fibres such as jute and coir is called natural geotextiles.

2602 TYPES OF GEOSYNTHETICS

a) *Geotextiles*: Any permeable synthetic fabric used with foundation, soil, rock and earth comes under this. The geotextile may be woven, non-woven or knitted fabric made from yarns or filaments of poly propylene, polyethylene or polyester or its compounds. Geotextiles are used in several areas like separation filtration, drainage, reinforcement etc.

b) *Geogrids*: They are netlike polymeric material used with foundation, soil, rock earth etc. Geogrids have relatively high strength, high modulus and low-creep sensitive polymers. The apertures varying from 10 to 100 mm size are either elongated ellipses, squares with rounded corners, rectangles etc. Geostrip is another form of geogrid in the form of strips made of high tenacity polyester yarn and contained in suitable polymer sheath. Geogrids and Geostrips are used as reinforcement in pavements and reinforced soil slopes.

c) *Geomembranes*: It is an impermeable membrane used with foundation, soil, rock, earth etc., to control fluid migration. Geomembranes are made from PVC or polyethylene sheets which are duly protected from ultraviolet (UV) exposures by carbon black or any antioxidants and thermal stabilizers.

d) *Geonets*: These are formed by continuous polymeric ribs at acute angle to one another. Geonets are used in combination with other geosynthetic materials to form a composite material.

e) *Geocomposites*: They are manufactured by combination of two or more synthetic materials like geotextiles, geogrids, geonets, geomembranes etc. Drainage composites are popular materials under this category. Examples of geocomposites are prefabricated vertical drains (PVD)/band drains and fin drains.

f) *Geocells*: It is a three dimensional structures with interconnected cells used in erosion control of slopes.

g) *Geosynthetic mats*: There are two dimensional or three dimensional mats made of multi-filaments with apertures to allow growth of vegetation. Geosynthetic mats consist of UV stabilised, heat bounded non-degradable polyethylene/ polypropylene or similar fibres. These mats are sometimes reinforced with steel mesh to provide more strength against erosion in slopes or areas of heavy rain fall.

h) *Natural geotextiles*: These are made from natural fibres like jute or coir. The jute or coir mats are further reinforced with polymeric netting stitched to either side to form a strong quilted mat.

i) *Paving fabric and glass grids*: Paving fabrics are non-woven heat set material consisting of minimum 85% of polyolefin, polyester or polyamides by weight.

Glass grids are composite glass fibre reinforced geogrids with continuous filament nonwoven geotextile, properly bonded. Glass grids also made from bituminous material coated glass fibre geogrids with or without adhesive coating on one side.

2603 QUALITY OF GEOSYNTHETICS

The following points shall be looked into for assuring the quality of the geosynthetic material for work:

a) Every lot of material supplied shall be accompanied by manufacturer's certificate.
b) Further, the supplier shall provide a third party test report from an independent testing laboratory with valid accreditation.
c) The manufacturer shall have ISO or CE (Conformité Européenne) certification for the manufacturing process and quality control of the geosynthetics.
d) The testing of the material shall be in accordance with relevant IS, BS, ASTM or EN codes.
e) The roll of geosynthetics shall contain the manufacturer's name, roll number, grade, length, date manufactured, product identification details etc.
f) Each roll of geosynthetic shall be wrapped with tarpaulin or opaque plastic sheets for protection during transport and storage.
g) During storage, geosynthetic rolls shall be kept above the ground adequately covered to protect from construction damage, precipitation, prolonged UV radiation, flames and sparks from welding etc.
h) The outer most wrap of the geosynthetic rolls, if damaged, shall be discarded.
i) Paving fabric used with bituminous overlays shall be completely dry prior to installation.

2604 GEOTEXTILES FOR DRAINAGE, SEPARATION AND EROSION CONTROL

The following points shall be given importance in supplying and laying geotextiles for drainage, separation and erosion control.

a) Geotextiles when used for drainage/filtration purposes shall be able to allow passage of water throughout its life.
b) The minimum strength of geotextiles in terms of Minimum Average Roll Value (MARV) for different condition of installation shall be given as in table 2600-1 (Ref: Table 700-1 of MoRTH Specifications).

Table 2600-1: *Minimum geotextile strength property requirements*

Installation condition	*Type*	*Strength property requirement (MARV)*							
		Grab strength in Newton (N) as per ASTM D 4632/ IS:13162 Part 5		*Tear strength in Newton (N) as per ASTM D 4533/IS: 14293*		*Puncture strength in Newton (N) as per IS:13162 Part 4*		*Burst strength in Newton (N) as per ASTM D 3786/ IS:1966*	
		Elongation at failure							
		<50%	*>50%*	*<50%*	*>50%*	*<50%*	*>50%*	*<50%*	*> 50%*
Harsh	Type I	1400	900	500	350	500	350	3600	1700
Moderate	Type II	1100	700	400	250	400	250	2700	1300
Less severe	Type III	800	500	300	180	300	180	2100	950

NOTE:

1) All numeric values in the above table represent MARV in weaker principal direction. The MARV is derived statistically as the average value minus two standard deviations.
2) When the geotextiles are joined together by field sewing, the seam strength shall be at least 60% of the material's tensile strength. All field seams shall be sewn with thread as strong as the material in the fabric.

c) When used for the separation of layers, the intermixing of the two layers shall be prevented throughout the life period.

d) When used below stone pitching or stone filter mattresses over slopes, geotextiles shall allow the water to flow out but shall prevent loss of soil fines.

e) The puncture strength in Newton (N) as per ASTM D 6241 shall be as given in table 2600-2.

Table 2600-2: *Puncture strength requirement for geotextiles*

Installation condition	*Strength property requirement (MARV)*	
	Puncture strength in Newton (N)	
	Elongation at failure	
	<50%	>50%
Harsh	2800	2000
Moderate	2250	1400
Less severe	1700	1000

f) The material shall satisfy the UV stability requirements specified in table 2600-3 (Ref: Table 700-2 of MoRTH Specifications).

Table 2600-3: *Requirement of UV stability*

Sl. No.	*Properties of fabric*	*Requirements (Retained strength)*
1	Grab strength	Not less than 70% after 500 hrs of exposure.
2	Tear strength	
3	Puncture strength	
4	Burst strength	

g) The physical requirement of geotextile shall conform to the requirements specified in table 2600-4 (Ref: Table 700-3 of MoRTH Specifications).

Table 2600-4: *Geotextile requirements for subsurface drainage*

In-situ soil passing 0.075 mm sieve (%)	*Permittivity, per sec, as per ASTM D 4491/ IS:14324*	*Maximum apparent opening size, mm ASTM D 4751/IS:14294*
<15	0.5	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

h) The geotextiles for different subgrade soil condition shall meet the requirement given in tables 2600-5 & 6 (Ref: Tables 700-4 & 5 of MoRTH Specifications).

Table 2600-5: *Geotextile requirements for separation (Subgrade soaked CBR >3)*

Sl. No.	*Geotextile property*	*Requirement*
1	Permittivity as per ASTM D 4491	0.02 Sec^{-1} (per sec)
2	Maximum apparent opening size as per ASTM D 4751	0.60 mm

Table 2600-6: *Geotextile requirements for separation (Subgrade soaked CBR ≤3)*

Sl. No.	*Geotextile property*	*Requirement*
1	Permittivity as per ASTM D 4491	0.05 Sec^{-1} (per sec)
2	Maximum apparent opening size as per ASTM D 4751	0.43

i) Geotextiles selected for erosion control shall have the property specified in table 2600-7 (Ref: Table 700-6 of MoRTH Specifications).

Table 2600-7: *Geotextile requirements for erosion control*

In-situ soil passing 0.075 mm sieve (%)	*Permittivity, per sec, ASTM D 4491*	*Maximum apparent opening size, mm ASTM D 4751*
<15	0.7	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

j) Geotextiles placed shall be covered within 14 days.

k) Care shall be taken to avoid damages to the geotextiles. Damages if any shall be rectified by providing patches.

l) Overlaps of adjacent dolls shall be minimum 450 mm. If placed under water, the overlap shall be minimum 1.0 m.

m) Wrinkles or folds in the fabric shall be removed before covering.

n) During slope protection works, geotextiles shall not be damaged by stone or stone filled mattresses placed over it.

2605 GEOGRIDS IN SUBBASE REINFORCEMENT

The following points shall be carefully considered in using geogrids for subbase of pavements and soil reinforcing.

a) The requirement under table 2600-8 (Ref: Table 700-7 of MoRTH Specifications) shall be met for geogrids used to reinforced subbase layers of flexible pavements.

Table 2600-8: *Minimum requirements for geogrids for subbase (For flexible pavement)*

Property	*Code*	*Unit*	*Requirement*
Stiffness at 0.5% strain	ISO-10319	kN/m	≥350; both in machine and cross- machine direction.
Tensile strength @ 2% strain	ASTM D 6637	kN/m	≥15% of T_{ult}; both in machine and cross-machine direction.
Tensile strength @ 5% strain	ASTM D 6637	kN/m	≥ 20% of T_{ult}; both in machine and cross-machine direction.
Junction efficiency for extruded geogrids	GRI-GG2-87 or ASTM-WK 14256	-	90% of rib ultimate tensile strength.
Ultraviolet stability	ASTM D 4355	-	70% after 500 hours exposure.

b) Geogrids for erosion control shall have minimum tensile strength of 4 kN/m when tested as per ASTM D5035 (MARV in machine direction). The aperture opening shall be minimum 20 mm x 20 mm with average grid thickness of 1.0 mm. The UV stability shall be 70% minimum after 500 hrs of exposures as per ASTM D 4355.

c) The geogrid shall have certification for using as soil reinforcing materials.

d) The reduction factors shall be determined in accordance with the provisions of ISO/TR 20432 – guide to the determination of long term strength of geo

synthetics for soil reinforcement. Necessary test reports shall be provided by the supplier.

e) Tests shall be carried out to provide values of pull–out coefficient as per ASTM D 6706 – Standard test method for measuring geosynthetic pull out resistance in soil.

f) Coefficient of interaction shall be determined as per ASTM D 5321 or IS: 13326 (Part 1).

g) Each roll shall have at least one identification label with roll number and product type.

h) Before placing the geogrid, the surface shall be properly prepared, cleaned and dressed to the required lines and level.

i) Geogrid shall be placed at the position as specified in the pavement design.

j) The geogrid reinforcement shall be placed flat, pulled tight and held in position by pins or other suitable means.

k) No vehicle shall be allowed on geogrid unless it is covered by at least 150 mm thick subbase material.

2606 GEOCOMPOSITE DRAINS

The geocomposite drainage system is carried out as (i) Fin drain and (ii) Pre-fabricated vertical drain (PVD).

2606.1 Fin drains

The fin drains are made of light weight three dimensional high compressive strength polyethylene core and heat bounded or needle punched polyethylene/polyester geotextiles provided in one or both sides of the core as required.

The following points shall be looked into on supply and installing fine drains.

a) The requirements of geotextile used in composite drainage system shall meet the requirements specified in table 2600-9 (Ref: Table 700-9 of MoRTH Specifications).

Table 2600-9: *Geotextile requirements for fin drains*

In-situ soil passing 0.075 mm sieve (%)	*Permittivity, per sec ASTM D 4491/ IS:14324*	*Maximum apparent opening size, mm as per ASTM D 4751/ IS:14294*
<15	0.5	0.43
15 to 50	0.2	0.25
>50	0.1	0.22

b) The core material shall meet the requirements given in table 2600-10 (Ref: Table 700-10 of MoRTH Specifications).

Table 2600-10: *Properties for fin drain core*

Property		*Code*	*Unit*	*MARV*
Tensile strength		EN ISO-10319	kN/m	16
CBR puncture resistance		EN ISO-12236	N	3000
Mass per unit area		EN ISO-9864	gm/m^2	710
Thickness of composite		EN ISO-9863	mm	4.5
In–plane permeability	Hydraulic gradient, i =1 at 100 kPa pressure	EN ISO-12958	1/m	0.55
	Hydraulic gradient, i =1 at 200 kPa pressure			0.45

2606.2 Prefabricated vertical drains (PVDs)/band drains

The design and construction of PVDs shall generally be done in accordance with IS: 15284 (Part 2). The specification of materials and construction requirements are given under Clause 314 of MoRTH Specifications.

Following points shall be considered in improving the ground condition using geosynthetic drains (PVD).

a) Geosynthetic strip or band drain shall be manufactured by an ISO 9001 certified manufacturer.
b) Band drains shall be of a minimum width of 100 mm and thickness 5 mm.
c) The core made of polyester or equivalent material serve as the drainage medium conveying pore water from subsoil to the drainage layer at top.
d) The filter shall be made of nonwoven needle punctured adhesive bounded fabric.
e) The filter and core shall be ultrasonically welded together at edges to produce a full integrated product.
f) The drain shall meet the properties specified in table 2600-4 under Clause 2604 (g) (Ref: Table 700-3 of MoRTH Specifications).
g) After the vertical band drains are installed into the subsoil, a blanket of well draining granular/coarse sand material, compacted to 75% to 80% MDD, is provided to the design thickness.
h) The sand blanket material shall conform to grading given in table 2600-11 (Ref: Table 300-4 of MoRTH Specifications).

Table 2600-11: *Grading requirements for aggregate drains*

Sieve designation	*Percent passing by weight*	
	Type A	*Type B*
63 mm	-	100
37.5 mm	100	85-100
19 mm	-	0-20
9.5 mm	45-100	0-5
3.35 mm	25-80	-
600 micron	8-45	-
150 micron	0-10	-
75 micron	0-5	-

i) The geosynthetic fabric shall meet the specification given in table 2600-1 under Clause 2604 (b).
j) The geosynthetic band drain shall be dry and wrapped to protect from exposure to UV rays during transport and storage.
k) The installation of band drains shall be done using an installation rig/sticher mounted on a base machine.
l) The blanket of granular coarse sand shall be provided over a layer of geotextile.
m) A layer of geotextile shall be provided over the sand blanket before further construction is carried out.

2607 GEOCELL FOR SLOPE PROTECTION

a) A geocell is a three dimensional structure resembling a honey comb made of high density polyethylene stabilized with carbon black.
b) Geocells filled with local soil or with granular material shall be placed on cut or fill slopes to hold top cover soil and allow vegetation to grow.
c) Geocell shall meet the specification and properties specified in table 2600-12 (Ref: Table 700-12 of MoRTH Specifications).

Table 2600-12: *Requirements of geocell for slope protection*

Property	*Code*	*Unit*	*Minimum required value*
Density	ASTM D 1505	gm/cm^3	0.900
Environmental stress crack resistance (ESCR)	ASTM D 1693	Hours	3000
Carbon black content		% by weight	1.5 to 2
Strip/cell wall thickness	ASTM D 5199	mm	1.20
Seam peel-strength test		N per 25 mm of cell depth	350
Creep rupture strength	ASTM D 2990		Creep rupture load at 10,000 hours shall be 1 kN (Min) obtained from the 95% prediction interval at 10,000 hours considering a logarithmic time creep rupture model.

d) Suitable arrangement shall be made for anchoring the cells on the slopes.
e) The surface to place the geocell shall be cleaned and dressed to the specified lines and levels. Trench keys are dug along the crest and at the bottom of the slope area to fix the cellular system in the ground.
f) Cellular sections are placed on the slopes and fastened together using accessories prescribed by the manufacturer.
g) After this, the cells are filled up from the toe of the slope to the crest with specified materials.
h) The filling shall be done 25 mm to 50 mm in excess and suitably tamped to leave the soil flush with the top edge of cell walls.
i) Once the soil filling is completed, turfing/seeding shall be done as specified.

2608 GEOSYNTHETIC MAT

Geosynthetic mat is a three dimensional structure UV stabilised nondegradable polypropylene/polyethylene /nylon or similar fibres, heat bonded at contact points. If required, a tension element like geogrids or steel wire mesh shall be included with the mat to provide strength against severe erosion forces.

2608.1 Requirements

a) The tensile strength requirement for geosynthetic mat under less severe environmental condition is given in table 2600-13 (Ref: Table 700-13 of MoRTH Specifications).

Table 2600-13: *Tensile strength requirement for normal (Non-reinforced) three dimensional geosynthetic mat for erosion control application (Less severe condition)*

Property	*Code*	*Unit*	*MARV*
Tensile strength requirement (For slopes less than 60^0)	ASTM D 5035	kN/m	2
UV stability at 500 hours - Retained strength percentage with respect to original strength	ASTM D 4355	%	80
Thickness	ASTM D 6525	mm	6.5
Mass per unit area	ASTM D 3776	gm/m^2	250

b) For severe environmental conditions the tensile strength requirements shall be as given in table 2600-14 (Ref: Table 700-14 of MoRTH Specifications).

Table 2600-14: *Tensile strength requirement for reinforced three dimensional geosynthetic mat for erosion control application (Severe condition)*

Property		*Code*	*Unit*	*MARV*
Tensile strength requirement	For slopes up to 60°C	ASTM D 5035	kN/m	10
	For slopes up to 80°C			35
Ultraviolet stability at 500 hours- Retained strength percentage with respect to original strength		ASTM D 4355	%	80
Thickness		ASTM D 6525	mm	12
Mass per unit area of the composite		ASTM D 3776	gm/m^2	500

2608.2 Installation

The following points related to the use of geosynthetic mats for control of slope erosions shall be kept in mind.

a) The mat shall be laid from top of the slope.
b) Anchor blankets are provided in 300 mm deep and 300 mm wide trenches anchored with staples/pins.
c) The mat is rolled down the slope in machine direction**.**
d) The blanket shall not be stretched but full contact with soil shall be ensured.
e) The blanket is then anchored using staples or stakes.
f) Adjacent parallel rolls shall be overlapped by 100 mm to 120 mm and anchored with staples at 600 mm to 800 mm spacing, depending on the slope.
g) A minimum cover of soil is spread followed by spreading of seed and fertilizer.
h) In the absence of rain, blanket shall be regularly watered for proper vegetation growth.
i) Any rain damages shall be corrected immediately.
j) Treated area shall be protected from the movement of cattle, till vegetation growth is completed.

2609 NATURAL GEOTEXTILES

Natural geotextiles are used to control erosion on cut or fill slopes. The details of materials and construction are given in Clause 707 of MoRTH Specifications.

The following points shall be carefully considered when natural geotextile is used.

a) Coir fibre geotextile shall meet the requirements given in table 2600-15 (Ref: Table 700-15 of MoRTH Specifications).

Table 2600-15: *Typical specifications of natural geotextile (MARV) using coir*

Type	*Weight (gsm)*	*Width (cm)*	*Thick-ness (mm)*	*Tensile strength (kN/m)*		*Elong-ation at break (%)*	*Water holding capacity (%)*	*Porometry (°95) Micron*
				MD	CD			
Open mesh fabric	300	120	4.0	5	2.5	20	-	-
Non-woven fabric	450	150	4.0	7.5	2.5	30	80	75

b) Natural geotextile made of jute shall meet the minimum requirement as stated in IS: 14715-Woven jute geotextile.
c) The surface to lay the natural geotextile shall be properly cleaned and prepared to the specified lines and levels.
d) Trench key to fix the natural geotextile along the crest and bottom of the slope shall be provided.
e) If the soil is not fertile, it shall be mixed with suitable amount of fertilisers or seeds.
f) The mat shall be laid from top.
g) Anchor blankets are provided in 300 mm deep and 300 mm wide trenches anchored with staples/pins.
h) The mat is rolled down the slope in machine direction**.**
i) The blanket shall not be stretched but full contact with soil shall be ensured.
j) The blanket is then anchored using staples or stakes.
k) Adjacent parallel rolls shall be overlapped by 100 mm to 120 mm and anchored with staples at 600 mm to 800 mm spacing, depending on the slope.
l) A minimum cover of soil is spread followed by spreading of seed and fertiliser.
m) In the absence of rain, blanket shall be regularly watered for proper vegetation growth.
n) Any rain damages shall be corrected immediately.
o) Treated area shall be protected from the movement of cattle till vegetation growth is completed.

2610 PAVING FABRICS/GLASS GRIDS

For pavement strengthening, nonwoven paving fabric or fibre glass coated grid is placed over the existing bituminous surface, prior to paving of a new layer. The details are provided under Clause 708 of MoRTH Specifications.

The following point shall be checked while carrying out this work.

a) The paving fabric shall be non-woven, chemical attack resistant material designed for pavement work, heat bounded on one side.
b) The fabric shall meet the physical requirement given in table 2600-16 (Ref: Table 700-16 of MoRTH Specifications).
c) Glass grids shall be either a composite glass fibre reinforced geogrid or bituminous coated glass fibre geogrid.
d) The properties required for glass fibre grid are given in table 2600-17 (Ref: Table 700-17 of MoRTH Specifications).

Table 2600-16: *Physical requirements for paving fabrics (MARV)*

Property	*Code*	*Unit*	*Standard requirements*
Grab tensile strength	ASTM D 4632	N	450
Elongation	ASTM D 4632	%	≥50
Mass per unit area	ASTM D 3776	gm/m^2	140
Asphalt retention	ASTM D 6140	kg/10 m^2	10*
Melting point	ASTM D 276	°C	150
Surface texture	Visual inspection	-	Heat bonded on one side only.

**The product asphalt retention property must meet MARV provided by the manufacturer.*

Table 2600-17: *Properties of glass fibre grid*

Property	*Code*	*Unit*	*Requirement*		
			Tensile strength in both machine and cross-machine direction		
Tensile strength	ASTM D 6637	kN/m	50	1000	200
% Elongation at break		%	>4	>4	>4
Minimum mesh size		mm	25 x 25	12.5 x 12.5	12.5 x 12.5
Melting point	ASTM D 276	^{0}C	>250	>250	>250

e) Bituminous reinforced geogrids are made of high modulus polyester yarns connected to low weight non-woven polypropylene fabric, the composite given a bituminous finish.

f) The requirements for bitumen reinforced geogrids are given in table 2600-18 (Ref: Table 700-18 of MoRTH Specifications).

Table 2600-18: *Properties of asphalt reinforcement geogrids*

Property	*Code*	*Unit*	*Requirements*		
			Tensile strength in both machine and cross-machine direction not less than		
Tensile strength	ISO-10319	kN/m	25	50	100
% Elongation at break	ISO-10319	%	12.5%	12.5%	12.5%
Mesh size		mm	35 x 35 20 x 20	35 x 35 20 x 20	35 x 35 20 x 20
Melting point		°C	>190	>190	>190

g) The air and pavement temperature shall be at least 10°C for placing hot bitumen or 16°C for asphalt emulsion tack coat.

h) The pavement surface shall be cleaned of all dirt and oil.

i) Cracks wider than 3 mm shall be cleaned and filled with suitable bituminous material.

j) Potholes and local failure of pavements shall be rectified/repaired.

k) If the existing pavement surface is rough or has been milled, a levelling course shall be placed.

l) Tack coat with VG-10 bitumen to bond the fabric to the pavement shall be applied.

m) Glass fibre grids with adhesive on one side may not require a tack coat.

n) The paving fabric shall be placed on the tack coat using mechanical or manual lay down equipment.

o) The fabric shall be placed without any wrinkles or folds before the tack coat cools down.

p) A small quantity of loose bituminous mix shall be spread on wheel path of the paver and tipper to avoid picking of the fabric by the wheels.

q) Overlaps of fabrics shall not exceed 150 mm in the direction of fabric.

r) The overlay process shall be completed at the earliest after laying the fabric.

s) The glass grid shall be placed after the tack coat is sprayed using mechanical or manual lay down equipment.

t) Severe wrinkles shall be slit and laid flat.

u) Brooming or rolling with rubber tyre may be required to maximize glass grid contact with pavement surface.
v) No traffic shall be allowed over the glass grid except paving machineries.
w) Bituminous paving shall be done following the paving fabric or glass grid placing.
x) In the event of rain after placing fabric, the same shall be allowed to dry before paving.
y) The minimum thickness of overlay over the fabric shall not be less than 40 mm.

2611 REFERENCES

1. MoRTH Specifications for Road and Bridge works, 5th edition 2013 - published by IRC, New Delhi.
2. IRC-SP: 11 Quality control for the construction of roads and runways - published by IRC, New Delhi.

+++++++

SECTION 2700 ROAD DRAINAGE

2701 GENERAL

An effective drainage system is required to minimise access of water into the pavement layers and prevent damages to pavement resulting from the saturation of the subgrade or fill immediately below. The road drainage should be effective in disposing the surface precipitation and controlling the underground seepage. For the design of drains, the IRC publications SP: 42 & SP: 50 can be referred.

Damages caused to the road by inadequate drainage are:

a) Reduction in bearing capacity of the subgrade soil due to the presence of water, leading to complete failure of the pavement.
b) Reduction in the design strength of pavement layers such as stabilized soil, water bound macadam etc due to the ingress of water.
c) Potholes, rutting, waviness and corrugation of the bituminous pavement layers.
d) Erosion of shoulder and pavement edges due to the flow of surface water.
e) Loss of soil from the subgrade and fill layers below the pavement due to seepage of water.
f) Erosion of slopes of fill/cut or hillside due to surface water.

2702 NEED FOR A DRAINAGE SYSTEM

a) It has been established by studies that cost of maintenance/repair of a road can be reduced considerably, if proper drainage is provided.
b) Drainage is essential for ensuring the structural and functional adequacy of the road.
c) Providing drainage measures at a later stage is both difficult and expensive. Hence provisions for adequate drainage shall be made at the initial phase of constructions.

2703 TYPES OF ROAD DRAINAGE

The road drainage works are broadly classified under (i) surface drainage and (ii) subsurface drainage.

Surface drainage deals with the interception of surface water or storm water. Subsurface drainage is for the removal of seepage or subsurface water. Internal drainage of pavement may be required, if the annual rain fall of the area is more than 500 mm.

2704 INVESTIGATIONS FOR ROAD DRAINAGE

For designing an efficient drainage system, a detailed survey and field investigation should be carried out. The following features are required for drainage design:

a) Preparation of alignment plan, longitudinal section, contour plan etc.
b) Hydrological data, such as rainfall, calculations of runoff etc.
c) Hydrographical survey, to cover the description and features of the lakes and rivers to which the water is discharged, related to their environmental protection and management.

d) Geotechnical investigation to collect the physical properties of the soil and other underlying strata, where the drainage system is to be provided.

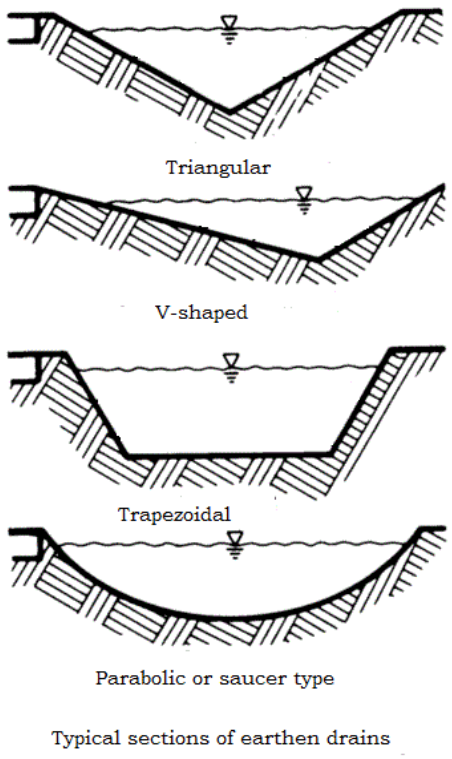
2705 SURFACE DRAINS

The water from the road and the adjacent areas should be collected and carried to natural out falls, through surface drains. The common types of surface drains are:

a) Drain along the side of the road (Gutter).
b) Shoulder drainage for easy disposal of water from the pavement layers.
c) Deep catch water rains, on the hill slopes, especially above the road cutting.

2705.1 Road side drains

The purpose of road side drains is to collect surface water from the roadway and carry to an outlet. The side drains are also intended to drain out the water in the base and subbase layers entering through the pores on the surface of the road.



Typical sections of earthen drains

In designing and constructing side drains, the following aspects shall be given due consideration:

a) The side drains are generally provided on both sides of the road. In hilly terrains, side drains on the hill side are made when road is built in a cut section.
b) Parabolic section is hydraulically the best and the most erosion resistant cross section for a side drain. However due to easiness in construction, trapezoidal sections are preferred. U-shaped drains are constructed when the discharge is high.
c) The road side drains are designed on the principles of open channel flow.
d) IRC: SP 42 - Guidelines on road drainage - may be referred for detailed hydraulic design of the drain.
e) The excavated bed and sides of the drains shall be dressed to bring them in close conformity with the specified dimensions, level and slopes.
f) As far as possible, the excavated earth from side drains shall be utilised in the construction of fill/subgrade, if found suitable.

2705.1.2 Lining of side drain

a) The lining of side drains (Gutter) is a costly proposal. Hence the selection of the type of lining is very critical.
b) It is more cost effective to provide earthen drains with larger sections than providing lining.
c) An unlined drain can withstand only a limited amount of discharge without erosion problem.
d) If the drain is cut in silt or sand, lining will be required, if the velocity of flow is between 0.3 m to 1.0 m/sec.
e) In case of drains made in stiff clay, velocity up to 1.5 m/sec can be allowed.
f) The permissible velocity can be increased considerably by providing lining.

g) The side slope of an unlined drain may be 4:1 to 2:1. But a lined drain can be made rectangular. The types of lining adopted for sides of drains are given in table 2700-1.

Table 2700-1: *Suitability of different types of lining in side drains.*

Type of lining	*Brief description*	*Suitable for*	*Unsuitable for*
Turfing	Turfing is useful in humid area for preventing erosion.	Triangular drains having 4:1 to 3:1 slopes.	Rectangular, Trapezoidal drains since maintenance is difficult.
Stone/brick	Stone/brick masonry can be laid dry or bedded in concrete with joints filled with cement mortar.	When drains are required to carry a large amount of debris or if the velocity of flow is high.	In known unstable area.
Concreting	-	As above	As above.
Stone slab lining	-	For triangular section drains and in other section in combination with masonry/ concreting and in areas where flat stone is easily available.	
Boulder pitching	-	For areas with stable slopes	In unstable loose strata.
Bituminous treatment	It is primarily quick sealing of the sides and base impregnated with bitumen cutback or emulsion 10 cm to 15 cm depth.	Used in conjunction with boulder pitching in catch water drains for prevention of seepage flow	

2705.2 Shoulder drains

Drainage from shoulder can be ensured by providing proper camber to the surface of the shoulder. Maintenance of the shoulder shall be carried out before and during monsoon to ensure easy drainage and avoid damage to the pavement. If the shoulder material is impervious like clay or black cotton soil, one the following measures may be adopted:

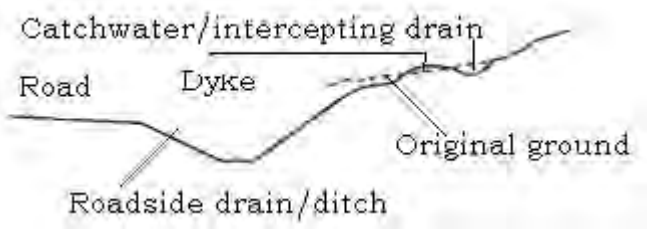
a) Provide a continuous drainage layer 75 mm to 100 mm thick below the subbase extending to the full width of the embankment/cut.
b) Constructing a subbase/base layer with drainage material, extending to the full width of the cut/fill, and provided with a generous cross slope for rapid drainage.
c) Providing shoulder drains with rubble or aggregate at 4 m to 10 m intervals. A longitudinal filter drain at the edge of the pavement connecting the shoulder drains will be more effective in ensuring drainage.
d) Providing shoulder with hard materials like granular or stabilised soil for effective drainage.

2706 CATCH WATER DRAIN

a) Catch water drains are constructed on the hill slopes to intercept water flowing from upper reaches and lead to the nearby culverts.

b) Catch water drains are normally trapezoidal in shape, lined with stones and pointed with cement mortar.

c) A stone masonry wall may be required at the upper side to retain the earth.



2707 SUBSURFACE DRAINS

a) In case of fine sand, silt or clayey subgrade or if the annual rainfall is more than 1000 mm, a continuous layer of drainage material is required for the full width of the formation, placed above the subgrade with low permeability.

b) Granular subbase (GSB) is considered as a good drainage layer for such conditions.

c) The suggested gradation of the drainage material is given in table 2700-2.

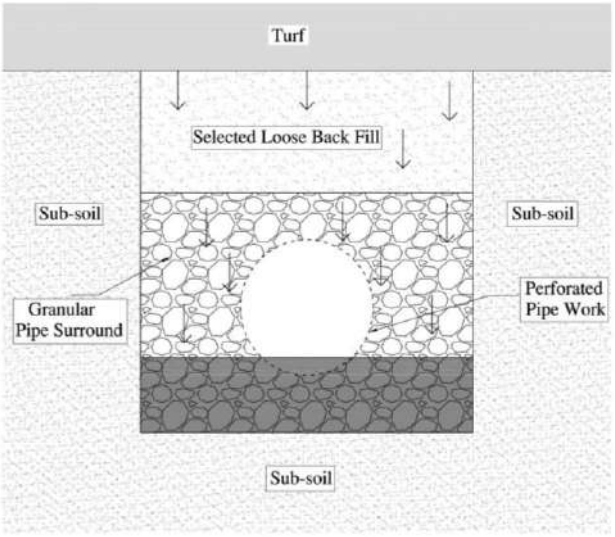
Table 2700-2: *Gradation of material for drainage layer*

IS sieve designation	*% by weight passing the IS sieve*
75 mm	100
53 mm	-
26.5 mm	55-75
9.5 mm	-
4.75 mm	10-30
2.36 mm	-
425 mic	-
75 mic	<5

2707.1 Perforated pipe drains

a) Subsurface drains may be constructed with close-jointed perforated pipes or open jointed un-perforated pipes laid in trenches with backfill material around the pipe.

b) The perforated pipes may be metal/cement concrete/poly vinyl chloride (PVC) /poly propylene (PP)/poly ethylene (PE) etc. Vitrified clay pipes also may be included if un-perforated pipes are used.



c) The top of the trench shall be sealed with an impervious material cap to prevent entry of surface water into the trench. The internal diameter of the pipe shall not be less than 100 mm, preferably 150 mm.

d) The perforations on the pipes are needed for one half of the circumference. The diameter of the holes shall be close to D_{85} size of the material surrounding the

pipe, subject to a minimum of 3 mm and maximum of 6 mm. D_{85} indicates the size of sieve that allows 85% of the material to pass through it.

e) The filter/backfill material for trench filling shall satisfy the grading requirement given in table 2700-3.

Table 2700-3: *Grading requirement for filter material*

IS Sieve designation	*% by weight passing the IS sieve*		
	Class I	*Class II*	*Class III*
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	50-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-10
1.4 mm	59-96	-	1-5
710 mm	35-80	6-18	-
355 µm	14-40	2-9	-
180 µm	3-15	-	-
90 µm	0-5	0-4	0-3

f) The thickness of backfill around the pipe shall not be less than 150 mm, and the minimum trench width shall be 450 mm.

g) The laying of pipe shall start from the outlet end and proceed towards the upper end.

h) The thickness of backfill material below the pipe shall be 150 mm minimum, and the minimum thickness of backfill above the pipe shall be 300 mm.

i) The perforations shall be placed down, while laying, to minimise clogging.

2707.2 Aggregate drains

The subsurface drains may be also constructed without using pipes. The trench may be filled with materials such as gravel, slag or stone aggregates, free from organic or deleterious substances. Such drains are known as aggregate drains.

a) The aggregates drains shall be placed within the verge/shoulders after completion of the pavement.

b) The trenches for aggregates drains shall be 300 mm width, minimum.

c) The suggested grading of backfill material for aggregates drains is given in table 2700-4.

Table 2700-4: *Gradation for backfill material aggregate drain*

IS sieve designation	*% by weight passing*
13.2 mm	100
11.2 mm	92-100
5.6 mm	27-46
2.8 mm	3-16
1.4 mm	0-6

d) Geotextiles are incorporated in subsurface drains, either along the trench or around the pipe or both, to extend the life of the drainage system.

e) The minimum overlap of filter fabric shall be 450 mm.

2707.3 Subsurface drains in other areas

Accumulation of moisture in the slopes of hill or road cut can lead to landslides. To facilitate quick drainage, perforated pipes are inserted horizontally on hill cuts and thus increase the stability of the slope.

In valley curves, subsoil drainage can be improved by providing an aggregate drain below the subbase layer to the full width of the formation. This type of subsurface drains can be adopted when pavement is to be constructed in areas susceptible to ingress of water.

2708 REFERENCES

1. IRC-SP: 20 Rural Roads Manual - published by Indian Road Congress, New Delhi 2002.
2. Manual of specifications and standards for two lining of highways through PPP - published by the Planning Commission, Government of India.

+++++++

SECTION 2800 TRAFFIC SIGNS AND ROAD MARKINGS

2801 GENERAL

The purpose of traffic signs is to promote road safety and efficiency by providing for the orderly movement of all road users on all roads in both urban and non-urban areas. Traffic signs notify road users of regulations and provide warning and guidance needed for reasonably safe, uniform and efficient operation.

To be effective, a traffic sign should meet five basic requirements:

i) Fulfill a need.
ii) Command attention.
iii) Convey a clear, simple meaning.
iv) Command respect from road users.
v) Give adequate time for proper response.

Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a traffic sign to meet these five basic requirements. The decision to use a particular sign at a particular location should be made on the basis of traffic engineering study.

2802 CLASSIFICATION OF TRAFFIC SIGNS

Traffic Signs are broadly classified as mandatory, cautionary and informatory signs.

2802.1 Mandatory/regulatory signs

These signs inform the road users about certain laws and regulations to be followed, to provide a safe and free flow of traffic. The violation of these signs is a legal offence. These signs are classified under the following six sub-heads:

i) 'Stop' and 'Give way, signs.
ii) 'Prohibitory' signs.
iii) 'No parking' and 'No stopping' signs.
iv) "Speed limit' and 'Vehicle control' signs.
v) 'Restriction ends' sign.
vi) 'Compulsory direction control' and other signs.

2802.2 Cautionary/warning signs

These signs warn the road users about any hazard on or adjacent to the roadway. These signs are in the shape of an equilateral triangle 90 cm or 60 cm, with apex pointing upwards. The sides have a red border 70 mm wide for 90 mm size boards and 45 mm for 60 cm size boards.

In non-urban areas, the warning signs should be located at the distances shown in table 2800-1 in ahead of the hazard location.

Table 2800-1: *Recommended locations for installing warning signs in non-urban roads.*

Sl. No.	*Class of road*	*Plain/rolling terrain*	*Hilly terrain*
1	National & State Highways	120 m	60 m
2	Major District Roads	90 m	50 m
3	Other District Roads	60 m	40 m
4	Village Roads	40 m	30 m

In urban areas, the warning signs should be located at about 50 m ahead of the hazard location.

2802.3 Informatory/guide signs

These signs are used to guide road users about destination and distance, useful information etc to make the travel safe, easier and pleasant.

The informatory signs are classified under the following sub-heads:

i) Direction and place identification signs.
ii) Facility information signs.
iii) Other useful information signs,
iv) Parking signs.
v) Flood gauge.

The colour, configuration, size and location of all the traffic signs for highways other than Express ways shall be in accordance with the code of practice for road signs, IRC:67 or as shown on the drawings. For expressways, the size of the signage, letters and their placement shall be as specified in the contract drawings and relevant specifications or as directed by the Engineer.

2803 MATERIALS FOR TRAFFIC SIGNS

2803.1 Concrete

Concrete shall be of M15 grade as per section 600 of this Manual or as specified in the contract Drawings.

2803.2 Reinforcing steel

Reinforcement steel shall conform to the requirements of IS: 1786 or as specified in the contract Drawings.

2803.3 Bolts, nuts and washers

High strength bolts shall conform to IS: 1367 whereas precision bolts, nuts etc shall conform to IS: 1364.

2803.4 Plates and supports

Plates and support sections for the sign posts shall conform to IS: 226 and IS: 2062 or any other relevant IS Specifications.

2803.5 Sign panels

Sign panels shall be fabricated on aluminium sheet, aluminium composite panel, fibre glass sheeting or sheet moulding compound.

Aluminium composite material (ACM) sheets used for sign boards is a sandwiched construction of a thermoplastic core of low density polyethylene (LDPE) between two thick skins/sheets of aluminium 0.5 mm or 0.3 mm on both sides.

The required mechanical properties of ACM and that of aluminium skin are given in table 800-1 of MoRTH Specifications for Road & Bridge works (5th Revision 2013).

2804 TRAFFIC SIGNS HAVING RETRO REFLECTIVE SHEETING

The retro-reflective sheeting used for sign boards consists of white or coloured sheeting, having a smooth outer surface which has the property of retro-reflection over its entire surface. The retro-reflective sheeting shall be either of engineering grade material with enclosed lens, high intensity grade with encapsulated lens or micro-prismatic grade retro-reflective element material. The guidance on the recommended application of each class of sheeting may be taken from IRC: 67.

2804.1 Classes of retro-reflective sheeting

Retro-reflective sheeting is divided into three classes as follows:

i) *Class A sheeting:* Engineering and super engineering grade sheeting as per ASTM D 4956-09 type I and II.

ii) *Class* B *sheeting:* High intensity and high intensity prismatic grade sheeting as per ASTM D 4956-09 type III and IV.

iii) *Class* C *sheeting:* All micro-prismatic grade sheeting as per ASTM D 4956-09 type VIII, IX and XI.

The class of the sheeting to be used will depend upon the type, functional hierarchy and importance of the road. The recommended applications for retro-reflective sheeting as per IRC: 67-2010 is given in table 2800-2.

Table 2800-2: *Recommended applications for retro-reflective sheeting.*

Sheeting type	*Category of road*				
	National/ State Highways	*Major Dist. Roads*	*Rural Roads*	*Urban Roads*	*Expressways*
Class A (Type I and II)	-	-	√	-	-
Class B* (Type III and IV)	√	√	√	√	-
Class C (Type VIII, IX and XI	√	-	-	√	√

**Type III sheeting is available both as glass beaded and micro prismatic technology as per ASTM D 4956-09. The light reflecting efficiency of glass beaded sheeting is lower than the micro prismatic sheeting.*

NOTE: The authority for selecting type of sheeting between classes or within a class is vested with the client.

2804.2 Class A retro-reflective sheeting

2804.2.1 Engineering grade (Type I)

a) This sheeting shall be of enclosed lens glass bead type consisting of microscopic lens elements embedded beneath the surface of a smooth, flexible, transparent, water-proof plastic, resulting in a non-exposed lens optical reflecting system.

b) The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum coefficient of retro-reflection (Determined in accordance with ASTM D 4956 - 09) as indicated in table 6.3 of IRC: 67-2010.

2804.2.2 Super engineering grade (Type II)

This sheeting is similar to type I but with higher level of retro-reflective properties as (Determined in accordance with ASTM D 4956 -09) as indicated in table 6.4 of IRC: 67-2010.

2804.3 Class B High intensity grade sheeting

2804.3.1 High intensity grade sheeting (Type III)

a) This high intensity retro-reflective sheeting shall be of encapsulated lens type consisting of spherical glass lens, elements adhered to a synthetic resin and encapsulated by a flexible, transparent waterproof plastic having a smooth surface or as an unmetallised micro-prismatic reflective material element.

b) The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (Determined in accordance with ASTM D 4956-09) as indicated in table 800-2 of MoRTH Specifications (Ref: Table 6.5 of IRC: 67-2010).

c) When totally wet, the sheeting shall show not less than 90% of the values of retro reflectance, indicated in table 800-2.
d) At the end of 7 years, the sheeting shall retain at least 80% of its original retro-reflectance.

2804.3.2 High intensity micro-prismatic grade (HIP) sheeting (Type IV)

a) This sheeting shall be of high intensity retro-reflective sheeting made of micro-prismatic retro-reflective element material coated with pressure sensitive adhesive.
b) The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (Determined in accordance with ASTM D 4956-09) as indicated in table 800-3 of MoRTH Specifications (Ref: Table 6.6 of IRC: 67-2010).
c) When totally wet, the sheeting shall show not less than 90% of the values of retro reflectance, indicated in table 800-3.
d) At the end of 7 years, the sheeting shall retain at least 80% of its original retro-reflectance.

2804.4 Class C Micro-prismatic grade sheeting

2804.4.1 Micro-prismatic grade sheeting (Type VIII)

a) This is a reflective sheeting typically manufactured as a cube corner. The reflective sheeting shall be retro-reflective type, made of micro-prismatic retro-reflective material.
b) The retro-reflective surface, after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro reflection (Determined in accordance with ASTM D 4956-09) as indicated in table 800-4 of MoRTH Specifications (Ref: Table 6.7 of IRC: 67-2010).
c) When totally wet, the sheeting shall show not less than 90% of the values of retro reflectance, indicated in table 800-4.
d) At the end of 10 years, the sheeting shall retain at least 80% of its original retro-reflectance.

2804.4.2 Micro-prismatic grade sheeting (Type IX)

This is a retro-reflective sheeting similar to Type VIII but with higher level of retro-reflective characteristics as indicted in table 800-5 of MoRTH Specifications (Ref: Table 6.8 of IRC: 67-2010).

2804.4.3 Micro-prismatic grade sheeting (Type XI)

This is a retro-reflective sheeting similar to Type IX but with higher level of retro-reflective characteristics as indicted in table 800-6 of MoRTH Specifications (Ref: Table 6.9 of IRC: 67-2010).

2804.5 Other requirements of traffic signs having retro-reflective sheeting

a) Traffic signs with retro-reflective sheeting shall be weather resistant and exhibit fastness.
b) It shall be new and unused and show no evidence of cracking, scaling, and pitting, blistering, edge lifting or curling and shall have negligible shrinkage or expansion.
c) A certificate of having the sheeting tested for coefficient of retro-reflection, daytime colour and luminance, shrinkage, flexibility, liner removal, adhesion, impact resistance, secular gloss and fungus resistance, three years outdoor

weathering and its having passed these tests shall be obtained from International/Government Laboratory/Institute by the manufacturer of the sheeting.

d) The Contractor shall obtain warranty for 10 years for type VII, IX and XI prismatic grade retro-reflective sheeting and 7 years for type III and IV High intensity prismatic retro-reflective sheeting as per Clause 801.3 of MoRTH Specifications and submit to the Engineer.

e) The coefficient of retro-reflection specified in tables 800-3 to 800-6 of MoRTH Specifications shall be checked at site using a 'reflectometer', before acceptance.

f) The sheeting shall have a pressure-sensitive adhesive of the aggressive-tack type requiring no heat, solvent or other preparation for adhesion to a smooth clean surface, in a manner recommended by the sheeting manufacturer.

g) Surface to be reflectorised shall be effectively prepared to receive the retro-reflective sheeting. The aluminium sheeting shall be de-greased either by acid or hot alkaline etching and all scale/dust removed to obtain a smooth plain surface before the application of retro-reflective sheeting.

h) The messages (legends, letters, numerals, etc.) and borders shall either be screen-printed or of cut out from durable transparent overlay or cut out from the same type of reflective sheeting for the cautionary/mandatory sign boards.

i) Signs shall be provided with retro-reflective sheeting and/or overlay film/screening ink as shown on the detailed Drawings. The reverse side of all signs shall be painted grey.

j) Except in the case of railway level crossing signs, the sign posts shall be painted in 250 mm wide bands, alternately black and white. The lowest band next to the ground shall be in black.

k) The colour of the material shall be located within the area defined by the chromaticity coordinates in table 800-7 of MoRTH Specifications and comply with the luminance factor when measured as per ASTM D 4956.

l) The colours shall be durable and uniform in acceptable hue when viewed in day light or under normal headlights at night.

m) The Regulatory/prohibitory and warning signs shall be provided with white background and red border. The legend/symbol for these signs shall be in black colour. The mandatory sign shall be provided with blue background and white symbol/letter.

n) The colours chosen for informatory or guide signs shall be distinct for different categories of roads. For National Highways and State Highways, these signs shall be of green background and for Expressways and Urban Roads, these signs shall be of blue background with white border, legends and word messages.

o) Letter size should be chosen with due regard to the speed, classification and location of the road, so that the sign is of adequate size for legibility but without being too large or obtrusive. The size of the letter, in terms of x-height, to be chosen as per the design speed is given in table 2800-3. The thickness of the letters and their relation to the x-height, the width and the heights are indicated in table IV (a) of the Annexure-IV of IRC: 67, to facilitate the design of the informatory signs and definition plates.

Table 2800-3: *Acceptable limits for sizes of letters*

Design speed (Km/hr)	Minimum 'x' height of the letters (mm)	Minimum sight distance/clear visibility distance (m)	Maximum distance from centre line (m)
40	100	45	12
50	125	50	14
65	150	60	16
80	250	80	21
100	300	90	24
120	400	115	32

2805 INSTALLATION OF TRAFFIC SIGNS

a) The signs shall be placed such that the drivers are able to recognise them easily and in time. Normally the signs are placed on the left hand side of the road.

b) The traffic signs shall be mounted on support posts, which may be of GI pipes conforming to IS: 1239, rectangular hollow section conforming to IS: 4923 or square hollow section conforming to IS: 3589.

c) Normally, signs with an area up to 0.9 m^2 shall be mounted on a single post, and for greater area, two or more supports shall be provided. In case of signs supported on two or more posts, if necessary, bracing may also be provided.

d) The support posts shall be firmly fixed to the ground by means of properly designed foundation. The work of foundation shall conform to the relevant contract specifications.

e) The signs shall be fixed to the posts by welding in the case of steel posts and by bolts and washers of suitable size in the case of reinforced concrete or GI posts. After the nuts have been tightened, the tails of the bolts shall be furred over with a hammer to prevent removal.

f) The signs should not obstruct vehicular traffic or pedestrians, if placed on the foot path.

g) The signs are to be oriented at right angles to the line of travel of approaching vehicle. However, parking signs specifying period shall be fixed parallel to the carriageway.

h) Signs are normally fixed vertical. But on grades, it may be tilted, if desirable.

i) In order to make signs more visible and legible at night, it shall be lighted or provided with reflective material including luminous paints or reflective devices and sheeting. Care should, however, be taken that this does not result in road users becoming dazzled.

j) Rectangular definition plates shall be fixed below the signs if the meaning of the sign or limit of its application is to be indicted.

k) All components of signs and supports, other than the reflective portion of GI posts shall be thoroughly de-scaled, cleaned, primed and painted with two coats of epoxy paint. Any part of mild steel (MS) post below ground shall be painted with three coats of red lead paint.

2806 OVERHEAD SIGNS

2806.1 General

On multi-lane roads, the signs may have to be mounted overhead, as this would ensure better visibility and more effective in communicating with the drivers and other road users. Overhead signs may be used in lieu of, or as an adjunct to, ground signs where the situation so warrants for proper information and guidance of the road user. The following conditions may be considered while deciding about the provision of overhead signs:

i) Traffic volume at or near capacity.
ii) Complex interchange design.
iii) Three or more lanes in each direction.
iv) Restricted visibility.
v) High speed traffic.
vi) Insufficient space for ground mounted signs.
vii) Large percentage of commercial vehicles.
viii) Closely spaced interchanges.

The details of the signs shall be as shown in the Drawings and in conformity with IRC: 67-2012.

2806.2 Materials

a) Aluminium alloy or galvanized steel to be used as truss design supports shall conform to the relevant IS.
b) After steel trusses have been fabricated and all holes punched, they shall be galvanized.
c) When aluminium sheets are used for road signs, they shall be smooth, hard and corrosion resistant conforming to IS: 736. The minimum thickness of sheet shall be 1.5 mm.
d) High strength bolts shall conform to IS: 1367 whereas precision bolts, nuts etc shall conform to IS: 1364.
e) Plates and support sections for the sign posts shall conform to IS: 226 and IS: 2062 or any other relevant IS Specifications.
f) The overhead signs shall be of micro prismatic retro-reflective sheeting.

In the absence of details or for any missing details in the contract documents, the signs shall be provided as directed by the Engineer.

2806.3 Installation

a) From safety and aesthetic standpoints, overhead signs shall be mounted on overhead bridge structures wherever possible.
b) Overhead signs shall provide a vertical clearance of not less than 5.5 m over the entire width of the pavement and shoulders.
c) The minimum lateral clearance from the edge of the usable roadway shoulder shall be 1.80 m for signs mounted on the road side or for overhead sign supports.
d) Where overhead sign supports cannot be placed at a safe distance away from the line of traffic or in an otherwise protected site, they should either be so designed as to minimize the impact forces or protect motorists adequately by a physical barrier or guard rail of suitable design.
e) For overhead signs, the support system should be properly designed based on sound engineering principles, to safely sustain the dead load, live load and wind load on the completed sign system.

f) Before erecting support structures, the bottom of each base plate shall be protected with an approved material to prevent any harmful reaction with foundation concrete.
g) All nuts on aluminium trusses, except those on the flanges shall be tightened only to a snug condition. All nuts on galvanized steel trusses, with the exception of high strength bolt connections, shall be tightened only till they are snug.
h) Field welding is not permitted.

2807 WARRANTY AND DURABILITY

a) The Contractor shall obtain from the manufacturer a ten year warranty for satisfactory field performance including stipulated retro-reflectance of the retro-reflective sheeting of micro prismatic sheeting and a seven year warranty for high intensity grade and submit the same to the Engineer. The warranty shall be inclusive of the screen printed or cut out letters/legends and their bonding to the retro-reflective sheeting.
b) The Contractor/supplier shall also furnish the Lot numbers and certification that the signs and materials supplied against the assigned work meets all the stipulated requirements and carry the stipulated warranty and that the Contractor/supplier is the authorized converter of the particular sheeting.
c) All signs shall be dated during fabrication with indelible markings to indicate the start of warranty. The warranty shall also cover the replacement obligation by the sheeting manufacturer as well as contractor for replacement/ repair/ restoration of the retro-reflective efficiency.
d) A certificate in original shall be given by the sheeting manufacturer that the retro-reflective sheeting has been tested for various parameters such as coefficient of retro reflection, day/night time colour and luminance, shrinkage, flexibility, liner removal, adhesion, impact resistance, secular gloss and fungus resistance. The tests shall be carried out by a Government Laboratory in accordance with various ASTM procedures and the results must show that the sheeting has passed the requirements for all the above mentioned.

2808 MAINTENANCE OF SIGNS

a) Prior to installing any road sign, the responsibility for the maintenance of the sign and the post required, and the timing plan(s) should be clearly established.
b) Signs become faded and their retro-reflective properties diminish with time. The signs along with the posts shall be maintained in proper position, and kept clean and legible at all times.
c) Signs should be cleaned at intervals appropriate to the site conditions. Signs at locations where they are subject to heavy soiling from passing traffic, or algae growth (A common problem with signs beneath tree canopies) will need more frequent cleaning.
d) A reference number along with the month and year of installation should be placed on the back of a sign in a contrasting colour or by stamping in characters not exceeding 50 mm in height.
e) All signs shall be inspected at least twice a year both in day and night times and at least once a year in the rain.

f) All signs should be replaced at the end of the warranty period provided for the retro-reflective sheeting used on the sign. Damaged signs shall be replaced immediately.
g) The authorities responsible for road signs should maintain a schedule of painting of the posts and signs periodically. It is recommended that painting of the signs (Where applicable) may be undertaken after every two years.
h) In case of overhead signs, adequate provision is to be made to have access to the signs for the purpose of maintenance activities. This must be ensured at the time of installation. Special care shall be taken to see that weeds, shrubbery, mud, etc. are not allowed to obscure any sign.

2809 ROAD MARKINGS

Road markings are defined as lines, patterns, words or other devices, except signs applied or attached to the carriageway for controlling, warning and guiding and informing the users. Road markings perform an important function of guiding and controlling traffic on a highway. They can also be applied in other facilities used by vehicles to mark parking spaces or designate areas for other uses.
Road markings shall be uniform in design, position and application so that they may be recognised and understood immediately.

2810 MATERIALS FOR ROAD MARKING

Road markings shall be of ordinary road marking paint, hot applied thermoplastic compound, reflectorised paint or cold applied reflective paint as specified in the item and the material shall meet the requirements as specified in Clause 803 of MoRTH Specifications.

2810.1 Ordinary road marking paint

a) Ordinary paint used for road marking shall conform to grade 1 as per IS: 164.
b) The road markings shall preferably be laid with appropriate road marking machinery.

2810.2 Thermoplastic material for road marking

a) The thermoplastic material shall be homogeneously composed of aggregate, pigment, resins and glass reflectorising beads.
b) The materials shall be free from all skins, dirt and foreign objects and shall comply with the requirements given in table 2800-4 (Ref: Table 800-9 of MoRTH Specifications).

Table 2800-4: *Proportions of constituents in road marking material.*

Component	*White*	*Yellow*
Binder	18% Min	18% Min
Glass beads	30% to 40%	30% to 40%
Titanium dioxide	10% Min	Manufacturer's option
Calcium carbonate & inert fillers	42% Max	Manufacturer's option

c) The colour of the compound shall be white or yellow (IS colour No. 356) as specified in the Drawings or as directed by the Engineer.
d) The properties of white/yellow thermoplastic material when tested in accordance with ASTM D 36/BS-3262 (Part1) shall be as given in table 2800-5.

Table 2800-5: *Properties required for thermoplastic material.*

Property	*Code*	*White*	*Yellow*
Luminance	AASHTO 249	65% Min at 45°	45% Min at 45°
Drying time	-	15 minutes max.	15 minutes max.
Skid resistance	BS: 6044	Not less than 45.	
Cracking resistance (At low temperature)	-	No cracks on application to concrete blocks.	
Softening point	ASTM D 36	102.5°C±9.5°C	
Yellowness index	AASHTO 249	Not more than 0.12	-

e) The thermoplastic material shall meet the requirements for a shell life period of one year. Any material not meeting the above requirements shall be replaced by the manufacturer/supplier/contractor.

f) Reflectorisation shall be achieved by incorporation of beads as specified.

g) Each container of the thermostatic material shall be clearly and indelibly marked with the following information
   i) The name, trade mark or other means of identification of manufacturer.
   ii) Batch number.
   iii) Date of manufacture.
   iv) Colour (White or yellow).
   v) Maximum application temperature and safe heating temperature.

h) The thermoplastic material shall readily get screeded/extruded at temperatures specified by the manufacturers for respective method of application to produce a line of specified thickness which shall be continuous and uniform in shape having clear and sharp edges.

i) The material upon heating to application temperatures shall not exude fumes, which are toxic, obnoxious or injurious to persons or property.

j) The thermostatic material shall be sampled and tested in accordance with the appropriate ASTM/BS method. The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturers showing results of the tests specified and certifying that the material meets all the requirements.

2810.3 Reflectorising glass beads

Glass beads used in association with the pavement marking paints or long life materials provide the night-time visibility. When millions of these tiny reflective spheres are embedded in highway markings, they shine brightly under headlights, making the marking more visible at night. The specific requirements of both types are detailed under Clause 803.4.2 of MoRTH Specifications.

2810.3.1 Types of glass beads

a) Generally two types of glass beads are used in reflectorized pavement markings. Type 1 beads are those which are a constituent of the basic thermostatic compound and type 2 beads are those to be sprayed on the surface.

b) The glass beads shall be transparent, colourless and free from milkiness, dark particles and excessive air inclusions.

2810.3.2 Requirements for glass beads

a) The glass beads shall meet the grading requirements given in table 2800-6 (Ref: Table 800-10 of MoRTH Specifications).

Table 2800-6: Grading requirements for glass beads

IS sieve designation	*% retained*	
	Type 1	*Type 2*
1.18 mm	0-3	-
850 micron	5-20	0-5
600 micron	-	5-20
425 micron	65-95	-
300 micron	-	30-75
180 micron	0-10	10-30
Below 180 micron	-	0-15

b) The glass beads shall have minimum 70% true spheres.
c) The minimum refractive index of glass beads shall be 1.50.
d) The glass beads shall pass free-flow test.

2810.3.3 Test methods

The specific requirements shall be tested with the following methods:

a) *Free-flow test*: Spread 100 grams of beads evenly in a 100 mm diameter glass dish. Place the dish in a 250 mm inside diameter dessicator which is filled within 25 mm of the top of a dessicator plate with sulphuric acid water solution (specific gravity 1.10). Cover the dessicator and let it stand for 4 hours at 20°C to 29°C. Remove sample from dessicator, transfer beads to a pan and inspect for lumps or clusters. Then pour beads into a clean, dry glass funnel having a 100 mm stem and 6 mm orifice. If necessary, initiate flow by lightly tapping the funnel. The glass spheres shall be free of lumps and clusters and shall flow freely through the funnel.
b) The requirements of gradation, roundness and refractive index of glass beads and the amount of glass beads in the compound shall be tested as per BS: 6088 and BS: 3262 (Part I).
c) The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all tests specified and certifying that the material meets all requirements. However, if required, these tests may be carried out as directed by the Engineer.

2810.4 Reflectorised paint

a) Reflectorised paint shall conform to the specification by the manufacturers and approved by the Engineer.
b) Reflectorising glass beads for reflectorising paints where used shall conform to the requirements given in Clause 2810.3.
c) Marking shall be done by a screed or extrusion machine. For locations where painting cannot be done by machine, approved manual methods shall be used with prior approval of the Engineer.
d) Where the compound is to be applied to cement concrete pavement, a sealing primer as recommended by the manufacturer, shall be applied to the pavement in advance of placing of the stripes to ensure proper bonding of the compound. On new concrete surface any laitance and/or curing compound shall be removed before the marking are applied.
e) In broken lines, the length of segment and the gap between segments shall be as indicated on the drawings. If these lengths are altered by the Engineer, the ratio of the lengths of the painted sections shall remain the same.

2810.5 Cold applied reflective paint

In this method, traffic stripes are marked using a solvent based cold applied paint, which shall be applied on the asphalt/cement concrete road surface by brush or by spray equipment capable of spraying the paint on the road (Road marker). Glass beads shall be subsequently spread pneumatically on to the paint, when it is still wet, so that the beads will be firmly held by the paint after drying.

2810.5.1 Requirements

a) The colour of the paint shall be white or yellow (IS colour No. 356).
b) The cold applied paint material shall be homogeneously composed of binder, pigment, extenders and other additives as required for the formulation.
c) The pigments and extenders shall be uniformly dispersed in the binder medium dissolved in organic solvents.
d) The material shall be free from skin, dirt and foreign objects and shall comply with the requirements shown in table 2800-7 (Ref: Table 800-11 of MoRTH Specifications).

Table 2800-7: *Proportions of constituents of paint.*

Component	*% by weight*	
	White	*Yellow*
Binder	25 (Min)	18 (Min)
Titanium dioxide	20 (Min)	-
Calcium carbonate & inert fillers	16 (Min)	29 (Min)
Yellow pigments	-	14 (Min)

e) The storage life of the paint to meet the specifications shall be one year. The paint stored in an air tight container during this period shall not form skin or form a cake at the bottom.
f) Each container of the cold paint shall be clearly and indelibly marked with the following information:
   i) The name, trade/patent mark.
   ii) Batch number.
   iii) Month of manufacture.
   iv) Colour (White or yellow).
g) The specific requirements of reflectorizing glass beads are given in Clause 2810.3.
h) The cold applied reflective paint shall be stirred well to form homogeneously with the thinner recommended/supplied by the manufacturer and put into the machine with the consistency level recommended by the manufacturer by using proper viscometers. The thinner shall not be added more than that recommended by the manufacturer to avoid bleeding.
i) The minimum thickness of the wet unbeaded coat of paint shall not be less than 400 micron and the minimum thickness of dry unbeaded coat of paint shall not be less than 200 micron.
j) The retro-reflective properties according to BS EN 1436:1998 shall be as given in table 2800-8 (Ref: Clause 800-7.2 of MoRTH Specifications).

Table 2800-8: *Retro-reflective properties required for paint.*

Property	*Specification*	
	White	*Yellow*
Coefficient of retro-reflection (On application)	300 mcd/m²/lux	200 mcd/m²/lux
Coefficient of retro-reflection (After defect liability period of one year)	100 mcd/m²/lux	100 mcd/m²/lux
Luminous coefficient (On application)	100 mcd/m²/lux	80 mcd/m²/lux

2810.5.2 Sampling and testing

a) The cold applied reflective paint shall be sampled and tested in accordance with appropriate ASTM/BS test methods.
b) Non-volatile matter in the paint determined as per ASTM D1644 shall be minimum 65% by weight.
c) The liquid paint shall have a density of 1.3 gm/cm³ when determined as per ASTM D1475.
d) Drying time of paint shall be 20 minutes maximum for a wet film thickness of 350 micron.
e) The paint shall not be applied when the surface temperature of the road is higher than 40°C.
f) The paint shall set to bear traffic after 40 minutes when the ambient temperature is higher than 24°C.
g) When tested according to ASTM D 968 using a sand abrasion tester, the quantity of sand required to remove 75 micron thick unbeaded dry film shall be more than 65 litres.
h) The unbeaded dry film shall pass the elongation test as per ASTM D 1737 and ASTM D 2205.
i) The unbeaded dry film shall pass the water resistance test as per ASTM D 1647 and ASTM D 2205.
j) The skid resistance of the beaded dry film shall not be less than 45 as per BS: 6044.
k) The Contractor shall furnish to the Engineer a copy of certified test methods from the manufacturer of cold applied reflective road marking paint showing the results of:
    i) No pick up time as per ASTM D 711.
    ii) Resistance to wear as per ASTM D 4060 or as per ASTM D 968 from approved laboratories.
    iii) Material safety data sheet shall be obtained from the manufacturer.

2811 PROPERTIES OF FINISHED ROAD MARKINGS

a) The finished lines shall be free from ruggedness on sides and ends and be parallel to the general alignment of the carriageway.
b) The upper surface of the lines shall be level, uniform and free from streaks.
a) The stripe shall not be slippery when wet.
b) The marking shall not lift from the pavement in freezing weather.
c) After application and proper drying, the stripe shall show no appreciable deformation or discolouration under the traffic and under road temperatures upto 60°C.

d) The marking shall not deteriorate by contact with sodium chloride, calcium chloride or oil dripping from traffic.
e) The stripe or marking shall maintain its original dimensions and position. Cold ductility of the material shall be such as to permit normal movement with the road surface without chopping or cracking.

2812 REFLECTIVE PAVEMENT MARKERS (ROAD STUDS) AND SOLAR POWERED ROAD MARKERS (SOLAR STUDS)

Retro-reflective road studs are frequently used to supplement longitudinal road markings. Road studs are bonded to or anchored within the road surface, for lane marking and delineation for night-time visibility. Road studs have a retro-reflective surface which reflects the light from vehicle headlights, making them visible to drivers in darkness.

2812.1 Reflective pavement markers (Road studs)

2812.1.1 Material

a) The plastic body of road stud shall be moulded from ASA (Acrylic styrene acrylonitrite) or HIPS (Hi-impact polystyrene) or acrylonitrile butadiene styrene (ABS) or any other suitable material approved by the Engineer.
b) The markers shall support a load of 13,635 kg tested in accordance with ASTM D 4280.
c) Reflective panels shall consist of number of lenses containing single or dual prismatic cubes capable of providing total internal reflection of the light entering the lens face.
d) Lenses shall be moulded of methyl methacrylate conforming to ASTM D 788 or equivalent.

2812.1.2 Requirements

a) The slope or retro-reflecting surface shall preferably be 35±5° to base and the area of each retro-reflecting surface shall not be less than 13.0 cm^2.
b) Each reflector or combination of reflectors on each face of the stud shall have a minimum coefficient of luminous intensity (CIL) shown in table 2800-9 (Ref: Tables 800-13 & 14 of MoRTH Specifications).

Table 2800-9: *Minimum values of coefficient of luminous intensity (CIL).*

Entrance angle	*Observation angle*	*CIL in mcd/lux*		
		White	*Amber*	*Red*
Category A studs:				
0° U 5° L&R	0.3°	220	110	44
0° U 10° L&R	0.5°	120	60	24
Category B studs:				
0° U 6° L&R	0.3°	20	10	4
0° U 10° L&R	0.5°	15	7.5	3

NOTE:

i) The entrance angle 0° U corresponds to the normal aspect of the reflectors when the reflecting road stud is installed in horizontal road surface.
ii) The stud incorporating one or more corner cubes reflectors shall be included in category A. The stud incorporating one or more bi-convex reflectors shall be included in category B.

2812.1.3 Sampling and testing

a) The sampling and testing of the road studs shall be in accordance with appropriate ASTM/BS test methods.
b) The CIL is measured by the procedure given in ASTM E 809 or as per BS: 873 (Part 4).
c) The stud is considered as not failed, if the CIL measured at any position is less than the values given in table 2800-9 provided:
    i) The value is not less than 80% of the minimum specified value and
    ii) The average of the left and right measurements for the specified angle is greater than the specified minimum.

2812.2 Solar powered road markers (Solar studs)

a) The solar studs shall be made of Aluminium alloy and polycarbonate material which shall be absolutely weather resistant and strong enough to support a load of 13,635 kg tested in accordance with ASTM D 4280.
b) Solar studs may be white, red, yellow, green or blue or combination as directed by the Engineer.
c) The water resistance of solar studs shall meet the requirements of IP 65 in accordance with IS: 12063 category 2 for protection against water ingress.
d) The dimensions of solar studs shall not be less than 100 mm x 100 mm x 10 mm.
e) Solar studs shall have super bright LEDs so as to provide long visibility from a distance of more than 800 m. Its flashing rate shall not be less than 1 Hz.
f) The life of solar studs shall not be less than 3 years and shall be able to give the prescribed performance in the temperature range of -40°C to +55°C.

2812.3 Installation of pavement markers

a) The profile of the head of the stud shall be smooth and the studs shall not present any sharp edges to the traffic.
b) The reflective marker shall be fixed to the road surface using the adhesives and as per the procedure recommended by the manufacturer. Nails shall not be used to affix the marker so as to cause safety hazard on the roads.
c) The markers shall not be fixed if the pavement surface is not dry and on new asphalt concrete surfacing until the surfacing has been opened to traffic for a period of not less than 14 hours.
d) The surface shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers, paint and any other material which would adversely affect the bond of the adhesive.

2813 WARRANTY AND DURABILITY

a) All road studs shall be legibly marked with the name, trademark or other means of identification of the manufacturer.
b) The Contractor shall submit a two year warranty for satisfactory field performance including stipulated retro-reflectance of the reflecting panel, to the Engineer.
c) In addition, a two year warranty for satisfactory infield performance of the finished road marker shall also be given by the contractor who carries out the work of fixing of reflective road markers.
d) In case the markers are displaced, damaged, get worn out or lose their reflectivity compared to stipulated standards, the Contractor would be required

to replace all such markers within 15 days of the intimation from the Engineer, at his own cost.

2814 REFERENCES

1. MoRTH Specifications for Road and Bridge works, 5th Edition 2013 - published by IRC, New Delhi.
2. IRC-SP: 11 Quality control for the construction of roads and runways.
3. IRC: 67 Code of practice for road signs.

+++++++

2901. USE OF PLASTIC WASTE IN HOT BITUMINOUS WEARING COURSE MIXES

2901.1 Introduction

Plastic in different forms found in municipal solid waste is toxic in nature. It is a common sight in both urban and rural areas to find empty plastic bags and other type of plastic packing material littering the roads as well as drains. Since waste plastic is not biodegradable, it creates environmental hazards. In order to contain this problem experiments have been carried out whether this waste plastic can be reused productively in the construction of roads.

The waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregates, when mixed with the binder is found to give higher strength. Further it has been found that such roads were not subjected to stripping when come in contact with water.

The roads constructed incorporating plastic, popularly known as 'Plastic Roads', exhibit better performance over a period of time, thereby increasing the life of pavement surfacing substantially. Therefore we may use waste plastic in the construction of PWD roads.

IRC publication SP: 98-2013 'Guidelines for the use of waste plastic in hot bituminous mixes (Dry process) in wearing courses' provides guidance on using waste plastic in road construction.

2901.2 Types of waste plastics

a) Depending on the physical properties, waste plastics may be classified as thermoplastic and thermosetting materials. Typical thermo thermoplastic and thermo setting materials are given in table 2900-1 (Ref: Table 1 of IRC SP: 98-2013).

Table 2900-1: *Types of waste plastics*

Thermoplastic	*Thermosetting*
Polyethylene teryphthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy
Poly vinyl acetate (PVA)	Melamine
Poly vinyl chloride (PVC)	Polyester
Polystyrene (PS)	Urea-formaldehyde
Low density polyethylene (LDPE)	Alkyd
High density polyethylene (HDPE)	

b) Research conducted by Central Road Research Institute (CRRI) and other organisations have proved that incorporation of selected thermoplastics and shredded plastic from discarded waste, natural plastic or any other suitable elastomers in bituminous premix has improved the performance of the pavement compared to those constructed with conventional materials.

c) Plastics are also classified based on their sources, into six groups, as indicated in table 2900-2 (Ref: Table 2 of IRC SP: 98-2013).

Table 2900-2: *Sources of waste plastics*

Waste plastic	*Origin*
Low density polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High density polyethylene (HDPE)	Carry bags, bottle caps, household articles etc.
Polyethylene teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit/wafer packets, microwave trays for readymade meals etc.
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps, Foamed polystyrene: Food trays, egg boxes, disposable cups, protective packaging etc.
Poly vinyl chloride (PVC)	Mineral water bottles, credit cards, toys, pipes, gutters, electrical fittings, furniture, folders, pens, medical disposables etc.

2901.3 Materials

2901.3.1 Shredded plastic

a) Only plastic conforming to LDPE, HDPE, PET and Polyurethane (PU) shall be used in pavement construction.
b) Poly vinyl chloride (PVC) sheets or flux sheets should not be used in any case as they release lethal levels of dioxins.
c) The shredded waste plastic should be free from dust passing 2.36 mm sieve and retaining on 600 mm sieve. Dust and impurities shall not exceed 1%.
d) It is found that the percentage of shredded waste plastic to be incorporated will be 6% to 8% of the weight of bitumen depending on the rain fall in the region is low or high.

2901.3.2 Bitumen

The bitumen shall be viscosity grade paving bitumen complying with IS: 73 or as specified in the contract as in case of conventional method. Guidelines for selecting viscosity grade bitumen are given in IRC: 111-2009.

2901.3.3 Aggregates

The aggregates shall comply with IRC: 111-2009 for dense graded mixes. For open graded mixes IRC: 14-2004, IRC: SP 78-2008 and IRC: 110-2005 shall apply.

2901.3.4 Filler

Filler for dense grade mixes shall comply with IRC: 111-2009.

2901.4 Design requirements of waste plastic incorporated mixes

The requirements for bituminous mixes modified with waste plastic are given below:

2901.4.1 Dense graded mixes

The properties required for dense graded plastic modified bituminous mixes are given in table 2900-3 (Ref: Table 3 of IRC: SP: 98-2013).

Table 2900-3: *Requirements for waste plastic modified dense graded mixes*

Property	*Requirement*
Marshall stability (kN at 60°C, minimum)	12
Marshall flow (mm)	2-4
Marshall quotient (kN/mm)	2.5-5
Number of blows (On each face)	75
Air voids in the compacted mix %	3-5
Stability retained %, minimum	98
ITS (Min) MPa	0.9
VMA %, minimum	16
VFB %	65-75
Quantity of waste plastic by % of weight of bitumen	6-8

2901.4.2 Open graded mixes

The recommended usage of waste plastic in open graded premix surfacing and mix seal surfacing is 6% to 8% and equivalent quantity of bitumen can be reduced.

2901.5 Construction

2901.5.1 Using Mini Hot Mix plant

a) The stone aggregate mix of the required grading is transferred to the mix cylinder where it is heated to 150°C to 165°C and then it is transferred to the mixing unit.
b) Temperature shall be monitored using suitable thermometer, while transferring the hot aggregate into the mixing unit.
c) Calculated quantity of shredded plastics is sprayed over the hot aggregate within 30 seconds.
d) The sprayed plastic films melts and gets coated over the aggregate, thus forming an oily coating.
e) Gas evolution and degradation of thermoplastics occur when heated beyond 180°C. Hence temperature control of waste plastic incorporated bituminous mix is critical.
f) Similarly, the bitumen is to be heated to a maximum of 160°C in a separate chamber and kept ready for adding to the coated aggregates.
g) The temperature should be properly maintained to ensure good coating of the aggregates and to prevent weak bonding.
h) At the mixing unit, the hot bitumen is added over the plastic coated aggregate and mixed for the required period, normally 15 seconds.
i) The laying temperature of the mix is between 110°C to 120°C.
j) The roller used is normal 8 tonnes capacity.

2901.5.2 Using Central Hot Mix plant

a) The aggregate mix will be transferred to the heating drum through the conveyer belt.
b) The shredded plastic is injected into the heating drum through a pipe fitted at about 2/3rd length in case of a continuous running plant.
c) In case of a batch mix plant, the plastic material is added into the pugmill through an opening.
e) The addition of plastics should be done quantitatively. Gas evolution and degradation of thermoplastics occur when heated beyond 180°C. Hence temperature control of waste plastic incorporated bituminous mix is critical.

d) In the heating unit, the plastic films get melted over the heated stone and get coated. Mixing time shall be set to ensure uniform coating of the plastic over the aggregate.
e) Slowly the plastic coated aggregate moves to the pug mill where this polymer coated aggregate is mixed with bitumen.
f) The amount of binder to be added is calculated and monitored in the control room of the central mixing plant. The temperature of the binder shall conform to the specified value for the type of binder used and mix produced.
g) The waste plastic coated aggregate is mixed with hot bitumen for 15 seconds.
h) The polymer coated aggregate bitumen mix is then unloaded to the tipper for transporting to the site.

2901.6 Quality control

a) The QC tests on material and work shall be as applicable for the item of work carried out.
b) The ability of plastic to mix with the binder is ascertained by determining the melt flow value as per ASTM D 1238. The melt-flow value shall be 0.14 to 58 gm/10 min for LDPE and 0.02 to 9.0 gm/10 min for HDPE.
c) The quantity of impurities in plastic is determined by ash test in accordance with ASTM D 5630.

2901.7 References

1. MoRTH Specifications for Road and Bridge works, 5th edition 2013 - published by IRC, New Delhi.
2. IRC-SP: 11 Quality control for the construction of roads and runways.
3. IRC-SP: 98 Guidelines for the use of waste plastic in hot bituminous mixes (Dry process) in wearing courses.

+++++++

Part - C
Bridges & Culverts

SECTION 3000 QUALITY CONTROL IN BRIDGE CONSTRUCTION

3001 GENERAL

Public Works Department is entrusted with the construction and maintenance of bridges and culverts of roads owned by the Department. Construction is undertaken by the Department based on designs approved by the competent authority. During the construction of bridge projects, it has to be ensured that the specifications are strictly adhered to and the standards prescribed by the relevant codes are achieved. The various Sections included under Part C of this Manual describes the quality aspects of each item forthcoming in a bridge project and the tests to be carried out and the standards fixed for each item by the various Codes. Quality of a work is to be maintained by controlling both the standards and requirements of the materials used and the workmanship as a whole.

3002 TECHNICAL SPECIFICATIONS AND STANDARDS/CODES

3002.1 MoRTH Specifications

Ministry of Road Transport and Highways (MoRTH) specifications are followed for execution of bridge projects undertaken by Kerala Public Works Department. These specifications are based on codes published by the Indian Roads Congress (IRC), Bureau of Indian Standards (BIS) and other International Standards.

3002.2 Indian Roads Congress Codes/ Special Publications

Codes published by the Indian Roads Congress prescribe specifications and standards for various items of road and bridge works. It also stipulates the tests to be done and methods of sampling. Guidelines regarding various constructional aspects in bridge construction are also published by the name Special Publication (SP) by IRC.

3002.3 Indian Standard Codes

Bureau of Indian Standards (BIS) have published several Codes prescribing specifications required for materials for bridge construction. It also stipulates the quality tests to be done and methods of sampling. BIS codes or any approved standards shall be followed in bridge construction wherever the IRC codes are not published or silent.

3002.4 American Society for Testing and Materials (ASTM)

ASTM/DIN standards are suggested to be followed for certain items of work where IRC/BIS codes are not published or silent.

3003 CLASSIFICATION OF BRIDGES AND CULVERTS

The bridges are generally classified based on the total span length as:

Culvert: It is a cross-drainage structure having a total length of 6 metres or less between the inner faces of the dirt walls or extreme ventway boundaries measured at right angles thereto.

Bridge: It is a structure having a total length above 6 metres between the inner faces of the dirt walls for carrying traffic or other moving loads over a depression or obstruction such as river, road or railway. Bridges are further classified into *minor* and *major* bridges. A minor bridge is a bridge having a total length of upto 60 metres while, a major bridge have a total length above 60 metres.

3004 COMPONENTS OF BRIDGE

The main components of the bridge are superstructure, substructure and foundation. The superstructure includes deck slab, longitudinal and cross girders, hand railings, crash barriers, footpath etc. The substructure consists of abutment and cap, pier and cap, dirt wall, wing wall, approach slab, pedestal and bearing. The foundation may be open foundation or well foundation with well cap or pile foundation with pile cap. The figure 3000-1 shows the components of a typical bridge.

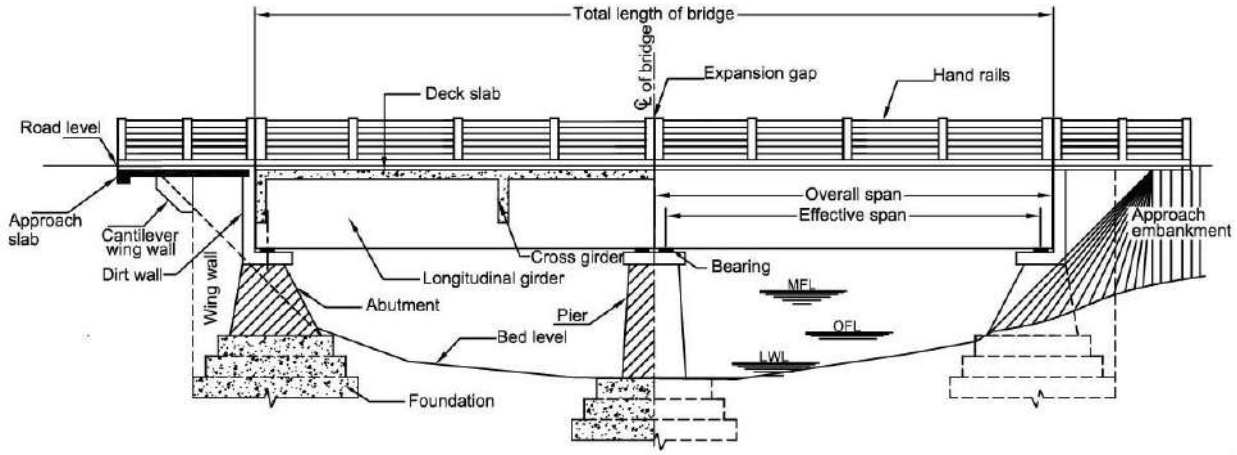


Fig. 3000-1: Components of a typical bridge

3005 OVER VIEW OF CONTENTS

The quality control aspects and standards related to the construction of bridges and culverts are detailed in Part C of this Quality Control Manual under 14 sections. The sections and the contents are mentioned below:

(a) *Site clearance and earthwork*: The quality control aspects in site clearance and earthwork related to bridge works is mentioned under this section.

(b) *Masonry for bridges & culverts*: Type of masonry to be adopted for bridges and culverts are mentioned under this section. The quality requirements and quality control tests related to masonry mortars and ingredients, including simple field tests are same as given in Section 400 of Part A.

(c) *Concrete for bridges & culverts:* Concrete is the major item in the construction of a bridge. The quality control aspects of materials for concrete work such as cement, fine aggregate, coarse aggregate, water, admixtures, reinforcing steel and formwork are same as that described in Section 600 of Part A. Additional measures to be adopted during concrete work such as proportioning, batching, mixing, transportation, placing and compaction based on IRC codes are presented in detail under this section.

(d) *Prestressing*: The quality control requirements of the materials and workmanship for prestressing in bridge construction are detailed under this section.

(e) *Steelwork for bridges*: This section provides certain specific requirement for quality control of steel bridges as per IRC codes, in addition to the provisions in Section 1200 of Part A of this Manual.

(f) *Culverts:* The quality control aspects during construction of pipe and RCC slab or box culverts are presented under this section.

(g) *Foundations*: The quality control aspects in the construction of foundation for bridge structures such as open, well and pile foundations, are presented in this

section. The quality control of materials shall comply with Section 3300 of this Manual.

(h) *Substructures*: This section consists of the quality control during construction of substructures for bridges and culverts in accordance with the IRC/MoRTH stipulations.

(i) *Superstructures*: This section consists of the quality control during construction of bridge superstructures in accordance with the IRC/MoRTH stipulations.

(j) *Bearings*: Bearing is one of the most important components of the bridge structure. The bearings commonly used and their quality control tests are detailed in this section.

(k) *Expansion joints*: This section deals with the commonly used expansion joints for bridge structures in accordance with requirements of MoRTH Specifications.

(l) *Wearing coat and appurtenances*: The quality control aspects of wearing coat and bridge appurtenances such as railing, crash barrier, approach slab, drainage spout and weep holes are mentioned under this section.

(m) *Retaining wall*: This section covers the quality control requirements and construction of retaining walls.

(n) *River protection works*: The quality control aspects in the construction of river training and protection works, such as guide bunds, guide walls, spurs, groynes, bank protection, flooring, cut-off walls, apron and approach embankment protection are mentioned under this section.

+++++++

SECTION 3100 SITE CLEARANCE AND EARTHWORK

3101 SITE CLEARANCE

a) The Contractor shall take all adequate precautions against soil erosion, water pollution, etc., and where required, undertake additional works to that effect.
b) Pole lines, fences, monuments, buildings, pipelines and sewers within or adjacent to the bridge proper are not to be disturbed and shall be protected from injury or damage.
c) Existing culverts, bridges, pavements and other structures which are within the bridge proper and which are designated for removal, shall be removed up to the limit and extent specified in the Drawings or as indicated by the Engineer.
d) Only such methods, tools and equipment as are approved by the Engineer and which will not affect any property to be preserved shall be adopted for the Work.
e) The existing structures shall be dismantled carefully and the resulting materials so removed as not to cause any damage to the part of the structure to be retained and any other properties or structures nearby.
f) All materials arising from clearing and grubbing operations shall be taken over and shall be disposed by the Contractor at suitable disposal sites. The disposal shall be in accordance with Local, State and Central Government regulations.

3102 EARTHWORK

a) The excavations shall conform to the lines, grades, side slopes and levels shown on the Drawings or as directed by the Engineer.
b) The Contractor shall not excavate outside the limits of excavation. Subject to the permitted tolerances, any excess depth/width excavated beyond the specified levels/dimensions on the Drawings shall be made good at the cost of the Contractor with suitable material of characteristics similar to that removed and compacted to the satisfaction of the Engineer.

3103 ROCK EXCAVATION

a) Rock shall be removed up to the foundation level as specified in the Drawing or as directed by the Engineer.
b) The excavation operations shall be so carried out that at no point on cut formations the rock protrudes above the specified levels.
c) Notwithstanding the foregoing, all loose pieces of rock on excavated slope surface which move when pierced by a crowbar shall be removed.
d) Where blasting is required, the same shall be carried out as per the MoRTH Specifications for Road and Bridge works.

3104 REFERENCES

1. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 3200 MASONRY FOR BRIDGES AND CULVERTS

3201 BRICK MASONRY

This work shall consist of construction of structures with brick jointed together by cement mortar, in accordance with the details shown in the Drawings and to the requirements laid down in Section 400 in Part A of this Manual.

3202 STONE MASONRY

This work shall consist of construction of structures with stones or concrete blocks jointed together by cement mortar in accordance with the details shown in the Drawings and to the requirements laid down in Section 400 in Part A of this Manual.

3203 TYPE OF MASONRY

The type of masonry used for structures shall be random rubble (coursed or un-coursed) or coursed rubble (first sort) or concrete block. For bridge works, generally coursed rubble masonry shall be used. The actual type of masonry used for different parts of structure shall be as specified in the Drawing.

3204 REFERENCES

1. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 3300 CONCRETE WORK FOR BRIDGES AND CULVERTS

3301 GENERAL

This section includes the quality control requirements for imparting prestress to structural members by stressing of wires/strands/tendons/cables with jacks of required capacity and holding them between approximately designed anchorages fixed internally or externally to the members.

3302 MATERIALS

3302.1 Cement

The quality control requirements such as cement identification, storage, sampling and testing of cement shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3302.2 Aggregate

a) The quality control requirements, storage, sampling and testing of fine and coarse aggregate for concrete shall be as per the respective Section in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

b) The size (Maximum nominal) of coarse aggregate for concrete to be used in various components shall be as given in table 3300-1.

Table 3300-1: *Maximum size of coarse aggregate*

Components	*Maximum nominal size of coarse aggregate (mm)*
RCC Well curb	20
RCC/PCC well steining	40
Well cap/pile cap	20
Solid type piers and abutments	40
RCC work in girder, slabs wearing coat, kerb, approach slabs, hollow piers and abutments, pier/abutment caps, piles	20
PSC work	20

c) Maximum nominal size of aggregate shall also be restricted to the smaller of the following values:
   i) 10 mm less than the minimum lateral clear distance between individual reinforcements.
   ii) 10 mm less than the minimum clear cover to the reinforcements.
   iii) One quarter of minimum thickness of member.

d) The proportion of the various individual sizes of aggregates shall be so adjusted that the grading produces the densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

e) For pumped concrete, the maximum size of aggregate shall not exceed one-third the internal diameter of the pipe. The grading of aggregate shall be continuous and shall have sufficient ultra fine materials (Material finer than 300 micron). Proportion of the fine aggregate passing through 300 micron shall

be between 15% and 30% and that passing through 600 micron sieve shall not be less than 5% of the total volume of aggregate.

3302.3 Water

The quality control requirements, sampling and testing of water used for mixing of concrete and curing shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3302.4 Admixtures

a) Chemical admixtures such as super-plasticizers, or air entraining, water reducing, accelerating and retarding agents for concrete may be used with the approval of the Engineer.
b) As the selection of an appropriate concrete is an integral part of the mix design, the Contractor shall ensure that any admixture shall be used only after obtaining complete information of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the work.
c) The quality control requirements, sampling and testing of admixtures shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.
d) Compatibility of the admixtures with the cement and any other pozzolana or hydraulic addition shall be ensured for avoiding the problems such as:
    i) Requirement of large dosage of super-plasticizer for achieving the desired workability.
    ii) Excessive retardation of setting.
    iii) Excessive entrainment of large air bubbles.
    iv) Unusually rapid stiffening of concrete.
    v) Rapid loss of slump.
    vi) Excessive segregation and bleeding.

3302.5 Steel reinforcement

a) The quality control requirements, storage, handling, inspection, sampling and testing of steel reinforcement for concrete work shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.
b) Portions of uncoated reinforcing steel and dowels projecting from concrete shall not be exposed to atmosphere. It shall be protected within one week after initial placing of concrete, with a brush coat of neat cement mixed with water to the consistency of thick paint. This coating shall be removed within one week by lightly tapping with a hammer or other tool before the next pour of concrete.
c) Coated reinforcing steel shall be protected against damage to the coating. If the coating on the bars is damaged during transportation or handling and cannot be repaired, the same shall be rejected.
d) Fusion bonded epoxy coated reinforcement shall conform to IS: 13620 or International Standards as approved by the Engineer. The location of the source of supply of the coated bars shall be as nearer to the site as possible, to avoid damages to the coating by long distance transportation. Additional requirements for the use of such reinforcement bars are given below:
    i) Patch up materials shall be procured in sealed containers with certificates from the agency who has supplied the fusion bonded epoxy bars.

ii) PVC coated GI binding wires of 18G shall only be used in conjunction with fusion bonded epoxy bars.
iii) Chairs for supporting the reinforcement shall be of fusion bonded epoxy coated bars.
iv) The cut ends and damaged portions shall be touched up with repair patch up material.
v) The bars shall be cut by saw-cutting and not by flame cutting.
vi) While bending the bars, the pins of work benches shall be provided with PVC or plastic sleeves.
vii) The coated steel shall not be directly exposed to sun rays or rains and shall be protected with opaque polyethylene sheets or such other approved materials.
viii) While concreting, the workman or trolley shall not move directly on coated bars but shall move only on wooden planks placed on the bars.
ix) Hot dipped galvanized reinforcing steel shall be provided wherever specified. The coating shall conform to IS: 12594.

3303 REQUIREMENTS FOR CONCRETE

3303.1 Grade of cement

a) The characteristic strength is defined as the strength of material below which not more than 5% of the test results are expected to fall.
b) The type and grade of concrete for bridge works shall be as designated in table 3300-2 (Ref: Table 6.4 of IRC: 112-2011).
c) Ordinary concrete is made on the basis of nominal mix proportioned by weight of its main ingredients.

Table 3300-2: *Types and grades of concrete*

Types of concrete/ Grade designation			*Characteristic compressive strength in 28 days (MPa)*
Ordinary concrete	*Standard concrete*	*High performance concrete*	
M15	M15	-	15
M20	M20	-	20
	M25	-	25
	M30	M30	30
	M35	M35	35
	M40	M40	40
	M45	M45	45
	M50	M50	50
		M55	55
		M60	60
		M65	65
		M70	70
		M75	75
		M80	80
		M85	85
		M90	90

f) Standard concrete is made on the basis of design mix proportioned by weight of its ingredients and may contain chemical admixtures to achieve certain target values of various properties in fresh condition.

g) High performance concrete is similar to standard concrete but contains additional one or more mineral admixtures providing binding characteristics and partly acting as inert filler material which increase its strength, reduce its porosity and modify its other properties in fresh as well as hardened condition.

h) The minimum grades of concrete and corresponding minimum cement content and maximum water/cement ratios for different exposure conditions shall be as indicated in table 3300-3 (Ref: Table 14.2 of IRC: 112).

Table 3300-3: *Requirement of concrete for different exposure conditions using 20 mm aggregate.*

Exposure condition	*Maximum water-cement ratio*	*Minimum cement content, kg/m³*	*Minimum grade of concrete*
Moderate	0.45	340	M25
Severe	0.45	360	M30
Very severe	0.40	380	M40
Extreme	0.35	400	M45

NOTE:

i) All three provisions given in the above table for a particular exposure condition, shall be satisfied.

ii) The term cement for maximum water-cement ratio and minimum cement content shown in table include all cementitious materials mentioned in Section 600 in Part A of this Manual. The maximum limit of fly ash and ground granulated blast furnace slag in the blended cement shall be as specified in IS: 1489 (Part-1) and IS: 455 respectively.

iii) For plain cement concrete with or without surface reinforcement, the minimum grade of concrete can be lowered by 5 MPa and maximum water-cement ratio exceeded by 0.05.

iv) Cement content shown in the above table shall be increased by 40 kg/m³ for use of 12.5 mm nominal size aggregates and decreased by 30 kg/m³ for use of 40 mm nominal size aggregate.

i) For concrete subjected to sulphate attack the minimum grades of concrete, minimum cement content and maximum water-cement ratios for different concentration of sulphate content shall be as indicated in table 3300-4 (Ref: Table 14.4 of IRC: 112).

j) The minimum cement content shall be as low as possible but not less than the quantities specified in tables 3300-3 and 3300-4.

k) The maximum cement content excluding any mineral admixtures (Portland cement component alone) shall not exceed 450 kg/m³.

l) For all items of concrete, only design mix shall be used, except where nominal mix concrete is permitted as per Drawing or by the Engineer. Nominal mix may be permitted only for minor works or for other incidental construction, where strength requirements are upto M20 only. Nominal mix may also be permitted for non-structural concrete or for screed below open foundations.

m) If the Contractor so proposes, the Engineer may permit the use of concrete of higher grade than that specified in the Drawing, provided the higher grade concrete meets the specifications applicable. The additional cost of such higher grade concrete shall be borne by the Contractor.

Table 3300-4: *Requirements of concrete exposed to sulphate attack*

Class	*Concentration Sulphates as SO_3*			*Type of cement*	*Min. cement content kg/m^3*	*Min. water cement ratio*	*Min. grade of concrete*
	In Soils		*In ground water, gm/l*				
	Total SO_3 %	*SO_3 in 2:1, Water: Soil extract, gm/l*					
1	Traces	<1	< 0.3	OPC, PPC or PSC	280	0.5	M25
2	2.0 to 0.5	1.0 to 1.9	0.3 to 1.2	OPC,PPC or PSC, SRPC	330	0.5	M25
3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5	SRPC, PPC	330	0.5	M25
				PSC	350	0.45	M30
4	1.0 to 2.0	3.1 to 5.0	2.5 to 5	SRPC	370	0.45	M35
5	>2.0	>5.0	>5.0	SRPC with protective coating	400	0.4	M40

NOTE: OPC-Ordinary Portland cement, PPC-Portland Pozzolana cement, PSC-Portland Slag cement, SRPC-Sulphate Resistant Portland cement.

n) Concrete shall meet any other requirements as specified in the Drawing or as directed by the Engineer. The overall limits of deleterious substances in concrete shall be as follows:
   i) Total acid soluble chloride content in the concrete mix expressed as chloride ions shall not exceed the following values by mass of cement:
      Prestressed concrete: - 0.10%
      Reinforced concrete:
      a) In severe, very severe or extreme exposure condition - 0.20%
      b) In moderate exposure condition - 0.30%
   ii) The total water soluble sulphate content of the concrete mix expressed as SO_3, shall not exceed 4% by mass of cement in the mix.

o) For concrete made with PPC, PSC or mineral admixtures, the setting time and rate of gain of strength are different from those for concrete made with OPC alone. Such modified properties shall be taken in to account while deciding the de-shuttering time, curing period, early age loading and time of prestressing. Additional cube samples may be required to be taken for verifying the concrete properties.

3303.2 Mix design

a) The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the current margin:
   i) The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of normally similar proportions produced at site by the same plant under similar supervision, over a period exceeding 5 days, but not exceeding 6 months.
   ii) Where there is insufficient data to satisfy the above, the current margin for the initial design mix shall be taken as given in table 3300-5.

Table 3300-5: *Current margin for initial design mix*

Concrete grade	*Current margin (MPa)*	*Target mean strength (MPa)*
M15	10	25
M20	10	30
M25	11	36
M30	12	42
M35	12	27
M40	12	52
M45	13	58
M50	13	63
M55	14	69
M60	14	74
M65	15	80
M70	15	85
M75	15	90
M80	15	95
M85	16	101
M90	16	106

b) The Contractor shall carry out the mix design within the limitations of parameters and other stipulations laid down in IS: 10262. The detailed procedure of concrete mix design is given in Appendix B of PWD Quality Control Laboratory Manual.

3303.3 Proportioning

a) Prior to start of construction, the Contractor shall design the mix in case of design mix concrete or proposed nominal mix in case of nominal mix concrete, and submit to the Engineer for approval, the proportions of materials, including admixtures to be used. Water reducing admixtures (Including plasticizers or super-plasticizers) may be used at Contractor's option, subject to approval of the Engineer.

b) The proportions of materials for nominal mix concrete shall be in accordance with table 3300-6 unless otherwise specified.

Table 3300-6: *Requirements for nominal mix concrete*

Concrete grade	*Total quantity of dry aggregates by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)*	*Proportion of fine to coarse aggregate (By mass)*	*Maximum quantity of water for 50 kg of cement (Litres)*	
			PCC	*RCC*
M15	350	Generally 1:2, subject to upper limit 1:1.5 and lower limit of 1:2.5	25	-
M20	250		25	22

c) The Contractor shall give notice to the Engineer to enable him to be present at the time of carrying out trial mixes and preliminary testing of the cubes.

d) Prior to the commencement of concreting, trial mix design shall be performed for all grades of concrete and trial mix which has been found successful, shall be submitted by the Contractor and approval obtained.

e) Prior to commencement of trial mix design, all materials forming constituents of proposed design mix should have been tested and approval obtained in writing from the Engineer.

f) Based on test results of material, a draft mix design calculation for all grades of concrete to be used in the works, shall be prepared after taking into account the provisions in the technical specifications of the Tender Document, Guidelines of IS: 10262, IS: SP-23 and IRC: 112 and submitted to the Engineer for approval.

g) During concreting with the approved trial mix design, if source of any constituents is changed, the mix design shall be revised and tested for satisfying the strength requirements.

h) The initial trial mixes shall be carried out in a laboratory approved by the Engineer. However, Engineer may permit the initial trial mixes to be prepared at the site laboratory of the Contractor, if a full-fledged concrete laboratory has been established well before the start of construction.

i) When the site laboratory is utilized for preparing initial mix design, the concrete production plant and means of transport employed to make the trial mixes shall be similar to those proposed to be used in the work.

j) For each trial mix, a set of minimum six cubes shall be made from each of three consecutive batches for the purpose of testing. Three test specimens constitute one sample. One sample shall be tested at an age of 28 days and the second sample at an earlier age approved by the Engineer. The average strength of these three specimens gives the test result value provided, the individual variation is within ±15% of the average. Extra cubes shall be cast and stored safely for testing later, if required. The cubes shall be made, cured, stored, transported and tested in accordance with these specifications.

k) Adjustment to mix proportions arrived at in trial mixes, shall be made subject to the Engineer's approval, in order to minimize the variability of strength and to maintain the target mean strength. Such adjustments shall not be taken to imply any change in the current margin.

l) When required by the Engineer, the Contractor shall recalculate the current margin in accordance with the steps followed in the mix design. The recalculated value shall be adopted as directed by the Engineer, and it shall become the current margin for concrete produced thereafter.

m) In case any changes are observed in the properties of fresh concrete and/or strength of hardened concrete on the basis of early age tests, additional mixes and tests shall be carried out during production, so as to control and bring the quality of concrete within acceptable limits, in case of any change in the source or properties of materials, the design of mix shall be established afresh.

n) The Contractor shall submit the following information for the approval of the Engineer:
   i) Nature and source of each material.
   ii) Quantities of each material per cubic metre of fully compacted concrete.
   iii) Either appropriate existing data, as evidence of satisfactory previous performance for the target mean strength, current margin, consistency/

water-cement ratio and any other additional requirement(s) as specified or full details of tests on trial mixes.

iv) Statement giving the proposed mix proportions for nominal mix concrete.

o) Any change in the source of material or in the mix proportions shall be subject to the Engineer's prior approval.

p) The mix shall have uniform consistency which will allow proper placement and compaction in the required position.

q) Slump test shall be used to measure consistency of the concrete as per IS: 516.

r) The optimum consistency for various types of structures shall be as indicated in table 3300-7 or as directed by the Engineer.

Table 3300-7: *Requirements of consistency*

Sl. No.	*Type*	*Slump (mm) at the time of placing of concrete*
	Structures with exposed inclined surface requiring low slump concrete to allow compaction.	25
	Plain cement concrete.	25
	RCC structure with widely spaced reinforcements like solid columns, piers, abutments, footings, well steining.	40-50
	RCC structure with fair degree of congestion of reinforcement such as pier and abutment caps, box culverts, well curb, well cap, walls with thickness greater than 300 mm.	50-75
	RCC and PSC structure with highly congested reinforcements such as deck slab girders, box girders, walls with thickness less than 300 mm.	75-125
	Under water concreting through tremie for bottom plug, cast in situ piling etc.	150-200

NOTE: Where the concrete is to be transported through transit mixer and placed using concrete pump, the optimum consistency during placement for the items of work of Sl. Nos. 1 to 3 can be considered ranging from 75 mm to 150 mm, subject to satisfying the other essential criteria of strength, durability etc., and approval of the Engineer.

3303.4 Design of formwork

a) The design, erection and removal of formwork shall conform to IRC: 87. The forms shall be such as to ensure that they can be conveniently removed without disturbing the concrete. The design shall facilitate proper and safe access to all parts of formwork for inspection.

b) The Contractor shall furnish the design and drawing of complete formwork (i.e., the formwork as well as their supports) for approval of the Engineer before any erection is taken up. Notwithstanding any approval or review of Drawing and Design by the Engineer, the Contractor shall be entirely responsible for the adequacy and safety of formwork.

3304 WORKMANSHIP

Workmanship of concrete works involved in the procedures of placing and fixing of formwork, steel reinforcements, batching, mixing, handling, placing and curing are explained below.

3304.1 Formwork

a) The formwork shall be robust and strong, and the joints shall be made leak proof by using of PVC joint sealing tapes.

b) Staging must have cross bracings and diagonal bracings in both directions. Staging shall be provided with an appropriately designed base plate resting on firm strata.

c) The number of joints in the formwork shall be kept to a minimum by using large sized panels. The design shall provide for proper "soldiers" to facilitate alignment.

d) As far as practicable, clamps shall be used to hold the forms together. Where use of nails is unavoidable, minimum number of nails shall be used and these shall be of the double-headed type. Alternatively, if nails are of the normal type, they shall be left partially projecting without being driven to their full length, so that they can be withdrawn easily.

e) Use of ties shall be restricted, as far as practicable. Wherever ties are used they shall be used with HDPE sheathing so that they can easily be removed. No parts prone to corrosion shall be left projecting near the surface.

f) Unless otherwise specified, or directed, chamfers or fillets of size 25 mm x 25 mm shall be provided at all angles of the formwork to avoid sharp corners. The chamfers, bevelled edges and mouldings shall be made in the formwork itself. Opening for fixtures and other fittings shall be provided in the shuttering as directed by the Engineer.

g) Shuttering for walls, sloping members and thin sections of considerable height shall be provided with temporary openings to permit inspection and cleaning out before placing of concrete.

h) The formwork shall be constructed with pre-camber to the soffit to allow for deflection of the formwork. This shall be in addition to the pre-camber for the permanent structure as shown in the Drawings.

i) Where centering trusses or launching trusses are adopted for casting of superstructure, the joints of the superstructure, the joints of the centering trusses, whether welded, riveted or bolted shall be thoroughly checked periodically.

j) Various members of the centering trusses should be periodically examined for proper alignment and unintended deformation before proceeding with the concreting. They shall also be periodically checked for any deterioration in quality due to steel corrosion. Launching trusses, casting trusses of span more than 40 m and travelling forms shall be tested before they are put to use.

k) The formwork shall be so made as to produce a finished concrete, true to shape, line and levels and dimensions as shown in the Drawings, subject to the tolerances specified in respective sections of this Manual or as directed by the Engineer.

l) Forms shall be made sufficiently rigid by the use of ties and bracings to prevent any displacement or sagging between supports. They shall be strong enough to prevent all pressure, ramming and vibration during and after placing the

concrete. Screw jacks or hard wood wedges where required shall be provided to make up any settlement in the formwork either before or during the placing of concrete.

m) The formwork shall ensure the correct final shape of the structure, with the calculated amount of positive or negative camber. The deformation of false work, scaffolding or propping and the instantaneous or deferred deformation due to various causes arising in prestressed structures shall be properly accounted for.

n) Suitable camber shall be provided to horizontal members of structure, especially in long spans, to counteract the effects of deflection. The formwork shall be so fixed as to provide for such camber.

o) The formwork shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete surface. Lubricating oils (machine oils) shall be prohibited for use as coating.

p) The formwork shall be lined with material approved by the Engineer so as to provide a smooth finish of uniform texture and appearance. This material shall leave no stain on the concrete and shall be so fixed to its backing as not to import any blemishes. The Contractor shall make good any imperfections in the resulting finish as required by the Engineer. Internal ties and embedded metal parts shall be carefully detailed and their use shall be subject to the approval of the Engineer.

q) When the formwork is dismantled, its individual components shall be examined for damage and damaged pieces shall be removed for rectification. Before re-use all components shall be cleaned of deposits of soil, concrete or other unwanted materials.

r) All bent steel props shall be straightened before re-use. The maximum permissible deviation from straightness is 1/600 of the length. The maximum permissible axial loads in used props shall be suitably reduced depending upon their condition.

s) The condition of the timber components, plywood and steel shuttering plates shall be examined closely for distortion and defects before use.

3304.2 Placing and fixing of steel reinforcements

a) Bar bending schedule shall be furnished by the Contractor and got approved by the Engineer before start of work.

b) Bars shall be bent cold to the specified shape and dimensions or as directed by the Engineer using a proper bar bender, operated by hand or power to obtain the correct shape and radii of bends.

c) Bars shall not be bent or straightened in a manner that will damage the parent material or the coating.

d) Placing and fixing of reinforcement shall be inspected and approved by the Engineer before concreting is commenced.

e) The reinforcement cage should generally be fabricated in the yard at ground level and then shifted and placed in position.

f) The reinforcement shall be placed strictly in accordance with the Drawings and shall be assembled in position only when the structure is otherwise ready for placing of concrete. Prolonged time gap between assembling of reinforcement and casting of concrete, which may result in rust formation on the surface of bars, shall not be permitted.

g) Bars shall be kept in position usually by the following methods:
   i) In case of beam and slab construction, industrially produced polymer cover blocks of thickness equal to the specified cover, shall be placed between the bars and formwork, subject to satisfactory evidence that the polymer composition is not harmful to concrete and reinforcement.
   ii) Cover blocks made of concrete may be permitted by the Engineer, provided they have the same strength and specification as those of the member.
   iii) In case of dowels for columns and walls, the vertical reinforcement shall be kept in position by means of timber templates with slots cut in them accurately, or with cover blocks tied to the reinforcement. Timber templates shall be removed after the concreting has progressed up to a level just below their location.
   iv) Layers of reinforcements shall be separated by spacer bars at approximately one metre intervals unless otherwise specified in the Drawing. The minimum diameter of spacers shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater. Horizontal reinforcement shall not be allowed to sag between supports.
   v) Necessary stays, blocks, metal chairs, spacers, metal hangers, supporting wires etc. or other subsidiary reinforcement shall be provided to fix the reinforcement firmly in its correct position.
   vi) Use of pebbles, broken stone, metal pipe, brick, mortar or wooden blocks etc., as devices for positioning reinforcement shall not be permitted.

h) Bars coated with epoxy shall be placed on supports that do not damage the coating. Supports shall be installed in a manner such that planes of weakness are not created in hardened concrete. The coated reinforcing steel shall be held in place by use of plastic or plastic coated binding wires especially manufactured for the purpose.

i) All reinforcement shall be furnished in full lengths as indicated in the Drawing. No splicing of bars, except where shown in the Drawing, shall be permitted without approval of the Engineer. The lengths of the splice shall be as indicated in the Drawing or as approved by the Engineer.

j) Where practicable, overlapping bars shall not touch each other, and shall be kept apart by 25 mm or 1.25 times the maximum size of coarse aggregate, whichever is greater. If this is not feasible, overlapping bars shall be bound with annealed steel binding wire not less than 1mm diameter and twisted tight in such a manner as to maintain minimum clear cover to the reinforcement from the concrete surface.

k) Lapped splices shall be staggered or located at points along the span where stresses are low.

l) Splicing by welding of reinforcement will be permitted only if detailed in the Drawing or approved by the Engineer. Weld shall develop an ultimate strength equal to or greater than that of the bars connected.

m) While welding may be permitted for mild steel reinforcing bars conforming to IS: 432, welding of deformed bars conforming to IS: 1786 shall in general be prohibited.

n) Welding may be permitted in case of bars of other than Fe 240 grade including special welding grade of Fe 415 grade bars conforming to IS: 1786, for which

necessary chemical analysis has been secured and the Carbon Equivalent (CE) calculated from the chemical composition using the formula is 0.4 or less.

o) The method of welding shall conform to IS: 2751 and IS: 9417, any supplemental specifications, IRC: 112, MoRTH Specifications and to the satisfaction of the Engineer.

p) Welded joints shall preferably be located at points where steel will not be subject to more than 75% of the maximum permissible stresses and welds so staggered that at any one section, not more than 20% of the bars are welded.

q) Bars may be joined with approved patented mechanical devices as indicated in the Drawing or as approved by the Engineer. In cases such devices are permitted by the Engineer, they shall develop at least 125% of the characteristic strength of the reinforcement bar.

r) Bars may be anchored with approved patented mechanical anchorages as indicated in the Drawing or as approved by the Engineer.

s) Anchorages shall be connected to the reinforcing bar by the use of taper thread system. The anchorage shall be capable of developing the characteristic strength of reinforcement without damage to concrete and shall have sufficient diameter and width to develop adequate shear cone strength. The connection shall develop 125% of the characteristic strength of reinforcement bar.

3304.3 Preparations required before placing concrete

Preparations required before placing concrete shall be as listed in Section 600 in Part A of this Manual.

3304.4 Batching

a) The Contractor shall submit details of the equipment and operating techniques he proposes for the batching and mixing of concrete, for the approval of the Engineer.

b) The quality control requirements for batching of concrete shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3304.5 Mixing

The quality control requirements for mixing of concrete shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3304.6 Transportation

a) The Contractor shall submit details of the equipment and operating techniques he proposes for the transportation and placing of concrete, for the approval of the Engineer.

b) The quality control requirements for transportation of concrete shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3304.7 Placing

The quality control requirements for placing of concrete shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3304.8 Compaction

The quality control requirements for compaction of concrete shall be as per Section 600 in Part A of this Manual, IRC: 112 and MoRTH Specifications for Road and Bridge works.

3304.9 Curing

a) Water for curing and curing methods shall comply with the requirements of Section 600 of Part A of this Manual. Sea water or saline water shall not be used for curing. Sea water shall not come into contact with concrete members before they have attained adequate strength.
b) Pouring of water shall not be done over green concrete for curing purpose.
c) The method of curing shall ensure that sufficient moisture is present to complete the hydration of the cement, and shall be subject to the approval of the Engineer. The method of curing shall not:
   i) Disfigure permanently exposed surfaces.
   ii) Affect bonding of subsequent coatings.
   iii) Increase the temperature of the concrete.
d) During the curing period, exposed concrete surface shall be protected from the direct rays of the sun.
e) Moist curing shall be applied for formed surfaces, including the underside of beams, girders and supported slabs with the forms in place, for the full curing period, or until the forms are removed.
f) In case of formed concrete if liquid membrane curing is used, it should be applied immediately after de-shuttering (removal of the form). In such a case, the concrete surface must be dampened with clean water prior the application.
g) Moisture curing shall be performed by:
   i) Covering the surface of the concrete with water and keeping it continuously wet.
   ii) Continuous use of fine fog water sprays.
   iii) Covering the surface with a saturated absorptive cover and keeping it continuously wet.
   iv) Jute mats, cotton mats, and other absorbent materials can be used to hold water on horizontal or vertical surfaces.
   v) Wet straw or hay can be used for wet-curing small areas, but there is the danger that wind might displace it unless it is held down with screen wire, burlap, or other means.
h) Where method (i) is employed for moisture curing, the bunds used shall not be made from fill from excavations or any other areas where there is the possibility of chloride contamination.
i) Where steam curing or curing compound is adopted, it shall be in accordance with the MoRTH Specifications.

3304.10 Removal of formwork

a) The methodology for removal of formwork (i.e. de-shuttering and de-centering) shall be planned in advance and furnished to the Engineer for scrutiny and approval. No formwork or any part thereof shall be removed without prior approval of the Engineer.
b) The formwork shall be so removed as not to cause any damage to concrete. Centering shall be gradually and uniformly lowered in such a manner as to permit the concrete to take stresses due to its own weight uniformly and gradually to avoid any shock or vibration.
c) Formwork shall not be released unless the concrete has achieved strength of at least twice the stress the concrete may be subjected at the time of the removal of formwork. When no test is conducted for determination of strength of

concrete and where the time of removal of formwork is not specified, the same shall be as per table 3300-8.

Table 3300-8: *Stripping time of form work*

Sl. No.	*Component of structure*	*Period*
1	Walls, piers, abutments, columns and vertical faces of structural members	12 to 48 hours as may be decided by the Engineer.
2	Soffits of slabs (with proper left under)	3 days
3	Props left under slabs	14 days
4	Soffits of girders (with props left under)	7 days
5	Props(left under girders)	21 days

d) Where there are re-entrant angles in the concrete sections, the formwork should be removed at these sections as soon as possible after the concrete has set, in order to avoid cracking due to shrinkage of concrete.

e) Precautions to be taken while removing formwork shall be followed as per IRC: 87.

f) Immediately on removal of forms, the concrete work shall be examined by the Engineer before any defects are made good. The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance of the member shall be rejected. Surface defects of minor nature may be accepted. On acceptance of such work, the same shall be rectified as directed by the Engineer without any extra cost.

g) Immediately after the removal of forms, exposed bars or bolts, if any shall be cut inside the concrete member to a depth of at least 50 mm below surface of the concrete and the resulting holes filled with cement mortar.

h) All fins caused by form joints, all cavities produced by the removal of form ties and all other holes and depressions, honeycomb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water and carefully pointed and rendered true with mortar. The mortar shall be of cement and fine aggregate mixed in the proportions used in the grade of concrete. Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids.

i) Surface which has been pointed shall be kept moist for a period of twenty four hours.

3304.11 Ready mixed concrete

a) Use of Ready Mixed Concrete (RMC) proportioned and mixed off the project site and delivered to site in a freshly mixed and unhardened state conforming to IS: 4926 shall be allowed with the approval of the Engineer.

b) The Contractor shall produce the certificate from the manufacturer of RMC for approval on the uniformity and consistency of the facility. The engineer may request to revalidate the uniformity tests under his supervision.

c) The Contractor shall satisfy the Engineer on the following:
   i) Materials used in RMC shall comply with the specification in all respects.
   ii) Manufacturing and delivery resources of the proposed supplier are adequate to ensure proper and timely completion.

d) The specified requirements as to the sampling, trial mixing, testing and quality of concrete, of various grades as described in the respective sections of this Manual shall apply equally to RMC.

e) Every additional facility, including but not limited to testing equipment, labour, laboratory facilities and transport, which the Engineer or persons authorised by him may require for the supervision and inspection of the batching, mixing, testing and transporting to site of RMC shall be provided by the Contractor at no extra cost.

f) Copies of all delivery notes shall be submitted to the Engineer in duplicate, on computer generated forms and shall include at least the following information:
   i) Name of supplier, serial number of ticket and date.
   ii) Truck number.
   iii) Name of Contractor.
   iv) Name of Contract and location of office.
   v) Grade of concrete.
   vi) Specified workability.
   vii) Type and source of cement.
   viii) Source of aggregate.
   ix) Nominal maximum size of aggregate.
   x) Quantity of each ingredient in the concrete mix.
   xi) Type of admixture and quantity.
   xii) Water content.
   xiii) Time of loading and departure from ready-mix plant.
   xiv) Arrival and departure times of truck.
   xv) Time of completion of discharge.
   xvi) Notations to indicate equipment was checked and found to be free of contaminants prior to batching.

g) A copy of the delivery note shall be given to the Engineer's site representative for each load.

h) Unless approved otherwise in advance of batching all concrete of single design mix for any one day's pour shall be from a single batch plant of a single supplier.

i) Transit mixers equipped with automatic devices for recording the number of revolutions of the drum shall be used.

j) Excess water over the maximum allowed by the mix design shall not be added.

k) Each mixer truck shall arrive at the job site with its water container full.

l) In the event that a container is not full or concrete tests give a greater slump than acceptable, the load shall be rejected.

m) Shade temperature and concrete temperature shall be recorded at the point of discharge of the mixer and at placement for each load of concrete delivered to site.

n) Maximum and minimum temperatures and wet bulb temperatures shall be recorded daily.

o) No water shall be added at the site.

3304.12 Mass concrete

a) Mass concrete is often cured with water for the additional cooling benefit in warm weather. However, this can be counterproductive when the temperature

gradient between the warmer interior and the cooler surface generates stress in the concrete.

b) Horizontal or sloping unformed surfaces of mass concrete can be maintained continuously wet by water spraying, wet sand, or water saturated fabrics.

c) For vertical and other formed surfaces, after the concrete has hardened and the forms are still in place, the form ties may be loosened and water supplied to run down the inside of the form to keep the concrete wet

d) Care shall be taken to prevent thermal shock and cracks when using water that is significantly cooler than the concrete surface. Curing water should not be more than about 11°C cooler than the concrete.

e) Curing shall start as soon as the concrete has hardened sufficiently to prevent surface damage.

f) For unreinforced massive sections not containing ground granulated blast-furnace slag or pozzolan, curing shall be continued for not less than 2 weeks. Where ground granulated blast-furnace slag or pozzolan is included in the concrete, the minimum time for curing shall be not less than 3 weeks.

g) For reinforced mass concrete, curing shall be continuous for a minimum of 7 days or until 70% of the specified compressive strength is obtained, if strength is the key concrete performance criterion. For construction joints, curing shall be continued until resumption of concrete placement or until the required curing period is completed.

h) Curing shall not stop until favourable differential temperature is attained and at the approval of the Engineer.

3305 TOLERANCES

a) The accuracy of the measuring equipment shall be within +2% of the quantity of cement being measured and within +3% of the quantity of aggregate, admixtures and water being measured. Standard test weights shall be available to permit the checking of scale accuracy.

b) Testing of the weighers shall be at three-month intervals. If water is dispensed by flow meter the frequency of testing shall be at three-month intervals. Such testing shall be undertaken by a calibration agency approved by the department.

c) Test certificates shall be displayed in the plant in prominent positions.

d) Operation of batching equipment shall be such that the concrete ingredients are consistently measured within the following tolerances. The plant shall have the ability to flag values that are outside these limits. The operator shall make manual adjustments to the batching and the final weights shall be within the given limits. Any adjustments shall be displayed on the batch weight printouts.

e) Cement supplied in bags shall be placed directly from the bag into the intake of the mixing plant and each batch must contain one or more complete bags of cement. No mixer having a rated capacity of less than a one-bag batch shall be used and the mixer shall not be charged in excess of its rated capacity.

3306 SAMPLING AND TESTING

a) Samples from fresh concrete shall be taken as per IS: 1199 and samples shall be made, cured and tested at specified number of days in accordance with IS: 516.

b) The strength parameters are based on 28 days strength. Tests at other age shall be performed, if specified.

c) Where automated batching plant is located away from the place of use or concrete is supplied from ready mix concrete plant and the time gap between production and placement is more than the initial setting time or where any ingredients are added subsequent mixing, separate sets of samples shall be collected and tested at batching plant and at location of placement. The results shall be compared and used to make suitable adjustments at batching plants so that properties of concrete at placement are as per the requirements.

d) In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for formula for modulus of rupture at 72±2h or at 7 days or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test. For this purpose, the acceptable values shall be arrived at based on actual testing. In all cases, the equivalent 28 days compressive strength shall be the criterion for the acceptance or rejection of the concrete.

e) Additional samples may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of transfer of prestress or striking the formwork, or to determine the duration of curing or to check the testing error. Additional samples may also be required for testing samples cured by accelerated methods as described in IS: 9013. The specimen shall be tested as described in IS: 516.

f) Three test specimens constitute one sample for any type of test at specified age of testing.

g) Average test value of the three specimens constitutes the test result of sample, provided that the individual variation is within ±15% of average. If variation is larger, the sample shall be discarded.

h) The minimum frequency of sampling of concrete of each grade shall be in accordance with table 3300-9.

Table 3300-9: *Minimum frequency of sampling of concrete*

Quantity of concrete in work (m^3)	*Number of samples*
1 - 5	1
6 - 15	2
16 - 30	3
31 - 50	4
51 and above	4 plus one additional sample for each additional 50m^3 or part thereof

i) At least one sample shall be taken from each batch of work. For the purpose of acceptance as per table 3300-9, quantity of concrete represented by a group of four consecutive samples shall include all batches and single sample shall represent the batch from which it is taken.

j) Where concrete is provided continuously at site from a batching plant or RMC plant, groups of four consecutive samples, shall not have overlapping common samples. Irrespective of other methods of controlling production used at the batching/RMC plant the requirements of this clause shall be met.

3307 ACCEPTANCE CRITERIA

a) Acceptance or rejection of concrete is mostly based on compressive strength. However, other properties of the concrete in fresh and hardened states including durability are also important.

b) Apart from meeting the acceptance criteria, concrete is liable to be rejected if it is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not met. However, the hardened concrete may be accepted after carrying out suitable remedial measures approved by the Engineer.

c) The test results of concrete shall deemed to comply with the criteria specified in table 3300-10.

Table 3300-10: *Acceptance criteria for concrete*

Test	*Code*	*Criteria*	*Requirement*
Compressive strength	IRC:112	Mean strength from any group of four consecutive non-overlapping samples	Shall exceed specified characteristic compressive strength +3 MPa.
		Strength of any sample	Shall not be less than specified characteristic compressive strength -3 MPa.
Flexural strength	IRC:112	Mean strength from any group of four consecutive non-overlapping samples	Shall exceed specified characteristic flexural strength +0.3 MPa.
		Strength of any sample	Shall not be less than specified characteristic flexural strength -0.3 MPa.
Density (Fresh & hardened)	IRC:112	Mean strength from any group of four consecutive non-overlapping samples	Shall not be less 97.5% of specified value.
Chloride content	IS:14959	-	Shall not exceed, for: i) PSC : 0.10% ii) RCC (Exposure: -severe to extreme) : 0.20% iii) RCC (Moderate) : 0.30%
Durability (Rapid Chloride Ion permeability test)	ASTM C1202	-	Shall not exceed, for: i) Extreme : 800 Coulombs ii) Very severe: 1200 Coulombs iii) Severe : 1500 Coulombs

d) If the concrete is deemed not to comply as per the above criteria, the structural adequacy of the bridge elements affected shall be investigated and any consequential action as needed shall be taken.

3308 REFERENCES

1.	IRC: 87	Guidelines for the design and erection of false work for road bridges.
2.	IRC: 112	Code of practice for concrete road bridges.
3.	IS: 516	Methods of tests for strength of concrete.
4.	IS: 1199	Methods of sampling and analysis of concrete.
5.	IS: 2751	Code of practice for welding of mild steel plain and deformed bars for reinforced concrete construction.
6.	IS: 4926	Code of practice for ready-mixed concrete.
7.	IS: 9013	Method of making, curing and determining compressive strength of accelerated cured concrete test specimen.
8	IS: 9417	Recommendations for welding cold worked bars for reinforced concrete construction.
9.	IS: 10262	Guidelines for concrete mix design proportioning.
10.	IS: 12594	Hot-dip zinc coating on structural steel bars for concrete reinforcement.
11.	IS: 13620	Fusion bonded epoxy coated reinforcing.
12.	IS: 14959	Determination of water soluble and acid soluble chlorides in mortar and concrete - method of test.
	(Part 1)	*Fresh mortar and concrete.*
13.	ASTM C1202	Standard test method for electrical indication of concrete's ability to resist chloride ion penetration.
14.	MoRTH	Specification for Road and Bridge works (5th revision).

+++++++

SECTION 3400 PRESTRESSING

3401 GENERAL

This part includes the quality control requirements of the materials and workmanship for prestressing in bridge construction. The materials required for prestressing and the prestressing operations shall conform to IRC: 112 and MoRTH Specifications or as directed by the Engineer.

a) Prestressing operation shall be carried out only under the direction of an experienced and competent supervisor and all personnel operating the stressing equipment shall have been properly trained in its use.
b) In addition to the normal precautions against accident, special care shall be taken when working with or near tendons which have been tensioned or are in the process of being tensioned.
c) The system of prestressing used shall be a system indicated in Drawing or approved by the Engineer. Such system shall be used strictly in accordance with the recommendations of the system manufacturer.
d) Under no circumstances shall equipment or fittings designed for use with one system of prestressing be used in conjunction with equipment and fittings designed for use with another system.
e) Prestressing components shall be stored in clean dry conditions. They shall be clean and free form rust and loose mill scale at the time of fixing in position and subsequent concreting. Slight rusting of the steel, which can be removed by moderate rubbing, is acceptable, but the surface shall not show signs of pitting.
f) Prestressing accessories like jacks, anchorages, wedges, block plates, etc. shall be procured from authorised manufacturers only.

3402 MATERIALS

3402.1 Wires and strands

a) Prestressing steel shall be in the form of plain or indented wires, stress-relieved multi-ply strands or high tensile steel bars and conform to the following BIS subject to the stipulations in IRC: 112 (Refer figure 3400-1):

Plain cold drawn stress-relieved wire	-	IS: 1785 (Part-I)
Indented hard-drawn stress relieved wires	-	IS: 6003
Stress relieved multi-ply strands of normal relaxation	-	IS: 6006
Stress relieved multi-ply strands of low relaxation	-	IS: 14268
High tensile steel bars	-	IS: 2090

b) The requirements for prestressing wires are given in table 3400-1 (Ref: Table 18.3 of IRC: 112).
c) The requirements for prestressing strands are given in table 3400-2 (Ref: Table 18.4 of IRC: 112).
d) All wires or strands to be stressed at the same time shall be taken from the same parcel. The coil numbers of the steel used for each tendon shall be recorded.
e) Welding of tendons shall not be permitted.

Table 3400-1: *Requirements of hard drawn stress relieved wires*

Type	*Diameter (mm)*	*Min. Tensile strength (MPa)*	*Minimum elongation at fracture (%)*
Plain wires	4	1715	3
	5	1570	4
	7	1470	4
	8	1375	4
Indented wires	4	1715	3
	5	1570	4

Table 3400-2: *Requirements of hard drawn stress relieved strands*

Class	*Designation*	*Nominal area (mm^2)*	*Normal relaxation*		*Low relaxation*	
			Breaking load (kN)	*0.2% proof load (kN)*	*Breaking load (kN)*	*0.2% proof load (kN)*
I	11.1 mm 7ply	70.0	124.54	105.86	120.1	108.0
	12.7 mm 7ply	92.0	166.18	139.9	160.1	144.1
	15.2 mm 7ply	139.0	226.86	192.83	240.2	216.2
II	11.1 mm 7ply	74.2	137.89	117.21	137.9	124.1
	12.7 mm 7ply	98.8	183.71	156.11	183.7	165.3
	15.2 mm 7ply	140.0	261.44	222.23	260.7	234.6

Fig. 3400-1: Prestressing wires and strands.

f) Cutting and trimming of wires and strands shall be carried out using a high-speed abrasive cutting wheel or friction saw at not less than one diameter from the anchorage or flame cutters at not less than 75 mm from anchorage or jacks. Care shall be taken to ensure that the flame does not come in contact with other stressed steel when a flame cutter is used.

g) Strands shall be sufficiently projected from the anchorage to allow jacking to take place at either end of the tendon.

h) The cable or individual strands comprising the cable shall not be kinked or bent. No strand that has become unravelled shall be used in the works.

3402.2 Sheaths and cores

a) The sheathing shall conform to the requirements specified in IRC: 112 as given in table 3400-3 (Refer figure 3400-2).

Table 3400-3: *Requirements of sheathing*

Strands Nos./Diameter (mm)	*Internal dia. of duct (mm)*		*Thickness of sheathing (mm)*	
	Metallic	*HDPE*	*Metallic*	*HDPE*
7/13	50	50	0.3	2.0
12/13	75	75	0.4	2.5
19/13	85	85	0.4	2.5
27/13	100	100	0.5	3.0
12/15	85	85	0.4	2.5
19/15	100	100	0.5	3.0
27/15	125	130	0.5	4.0

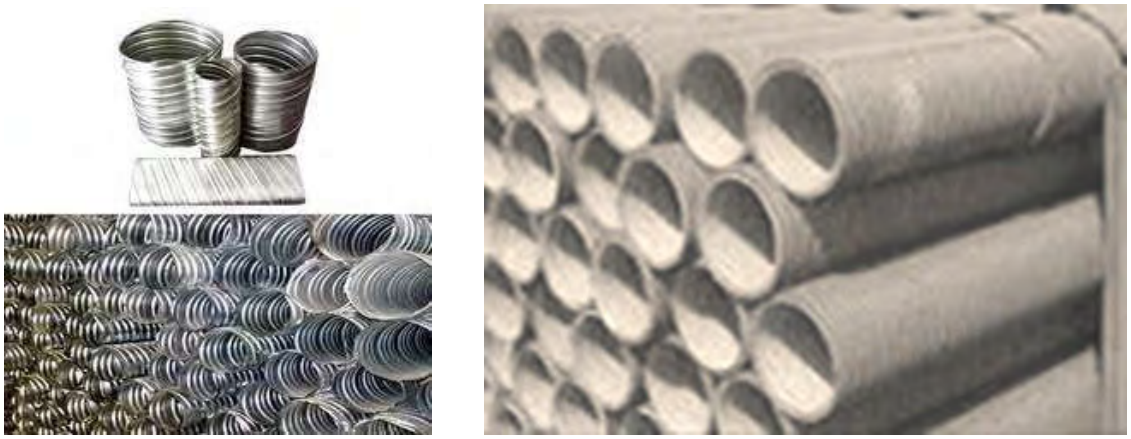


Fig. 3400-2: Metallic and HDPE sheaths for prestressing

b) Sheaths shall be accurately located both vertically and horizontally as described in the Drawing.

c) All sheaths shall be maintained in their correct positions during the placing of the concrete. Unless otherwise specified in the Drawing, sheaths shall be placed in correct position and profile by providing suitable ladders and spacers at intervals of approximately 1.0 m. The method of support shall be approved by the Engineer.

d) Where sheaths are used, the number of joints shall be kept to a minimum and sleeve connectors shall be used for jointing. Each joint shall be adequately water tight and shall withstand a pressure of 1.1 times the grouting pressure and maximum grouting head.

e) Joints in sheathing shall be neatly fitted without internal projection or reduction of diameter. Joints in adjacent sheaths shall be staggered by at least 300 mm.

f) Within 24 hours of the concrete being placed, the Contractor shall satisfy the Engineer that the tendons are free to move, if they are in ducts or that the ducts are free from obstruction.

g) The number and position of grout vents for entry and exit points shall be agreed with the Engineer before the ducts are formed so that the grouting for the entire length can be checked.

h) Vents shall be provided at low points in the tendon profile to allow the disposal of water that may have collected as a result of rain or curing. The vents shall be sealed before grouting operations begin.

3402.3 Anchorages

a) Anchorages, end blocks and plates shall be positioned and maintained in position during concreting so that the centre line of the duct passes axially through the anchorage assembly (Refer figure 3400-3).
b) All bearing surfaces shall be clean before concreting and tensioning.
c) No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plugs till used. Anchorage components shall be kept free from mortar and loose rust and any other deleterious coating.
d) Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to taking up the work.

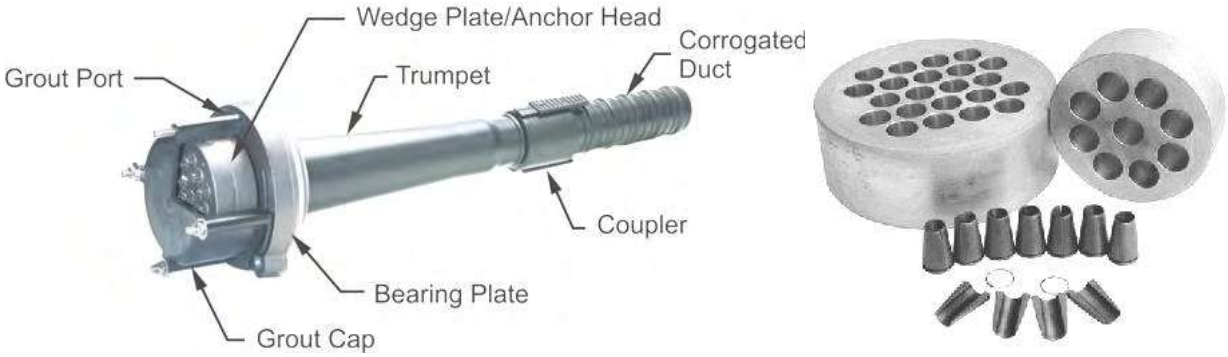


Fig. 3400-3: Components of a typical prestressing anchorage.

3402.4 Mechanical couplers

Couplers or other similar fixtures in conjunction with the prestressing strands or bars, shall have an ultimate tensile strength of not less than the strengths of the individual strands or bars being jointed and shall meet the requirements of individual anchorages as specified in IRC: 112.

3403 WORKMANSHIP

3403.1 Jacking equipment

a) All jacking equipment used for stressing operations shall be of the type applicable to the system adopted.
b) Jack and pumps shall be calibrated at an independent facility, in the presence of the Engineer, before beginning stressing operations. Calibration of the equipment shall take place at six-month intervals for equipment permanently present at site.
c) Whenever new equipment is brought to the site, or equipment is removed and returned, or serviced, recalibration of the equipment as described will be required.
d) All gauges, load cells, dynamometers and other devices used for measurement shall have a reading accuracy of within ±2%.

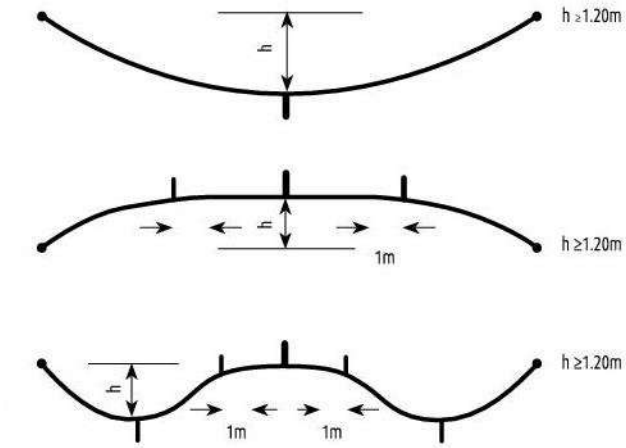
3403.2 Tensioning

a) The Contractor shall submit details of the proposed stressing loads and stressing sequence to the Engineer for approval.

b) Tensioning shall be carried out only in the presence of the Engineer or his representative unless permission has been granted otherwise.
c) The Contractor shall ensure that personnel carrying out the stressing are provided with particulars of the required tendon loads, order of stressing and extensions.
d) Immediately before tensioning, the Contractor shall prove that all tendons are free to move between jacking points.
e) Unless otherwise permitted in the Drawing, concrete shall not be stressed until two test cubes taken from it has attained the specified transfer strength.
f) The friction factors assumed for the calculation of tendon extension shall be verified by onsite measurement of the force-extension relationship of a typical sample of installed tendons.
g) When the required force, including overloads of short duration, has been applied to the satisfaction of the Engineer, the tendons shall be anchored. The jack pressure shall then be relieved in such a way as to avoid jerks to the anchorage or tendons.
h) If the pull-in of tendons at the completion of anchoring is greater than that acceptable to the Engineer, the tendons shall be de-tensioned and re-tensioned again.
i) If it is necessary to crop the tendons to enable the ducts to be grouted, this shall be delayed as long as practicable up to the time of grouting. In all other cases, unless otherwise agreed with the Engineer, the tendons shall not be cropped less than three days after grouting.
j) The Contractor shall keep full records of all tensioning operations, including the measured extensions, pressure gauge or load cell readings and the amount of pull-in at each anchorage. Copies of these records, on suitable formats, shall be supplied to the Engineer within 24 hours of each tensioning operation.

3403.3 Grouting

a) Grouting shall be done only with the written approval of the Engineer.
b) All ducts shall be thoroughly cleaned by means of compressed air and all anchorages shall be sealed before grouting.
c) Ducts shall be grouted at the earliest after the tendons in them have been stressed and the Engineer's written permission to commence has been obtained. Grout shall be injected in one continuous operation and allowed to flow from the vents until the consistency is equivalent to that being injected. The maximum time between mixing and injection shall not exceed 30 min.
d) The ducts shall be completely filled with grout (Refer figure 3400-4).
e) Vents shall be sealed consecutively in the direction of flow and the injection tube sealed under pressure until the grout has set. The filled ducts shall be protected to the satisfaction of the Engineer to ensure that they are not subject to shock or vibration for one day.
f) Two days after grouting, the level of grout in the injection and vent tubes shall be inspected and made good if necessary.
g) The Contractor shall keep full records of grouting including the date each duct was grouted, the proportions of the grout and admixtures used, the pressure, details of interruptions and topping up required. Copies of these records shall be supplied to the Engineer within three days of grouting.



a) Ideal location of vents in cable b) Cross section of well grouted cable

Fig. 3400-4

3403.4 Grout mixer

a) It is essential that the grout is maintained in a homogenous state and of uniform consistency so that there is no separation of cement during the entire grouting process. It is necessary that the grout be continuously mixed in a colloidal mixer with a minimum speed of 1000 rpm and travel of discharge not exceeding 15 m/sec.

b) The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a nozzle which can be locked off without loss of pressure in the duct.

c) The pressure gauges shall be calibrated before they are first used in the works and thereafter as required by the Engineer. All equipment shall be thoroughly washed with clean water at least once every three hours during grouting operations and at the end of use for each day.

d) The Contractor shall ensure that standby grouting equipment is available in the event of a breakdown.

3403.5 Properties of grout

a) Only clean potable water shall be used.

b) The same type of cement as used in construction of pre-stressed elements shall be used for making the grout.

c) It is not recommended to use sand for grouting of pre-stressing tendons.

d) Approved admixtures conforming to IS: 9103 may be used if tests have shown that their use increase fluidity, reducing bleeding, entraining air or expanding grout. Admixtures containing chloride, nitrates, sulphates or any other products which are likely to damage the steel shall not be used.

e) When expanding agent is used, the total unrestrained expansion shall not exceed 10%. Aluminium powder as an expanding agent is not recommended.

f) Admixtures shall be used only with the written permission of the Engineer and shall be used strictly in accordance with the manufacturer's instructions.

g) Water-cement ratio shall be as low as possible consistent with the necessary workability. Under no circumstances shall the water to cement ratio exceed 0.45.

h) The temperature of the grout after accounting for the ambient temperature of the structure shall not exceed 25°C.

i) The compressive strength of 100 mm cube of the grout shall not be less than 17 MPa at 7 days.
j) Initial setting time of grout shall be more than 3 hours and less than 12 hours. The final setting time shall not be less than 24 hours.
k) The bleeding shall not exceed 0.3% of volume of the initial volume of grout after three hours kept at rest.
l) The volume change of grout kept at rest for 24 hours and tested as per ASTM C1090 shall be within the range of -0.5% and +0.5% of the original volume.
m) Fluidity is tested as per ASTM C939 standard using standard flow cone.

3403.6 Post tensioning

a) Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally as per drawings.
b) The method of supporting and fixing shall be such that profile of cables is not disturbed during vibrations, by pressure of wet concrete, by workmen or by construction traffic.
c) Sheathing in which the permanent tendon will not be in place during concreting shall have a temporary tendon inserted or shall be stiffened by some other method to the approval of the Engineer. The temporary tendon shall be pulled out by a special threading machine or other contrivance, before threading the permanent tendon.
d) Where possible, tendons shall be placed prior to concreting. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendons which are damaged or contaminated shall be cleaned or replaced.
e) Tensioning force shall be applied in gradual and steady steps, in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing, applied tensions and elongations shall be in accordance with the approved Drawing or as directed by the Engineer.
f) It shall be ensured that in no case, the load is applied to the concrete before it attains the strength specified on the Drawing or as stipulated by the pre-stressing system supplier, whichever is more.
g) After prestressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the pre-stressing steel or anchorage.
h) The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamometers and by comparison of the measured elongation with the calculated elongation.
i) A complete record of prestressing operations along with elongation and jack pressure data shall be maintained in the required format.

3404 TOLERANCES

3404.1 Permissible tolerances for structural unit

The dimensional tolerances for precast girders shall be as under:

Length	: ±10 mm.
Flange width and thickness	: ±5 mm.
Depth	: ±5 mm.
Web thickness	: ±5 mm.
Minimum surface unevenness	: 1.5 mm on a 3.0 m template.

3404.2 Tolerances for prestressing strands

Permissible tolerances for positional deviation of prestressing strands shall be as under:

Variation from the specified horizontal profile	: 5 mm.
Variation from the specified vertical profile	: 5 mm.
Variation from the specified position in member	: 3 mm.

3405 SAMPLING AND TESTING

a) The materials shall be tested in accordance with the required specifications and shall meet the prescribed criteria and requirements.
b) Prestressing steel, sheaths and accessories like jacks, anchorages, wedges, block plates, etc. shall be procured from authorized manufactures only.
c) Anchorages shall conform to "Recommendations for acceptance and application of pre-stressing systems" published by FIB.
d) The prestressing accessories shall be subjected to an acceptance test prior to their actual use on the work. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificate shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

3406 REFERENCES

1.	IRC: 112	Code of practice for concrete road bridges.
2.	IS: 1785	Specification for plain hard-drawn steel wire for prestressed concrete.
	(Part -1)	*Cold drawn stress-relieved wire.*
	(Part -2)	*As drawn wire.*
3.	IS: 2090	Specification for high tensile steel bars used in prestressed concrete.
4.	IS: 6003	Indented wire for prestressed concrete - specification.
5.	IS: 6006	Specification for uncoated stress relieved strand for prestressed concrete.
6.	IS: 9103	Concrete admixtures - specification.
7.	IS: 14268	Uncoated stress relieved low relaxation seven ply strands for prestressed concrete - specification.
8.	ASTM C1090	Standard test method for measuring changes in height of cylindrical specimens from hydraulic-cement grout.
9.	ASTM C939	Standard test method for flow of grout for preplaced aggregate concrete (flow cone method).
10.	Technical report bulletin 7: "Corrugated plastic ducts for internal bonded post tensioning", published by FIB.	
11.	Technical report: "Recommendations for the acceptance of post-tensioning systems", published by FIB.	
12.	Technical report: "Quality assurance and quality control for post-tensioned concrete structures", published by FIB.	
13.	MoRTH	Specification for Road and Bridge works (5th revision).

+++++++

SECTION 3500 STEEL WORK FOR BRIDGES

3501 GENERAL

This section provides certain specific requirement for quality control of steel bridges in addition to the provisions in Section 1200 of this Manual.

3502 MATERIAL

a) Steel of Quality 'A' Grade Designation E250 (Fe410W) as rolled semi-killed or killed conforming to IS: 2062 shall be used for foot-over bridges and other structures subjected to non-critical loading.
b) Quality 'B' Grade Designation E250 (Fe410W) fully killed and normalized/ controlled cooled, conforming to IS: 2062 shall be used for welded/riveted girders subjected to dynamic loading.
c) Rolled sections like angles, channels, I-sections etc., conforming to IS: 2062 Quality 'A' shall be used in structures till such time rolled sections conforming to IS: 2062 Quality 'B' are not available in the market.
d) High tensile steel shall comply in all respects with the requirement of IS: 2062 Grade Designation E410 (Fe540) or E450 (Fe570) Quality 'D' (both copper bearing quality) according to the welded or riveted work respectively.
e) Steel for bolts shall conform to property class 4.6 or 6.6 as specified in IS: 1367 accordingly, as the structural steel specification is for mild steel or high tensile steel.
f) Steel for drifts shall be in accordance with IS: 1875 for forged quality steel or IS: 7283 for hot rolled bars.
g) Steel for rivets shall comply with the requirement of IS: 1148 for hot rolled rivet bars for general structural purposes and IS: 1149 for high tensile steel rivet bars for high strength structural purposes.
h) Steel casting shall comply with IS: 1030 for normal temperature zone and to IS: 4899 for use at low temperature zone.
i) The physical and chemical requirements of material shall be as per Section 1200 in Part A of this Manual.

3503 WORKMANSHIP

Contractor/Fabricator has to submit a quality assurance plan according to the nature of lubrication work such as welded fabrication or riveted fabrication for the approval of the Engineer. Quality assurance plan shall elaborate nodal point checking and inspection during the stages of fabrication and also the materials. Fabrication work shall be taken up only after receipt of approved Drawing. All members shall carry mark number and item number and, if required serial number.

3503.1 Storage of materials

a) All materials, consumable, including raw steel or fabricated material shall be stored specification wise and size wise above the ground upon platforms, skids or other supports.
b) The electrodes shall be stored specification wise and shall be kept in dry warm condition in properly designed racks.

c) Bolts, nuts, washers and other fasteners shall be stored in racks above the ground with protective oil coating in gunny bags.
d) The paint shall be stored under cover in air tight containers.

3503.2 Straightening, bending and pressing

a) Straightening and flattening of steel shall be done by methods that will not injure the metal. Hammering shall not be permitted.
b) For Straightening by heating, the temperature of steel shall not be more than 650°C.
c) Heating and cooling rate shall be appropriate to the particular type of steel and shall be agreed by the Engineer. Accelerated cooling shall not be used without the approval of the Engineer.
d) Steel having yield stress more than 360 MPa shall not be heat curved.
e) Rolled beams and girders may be curved by either continuous or V-type heating as approved by the Engineer.
f) For flange thickness of 32mm or more, both inside and outside surfaces shall be heated concurrently.
g) The heat of bending shall be conducted so that the temperature of steel does not exceed 620°C. The girder shall not be artificially cooled until temperature comes down to 315°C by natural cooling. The method of artificial cooling has to be approved by the Engineer.

3503.3 Preparation of edges, ends and surfaces

a) Material shall be cleaned and any burring, scales or abnormal irregularities shall be removed.
b) End/edge planing and cutting shall be done by any one of the following prescribed methods or left as rolled.
   i) Shearing, cropping, sawing, machining, machine flame cutting.
   ii) Hand flame cutting with subsequent grinding to a smooth edge.
   iii) Shearing edges of plate not more than 16mm thick with subsequent grinding to smooth profile, which are for secondary use such as stiffeners and gussets.
c) Where machining for edge preparation in butt joint is specified, the ends shall be machined after the members have been fabricated.
d) Outside edges of plate and section, which are prone to corrosion, shall be smoothened by grinding and filing.

3503.4 Rivet and bolt holes

a) All holes for rivets or bolts shall be either punched or drilled. The diameter of holes shall be 1.5 mm and 2.0 mm larger for bolts/rivets less than 25 mm dia. and greater than or equal to 25 mm respectively, if not specified in the Drawing.
b) The tolerance for diameter of the holes shall be equal to +0.15 mm/-0.0 mm.
c) For high strength friction grip bolts, the diameters of holes shall be 1.5 mm larger than those of bolts when the number of plies in the grip does not exceed three, while it is 1.5 mm to 3.0 mm when plies in grip is more than three, unless otherwise specified in the Drawing.

3503.5 Bolted construction

a) All joint surfaces for bolted connection including bolts, nuts, washers shall be free of scale, dirt, burrs or other foreign material and defects that would prevent solid seating of parts.

b) The slope of surface of bolted parts in contact with bolt head and nuts shall not exceed 1:20, plane normal to bolts axis, otherwise suitable tapered washers shall be used.
c) All fasteners shall have a washer under nut or bolt head, whichever is turned in tightening.
d) Each fastener of joint shall be tightened to specified value or equal to 70% of specified minimum tensile strength by hand wrenches (turn of nut method) or calibrated wrenches or manual torque wrenches, impact wrench or any other method as insisted by the Engineer.
e) Bolted connections of structural joints using high tensile friction grip bolts shall comply with requirements mentioned in IS: 4000.

3503.6 Riveted construction

a) Assembled riveted joint surface including those adjacent to the rivet head shall be free of scale, dirt, burrs or foreign material and defects that would prevent solid seating of parts.
b) The part/members to be riveted shall be firmly drawn together with bolts, clamps or track weld. Every third hole of the joint shall have assembly bolts till riveted. Drift shall be used only for matching of holes of the parts/members, but not to the extent as to distort the holes. Drift of larger size than the normal diameter of the holes shall not be used.
c) Rivets shall be heated uniformly to a 'light cherry red colour' from 650°C to 700°C for hydraulic riveting and 'Orange colour' for pneumatic riveting of mild steel rivets. High tensile steel rivets shall be heated up to 1100°C. Any rivet which is heated more than the prescribed limit shall not be driven.
d) Rivet shall be driven in hole when hot so as to fill the hole as completely as possible and shall be of sufficient length to form a head of the standard dimension. When countersunk head is required the head shall fill the countersunk hole. Projection after countersinking shall be ground off wherever necessary.
e) The riveting shall be done by hydraulic or pneumatic machine unless otherwise specified by the Engineer.
f) Any defective rivet due to defect in head size or head driven off the centre shall be removed and replaced.
g) The parts not completely riveted in the shop shall be secured by bolts to prevent damage during transport and handling.

3503.7 Welded construction

a) Surfaces of edges to be welded shall be smooth, uniform and free from fins, tears, cracks and other discontinuities. Surface shall also be free from loose or thick scale, slag rust, moisture oil and other foreign materials.
b) The general welding procedures including particulars of the preparation of fusion faces for metal arc welding shall be carried out in accordance with IS: 9595.
c) The welding procedures for shop and site welds including edge preparation of fusion faces shall be submitted in writing in accordance with IS: 9595 for the approval of the Engineer before commencing fabrication.
d) Electrodes to be used for metal arc welding shall comply with relevant BIS specifications mentioned in Section 1200 in Part A of this Manual.

e) Procedure test shall be carried out as per IS: 3613 to find out suitable wire-flux combination for welded joint.
f) Assembly part for welding shall be in accordance with IS: 9595.
g) The welded temporary attachment shall be avoided as far as possible and if unavoidable, the same shall be approved by the Engineer and any scars due to this shall be removed by cutting, chipping and surface shall be finished smooth by grinding to the satisfaction of the Engineer.
h) For welding any particular type of joint, welders shall qualify to the satisfaction of the Engineer in accordance with appropriate welders qualification test as prescribed in the relevant BIS standards.
i) In assembling and joining parts of a structure or of built-up members, the procedure and sequence of welding shall be such as to avoid distortion and minimise shrinkage stress.
j) All requirements regarding preheating of present material and inter pass temperature shall be in accordance with IS: 9595.
k) Peening of welding shall be carried out wherever insisted by the Engineer.
l) Where it is specified that the butt welds are to be ground flush, the loss of parent metal shall be not greater than that allowed for minor surface defects.
m) The joints and welds listed below are prohibited as these do not perform well under cyclic loading:
    i) Butt joints not fully welded throughout their cross section.
    ii) Butt welds made from one side only without any backing strip.
    iii) Intermittent butt welds.
    iv) Bevel and J-preparations in butt joints for other than horizontal position.
    v) Plug and slot welds.

3503.8 Welding of stud shear connectors

a) The stud shear connectors shall be welded in accordance with the manufacturer's instructions including preheating.
b) The stud and surface to which studs are welded shall be free from scale, moisture, rust and other foreign material. The stud base shall not be painted, galvanised or cadmium plated prior to welding.
c) Welding shall not be carried out when temperature is below 0°C or surface is wet.
d) The welds shall be visually free from cracks and lack of fusion and shall be capable of developing at least the nominal ultimate strength of studs.
e) The procedural trial for welding the stud shall be carried out when insisted by the Engineer.

3503.9 Shop assembly

a) The steel work shall be temporarily assembled at place of fabrication.
b) Assembly shall be full truss or girder, unless progressive truss or girder assembly, full chord assembly or progressive chord assembly as specified by the Engineer.
c) The field connections of main members of truss, arches, continuous beam spans, bents, plate girders and rigid frame assembled, aligned, accuracy of holes, camber shall be checked by the Engineer and then only reaming of subsize holes to specified size shall be taken up.
d) The assembly will be dismantled after final drilling of holes and approval of the Engineer.

e) The camber diagram showing camber at each panel point, and method of shop assembly and any other relevant detail shall be submitted to the Engineer for approval.

3503.10 Painting

Typical guidelines for epoxy based paints and the conventional painting system for bridge girders are specified under Section1900 of MoRTH Specifications.

3504 FABRICATION TOLERANCES

a) The fabrication tolerance for various superstructure elements shall be as per *IRS Specification for fabrication and erection of steel girder bridges and locomotive turn-tables* as shown in the tables 3500-1, 3500-2, 3500-3 and 3500-4.

Table 3500-1: *Manufacturing tolerances for plate girders*

Sl. No.	*Dimensions specified*	*Toler-ances (mm)*	*Notation in Fig.3500-1*
1	Overall length of the girder	+6/-3	*a*
2	Distance between centers of bearings	+1/-1	*b*
3	Depth over angles	+3/-1	*c*
4	Corner of flange angle to edge of web at any place	+0/-2	*d*
5	Diagonal at either end of the assembled span	+3/-3	*e*
6	Centers of intersection of diagonals with girder flange measured along the girder flange	+3/-3	*f*
7	Butting of compression ends:		
	(i) Throughout	+0/-0.15	*g*
	(ii) Locally	+0/-0.25	*g*
8	Butting edge at web splices	+0/-1	*h*
9	Straightness of girder bottom laid on the ground and checked with piano wire:		
	(i) Vertical plane:		
	Convexity	+0/-3	*j*
	Concavity	+0/-0	*j*
	(ii) Horizontal plane	+2/-2	*j*

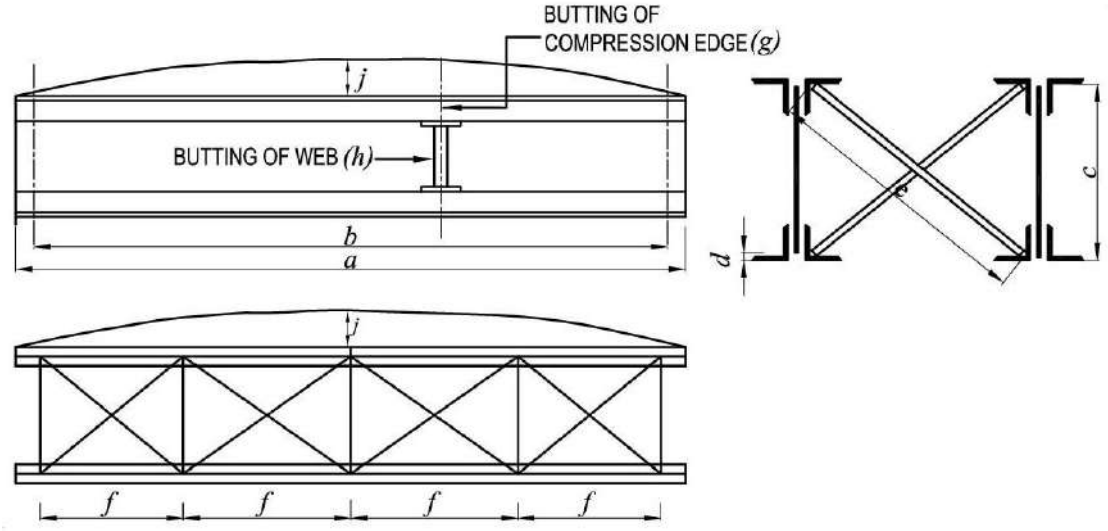


Fig. 3500-1

Table 3500-2: *Manufacturing tolerances for open web girders*

Sl. No.	*Dimensions specified*	*Tolerances (mm)*	*Notation in Fig.3500-2*
1	Over-all length of girders	+1/-1	*k*
2	Distance between centre to centre of bearing	+1/-1	*l*
3	Cross diagonals of assembled bays	+1/-1	*m*
4	Centre to centre of cross girders	+1/-1	*n*
5	Centre to centre of rail bearer	+1/-1	*p*
6	Panel length in lateral bracing system	+1/-1	*q*
7	Distance between inter section line of chords: vertical and horizontal	+1/-1	*r*
8	Butting edges of compression members:		
	(i) Throughout	+0/-0.15	*s*
	(ii) Locally	+0/-0.15	*s*
9	Twist in members	+0/-0	*t*
10	Lateral distortion between points of lateral supports	+0.001 L/ -0.001L	*u*

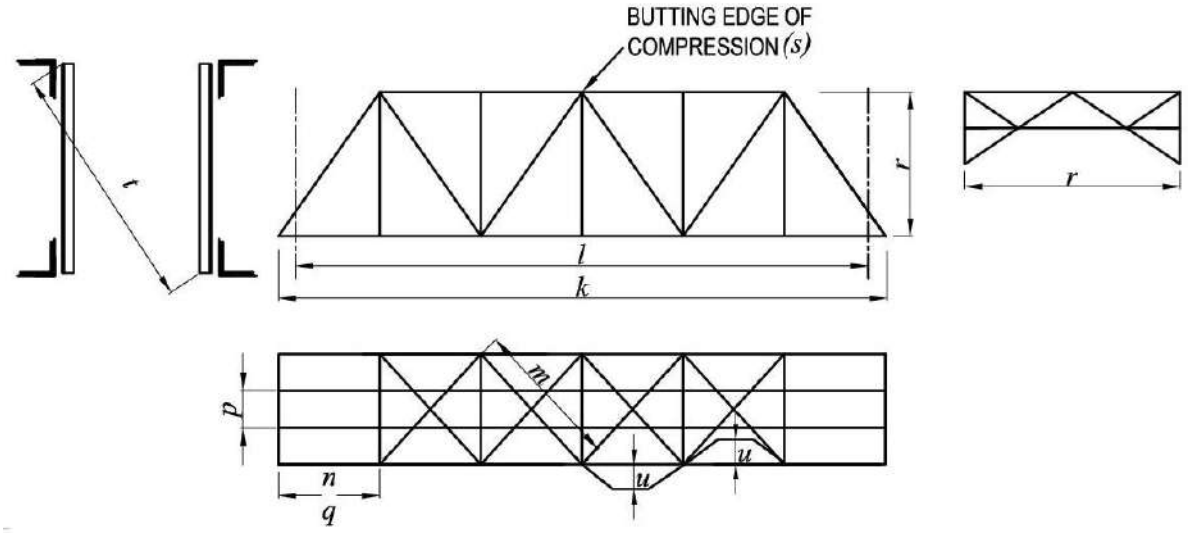


Fig. 3500-2

Table 3500-3: *Manufacturing tolerances for holes on nominal diameter of hole*

Sl. No.	*Dimensions specified*	*Toler-ances (mm)*	*Notation in Fig.3500-3*
1	Between any two holes in group	+0.5/-0.5	*v*
2	Between holes of one group and another	+1/-1	*w*
3	Edge distance	+0.5/-0.5	*x*
4	Distance of 'GO' gauge open holes in two or more thicknesses	+0/-0.8	*y*

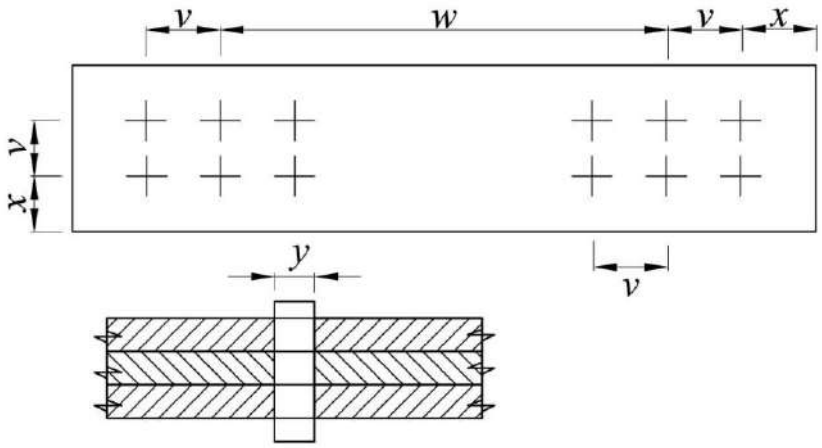


Fig. 3500-3

Table 3500-4: *Manufacturing tolerances for special fabrication as applicable to welded plate girder*

Sl. No.	*Dimension specified*	*Tolerances (mm)*
1	Depth at the centre of web	+2/-1
2	Flange out of square for compression member and beams	1/200 or 3 max from edge (whichever is less)
3	Displacement of vertical axis of the web with reference to flange.	2
4	Box width of member	-0/+3
5	Verticality of stiffener or diaphragm out of plumb.	2
6	Overall length of girder	+6/-3
7	Depth of the girder at the ends	+3/-1
8	Depth of the girder at the centre of span	+2/-1
9	Distance between centre of bearings	+1/-1
10	Diagonal at either end of assembled span	+3/-3

b) Bolted splice shall be provided with steel packing plates where necessary to ensure that the sum of any unintended steps between adjacent surfaces does not exceed 1 mm for HSFG bolted joints and 2 mm for other joints.

c) All parts in an assembly shall fit together accurately within tolerances specified in IRC: 24 as shown in table 3500-5, unless otherwise specified in the Drawing.

d) A machined bearing surface as specified in the Drawing, shall be machined within a deviation of 0.25 mm for surfaces that can be inscribed within a square of side 0.5 m.

e) In welded butt joints, misalignment of parts shall not exceed the lesser of 0.15 times the thickness of thinner pats or 3 mm. However, if due either to different thickness arising from rolling tolerances or combination of rolling tolerances with above permitted misalignment, the deviation is more than 3 mm, it shall be smoothened by slopes not steeper than 1:4.

Table 3500-5: *Manufacturing tolerances for individual components*

Sl. No.	*Dimensions specified*	*Tolerances (mm)*
1	Length:	
	a) Member with both ends finished for contact bearing	± 1
	b) Individual component of members with end plate connection.	+0/-2
	c) Other Members:	
	i) Upto and including 12 m	± 2
	ii) Over 12 m	± 3.5
2	Width:	
	a) Width of built-up girders.	± 3
	b) Deviation in the width of members required to be inserted in other members.	+0/-3
3	Depth:	
	Deviation in the depths of solid web and open web.	+3/-2
4	Straightness:	
	a) Deviation from straightness of columns.	L/300 (15 Max)
	i) In elevation	+5
	ii) In plan	+0
5	Deviation of centre line of web from centre line of flanges in built-up members at contact surfaces.	+3
6	Deviation from flatness of plate webs of built-up members in a length equal to the depth of the member	0.005d (2 Max)
7	Tilt of flange of plate girders.	
	a) At splices & stiffeners, at supports, at the top flanges of plate girders, at bearings.	0.005b (2 Max)
	b) At other places.	0.015b (4 Max)
8	Deviation from squareness of flange to web of columns and box girders.	L/1000
9	Deviation from squareness of fixed base plate (not machined) to axis of column. The dimension shall be measured parallel to the longitudinal axis of the column at points where the outer surfaces of column section make contact with the base plate.	D/500
10	Deviation from squareness to machined ends to axis of columns.	D/1000
11	Deviation from squareness of machined ends to axis of beam or girders.	D/1000
12	Ends of members abutting at joints through cleats or end plates, permissible deviation from squareness of ends.	1/600 of depth (1.5 Max)

f) Rolling and cutting tolerance shall be as per IS: 1852. The thickness tolerance check measurements of plates and rolled sections shall be taken at not less than 15 mm from edge.

3505 INSPECTION

a) No protective treatment shall be applied to the work until the appropriate inspection & testing has been carried out.
b) The stage inspection shall be carried out for all operations so as to ensure the correctness of fabrication and good quality.
c) All the steel sections used in the fabrication shall have mill test certificate clearly indicating the specification to which the steel conforms and whether steel is killed and normalized. All the cast mark numbers/heat mark numbers shall be recorded along with the number of plates in a register as soon as the plates are received. Whenever the steel is received without any test certificate, a sample test piece from plate of each cast mark number is to be cut and sent for testing. If required, rivets, bolts, nuts, washers, welding consumables, steel forging, casting and stainless steel shall be tested for mechanical and chemical properties as per various Indian standards as may be applicable and shall conform to requirements specified in IS: 2062 and IS: 11587.
d) Lamination check in plates shall be carried out by ultrasonic testing or any other approved methods or should have the mill test certificate for the testing. Flame cut edges without visual signs of laminations need not be tested unless insisted by the Engineer.
e) Steelwork shall be inspected for surface defects and exposed edge lamination during fabrication and blast cleaning. Significant edge laminations found shall be reported to Engineer for his decision.
f) Chipping, grinding, machining or ultrasound testing shall be used to determine depth of imperfection.
g) For dynamically loaded structures recommended criteria for allowable discontinuities for edge defects and repair procedure shall be as given in table 3500-6, until and unless specified otherwise. The weld procedure shall be appropriate to the material.
h) Horizontal curvature and vertical camber shall not be measured for final acceptance before all welding and heating operations are completed and flanges have cooled to uniform temperature.
i) Horizontal curvature shall be checked with girder in the vertical position by measuring offsets from a string line or wire attached to both flanges or by any other suitable means. Camber shall be checked by adequate means.
j) Acceptable deviation in holes drilled and reamed for mild steel and high strength friction grip bolts should be as per appropriate BIS.
k) Bolted connection joints, black bolts and high strength bolts shall be inspected and tested for compliance or requirements mentioned in IRC: 24.
l) The Engineer shall observe the installation and tightness of bolts so as correct tightening procedures is used and shall determine that all bolts are tightened.
m) Regardless of tightening method used, tightening of bolts in a joint should commence at the most rigidly fixed or stiffest point and progress towards the free edges, both in initial snug tightening and in final tightening.
n) The tightness of bolts in connection shall be checked by inspection wrench,

which can be torque wrench, power wrench or calibrated wrench.

o) Tightness of 10% bolts, but not less than two bolts, selected at random in each connection shall be checked by applying inspection torque.

Table 3500-6: *Discontinuity of edge*

Sl. No.	*Discontinuity*	*Repairs required*
1	Discontinuities of maximum 3 mm in depth, any length for material thickness up to 200 mm	None.
2	Discontinuities of 3 mm to 6 mm in depth and over 25 mm in length for thickness up to 100 mm and 6 mm to 12 mm depth, over 50 mm in length for thickness 100 mm to 200 mm	Remove and need not be welded.
3	Discontinuities of 6 mm to 25 mm in depth over 25 mm in length for thickness upto 100 mm and 12 mm to 25 mm in depth, over 25 mm in length for thickness over 100 mm to 200 mm	Remove and weld. No single repair shall exceed 20% of edge being repaired.
4	Discontinuities over 25 mm in depth, any length for thickness 100 mm to 200 mm	With approval of Engineer remove to depth of 25 mm and repair by weld block.
5	On edges cut in fabrication, discontinuities of 12 mm maximum depth any length	None.

p) If no nut or bolt head is turned by this application connection can be accepted as properly tightened, but if any nut or head has turned all bolts shall be checked and if necessary retightened.

q) Bolts and bolted connection joints with high strength friction grip bolts shall be inspected and tested according to IS: 4000.

r) Rivets and riveted connection shall be inspected and tested for compliance or requirements mentioned in IRC: 24.

s) The firmness of the joint shall be checked by 0.2 mm filler gauge, which shall not go inside under the rivet head by more than 3 mm. There shall not be any gap between members to be riveted.

t) Driven rivets shall be checked with rivet testing hammer. When struck sharply on head with rivet testing hammer, rivet shall be free from movement vibration.

u) All loose rivets and rivets with cracked, badly formed or deficient heads or with heads which unduly eccentric with shanks, shall be cut out and replaced.

v) The alignment of plates at all bolted splice joint and welded butt joints shall be checked for compliance with requirements of IRC: 24.

w) Testing of flame cut and sheared edges are to be done where the hardness criteria of IRC: 24 is adopted. Hardness testing shall be carried out on six specimens.

x) Welders qualification test shall be carried out as per requirements laid down in IS: 7318 (Part1), for respective approved welding procedure, they shall satisfy relevant requirements of IS: 7310 (Part 1).

y) Welding procedures, welded connection and testing shall be in compliance of requirements mentioned in IRC: 24.

z) All metal arc welding shall be in compliance with the provision of IS: 9595. The method of inspection shall be according to IS: 822 and extent of inspection and

testing shall be in accordance with the relevant standards or in the absence of such a standard, as agreed with the Engineer.

3506 TESTING

The destructive and non-destructive test of weld shall be carried out according to IS: 7307 (Part-1).

3506.1 Non-destructive testing of welds

One or more of following methods may be applied for inspection or testing of weld.

3506.1.1 Visual inspection

a) All welds shall be visually inspected, which should cover all defects of weld such as size, porosity, crack in the weld or in the HAZ (Heat affected zone) etc. Suitable magnifying glass may be used for visual inspection.
b) A weld shall be acceptable by visual inspection if it shows that:
   i) The weld has no crack.
   ii) Thorough fusion exists between weld and base metal, and between adjacent layers of weld metal.
   iii) Weld profiles are in accordance with requisite clauses of IS: 9595 as agreed with Engineer.
   iv) The weld shall be of full cross section, except for the ends of intermittent fillet welds outside of their effective length.
   v) When weld in transverse to primary stress, undercut shall not be more than 0.25 mm deep in the part that is under cut and shall not be more than 0.8 mm deep when the weld is parallel to the primary stress in the part that is undercut.
   vi) The fillet weld in any single continuous weld shall be permitted to underrun the nominal fillet weld size specified by 1.6 mm without correction provided that undersize portion of the weld does not exceed 10% of the length of the weld. On the web to flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.
   vii) The piping porosity in fillet welds shall not exceed 1 in each 100 mm of weld length and the maximum diameter shall not exceed 2.4 mm, except for fillet welds connecting stiffeners to web where the sum of diameters of piping porosity shall not exceed 9.5 mm in any 25 mm length of weld and shall not exceed 19 mm in any 300 mm length of weld.
   viii) The full penetration grove weld in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the maximum diameter shall not exceed 2.4 mm.

3506.1.2 Magnetic particle and radiographic inspection

a) Welds that are subject to radiographic or magnetic particle testing in addition to visual inspection shall have no crack.
b) Magnetic particle test shall be carried out for detection of crack and other discontinuity in the weld according to IS: 5334.
c) Radiographic test shall be carried out for detection of internal flaws in the weld such as crack, piping porosity, inclusion, lack of fusion, incomplete penetration etc. This test may be carried out as per IS: 1182 and IS: 4853.

3506.1.3 Ultrasonic inspection

a) The ultrasonic testing in addition to visual inspection shall be carried out for

detection of internal flaws in the weld such as cracks, piping porosity inclusion, lack of fusion, incomplete penetration etc.

b) Acceptance criteria shall be as per IS: 4260 or any other relevant BIS Specifications and as agreed by Engineer.

3506.1.4 Liquid penetrant inspection

The liquid penetrant test shall be carried out for detection of surface defect in the weld as per IS: 3658, in addition to visual inspection.

3506.1.5 Stud shear connectors

a) Stud shear connectors shall be subject to the following tests:
   i) The fixing of studs after being welded in position shall be tested by striking the side of the head of the stud with 2 kg hammer, to the satisfaction of the Engineer.
   ii) The selected stud head stroked with 6 kg hammer shall be capable of lateral displacement of approximately 0.25 height of the stud from its original position. The stud weld shall not show any signs of cracks or lack of fusion.

b) The studs whose welds have failed the test given in (i) and (ii) shall be replaced.

3506.2 Inspection of members and components

3506.2.1 Inspection requirement

a) The fabricated member/ component made out of rolled and built-up section shall be checked for compliance of tolerances given in table 3500-1.
b) Inspection of members/components for compliance with tolerances, the check for deviation shall be made over the full length.
c) During checking the inspection requirement shall be placed in such a manner that local surface irregularities do not influence the results.
d) For plate, out of plane deviation shall be checked at right angle to the surface over the full area of plate.
e) The relative cross girder or cross frame deviation shall be checked over the middle third of length of cross girder or frame between each pair of webs and for cantilever at the end of member.
f) During inspection, the component/member shall not have any load or external restraint.

3506.2.2 Inspection stages

The inspection to be carried out for compliance to tolerances shall include but not be limited to the following stages:

a) For completed parts, component/members on completion of fabrication and before any subsequent operation such as surface preparation, painting transportation, erection.
b) For webs of plate and box girders, longitudinal compression flange stiffeners in box girder and orthotropic decks and all web stiffeners after completion of site joint.
c) For cross girders and frames, cantilevers in orthotropic decks and other parts in which deviations have apparently increased on completion of site assembly.

3506.2.3 Acceptance criteria

a) Where, on checking member/component for the deviations in respect of out-of-plane or out-of straightness at right angles to the plate surface, and any other instances, exceed tolerance, the maximum deviation shall be measured and recorded.

b) The recorded measurements shall be submitted to the Engineer, who will determine whether the component/member may be accepted without rectification, with rectification, or rejected.

3507 REFERENCES

For detailed list of IS codes and specifications regarding the steel construction work, refer Section 1200 in Part A of this Manual.

1. IRC: 22 Standard specification and code of practice for road bridges: Composite construction.
2. IRC: 24 Standard specification and code of practice for road bridges: Steel road bridges.
3. IRC: SP-104 Guidelines for fabrication and erection of steel bridges.
4. Indian Railway Standard: "*Specification for fabrication and erection for steel girder bridges and locomotive turn tables*".
5. Indian Railway Standard: *"Guidelines on fabrication of steel structure of foot over bridges"*.
6. Indian Railway Standard: "Code of practice for metal arc welding in structural steel bridges carrying rail, rail-cum-road or pedestrian traffic."
7. MoRTH Specification for Road and Bridge works (5th revision).

+++++++

SECTION 3600 CULVERTS

3601 GENERAL

Culvert is a cross drainage structure having a total length of 6 m or less between the inner faces of the dirt walls or extreme vent way boundaries measured at right angles thereto. Pipe and RCC slab/box culverts are discussed under this section. Construction of culverts shall conform to IRC: SP-13 and MoRTH Specifications or as directed by the Engineer.

3602 PIPE CULVERTS

3602.1 Requirements

a) Reinforced concrete pipes NP-3 or NP-4 type conforming to IS: 458 shall be used. The internal diameter shall not be less than 900 mm except in unavoidable situations.
b) Masonry work for pipe culverts shall conform to Section 3200 of this Manual.
c) Concrete work including reinforcing steel for pipe culverts shall conform to Section 3300 of this Manaul.
d) Provide concrete cradle bedding for pipes of internal dia. 1000 mm or more and when height of fill is more than 4 m above the pipe. Make concrete cradle bedding having mix not leaner than M15 with shape and dimensions as indicated in the Drawing or as directed by the Engineer. The pipe shall be laid on the concrete bedding before the concrete has set.
e) Provide first class bedding when height of filling is less than 4 m above the pipe. Make a continuous layer of well compacted approved granular material, passing 5.6 mm suitably compacted/rammed. The compacted thickness of the granular bedding layer shall not be less than 75 mm.
f) For expansive soils, provide a layer of approved granular material or non-expansive material of minimum 450 mm thickness under the bedding.
g) The back fill of soil shall be clean from boulders, large roots, excessive amounts of sods and other vegetable matter and lumps which shall be approved by the Engineer.
h) Backfilling upto 300 mm above the top of the pipe shall be carefully done and the soil thoroughly rammed, tamped or vibrated in layers not exceeding 150 mm. Approved pneumatic or light mechanical tamping equipment can be used.

3602.2 Workmanship

a) For height of fill more than 3 m, or three times the external dia of pipe above bed level, construct the embankment to the level above the top of the pipe (equal to external dia of pipe) and width not less than five times the dia of pipe. Lay the pipe in trench after the construction of embankments.
b) If spongy, soft or other unstable material is met with at the location of pipe culvert, remove the material to the required depth, width and length, back fill with approved granular material and compact to the required level.
c) Where rock or bouldery strata is met with, take down excavation to at least 200 mm below the bottom level of pipe, remove all loose material and fill the space with approved earth.

d) Make arrangements for lifting, loading and unloading of pipes from factory/yard to site, such that no undue strain or damage occurs due to fall or impact.
e) For manual unloading from trucks, roll down pipes on a pair of skids hooked onto the trucks and control movement with a rope passing round the pipes.
f) Preload the areas to induce major portion of settlement before the pipe is installed.
g) Provide a bedding surface of firm foundation of uniform density, throughout the length of culvert with specified bedding material depending on dia of pipe and height of fill above pipe.
h) Lower the pipes in bed either by tripod pulley arrangement or by manual labour using chain pulley blocks in a manner to place them in proper position without damage.
i) When two or more pipes are laid adjacent to each other, place them separated by a distance equal to half the dia of the pipe subject to a minimum of 450 mm.
j) When pipes are laid in two layers, keep the centres of pipes such that when joined shall form equilateral triangles.
k) Lay the pipes as specified in IS: 783 for different conditions such as positive projecting condition, trench condition etc.
l) Lay the pipes on the prepared foundation, commencing from outlet and proceed towards the inlet. In case of pipes with bell mouth, keeps the belled end facing the upstream. Keep the invert of pipe minimum 150 mm below average bed level. However, if the invert level is more than 300 mm, a catch pit of size 1500 mm x 1000 mm up to ground level shall be constructed.
m) Join the pipes either by collar joint or by flush joint. Place the collar such that its centre coincides with the joints and even annular space is left between the collar and the pipe.
n) Choose either internal flush joint or external flush joint. Fill the jointing space with cement mortar 1:2, which remains in position when forced with a trowel or rammer.
o) Fill the recess at the end of the pipe with jute braiding dipped in hot bitumen or suitable approved compound, while jointing pipe lines.
p) Keep the width of collars 150 mm to 200 mm and caulking space between 13 mm and 20 mm according to diameter of pipes.
q) Back fill trenches after the pipes have been laid and after jointing material has hardened. On top of pipe upto 300 mm, thoroughly ram, tamp or vibrate the soil in two layers. Thoroughly consolidate the materials under the 'haunches' of pipes using light mechanical tamping equipment.
r) Carryout filling of the trench simultaneously on both sides of the pipe, such that unequal pressures do not occur.
s) Ensure that the minimum height of fill above the pipe including road crest shall be 1000 mm.
t) When minimum specified cushion cannot be provided over the pipe, encase the pipe in M10 concrete of specified thickness.

3602.3 Tolerances

The following tolerances are permitted for concrete pipes as per IS: 458.

i) Overall length : ±1% of standard length.
ii) Internal dia. : ±10 mm.

iii) Barrel thickness :

For 80 mm to 95 mm : +5 mm/-2.5 mm.

Over 95 mm : +7 mm/-3.5 mm.

3602.4 Sampling and testing

a) Quality control tests for masonry work shall be carried out by the contractor as per Engineer's instructions conforming to Section 3200 of this Manual.

b) The Contractor shall submit to the Engineer the manufacturer's certificate for concrete pipes regarding the dimensions, manufacturing defects, tolerances (IS: 458) and three edge bearing test (IS: 3597) before delivery at site.

c) During construction of pipe culverts, the Contractor shall carry out the tests indicated in the table 3600-1 as per Engineer's instructions.

Table 3600-1: *Quality control tests for pipe culverts*

Sl. No.	*Material/ work*	*Test / check*	*Frequency*
1	Bedding	-Materials (as per specification) -Length, width and thickness. -Preformation of cradle to lay pipes in bedding. -Top and bottom levels.	While laying.
2	Laying and jointing of pipe	-Invert level. -Longitudinal gradient. -Spacing when 2 or more pipes are laid in single or multiple rows. -Jointing of pipes	Before back filling.
3	Backfill	-Filling of trench on both sides. (simultaneously) -Tamping around pipe.	During filling earth/ granular material around pipe after laying.
4	Cushion over pipes	Thickness	While filling.
5	Brick/Stone masonry for head walls	Section 3200 of this Manual.	As per relevant clauses.
6	Side slopes on head walls	-Slope -Stone pitching.	Before construction of guard stones.

3603 RCC SLAB CULVERTS – SOLID SLABS AND BOX CULVERTS

3603.1 General

The cross sections of foundations, substructures such as abutments, return walls, superstructure, drainage spouts, railings, parapets etc. and all other details shall be strictly in accordance with Drawings or as directed by the Engineer.

3603.2 Requirements/Workmanship

a) The requirements and quality control for various types of materials used for the construction of culverts shall comply with Section 3300 of this Manual.

b) Take the minimum depth of foundation up to the stratum having specified bearing capacity shown in the Drawing but not less than 2 m below the scour level where no bed protection is provided or 1.5 m below the protected bed level.

c) In case of rocky bed, ensure embedment of foundation into the rock below, the minimum depth being 500 mm for hard rocks and 1200 mm for soft erodible rocks.
d) Provide 300 mm thick plain concrete M15 grade footing, unless otherwise specified in the Drawings. Provide a minimum offset of 150 mm for the base of substructure.
e) Set out plan dimension of the foundation at the bottom of foundation trench and check with respect to original reference line and axis.
f) Before laying foundation concrete, clean the earth surface of all loose material and sprinkle water to wet. Provide side formwork as per required dimensions and height.
g) Lay foundation concrete continuously to the required thickness up to the level of construction joint proposed.
h) Finish the concrete surface smooth with a trowel and ensure curing as specified in Section 3300 of this Manual.
i) Carryout dewatering where necessary for laying of concrete so as to keep the water level below foundation level with adequate provisions/precautions.
j) Remove loose sand laid on foundation before commencement of back filling. Refill all spaces excavated and not occupied by permanent work with earth up to surface of surrounding ground.
k) In case of excavation in rock, fill the circular space with M15 concrete.
l) Adopt coursed rubble/stone masonry or plain/reinforced cement concrete for piers, abutments and wing/return walls. For wings and return walls up to 3 m height, use random rubble masonry or plain cement concrete.
m) Before commencing the masonry/concrete work, scrub the foundation with wire brush and remove all loose material and wet the surface.
n) Make provision for weep holes in solid abutments and provide filter media.
o) Provide vertical expansion gaps of 20 mm width between abutments and wing walls.
p) Provide plain/reinforced concrete components as per Section 3300 of this Manual.
q) Wearing coat, railings/parapets, approach slabs and drainage spouts shall be provided for the structure as per the Drawing or as instructed by the Engineer.

3603.3 Sampling and testing

Quality control tests of the concrete work shall be carried out in accordance with Section 3300 of this Manual.

3604 REFERENCES

1. IRC: SP: 13 Guidelines for the design of small bridges and culverts.
2. IS: 458 Precast concrete pipes (with and without reinforcement) - specification.
3. IS: 783 Laying of concrete pipes.
4. IS: 3597 Methods of test for concrete pipes.
5. MoRTH Specification for Road and Bridge works (5th revision).

+++++++

SECTION 3700 FOUNDATIONS

3701 GENERAL

Quality aspects in the construction of foundation for bridge structures are discussed in this section. The work may be carried out in accordance with the details shown in the Drawings and conforming to the requirements stipulated in IRC: 78, MoRTH Specifications as applicable or as directed by the Engineer. The materials shall comply with Section 3300 of this Manual.

3702 OPEN FOUNDATION

Open foundations are provided where the foundations can be laid in a stratum which is inerodible or where the extent of scour of bed is reliably known and the work is constructed with plain or reinforced concrete.

3702.1 Workmanship

a) Excavation for laying the foundation shall be carried out in accordance with Section 3100 of this Manual. The bottom 300 mm of excavation may preferably be done just before laying the levelling course below foundation.

b) In the event of excavation having been made deeper than that shown in the Drawing or as ordered by the Engineer, the extra depth shall be made up with M10 concrete in case of foundation resting on soil and with concrete of the same grade as that of the foundation, in case of foundation resting on rock. This shall be done at the cost of the Contractor unless specified in the Contract.

c) Open foundations shall be constructed in dry conditions and the Contractor shall provide for adequate dewatering arrangements, wherever required, to the satisfaction of the Engineer.

d) For foundation resting on soil, a levelling course of M10 concrete of minimum thickness 100 mm or as specified in the Drawing shall be provided above the natural ground to support the foundation concrete. No construction joint shall be provided in the levelling course.

e) For foundations resting on rock, the rock surface shall be cleaned of any loose material and then levelled with a layer of concrete of the same grade as that of the foundation, so as to provide an even surface. In case of sloping rock profile, the rock surface can be prepared by providing suitable benching (Refer figure 3700-1).

f) Levels of the surface shall be taken at suitable intervals to check the precision of work.

g) Side formwork shall be used for foundation concrete work. When concrete is laid in slope without top formwork, the slump of the concrete shall be carefully maintained to ensure that compaction is possible without slippage of freshly placed concrete down the slope.

h) Foundation concrete of required dimensions and shape shall be laid continuously up to the location of construction joint shown in the Drawing or as directed by the Engineer.

i) Formwork shall not be removed earlier than 24 hours after placing of concrete. Where formwork has been provided for slanting surface of the footing, the same shall be removed as soon as concrete has hardened.

j) Curing of concrete shall be carried out by wetting of formwork before removal. After its removal, curing shall be as given in Section 3300 of this Manual. Alternately curing may be also carried out by laying not less than 100 mm thickness of loose moistened sand, free from clods or gravel, over the concrete. The sand shall be kept continuously moist for a period of 7 days. Before backfilling is commenced, the loose sand shall be removed and disposed of or as directed by the Engineer.

k) In situations where foundations cannot be laid dry, concrete shall be laid under water only by tremie and no pumping of water shall be permitted from the time of placing of concrete up to 24 hours after placement.

l) Where blasting is required, it shall be carried out in accordance with Section 3100 of this Manual.

m) All spaces excavated and not occupied by the foundations or other permanent works shall be backfilled with earth up to surface of surrounding ground with sufficient allowance for settlement. Backfilling shall be in accordance with Section 3100 of this Manual.

n) In case of rock excavation, the backfill up to 1.5 m in soft rock or 0.6 m in hard rock, the annular space around the foundation shall be filled with M15 concrete up to the top level of rock.

o) If the depth of backfill required is more than 1.5 m in soft rock or 0.6 m in hard rock above the foundation level, then backfill shall be made up to this level by M15 concrete and the portion above shall be filled up a leaner concrete or with boulders grouted with cement.

p) For guidance regarding safety precautions to be taken IS: 3764 may be referred to.

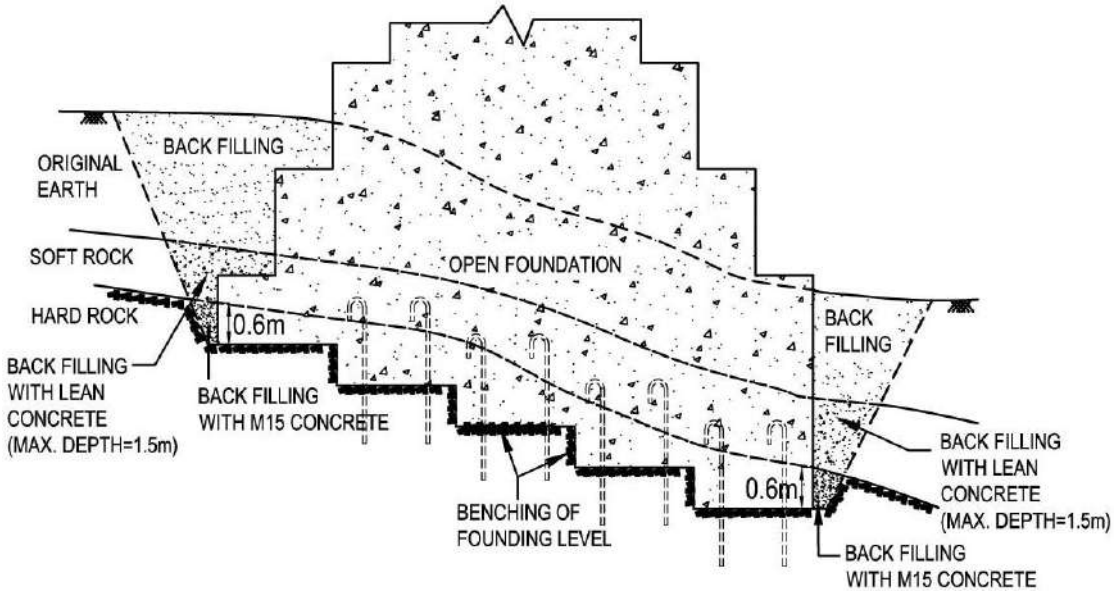


Fig. 3700-1: Open foundation on sloping rock profile.

3702.2 Tolerances

The following tolerances are permitted for open foundations.

a) Variation in dimensions : +50 mm/-10 mm.

b) Misplacement from specified position in plan : ±15 mm.

c) Surface unevenness measured with 3 m straight edge : ±5 mm.
d) Variation of levels at the top : ±25 mm.

3703 PILE FOUNDATION

Piles transmit the load of a structure to competent sub-surface strata by the resistance developed from bearing at the toe or skin friction along the surface or both. The piles shall be required to carry vertical downward or upward (uplift) loads and lateral loads.

3703.1 Requirements/Workmanship

a) For construction of piles, guidance shall be taken from IS: 2911 (With latest amendments) subject to limitations/stipulations given in IRC: 78 and MoRTH Specifications.
b) For both precast and cast-in-situ piles, the grade of concrete, minimum cement content, water to cement (w/c) ratio and slump at the time of placement shall be as per table 3700-1.

Table 3700-1: *Requirements for concrete for pile foundation*

Item	*Driven cast in – situ piles*	*Precast piles*
Grade of concrete	M35	M35
Minimum cement content	400 kg/m3	400 kg/m3
Maximum w/c ratio	0.4	0.4
Slump	150 - 200	50 - 75

c) High alumina cements (quick setting cement) shall not be used in marine conditions.
d) When both chlorides and sulphates are present, in soil or ground water, sulphate resistant cement shall not be used. For improving resistance against the penetration of chlorides and sulphates, mineral admixtures such as fly-ash, silica fumes as per IRC: 112 shall be used.

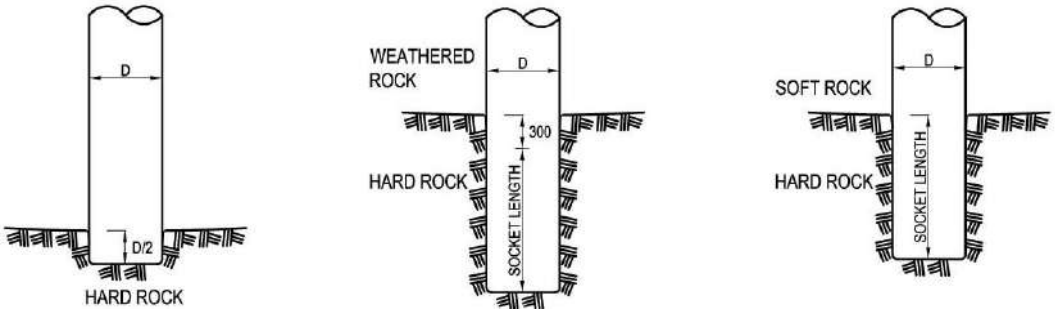
3703.2 Precast concrete piles

Manufacture and driving of precast/pre-stressed concrete piles shall conform to the guidelines contained in IS: 2911, IRC: 78 and MoRTH Specifications.

3703.3 Bored cast-in-situ concrete piles

a) Boring shall be carried out using rotary equipment. Percussion type of equipment shall be used only if approved by the Engineer. The capacity of rig shall be adequate so as to reach the required depth.
b) A continuous record shall be kept by the Engineer as to the volume of concrete placed in relation to the length of pile that is cast.
c) Defective piles shall be removed or left in place as judged convenient without affecting performance of adjacent piles or pile cap. Additional piles shall be provided to replace defective piles.
d) Uncased cast in-situ piles shall not be allowed where mud flow conditions exist. The drilling mud such as bentonite suspension shall be maintained at a level sufficiently above the surrounding ground water level throughout the boring operation.
e) Chiselling shall be carried out within the borehole in case of any underground obstruction or hard strata only with the approval of the Engineer.
f) In case pile is to be socketed into medium or hard rock, the equipment mobilised shall have adequate capability to do so up to the required socket length as per the Drawing (Refer figure 3700-2).

g) Prior to the placing of the reinforcement cage, the pile shaft shall be cleaned of all loose materials. Inadequate cleaning of the base can lead to formation of a soft base or soft toe which may result in reduction of load bearing capacity of the pile.



a) Normal pile b) Rock socketed pile

Fig. 3700-2: Founding of bored piles in hard rock

h) Pile reinforcements as shown in the Drawing shall be tied in place to form a cage which is lowered into the pile shaft. Reinforcement at the bottom shall not be provided with L-bends as these may interfere with cleaning of the pile base.

i) Where concrete is placed in dry and a casing is present, the top 3 m of the pile shall be compacted using internal vibrators. Where mud flow conditions exist, the casing of cast in-situ piles shall not be allowed to be withdrawn.

j) Concrete shall be properly graded, shall be self compacting and shall not get mixed with soil, excess water, or other extraneous matter. Care shall be taken in silty clays and other soils which have the tendency to squeeze into the newly deposited concrete and cause necking. Sufficient head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

k) The slump of concrete shall be in the range between 100mm to 180mm depending on the manner of concreting. Table 3700-2 gives general guidance to select slump of concrete.

Table 3700-2: *Slump of concrete for pile foundation*

Slump (mm)		*Condition of concreting*
Minimum	*Maximum*	
100	180	- Pouring into water free unlined bore. - Reinforcement is not spaced widely.
150	180	- Concrete is to be placed under water or drilling mud by tremie.

l) Bored cast in-situ piles in soils which are stable, may often be installed with only a small liner length at the top. A minimum of 2 m length of top of bore shall invariably be provided with casing to ensure against loose soil falling into the bore.

m) Permanent steel liner shall be provided at least up to maximum scour level. The minimum thickness of steel liner shall be 6 mm.

n) Permanent steel liner shall be provided for the required depth of the pile in the following situations:
   i) The surrounding soil is marine clay.
   ii) Soft soil is present.
   iii) Under ground water flow is predominant to cause loss of cement.
   iv) Surrounding soil has sulphate content equal to or more than 1%.
   v) Surrounding water has sulphate content equal to or more than 2500 ppm.
   vi) Leakage of sewage is expected.

o) Where bored cast in-situ piles are used in soils liable to flow, the bottom of the casing shall be kept sufficiently in advance of the boring tool to prevent the entry of soil into the casing leading to formation of cavities and settlements in the adjoining ground. The water level in the casing should generally be maintained at the natural ground water level for the same reasons.

p) The diameter of the boreholes shall not be more than the inside diameter of the liner when the liners are installed before boring. When the liners are installed after boring, the diameter of the boreholes shall not be more than the outside diameter of liner +2 mm, unless otherwise approved by Engineer.

q) The concrete should invariably be poured through a tremie with a funnel, so that the concrete can be properly deposited in the hole without segregation.

r) It is desirable that the concrete above cut-off level is removed before the concrete is set. This may be done manually or by specially made bailer or other device. Such removal of concrete helps in preventing the damage of the good concrete below the cut-off level, which results from chipping by percussion method. The removal of concrete shall be within ±25 mm from the specified cut off level, preferably on the minus side.

3703.4 Pile cap

a) In marine conditions or areas exposed to harmful chemicals, the pile cap shall be protected with a coating such as bituminous based coal tar, epoxy or epoxy based coating or with suitable anti-corrosive paint.

b) Concrete with high alumina cement, shall not be used in marine environment.

3703.5 Tolerances

The following tolerances are permitted for pile foundation as per table 3700-3.

Table 3700-3: *Permissible tolerances for piles*

Sl. No.		*Type of pile*	*Limits prescribed*
I.	Precast Concrete piles:		
	a)	Variation in cross-sectional dimensions	±5 mm
	b)	Variation in length	±25 mm
	c)	Surface irregularities measured with 3 m straight edge	5 mm
	d)	Bow for total length of pile in mm	1 mm/m length of pile limited to 20 mm
II.	Driven piles:		
	a)	Variation in cross-sectional dimensions	+50 mm/-10 mm
	b)	Variation from vertical for vertical piles	1 in 150
	c)	For vertical piles deviation at piling platform level	75 mm
	d)	Variation of level of top of piles	±25 mm
III.	Bored piles:		
	a)	Variation in cross-sectional dimensions	+50 mm/-10 mm
	b)	Variation from vertical for vertical piles	1 in 150
	c)	For vertical piles deviation at piling platform level	75 mm
	d)	Variation of level of top of piles	±25 mm
IV.	Pile caps		
	a)	Variation in dimensions	+50 mm/-10 mm.
	b)	Misplacement from specified position in plan	15 mm
	c)	Surface irregularities measured with 3 mm straight edge	5 mm
	d)	Variation of level of top of piles	±25 mm

3703.6. Testing of piles

3703.6.1 Initial load test on test pile

a) Test piles which are used to arrive at the load carrying capacity shall not be incorporated in the structure.
b) All test piles shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.
c) Test piles which are not to be incorporated in the completed structure shall be removed to at least 600 mm below the proposed soffit level of pile cap and the remaining hole so formed shall be backfilled with earth or other suitable material.
d) The procedure for testing of pile shall be as per IS: 2911 (Part 4).

3703.6.2 Routine load test on working pile

a) Pile load test for vertical load capacity of pile to be conducted as per Section 300 in Part A of this Manual.
b) Lateral load tests shall be carried out for ensuring the lateral load capacity of the piles. The test procedure shall be carried out as per IS: 2911 (Part 4). However the permissible deflection shall be as per IRC: 78.
c) The minimum number of piles to be tested shall be as per table 3700-4 in cases where it is not specified in the Drawing. The test pile shall be one of the working piles as decided by the Engineer.
d) In particular cases where upper part of pile is likely to be exposed later due to scour, then the capacity contributed by that portion of the pile during load test, shall be accounted for.
e) Results of routine load tests done for reconfirm the allowable loads shall not be used for upward revision of design capacity of piles.

Table 3700-4: *Minimum number of tests*

Total number of piles for the bridge	*Minimum number of test piles*
Up to 50	2
50-150	3
Beyond 150	2% of total piles (fractional number rounded to next higher integer number)

f) While conducting routine test on one of the piles belonging to a pile group, if the pile capacity is found to be deficient an overload up to 10% of the capacity may be allowed.

3703.5.3 Dynamic pile load test

a) For a quick assessment of pile capacity, strain dynamic tests as prescribed in IRC: 78 may be conducted after establishing co-relation using the results of load tests.
b) The results of strain dynamic tests shall not be used for upward revision of design pile capacity.
c) If there exists doubt about the quality of concrete and construction defects like voids, discontinuities etc. the Engineer shall insist to conduct pile integrity tests as per the guidelines given in IRC: 78.

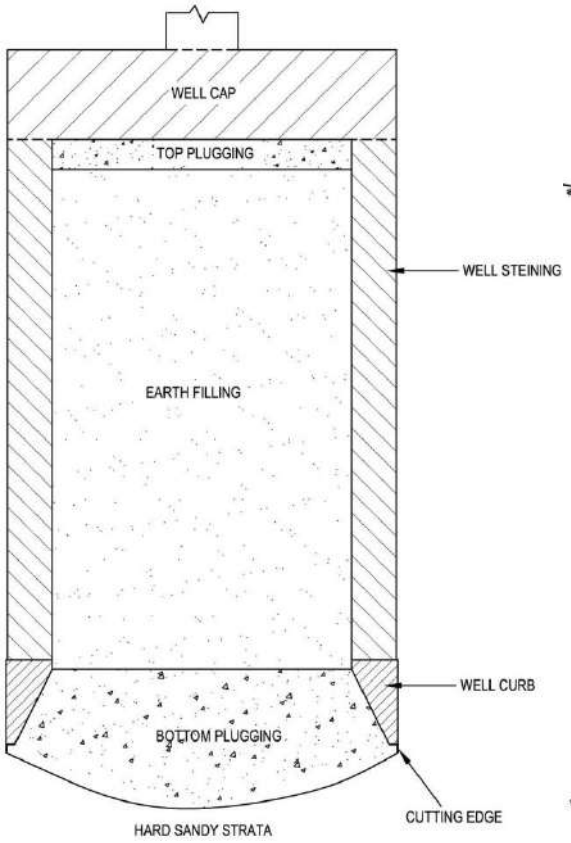
3703.5.4 Pile integrity test

a) If there exists doubt about the quality of concrete and construction defects like voids, discontinuities etc. the Engineer shall insist to conduct pile integrity test as per the guidelines given in IRC: 78.

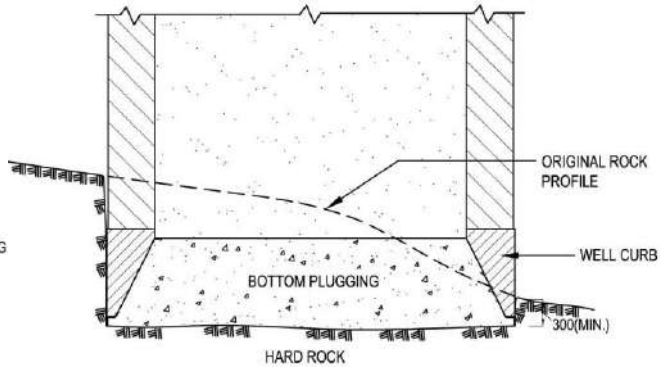
b) Pile integrity test is a non-destructive integrity test method for pile foundation.
c) The method evaluates continuity of the pile shaft and provides information on any potential defects due to honeycombs, necking, cross sectional reduction, potential bulbs, sudden changes in soil stratum, concrete quality in terms of wave speed etc.
d) The test procedure is standardised as per ASTM D 5882.
e) The number of tests shall be decided by the Engineer.

3704 WELL FOUNDATION

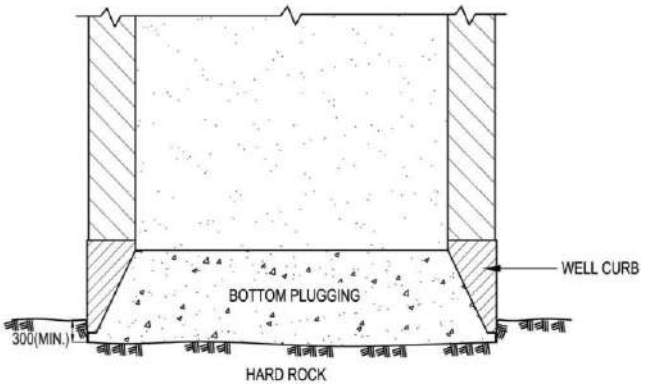
Well foundations shall be constructed taking it down to the founding level by sinking through all kinds of substrata, plugging the bottom, filling the well with approved material, plugging the top and providing a well cap, in accordance with the details shown in the Drawings and as per the Specifications, or as directed by the Engineer. Typical cross sectional details of well foundation resting on sandy soil and hard rock are shown in figure 3700-3.



a) Resting on sandy strata



b) Resting on sloping rock surface



c) Resting on levelled rock surface

Fig. 3700-3: Founding details of well foundation.

3704.1 Sinking of well

a) In case blasting is anticipated for facilitating sinking through difficult strata, special protective/strengthening measures for the curb and steining of the well will be required.
b) Pneumatic sinking may have to be resorted to in cases where there are obstacles such as tree trunks, large sized boulders etc., which cannot be removed by open dredging.

c) Reference points shall be accurately fixed and it shall be away from the zone of blow-ups or possible settlements which may result from well sinking operations and shall be connected to the permanent stations with the base line on the banks. Individual wells shall be marked with reference to these stations. A temporary benchmark shall be established in addition to this near the well foundation.

d) For wells in dry area, the bed may be prepared by excavating the soil up to 1.5m, followed by levelling and dressing before placing the cutting edge. For wells in water, an earthen island up to 5 m maximum height shall be constructed for laying the cutting edge and well curb. For locations where soil is too weak to sustain earthen island, floating caissons may have to be adopted.

e) In earthen islands, a working space of at least 2.0 m all around the steining of the well shall be available. The earthen island shall be held in position and protected against scour by means of wooden ballies properly braced or sheet piles.

3704.2 Cutting edge

a) In V-shaped cutting edge, the inclined plate should meet the vertical plate in such a way that full strength connection by welding is feasible.

b) The parts of cutting edge shall be erected on level firm ground about 300 mm above prevalent water level. Steel sections shall not be heated and forced into shape. However, "V" cuts may be made in the horizontal portion, uniformly throughout the length, to facilitate cold bending. Joints in the lengths of structural sections, unless otherwise specified, shall be fillet welded using single cover plate to ensure the requisite strength of the original section.

3704.3 Well curb

a) Concreting of the well curb shall be done in one continuous operation.

b) The formwork on outer face of curb may be removed within 24 hours after concreting while that on inner face shall be removed only after 72 hours.

c) In case blasting is anticipated, the inner face of the well curb shall be protected with steel plates of thickness not less than 10 mm up to the top of the well curb.

d) If considered necessary, the inner face of steining may also be protected with steel plates of 6 mm thickness up to a height of 3 m above the top of the well curb or as specified by the Engineer.

3704.4 Well steining

a) Concreting of steining may be carried out in subsequent lifts of about 2 m to 2.5 m. Attempts should be made to minimize the number of construction joints. The concreting layers shall be limited to 450 mm restricting the free fall of concrete to not more than 1.5 m. Laitance formed at the top surface of a lift shall be removed to expose coarse aggregates before setting of concrete at the proposed construction joint. As far as possible, construction joints shall not be kept at the location of laps in the vertical steining bars.

b) The steining of the well shall be built in one straight line from bottom to top such that if the well is titled, the next lift of steining will be aligned in the direction of the tilt. After sinking of a stage is complete, damaged portions, if any, of steining at top of the previous stage shall be properly repaired before constructing the next stage.

3704.5 Well sinking

a) The well shall be sunk true and vertical through all types of strata. No well shall be permitted to be placed in a pre-dredged hole. Sinking or loading of the well with kentledge shall be commenced only after the steining has been cured for at least 48 hours or as specified in the Drawings.

b) The well shall be sunk by excavating the material uniformly from inside the dredge hole. Use of water jetting, explosives and divers may be adopted for sinking of wells through difficult strata, with prior approval of the Engineer. Dewatering shall be done when well is to be founded in rock.

c) Complete history of sinking of each well giving details of concreting, sinking and problems met, if any, shall be maintained in the format given in MoRTH Specifications.

d) Dewatering of the well shall not be carried out if sand blows are expected. Sand blow can often be minimized by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge.

e) Kentledge shall be placed in an orderly and safe manner on the loading platform and in such a way that it does not interfere with the excavation of the material from inside the dredge hole and also does not in any way damage the steining of the well.

f) Water jetting can be used to facilitate sinking of wells through clay/hard strata. For carrying out water jetting, the required number of steel pipes of 40 mm to 50 mm diameter shall be embedded in the steining of the well, spaced evenly around its periphery. The diameter of the nozzle shall be 6 mm. The steel pipe shall be kept about 1m above the top of each lift of steining, so that it can be extended by means of suitable couplers before the next lift of steining is cast.

g) When water jetting is to be adopted, the Contractor shall furnish a method statement for approval of the Engineer covering all aspects of the work including the number, capacity and location of the high pressure pumps and other ancillaries required for executing the work.

h) For use of jack down method of sinking, the Contractor shall furnish a method statement for approval of the Engineer, giving full details of construction of ground anchors, fabrication of pressurizing girder, type, number and capacity of jacks to be used, method of dredging and application of jack down force and all other relevant aspects for proper execution of the work.

i) All safety precautions shall be taken as per IS: 4081 and/or IS: 4138. Protection of the bottom portion of the well shall be done as per MoRTH Specifications.

j) Blasting of any sort shall be done only with prior permission and in the presence of the Engineer. Blasting shall not be done before the concrete in the steining has hardened sufficiently and more than 7 days old. Use of large charges, 0.7 kg or above may not be allowed, except under expert direction and with the permission of the Engineer.

k) The pattern of charges may be suitably arranged with delay detonators so as to reduce the number of charges fired at a time. The burden of the charge may be limited to 1 m and spacing of holes may normally be kept as 0.5 m to 0.6 m.

l) If rock blasting is to be done for seating of the well, the damage caused by flying debris should be minimised by covering blasting holes with rubber mats before detonating the charge.

m) Separate high pressure connection shall be made for use of pneumatic tools. Electric lights where provided shall be at 50 volts (maximum).
n) Pneumatic sinking shall be limited to a depth of 30 m below ground level.
q) A pair of wells close to each other has a tendency to come closer while sinking. Timber struts may be introduced in between the steining of these wells to prevent such movement.
r) Tilts occurring in a well during sinking in dipping rocky strata can be controlled by suitably supporting the curb.
s) Diameter of sump made in hard rock shall be 1.5 m to 2 m less than that of the dredge hole.
t) Before concreting the bottom plug, it shall be ensured that the inside faces of curb and steining have been cleaned thoroughly.
u) Any dewatering required, shall only be done 7 days after casting of bottom plug.
v) The soundness of the bottom plug may be tested by dewatering the well to a level 5m below the surrounding water level and checking the rise of water.
w) If necessary, filling inside the well shall commence 7 days after laying of bottom plug with sand or excavated material free from organic matter.
x) Well cap concreting shall be carried out in dry condition. A properly designed false steining may be provided if required, to ensure that the well cap is laid in dry condition.

3704.6 Precautions during well sinking

The following precautions shall be taken during sinking of well foundation:

a) When clear distance between wells is less than the diameter of wells, sinking shall be taken up on all wells and they shall be sunk alternately so that the sinking proceeds uniformly. The difference in the levels does not exceed half the clear gap between them. Plugging of all the wells shall be done together.
b) The type of soils obtained during the well sinking should be compared with bore chart so as to take prompt decisions.
c) Before seasonal floods, all wells on which sinking is in progress shall be sunk to sufficient depths below the designed scour level. Further, they shall be temporarily filled and plugged so that they do not suffer any tilt or shift during the floods.
d) All necessary precautions shall be taken against any possible damage to the foundations of existing structures in the vicinity of the wells, prior to commencement of dredging from inside the well.
e) Very deep sump shall not be made below the well curb, as it entails risk of jumping (sudden sinking) of the well. The depth of sump shall be generally limited to one-sixth of the outer diameter/least lateral dimension of the well in plan. Normally the depth of sump shall not exceed 3.0 m below the level of the cutting edge unless otherwise specially permitted by the Engineer.
f) In case a well sinks suddenly with a jerk, the steining of the well shall be examined to the satisfaction of the Engineer to see that no damage has occurred to it.
g) Dewatering shall be avoided if sand blows are expected. Any equipment and men working inside the well shall be brought out of the well as soon as there are any indications of a sand-blow.

h) Sand blowing in wells can often be minimized by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge.

i) In soft strata prone to settlement/creep, the construction of the abutment wells shall be taken up only after the approach embankment for a sufficient distance near the abutment, has been completed.

3704.7 Tolerances

a) The permissible tilt and shift shall not exceed 1 (horizontal) in 80 (vertical) and the shift at the well base shall not be more than 150 mm in any resultant direction.

b) For the purpose of measuring the tilts along the two axes of the bridge, reduced level of the marks painted on the surface of the steining of the well shall be taken. For determination of shift, locations of the ends of the two diameters shall be precisely measured along the two axes, with reference to fixed reference points.

c) For the well steining and well cap, the permissible tolerances shall be as given in table 3700-5.

Table 3700-5: *Permissible tolerances for well foundation*

a)	Variation in dimension	+50 mm/-10 mm.
b)	Misplacement from specified position in plan	15 mm.
c)	Surface unevenness measured with 3 m straight edge	5 mm.
d)	Variation of level at the top	±25 mm.

3705 SAMPLING AND TESTING

The materials and work shall be tested in accordance with the relevant sections of this Manual and shall meet the prescribed standards of acceptance.

3706 REFERENCES

1. IRC: 78 Standard specification and code of practice for road bridges: *Foundations and substructures.*
2. IS: 2911 (Part-1/Sec. 2) Code of practice for design and construction of pile foundations. *Bored cast in situ piles.*
3. (Part-4) *Load test on piles.*
4. ASTM D 5882 Standard test method for low strain integrity testing of piles.
5. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 3800 SUBSTRUCTURES

3801 GENERAL

This part consists of construction of substructures for bridges and culverts in accordance with the details shown in the Drawing and conforming to the specifications or as directed by the Engineer.

a) A method statement for construction shall be submitted by the Contractor for the approval of the Engineer well in advance of the commencement of the substructure work.
b) The method statement shall include:
   i) Sources of materials.
   ii) Design, erection and removal of form work.
   iii) Production, transportation, laying and curing of concrete.
   iv) Personnel employed for execution and supervision.
   v) Tests and sampling procedures.
   vi) Equipment details.
   vii) Quality management system to be adopted as per this Manual.
   viii) Safety measures.
   ix) Any other relevant information.
c) Arrangements for execution under water wherever necessary, shall be included in the method statement.
d) Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark so that the substructure is constructed in accordance with the Drawings.

3802 MATERIALS

The basic materials shall comply with respective sections of this Manual.

3803 REQUIREMENTS/WORKMANSHIP

3803.1 Abutment and piers

The work shall be strictly in accordance with the Drawings or as directed by the Engineer.

a) For concrete piers and abutments, horizontal construction joints shall be avoided as far as possible, by arranging the concrete pour in one single operation.
b) Where construction joints are unavoidable, they shall be prepared in accordance with the relevant provisions or as directed by the Engineer.
c) No vertical construction joints shall be permitted. Construction joints shall not be permitted in splash zones.
d) In case of tall piers and abutments, use of slip-form shall be preferred. The design, erection and raising of slip-form shall be subjected to special specifications which shall be furnished by the Contractor. The concrete shall also be subjected to additional specifications as necessary. All specifications and arrangements for use of slip form and placing of concrete therein shall be subjected to the approval of the Engineer.

e) The top surface of foundation/well cap/pile cap over which new concrete is to be laid, shall be scraped with wire brush and all loose materials removed.
f) In case reinforcing bars projecting from foundations are found coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. Just before commencing masonry or concrete work, the surface shall be thoroughly wetted.
g) In case of solid (non-spill through type) abutments and hollow concrete piers, weep holes as shown on the Drawings or as directed by the Engineer, shall be provided in conformity with relevant specifications.
h) The surface finish shall be smooth, except on the earth face of abutments which shall be rough finished.
i) In case of abutments likely to experience considerable movement on account of earth pressure from backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers to the full height to allow for the anticipated movement during construction. Casting of superstructure resting on the abutment shall be taken up only thereafter.

3803.2 Abutment cap and pier cap

a) The locations and levels of pier cap, abutment cap, pedestals and bolts for fixing bearings shall be checked carefully to ensure correct alignment in accordance with the Drawings.
b) The surface of cap shall be finished smooth and shall have a slope for draining off water as shown on the Drawings or as directed by the Engineer.
c) The surface on which bearings are to be placed shall be prepared as indicated in the Drawing.

3803.3 Dirt wall, return/wing walls

a) In case of cantilever return/wing walls, no construction joint shall be permitted. The dirt wall and cantilever return/wing wall shall be cast in one operation.
b) For gravity type masonry and concrete return/wing wall, the surface of foundations shall be prepared in the same manner as that prescribed for construction of abutment. No horizontal construction joint shall be provided.
c) Vertical construction joint may be provided, if shown in the Drawing or as directed by the Engineer.
d) Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 metre intervals or as directed by the Engineer. The 20 mm gaps shall be filled with suitable type of asphaltic/bituminous board, so as to prevent embankment material from coming out.
e) For masonry/concrete return/wing walls, weep holes shall be provided as prescribed for abutments or as shown in the Drawing.
f) The finish of the surface on the earth side shall be rough while that of the front face shall be smooth.

3804 TOLERANCES

The permissible tolerances for substructures shall be as given in table 3800-1.

3805 SAMPLING AND TESTING

The materials and work shall be tested in accordance with the relevant sections of this Manual and shall meet the prescribed standards of acceptance.

Table 3800-1: *Permissible tolerances for substructures*

Sl. No.	*Item*	*Permissible limits*
1	Variation in cross-sectional dimensions.	+10 mm/-5 mm
2	Misplacement from specified position in plan.	10 mm
3	Variation of levels at top.	±10 mm
4	Variation of reduced levels of bearing areas.	±5 mm
5	Variation from plumb over full height.	±10 mm
6	Surface unevenness measured with 3m straight edge for all surfaces except bearing areas.	5 mm
7	Surface unevenness measured with 3m straight edge for bearing areas.	3 mm

3806 REFERENCES

1. IRC: 78 Standard specification and code of practice for road bridges: *Foundations and substructures.*
2. MoRTH Specifications for road and bridge works (5th revision).

+++++++

SECTION 3900 SUPERSTRUCTURES

3901 GENERAL

This part consists of construction of superstructures for bridges and culverts in accordance with the details shown in the Drawings and conforming to the specifications or as directed by the Engineer.

a) A method statement for construction shall be submitted by the Contractor for the approval of the Engineer well in advance of the commencement of the superstructure work.
b) The statement shall include:
   i) Sources of materials.
   ii) Design, erection and removal of form work.
   iii) Production, transportation, laying and curing of concrete.
   iv) Launching procedures in case of precast girders/segmental construction.
   v) Personnel employed for execution and supervision.
   vi) Tests and sampling procedures.
   vii) Equipment details.
   viii) Quality management system to be adopted as per this Manual.
   ix) Safety measures.
   x) Any other relevant information.

3902 MATERIALS

The basic materials shall comply with respective sections of this Manual.

3903 REQUIREMENTS/WORKMANSHIP

3903.1 Cast-in-situ decks

a) Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark so that the completed superstructure is in full and in accordance with the Drawings and as approved by the Engineer.
b) The formwork, steel reinforcement, structural concrete and pre-stressing for concrete superstructure shall conform to specifications or as directed by the Engineer.

3903.1.1 Solid slabs

a) Solid slabs may be constructed with reinforced concrete or prestressed concrete and the cross section of a typical solid slab is shown in figure 3900-1.

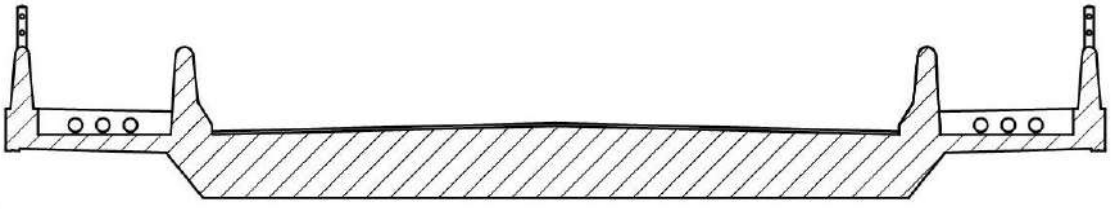


Fig. 3900-1: Typical cross section of solid slab.

b) Where adjacent span of slab has already been cast, the expansion joint and filler board shall be placed abutting the already cast span, which shall form the shutter on that side of the new span to be cast.

c) The reinforcement for the road kerb and railings embedded in the slab shall be tied in position before casting of slab. The entire slab shall be cast in one go. Where the slab is continuous over two spans or more, the entire span of the first slab and the length the slab in the next adjacent span up to the point of contra-flexure, shall be cast in one go, the same sequence of concreting being repeated for additional spans as required.

d) Normally no construction joint shall be allowed in deck slabs. In very wide slabs, however, longitudinal construction joints may be permitted with the approval of the Engineer.

e) Constructions joints, if provided, shall be made in the prescribed manner as per specifications in the codes.

f) The portions of solid slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of solid slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer or as indicated in the Drawing.

g) Where wearing coat is required to be provided after the slab has been cast, the surface of the slab shall be finished rough, but true to lines and levels as shown in the Drawing, before the concrete has hardened.

h) The top of the slab shall be covered with clean moist sand as soon as the surface has hardened. Curing shall be carried out as per specifications.

i) If bearings are provided for the solid slab, the same shall be placed in position in accordance with the Drawing, before casting of slab.

3903.1.2 Voided slabs

a) Voided slabs can be either in reinforced concrete or in pre-stressed concrete. Typical cross section of voided slab is shown in figure 3900-2.

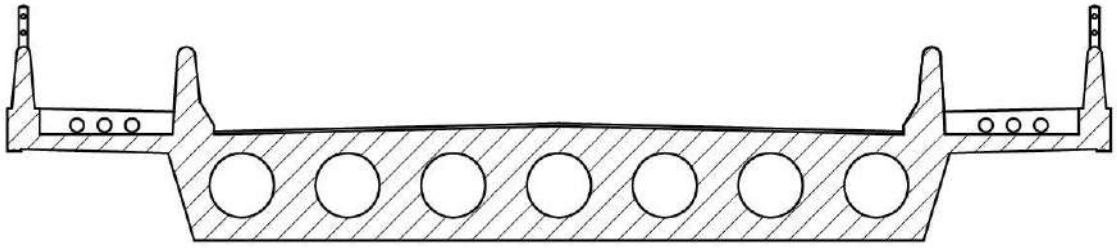


Fig. 3900-2: Typical cross section of voided slab.

b) Voids can be either circular or rectangular in shape. Void formers may be manufactured from steel sheets, fibre-reinforced cement, expanded polystyrene, HDPE, etc. They are generally corrugated to attain sufficient rigidity in order to prevent distortion or collapse during concreting. They should also be leak proof.

c) Void formers shall be suitably tied down in order to prevent flotation during concreting. Care shall be taken during placement of concrete to ensure that the concrete flows fully into the space beneath the void formers.

3903.1.3 Box girders

a) Box girder may be constructed with either reinforced concrete or prestressed concrete. A typical cross section of box girder is shown in figure 3900-3.

b) Box girders may be simply supported or continuous. Simply supported box girders shall have the minimum construction joints as approved by the Engineer.

c) In the case of continuous box girders, the sequence of construction and location of construction joints shall be strictly in accordance with the Drawing.

d) The box section shall be constructed with only one construction joint located in the web below the fillet between the deck slab and the web.

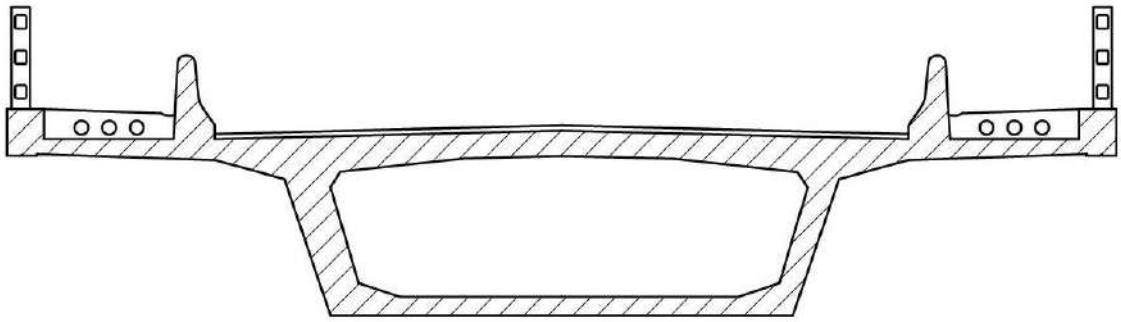


Fig. 3900-3: Typical cross section of box girder.

e) The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

f) The surface of the deck slab shall be finished rough but true to lines and levels as shown in the Drawing before the concrete has hardened. Care shall be taken for setting of bearings as indicated in the Drawing.

3903.1.4 RCC T-beam and slab

a) A typical cross section of a T-beam and slab superstructure is shown in figure 3009-4.

b) Provision of construction joint shall conform to the Drawings or as per directions of the Engineer. No construction joint shall be provided between the bottom flange/bulb and the web. If not indicated in the Drawing, construction joint may be provided at the junction of the web and the fillet between the web and the deck slab, with the approval of the Engineer.

c) The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer or as indicated in the Drawing.

d) The surface of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated in the Drawing.

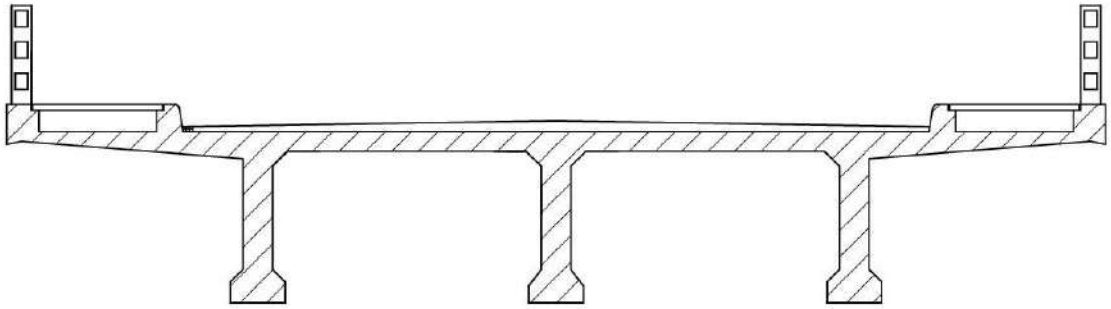


Fig. 3900-4: Typical cross section of T-beam and slab.

3903.1.5 PSC/RCC/Steel girder and composite RCC slab

a) PSC/RCC girder may be precast or cast in-situ as shown in figure 3900-5. Girders may be post tensioned or pre-tensioned. Steel girders may also be adopted instead of concrete girders as shown in figure 3900-6. Where precast construction is required to be adopted, selection of casting yard and details of methodology and equipment for shifting and launching of girders shall be included in the method statement.

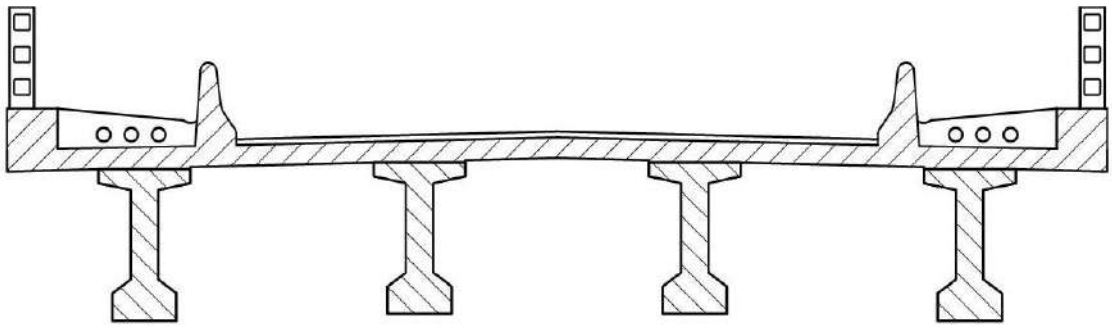


Fig. 3900-5: Typical cross section of RCC/PSC girder composite with RCC slab

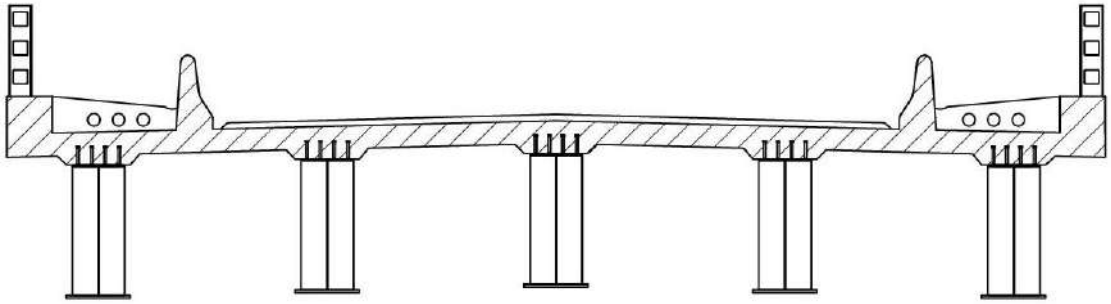


Fig. 3900-6: Typical cross section of steel girder composite with RCC slab

b) In case of cast in-situ construction, the sequence of construction including side shifting of girders, if required, and placing on bearings shall be in accordance with the Drawing.
c) The PSC/RCC girder constituting the top flange, web and bottom flange shall be concreted in a single operation without any construction joint.
d) The portions of deck slab near expansion joints shall be cast along with reinforcements and embedment for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer or as indicated in the Drawing.
e) The surface of the deck slab shall be finished rough but true to lines and levels as shown in the Drawings before the concrete has hardened.
f) Care shall be taken for correct alignment and setting of bearings as indicated in the Drawing.

3903.1.6 PSC/RCC Bow string girder

a) Bow string girders are cast in-situ type superstructure as shown in figure 3900-7.
b) Bottom string (tie) beam may be post tensioned or RCC and top arch rib is RCC.
c) High strength steel hangers may also be adopted instead of traditionally used concrete hangers.

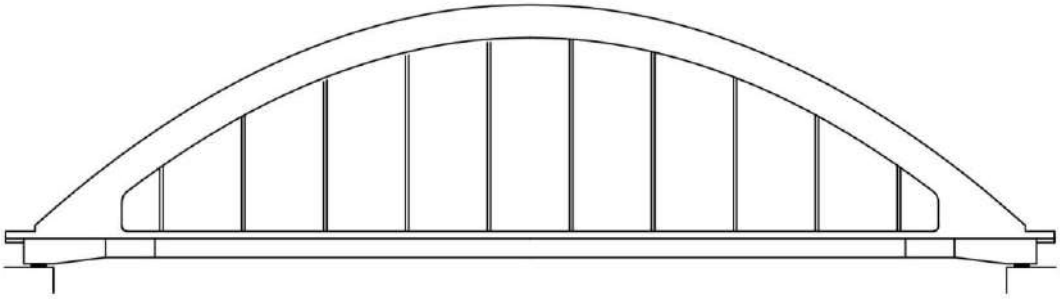


Fig. 3900-7: Typical longitudinal section of Bow string girder

3903.1.7 Tolerances

The permissible tolerances for cast in-situ superstructures shall be as given in table 3900-1.

Table 3900-1: *Permissible tolerances for cast in-situ superstructures*

Sl. No.	*Item*	*Permissible limits*
1	Variations in thickness of top and bottom slab for box girders, top and bottom flange for T-girders and slabs.	-5 mm/+10 mm.
2	Variations in web thickness.	-5 mm/+10 mm.
3	Variations in overall depth or width.	±5 mm.
4	Variation in length overall and length between bearings.	±10 mm or ±0.1% of the span length, whichever is less.
5	Surface unevenness in deck slab measured with 3 m straight edge.	5 mm.

3903.2 Pre-cast girders

a) All forms shall be of steel and of sufficient thickness, with adequate external bracing, stiffened and adequately anchored to withstand the forces due to placement and vibration of concrete.

b) Compaction of concrete may be achieved through needle vibrators or form (shutter) vibrators along with needle vibrators.

c) For casting of precast components, any of the two commonly used techniques of precasting viz. Long Line method or Short Bench method may be used. After the first segment of each unit is cast, succeeding segments shall be match cast against the previous ones and shall be given a unique identification mark so that it is placed at the intended locations in the superstructure.

d) A bond breaking material such as flax, soap, talc, wax or any other approved material shall be used between previously cast segment and newly cast segments, as well as the end headers, where ever required.

e) Segments shall not be moved from the casting yard until stipulated strength requirements have been met. They shall be supported in a manner that will minimize warping.

f) Under all circumstances, the concrete shall have attained a minimum compressive strength of 20 MPa at the time of removal of forms. At the time of lifting and assembly of precast segments, the concrete shall have attained sufficient strength to withstand the handling stresses.

g) Curing of segments may be achieved through water curing or steam curing followed by water curing. Approved curing compound may also be used.
h) In case of spliced girder system, match casting is not necessary because the gap between the girder segments is filled with concrete or epoxy material at the location of splices.
i) The faces which are required to receive the cast-in-situ stitch concrete shall be adequately roughened and prepared as construction joint before pouring the stitch concrete. In case of epoxy jointed spliced girder system (with no gap between the girder segments), match casting shall be resorted to and all provisions of epoxy jointed segmental structure shall apply.
j) A full scale mock-up of the lifting and holding equipment (including assembly truss, cantilevering formwork etc.) shall be performed to demonstrate their adequacy and efficacy prior to start of erection/assembly of the segments.

3903.2.1 Tolerances

The permissible tolerances for precast girders shall be as given in table 3900-2.

Table 3900-2: *Permissible tolerances for precast girders*

Sl. No.	*Item*	*Permissible limits*
1	Variations in thickness of top and bottom slab for box girders, top and bottom flange for T-girders and slabs.	±5 mm.
2	Variations in web thickness.	-5 mm/+10 mm.
3	Variations in overall depth or width.	±5 mm.
4	Variation in length overall and length between bearings.	±10 mm or ±0.1% of the span length, whichever is less.
5	Surface unevenness in deck slab measured with 3 m straight edge.	5 mm.

3904 LOAD TEST ON SUPERSTRUCTURE

a) The materials and work shall be tested in accordance with the relevant sections of this Manual and shall meet the prescribed standards of acceptance.
b) When a newly constructed bridge is to be accepted, where the design is of an unusual type or if the quality of construction is suspected to be not as specified, then a full-fledged testing of the bridge has to be resorted to, as an assurance test, by the application of loads atleast equivalent to the design loads.
c) Such load testing shall also to be employed if it is specified in Contract conditions.
d) The load testing of bridges shall be carried out as per IRC: SP: 51.

3905 REFERENCES

1. IRC: 112 Code of practice for concrete road bridges.
2. IRC: SP: 51 Guidelines for load testing of bridges.
3. MoRTH Specifications for road and bridge works (5th revision).

+++++++

SECTION 4000 BEARINGS

4001 GENERAL

Bearings are part of the bridge structure which bears directly all the forces from the superstructure and transmits the same to the substructure and are classified as Metallic, Elastomeric, POT/PTFE bearings. Since Metallic bearings are not commonly used by the department, only Elastomeric and POT/PTFE bearings are included under this section.

a) The bearings shall be supplied and installed by the Contractor or otherwise specified in the Contract. The Contractor shall be solely responsible for the satisfactory supply and installation of the bearing. In the detailed description of the specification, a general reference shall be made about the manufacturer.
b) The Contractor shall exercise the utmost care in setting and fixing all bearings in their correct positions and ensuring that uniformity is obtained on all bearing surfaces.
c) Bearings shall be handled with care and stored under cover.
d) For bridges with skew angle less than 20°, the bearings shall be placed at right angles to the longitudinal axis of the bridge. For bridges with skew angle greater than 20°, very wide bridges and curved bridges, the location of bearings shall be ensured as shown in the Drawing.
e) Easy access to the bearing shall be made available for purposes of inspection and maintenance. Provision shall also be made for jacking up of the superstructure so as to allow repair/replacement of bearings.

4002 ELASTOMERIC BEARINGS

Elastomeric bearings shall cater for translation and/or rotation of the superstructure by elastic deformation. A typical cross section of elastomeric bearing is shown in figure 4000-1.

4002.1 Materials

a) Chloroprene Rubber (CR) only shall be used.
b) Grades of raw elastomer of proven use in elastomeric bearings, with low crystallization rates and adequate shelf life viz. Neoprene WRT Neoprene W, Bayprene 110, Bayprene 210, Skyprene B-5, Skyprene B-30, Denka S-40V and Denka M-40, shall be used.
c) No reclaimed rubber or vulcanized wastes or natural rubber shall be used.
d) The Polychloropene content of the bearing shall not be lower than 60%. The ash content shall not exceed 5% of its weight. Polychloropene content shall be determined in accordance with ASTM-D297 and ash content as per IS: 3400 (Part XXII).
e) Use of synthetic rubber-like materials such as Ethylene Propylene Diene Monomer (EPDM) and similar candidate elastomers shall not be permitted.
f) The elastomer for use in elastomeric bearings shall conform to the properties specified in the table 4000-1.

g) Shear modulus (G) is the apparent "conventional shear modulus" of the elastomeric bearing determined by testing. At nominal temperature of 23±2°C, the value of G shall comply with the values given in the table 4000-2.

Table 4000-1: *Properties of elastomer*

Sl. No.	*Property*	*Unit*	*Code*	*Value of the characteristic specified*		
1	Physical properties:					
1.1	Hardness	IRHD	IS: 3400 (Part-2)	50±5	60±5	70±5
1.2	Minimum tensile strength - Moulded test piece - Test piece from bearing	 MPa MPa	IS: 3400 (Part-1)	 17 14	 17 14	 17 14
1.3	Minimum Elongation at break - Moulded test piece - Test piece from bearing	 % %	 IS: 3400 (Part-2) IS: 3400 (Part-2)	 450 400	 400 350	 300 250
2	Maximum compression: - set (%) (24h, 100±1°C)	 %	IS: 3400 (Part-9)	35		
3	Accelerated aging: (72 h, 100 ± 1°C) (Maximum change from un-aged value)					
3.1	Maximum change in hardness	IRHD	IS: 3400 (Part-4)	±5		
3.2	Maximum change in tensile strength	%	IS: 3400 (Part-4)	-15		
3.3	Maximum change in elongation	%	IS: 3400 (Part-4)	-30		

Table 4000-2: *Shear modulus (G) at nominal temperature*

Hardness (IRHD)	*G (MPa)*	*Tolerances of G (MPa)*
50±5	0.70	±0.15
60±5	0.90	±0.18
70±5	1.15	±0.20

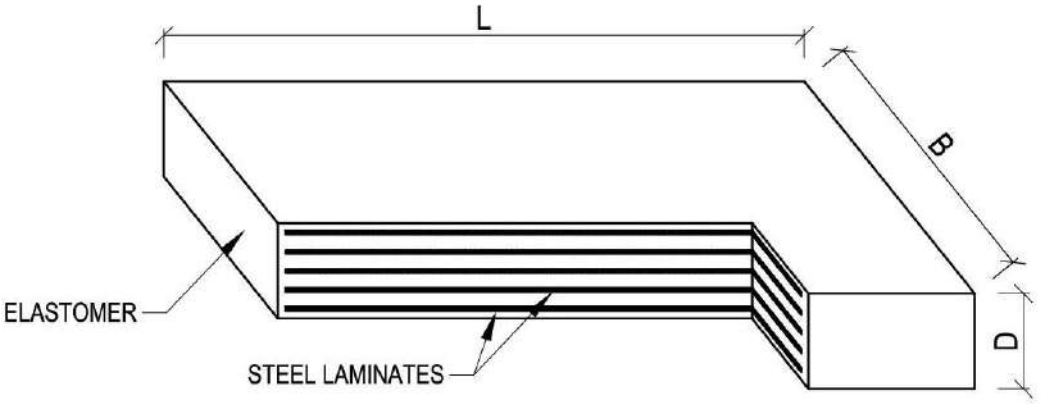


Fig. 4000-1: Typical cut sectional view of elastomeric bearing.

h) The adhesion strength of elastomer to steel plates, determined according to IS: 3400 (Part XIV) method A, shall not be less than 7 kN/m.

i) For elastomeric bearings (CR) used in adverse climatic conditions, the ozone resistance of elastomer shall be proved satisfactory when assessed by test according to IS: 3400 (Part XX). The testing shall be carried out for a duration of 96 hours at a temperature of 40±1°C, strain of 30% and ozone concentration of 100 pphm by volume.

j) If any cracking is detected by visual observation at the end of the test, the material shall be considered unsatisfactory. No specific tests for assessment of low temperature resistance are deemed necessary.

k) Laminates of mild steel conforming to IS: 2062/IS: 1079 or equivalent international grade, shall only be permitted. The yield stress of the material shall not be less than 250 MPa. Use of any other material like fibre glass or similar fabric as laminates, shall not be permitted.

4002.2 Workmanship

a) Each elastomeric bearing shall be clearly labelled or marked. The bearing shall be wrapped in a cover and packed in wooden crates with suitable arrangement to prevent movement and to protect corners and edges.

b) Care shall be taken to avoid mechanical damage, contamination with oil, grease and dirt, undue exposure to sunlight and weather of the bearings during transport and handling prior to and during installation.

c) Bearings shall be installed in the structure as per the Drawing or as directed by the Engineer to ensure that right bearing is being installed at the correct location.

d) Bearings must be placed between true horizontal surfaces (maximum tolerance 0.2 percent perpendicular to the load) and at true plan position of their control lines marked on receiving surfaces (maximum tolerance ±3 mm).

e) Concrete surfaces shall be free from local irregularities (maximum tolerance ±1 mm in height).

f) Variation from common planarity of twin or multiple bearings shall be within such tolerance as may be specified or approved by the Engineer.

g) Design shall be got checked for the actual inclination in seating if larger inaccuracies than those specified are permitted.

h) For cast in-situ concrete superstructure, where bearings are installed prior to concreting, the forms around the bearings shall be capable of easy removal. Forms shall also fit the bearings securely and prevent any leakage of mortar/grout. Any mortar contaminating the bearings during concreting shall be completely removed before setting.

i) For precast concrete or steel superstructure elements, fixing shall be done by application of epoxy resin adhesive to interface, after specified surface preparation. The specification for adhesive material, workmanship and control shall be approved by the Engineer. Care shall be taken to guard against faulty application and consequent behaviour of the adhesive layer as a lubricant. The bonding by the adhesive shall be deemed effective only as a device for installation and shall not be deemed to secure bearings against displacement for the purpose of design.

j) Lifting of a cast in-situ post-tensioned bridge deck for relieving time dependent deformation shortly after installation of bearings should be avoided. In case such lifting is unavoidable, the lifting arrangement, proper seating of the girder

on the bearing, etc. shall be rigidly controlled to avoid any risk of misalignment.

k) Under load, bulging of the rubber layer between the reinforcing steel laminates on free exposed perimeter is a normal phenomenon and is not detrimental to the performance of the bearing unless any crack or evidence of bond failure is detected.

l) In case seating of bearings on a non-horizontal plane is required, it shall be carried out in accordance with acceptable practice and particular specifications as may be laid out and directed by the Engineer.

m) After installation, bearings and their surrounding areas shall be left clean.

4002.3 Tolerances

The bearings shall be fabricated/manufactured with tolerances not exceeding the values specified in the table 4000-3.

Table 4000-3: *Manufacturing tolerances*

No.	*Items*	*Tolerances*
1	Overall linear plan dimensions	-0 mm/+6 mm
2	*Total mean bearing thickness*: (The mean thickness is the arithmetic average of the thickness measured at five points on the major surface as indicated for various shaped bearings: Rectangular-corners and centre, Circular-corners of inscribed square and centre)	-0%/+5%.
3	*Parallelism*:	
i)	Of top surface of bearing with respect to the bottom surface as datum	1 in 200.
ii)	Of one side surface with respect to the other as datum	1 in 100.
4	*Thickness of individual layer of elastomer*:	
i)	Inner layer of elastomer	±10%.
ii)	Outer layer of elastomer	-0 mm/+2 mm.
iii)	Side cover	-0 mm/+3 mm.
5	*Dimension of laminates*:	
i)	Plan dimensions of laminates	-3 mm/+0 mm.
ii)	Thickness of laminate	±10%.
iii)	Parallelism of laminate with respect to bearing base as 1 in 100 datum (with respect to diameter for plates circular in plan and shorter side for plates rectangular in plan)	1 in 100.
6	*Flatness*: Flatness shall be assessed by placing a straightedge along the diagonal or diameter. The gap between the straight edge and the surface shall not exceed the tolerances specified below:	
i)	Load bearing surface of the bearing	0.3% of diameter or diagonal or 2% of mean bearing thickness whichever is higher.
ii)	Steel laminate	1% of diameter or diagonal (Max of 1.5 mm).

4002.4 Testing

a) The manufacturer shall have all test facilities required for process and acceptance control tests installed at his plant to the complete satisfaction of the Engineer. The test facilities and their operation shall be open to inspection by the Engineer on demand.

b) All acceptance and process control tests shall be conducted at manufacturer's plant. Cost of all materials, equipment and labour shall be borne by the manufacturer/Contractor.

c) Acceptance testing shall be commenced with the prior submittal of testing programme by the manufacturer/Contractor to the Engineer and after obtaining his approval.

d) Any acceptance testing delayed beyond 180 days of production shall require special approval of the Engineer and modified acceptance specification, if deemed necessary by him.

e) Lot by lot inspection and acceptance shall be made. Size and composition of acceptance lot shall be got approved by the Engineer.

f) A lot shall comprise all the bearings, including the pair of extra test bearings where applicable, of equal or near equal size produced under identical conditions of manufacture, to be supplied for a particular project.

g) For the purpose of grading levels of acceptance testing lots will be classified as below:
   i) A lot size of 24 or larger number of bearings shall be defined as a *large lot.*
   ii) A lot size of less than 24 bearings shall be defined as a *small lot.*

h) When the number of bearings of equal or near equal size for a single bridge project is large and phased production and acceptance is permitted, the number of bearings supplied in any single phase of supply shall comprise a lot under acceptance. When such phased supply is made, each such lot shall be considered as a *large lot* for the purpose of acceptance testing.

i) The level of acceptance testing shall generally be graded into the following two levels depending on lot size:
   (i) Level 1 acceptance testing.
   (ii) Level 2 acceptance testing.

j) Acceptance testing level 1 is a higher level inspection and shall be applicable to large lots only, unless otherwise specified. This shall involve manufacture of two extra bearings for each lot to be used as test bearing and eventually consumed in destructive testing.

k) Acceptance inspection level 1 may be specified at the sole discretion of the Engineer, taking into account the special importance of bridge project, for small lots also under the purview of special acceptance inspection.

l) Acceptance testing level 2 shall be applicable to small lots only unless otherwise specified and shall not involve any destructive testing of finished bearings.

m) In acceptance testing level 2, all bearings of the lot shall be visually inspected for absence of any defects in surface finish, shape, hardness or any other discernible superficial defects. Also, all bearings shall be checked for overall dimensions, mean bearing thickness, parallelism of bearing surfaces and flatness of load bearing surfaces specified in table 4000-3.

n) Testing and inspection procedures shall be as per IRC: 83 (Part-2) and MoRTH Specifications.

4002.4.1 Tests on specially moulded test pieces

a) Test pieces shall be moulded by the manufacturer with identical compound and under identical vulcanising conditions as used in the manufacture of the bearings of the acceptance lot. The process shall be open to for inspection.
b) Test pieces offered for inspection shall be identified by notable markings and duly certified by the manufacturer.
c) The quality characteristics to be tested are listed below. Test specifications and acceptance criteria shall be as per IRC: 83 (Part-2).
   i) Composition
   ii) Hardness
   iii) Tensile strength
   iv) Elongation at break
   v) Compression set
   vi) Accelerated ageing
   vii) Adhesion strength
   viii) Ozone resistance

4002.4.2 Tests on complete bearings or sections

a) Two bearings shall be selected at random from the lot as test bearings. These bearings shall be excluded from the lot accepted.
b) The following tests shall be conducted on test bearings:
   i) Test for determination of shear modulus.
   ii) Test for determination of compression stiffness.
   iii) Test for determination of shear bond strength.
c) Test specifications and acceptance criteria shall be as per IRC: 83 (Part-2).

4002.4.3 Acceptance criteria

a) The manufacturer shall furnish the following to the Engineer for the acceptance judgment:
   i) Quality control certificate as laid down in IRC: 83 (Part-2).
   ii) Inspection certificate as laid down in IRC: 83 (Part-2).
b) The manufacturer shall furnish any supplementary information on the system of quality control and/or process and acceptance control testing as may be deemed necessary by the Engineer.
c) In case of any evidence of process or acceptance control testing being deemed unsatisfactory by him, the Engineer at his sole discretion may call for a special acceptance inspection of the lot according to specifications laid down by him, without any prejudice to his right to reject the lot. The entire cost of such supplementary inspection shall be borne by the manufacturer/Contractor.
d) Engineer shall be the sole authority for acceptance of a lot on scrutiny of the certificates according to IRC: 83 (Part-2), along with any supplementary evidence; and complete satisfaction therewith.
e) In case of rejection of a lot, the Engineer shall reserve the right to call for special acceptance inspection for the succeeding lots offered for inspection, according to the specifications laid down by him. The entire cost of such tightened inspection shall be borne by the manufacturer/Contractor.

4002.5 Certification and marking

a) Bearings shall be transported to bridge site after final acceptance by Engineer and along with an authenticated copy of the certificate to that effect.
b) Each bearing shall be uniquely and individually numbered on its external faces for identification. The identification number shall be unique and such as to enable other bearings manufactured at the same time, to be traced through the production control records, should the need arise.
c) The manufacturer's name and unique identification number of the bearing should be vulcanized on the top or bottom of the bearing.
d) An information card giving the following details for the bearings, duly certified by the manufacturer, shall also be appended:
    i) Name of manufacturer.
    ii) Date of manufacture.
    iii) Bearing dimensions.
    iv) Production batch number.
    v) Acceptance lot number.
    vi) Specific location of bridge, if any.
    vii) Explanation of markings used on the bearing.
e) All bearings shall have suitable index markings identifying the information. The markings shall be made in indelible ink or flexible paint and if practicable, should be visible after installation. The top of the bearing and direction of installation shall be indicated.

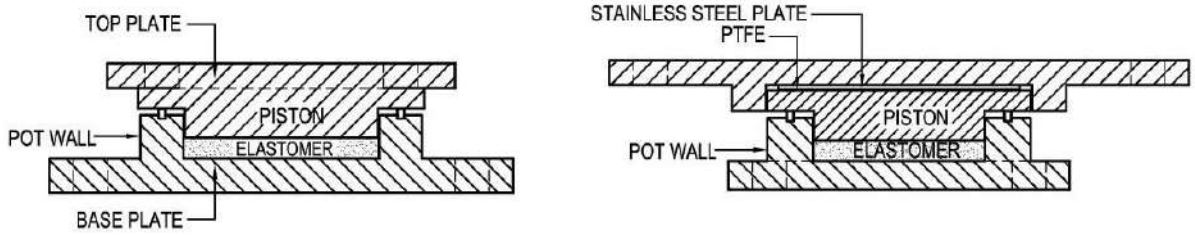
4002.6 Maintenance

a) The maintenance of bearings shall be carried out according to a planned schedule.
b) The structure should be designed and detailed in such a way that the bearings are easily accessible after installation for inspection and maintenance. Arrangements for insertion of jacks to lift the bridge deck shall be made in detailing of structure.
c) The exposed bearing surface shall be maintained clean and free from contamination with grease, oil or other deleterious matter.
d) Annual routine maintenance inspection or special maintenance inspection of all bearings shall be made to check the following aspects and results reported.
e) The top and bottom load bearing surfaces shall be in full contact with the plinth (bottom supporting surface) and the soffit (top supporting surface). If there is imperfect contact between the bearing and the soffit and plinth, the angle between the soffit and shall be checked against the design specifications.
f) The magnitude of the shear deflection of each bearing shall be checked to ensure that it is within the design specifications.
g) A visual inspection shall be made of all the accessible edges. A note shall be made of the size and position of any cracks, splits or uneven bulges.
h) The plinth and soffit shall be examined for signs of displacement from original position of bearing which may be indicated by black marks left on the plinth and soffit.
i) Where applicable, the sliding surfaces shall be examined for cleanliness and for any movements beyond the design range.
j) Where applicable, protective coating and/or dust protection shall be examined for signs of deterioration.

k) Damaged bearings shall be replaced immediately. To avoid differences in stiffness, all adjacent bearings on the same line of support shall also be replaced.

4003 POT/POT CUM PTFE BEARINGS

a) Pot bearings shall consist of a metal piston supported by a disc of unreinforced elastomer confined within a metal cylinder to take care of rotation. Typical cross sections of pot bearings are shown in figure 4000-2.



a) Pot bearing (Fixed type) b) Pot cum PTFE (Sliding type)

Fig. 4000-2: Typical cross sections of Pot bearings.

b) Horizontal movement, if required, shall be provided by sliding surfaces of PTFE pads sliding against stainless steel mating surfaces, with a system of sealing rings.

c) Pot bearings shall consist of cast steel assemblies or fabricated structural steel assemblies.

4003.1 Materials

a) Mild steel to be used for the components of the bearings shall generally comply with Grade B of IS: 2062.

b) High tensile steel to be used for the components of the bearings shall comply with IS: 961.

c) Cast steel shall comply with Grade 280-520W or 340-570W of IS: 1030.

d) Stainless steel shall conform to AISI 316L or O_2 Cr_{17} Ni_{12} Mo_2 of IS: 6911.

e) The raw material for PTFE used in bearings shall be pure poly tetra fluoro ethylene, free sintered without regenerated materials or fillers. The mechanical and physical properties of unfilled PTFE shall comply with Grade A of BS: 3784 or equivalent. PTFE shall be either in the form of solid rectangular modules or large sheet with dimples formed by hot pressing or moulding. Sheet with dimples formed by machining or drilling from a solid PTFE sheet, shall not be permitted. The surface of PTFE sheets/modules which are to be in contact with metal backing plates shall be provided with suitable chemical treatment for proper bonding. Adhesives used for bonding PTFE to backing plates, shall produce a bond with minimum peel strength of 4 N/mm width when tested in accordance with BS: 5350 (Part C9).

f) The elastomer including the confined elastomer to be used for the components of bearings shall comply with provisions of table 4000-4.

Table 4000-4: *Properties of confined elastomer*

Sl. No.	*Property*	*Unit*	*Code*	*Limits specified*
1)	Hardness	IRHD	IS: 3400 (Part-2)	50±5
2)	Min. tensile strength	MPa	IS: 3400 (Part-1)	15.5
3)	Minimum elongation at break		As per table 4000-1 above (Ref: IRC: 83 Part-2)	
4)	Max. compression set		-do-	
5)	Accelerated aging		-do-	

g) For guide of pot bearings, composite material may be used for achieving lower coefficient of friction and higher strength. Such composite material shall consist of either (a) a bronze backing strip and a sintered inter-locking porous matrix impregnated and overlaid with a PTFE/lead mixture or (b) a mixture of PTFE, glass fibre and graphite embedded in a bronze mesh which is bonded to a galvanized steel backing strip.

h) The internal seals shall be either of the following:
   (i) Brass sealing ring made of metallic brass conforming to 1S: 410.
   (ii) Poly oxy methylene (POM) sealing chain of proven type consisting of individual interlocking elements made of moulded POM having properties as specified in IRC:83 (Part 3).

i) External seals and wiper seals shall be made of elastomer conforming to respective provisions.

j) Fasteners such as bolts, screws, nuts and lock nuts, shall generally conform to 1S:1363, 1S:1364, 1S:1365, 1S: 2269, 1S: 3138, 1S: 6761 and 1S: 6639 as appropriate with mechanical properties conforming to 1S: 1367. Threads shall generally conform to 1S: 4218. Washers shall conform to 1S: 2016 and 1S: 6610 as appropriate.

4003.2 Workmanship

The following points shall be carefully looked into while installing bearings.

a) Bearings shall be so located as to avoid the accumulation of dirt and debris on or around them.

b) Construction of the structure shall be such that water is prevented from reaching the bearings.

c) In order to avoid contamination of moving surfaces, bearings should not normally be dismantled after leaving the manufacturer's workshop. However, if for any reason, a bearing is required to be dismantled, it shall be done only under expert supervision for which the manufacturer's help may be sought.

d) Transfer of load from the superstructure to the bearings should not be allowed until the bedding material has developed sufficient strength.

e) Temporary clamping devices should be removed at the appropriate time before the bearings are required to accommodate movement. The holes exposed on removal of temporary transit clamps should be filled with selected material. Where re-use of these fixing holes are required, the material used for filling the holes should be capable of being easily removed without damaging the threads.

f) Suitable temporary supporting arrangements under bearing base plates should be made to accommodate thermal movement and elastic deformation of the incomplete superstructure. Such temporary supports, if provided, should be removed once the bedding material has reached its required strength. Any voids left as a consequence of their removal should be made good using the same bedding material. Steel folding wedges and rubber pads are suitable for use as temporary supports under bearing plates.

g) The bedding material shall be selected keeping in view a number of factors such as the type and size of bearing, construction sequence, load on the bearing, required setting time, friction requirements, access around bearings, design and condition of surface in the bearing area and thickness, strength and shrinkage of bedding material.

h) Commonly used bedding materials are cementitious or chemical resin mortar and grout. In some cases, it may be necessary to carry out trials to ascertain the most suitable material.

i) The bedding material, whether above or below the bearing, should extend over the whole area of the bearing in order to ensure even loading. After installation, there shall be no voids or hard spots. The top surface of any extension of the bedding beyond the bearing shall have a downward slope away from the bearing.

j) The bedding material shall be capable of transmitting the applied load to the structure without being damaged. Surfaces to receive bedding mortar shall be suitably prepared so as to be compatible with the mortar chosen.

k) Bearings shall be anchored in order to counter vibration and accidental impact. Anchorage shall be accurately set into recesses cast into structure using templates. The remaining space in the recesses shall be filled with material capable of withstanding the loads.

l) Bearings that are to be installed on temporary supports should firmly fixed to the substructure by anchorage or other means to prevent disturbance during subsequent operations. Voids beneath the bearings should be completely filled with bedding material using the method.

m) Bearings may be fixed directly to metal bedding plates that may be in or bedded on top of the supporting structure to the correct level location.

n) Threaded fasteners shall be tightened uniformly to avoid overstressing of any part of the bearing.

o) Where bearings are installed prior to casting of an in-situ concrete deck, formwork around bearings should be properly sealed to prevent grout leakage. It is essential that the bearings and particularly the working surfaces are protected during concreting operations. Sliding plates should be fully supported and care taken to prevent tilting, displacement or distortion of the bearings under the weight of green concrete. Mortar contaminating the bearings should be completely removed before it sets.

p) For bearings supporting precast concrete or steel beams, a thin layer of synthetic resin mortar should be used between bearings and the beams. Bearings shall be bolted to anchor plates or sleeves embedded in precast concrete elements or to machined sole plates on steel elements.

q) Bearings shall be located so that their centre lines are within ±3 mm of their correct position.

r) The level of a bearing or the mean levels of more than one bearing at any support, shall be within a tolerance of ±0.0001 times the sum of the adjacent spans of a continuous girder, but not exceeding ±5 mm.

s) Bearings shall be placed in a horizontal plane within a tolerance of 1 in 200 in any direction, even under superstructure in gradient.

4003.3 Inspection and testing

a) Where any patented items are used, the manufacturer's certificate for the same with test proofs shall be submitted along with the design and got approved by the Engineer before their use in work.

b) The manufacturer shall have all test facilities required for process and acceptance control tests, installed at his plant to the complete satisfaction of the Engineer.
c) The test facilities and their operation shall be open for inspection by the Engineer at any time.
d) The detailed procedure for inspection and testing shall be as stipulated in MoRTH Specifications and IRC: 83 Part 3.

4003.4 Maintenance

a) Bearings shall be designed and manufactured to make them maintenance free so as to withstand undesirable effects caused by extreme atmosphere or aggressive environmental conditions/unforeseen events.
b) Suitable easy access to the bearings shall be provided for inspection and maintenance.
c) Provision shall also be available for jacking up the superstructure so as to allow repair/replacement of bearings.
d) The area surrounding the bearings shall be kept clean and dry to avoid damage to the bearings. The bearings shall also be periodically cleaned to remove deposits of salts, debris, dust or other foreign material.
e) Periodic inspection and nominal maintenance of bearings shall be carried out in order to ensure their better performance and longer life. The bearings are required to be inspected at intervals of one year for the first five years after installation and at intervals of two years thereafter.
f) The bearings shall also be examined carefully after unusual occurrences such as passage of heavy traffic/oversized loads, earthquakes and battering by floating debris in high floods.

4004 REFERENCES

1. IRC: 83 Standard specification and code of practice for road bridges:
   (Part 1) *Metallic bearings.*
   (Part 2) *Elastomeric bearings.*
   (Part 3) *Pot, Pot-cum-PTFE, Pin and Metallic guide bearings.*
2. IS: 1030 Carbon steel castings for general engineering purposes- specification.
3. IS: 6911 Stainless steel plate, sheet and strip - specification.
4. IS: 3400 Methods of test for vulcanized rubber:
   (Part 1) *Tensile stress-strain properties.*
   (Part 2) *Rubber, vulcanized or thermoplastic - determination of hardness.*
   (Part 4) *Accelerated ageing and heat resistance.*
   (Part 10) *Compression set at constant strain.*
   (Part 14) *Adhesion of rubber to metal.*
5. BS 3784 Specification for poly tetra fluoro ethylene (PTFE).
6. ASTM D297 Standard test methods for rubber products- chemical analysis.
7. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 4100 EXPANSION JOINTS

4101 GENERAL

This section deals with the expansion joints in bridge structures in accordance with the details shown on the Drawings and conforming to the requirements of MoRTH Specifications and IRC: SP-69 or as directed by the Engineer.

The types of expansion joints generally adopted in bridge construction are:

i) Buried joint.
ii) Filler joint.
iii) Asphaltic plug joint.
iv) Compression seal joint.
v) Single strip/box seal joint.
vi) Reinforced elastomeric joint etc.

Since single strip/box seal joint and compression seal joint are the commonly used expansion joints in bridges by the department, these types of joints alone are mentioned under this section. For details of other type of joints, IRC: SP-69 shall be referred to.

4102 SINGLE STRIP/BOX SEAL JOINT

Single strip/box seal expansion joint consists of two edge beams with anchorages and an elastomeric sealing element held firmly in the housings of edge beams that guarantee the water tightness of the joint. The maximum gap between the edge beams at road surface when the joint fully opens due to maximum contraction of deck shall be limited to 80 mm for the comfortable passage of the traffic. The edge beams protect the adjacent edges of bridge deck from damage due to vehicular impact and also transfer the vehicular load to the deck structure through robust anchorage system. Typical single strip seal joint is shown in figure 4100-1.

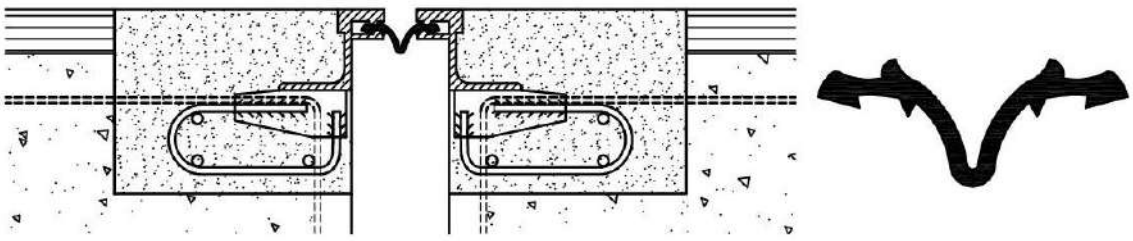


Fig. 4100-1: Typical cross section of single strip joint and arrangement.

4102.1 Components

a) The edge beam shall be either extruded or hot rolled steel section including continuously shop welded section with suitable profile to mechanically lock the sealing element in place throughout the normal movement cycle. Further, the configuration shall be such that the section has a minimum thickness of 10 mm all along its cross section (flange and web). Thickness of lips holding the seal shall not be less than 6 mm. The minimum height of the edge beam

section shall be 80 mm. The minimum cross sectional area of the edge beam shall be 1500 mm^2.

b) The edge beams of single strip/box seal joints shall be anchored in the concrete with rigid loop anchorage. The anchor loops shall be connected to the edge beam by means of anchor plate welded to the edge beam. Total cross sectional area of anchor loop on each side of the joint shall not be less than 1600 mm^2 per metre length of the joint and the centre to centre spacing shall not exceed 250 mm. The thickness of anchor plate shall not be less than 0.7 times the diameter of anchor loop or 12 mm whichever is higher. The anchor loop at the edge profiles should be at right angles to the joint. Planned deviations of this direction are allowable only for the range of 90°±20°. The anchoring reinforcement of the construction must lie parallel to the anchor loops.

c) The sealing element shall be a preformed/extruded single strip of such a shape as to promote self-removal of foreign material during normal joint operation. The seal shall possess high tear strength and be insensitive to oil, gasoline and ozone. It shall have high resistance to ageing. The specially designed proprietary type of locking system of seal in the housing of edge beam shall be such as to ensure 100% water tightness as well as ease of installation and replacement. Mechanical fastening of sealing element with edge beam shall not be permitted. Sealing element shall be continuous over the entire joint. The working movement range of the sealing element shall be at least 80 mm with a maximum of 100 mm at right angles to 'the joint and ± 40 mm parallel to the joint. Minimum gap for inserting the Chloroprene seals in the expansion joint shall be 25 mm.

d) The steel for edge beams shall conform to any of the steel grade equivalent to RST 37-2 or 37-3 (DIN), S235JRG2 or S355K2G3 of EN10025 (DIN 17100), ASTM A 36 or A 588, CAN/CSA Standard G40.21 Grade 300 Wand Grade B of IS: 2062. For subzero condition, material for steel shall conform to Grade C of IS: 2062.

e) The sealing element shall be made of Choloroprene Rubber (CR). The properties of CR shall be as specified in table 4100-1.

f) Anchorage steel shall conform to Grade B of IS: 2062 or equivalent standard.

4102.2 Fabrication

a) Rolled steel profiles for edge beams shall be long enough to cater for the full carriageway width. These shall be cut to size as per actual requirements. Alignment of the steel profiles shall then be made on work tables in accordance with the actual bridge cross-section. For this purpose, the contour of bridge cross-section shall be sketched on the tables. After the steel profiles are aligned, these will be fixed to the tables by means of screw clamps and tacked by arc welding.

b) Anchor plates shall be cut to the required size by gas cutting. These shall be welded to the edge beams.

c) Anchor loops shall be bent to the required shape and welded to anchor plates.

d) All steel sections shall be protected against corrosion by either hot dip galvanizing with a minimum thickness of 150 micron or by epoxy coating.

e) All surfaces of the steel inserts and anchorage including the surfaces to be in contact with or embedded in concrete shall be given treatment as per MoRTH specification.

f) The finally assembled joints shall then be clamped and transported to the work site.

Table 4100-1*: Properties of chloroprene seal*

Property	*Code*	*Specified value*
Hardness	DIN 53505 ASTM D 2240*	63+5 Shore A. 55+5 Shore A.
Tensile strength	DIN 53504 ASTM D 412*	Min 11 MPa. Min 13.8 MPa.
Elongation at failure	DIN 53504 ASTM D 412*	Min 350%. Min 250%.
Tear propagation strength longitudinal transverse	DIN 53507 ASTM D 624*(Dia C)	Min 10 N/mm. Min 10 N/mm.
Shock elasticity	DIN 53512	Min 25%.
Abrasion	DIN 53516	Max 220 mm^2.
Residual compression strain (22 hours/70°C/30% strain)	DIN 53517 ASTM D 395* (Method B)	Max 28%.
Ageing in hot air (14 days/ 70°C):	DIN 53508	
Change in hardness Change in tensile strength Change in elongation at fracture		Max +7 Shore A. Max -20%. Max -20%.
Ageing in ozone (24 h/50 pphm/25°C/20% strain)	DIN 53509	No cracks.
Swelling behavior in oil: (168 hours/25°C)	DIN 53521	
ASTM oil No.1 Volume Change Change in hardness		Max +5%. Max -10 Shore A.
ASTM oil No.3 Volume Change Change in hardness		Max +25%. Max -20 Shore A.
Cold hardening point	ASTM D 1043	Min -35°C.

***** *Either ASTM or DIN shall be followed depending on the source of supply.*

4102.3 Installation

Expansion joints shall be installed as per approved Drawing. The procedure for installation of various components shall be as follows:

a) The width of the gap to cater for movement due to thermal effect, prestress, shrinkage and creep, superstructure deformations (if any) and substructure deformations (if any) shall be determined and intimated to the manufacturer.

b) Depending upon the temperature at which the joint is likely to be installed, the gap dimension shall be preset.

c) Immediately prior to placing the joint, the pre-setting shall be inspected. In case the actual temperature of the structure is different from that taken for pre-setting, suitable correction shall be done. After adjustment, the brackets shall be tightened again.

d) Rolled up neoprene strip seal shall be cut to the required length and inserted between the edge beams by using a crow bar pushing the bulb of the seal into the steel grooves of the edge beams.

e) The carriageway surfacing shall be finished flush with the top of the steel sections. The actual junction of the surfacing/wearing coat with the steel edge

section shall be formed by a wedge shaped joint with a sealing compound. The horizontal leg of the edge beam shall be cleaned beforehand.

f) It is particularly important to ensure thorough and careful compaction of the surfacing in order to prevent any premature depression forming in it.

4103 COMPRESSION SEAL JOINT

Compression seal joint shall consists of steel armoured nosing at two edges of the joint gap suitably anchored to the deck concrete and a preformed chloroprene elastomer or closed cell foam joint sealer compressed and fixed into the joint gap with special adhesive binder. The seal is supposed to remain in continual compression due to pressing of the seal wall against joint faces throughout the service life to ensure that the joint remains water tight and capable of rebelling debris. The maximum gap when the joint fully opens due to maximum contraction of deck shall be limited to 40 mm. A typical compression seal joint is shown in figure 4100-2.

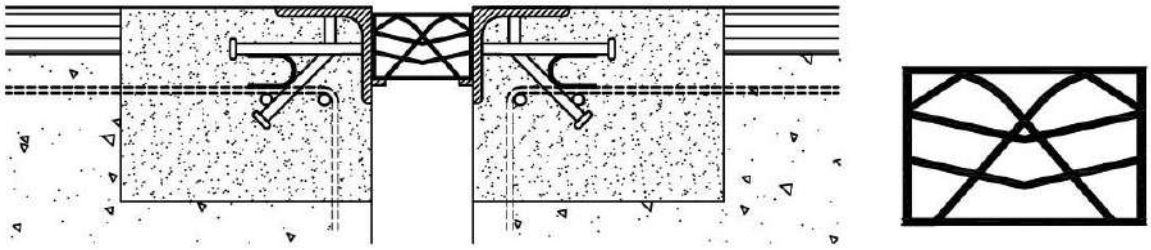


Fig. 4100-2: Typical cross section of compression seal joint and arrangement.

4103.1 Components

a) The steel nosing shall be of angle section ISA 100x100. The thickness of legs shall not be less than 12 mm. The top face of the angle shall be provided with bleeder holes of 12 mm diameter spaced at maximum 100 mm centres so as to ensure that there are no voids in the concrete beneath the angle.

b) The steel nosing shall be anchored to the deck by headed shear studs or anchor plates cast in concrete or a combination of anchor loops. Anchor bars shall engage the main structural reinforcement of the deck and in case of anchor plates and anchor loops, transverse bars shall be passed through them. The minimum thickness of anchor plates shall be 12 mm. Total cross sectional area of bars on each side of the joint shall not be less than 1600 mm^2 per metre length of the joint and the centre to centre spacing shall not exceed 250 mm for loop anchors and 150 mm for headed shear studs. The ultimate resistance of each anchorage shall not be less than 600 in kN/m any direction. Steel shall conform to Grade B of IS: 2062. For sub zero condition material for steel shall conform to IS: 2062 Grade C.

c) The sealing element shall be a preformed continuous chloroprene/closed cell foam seal with high tear strength, insensitive to oil, gasoline and ozone. It shall have high resistance to ageing and ensure water tightness. The seal should be continuous for the full length of the joint required for carriageway, kerbs and footpaths, if any. The seal shall cater for a horizontal movement up to 40 mm and vertical movement of 3 mm.

d) The steel for nosing and anchorage shall conform to weldable structural steel as per IS: 2062 Grade B.

e) The physical properties of chloroprene/closed cell foam sealing element shall conform to the following:

i) Chloroprene seal shall be preformed extruded multi-web cellular section of chloroprene of such a shape as to promote self removal of foreign material during normal service operations. Chloroprene of joint seal shall satisfy the properties stipulated in MoRTH Specifications.

ii) Closed cell foam seal shall be of preformed non-extruded non-cellular section made from low density closed cell, cross linked ethylene vinyl acetate, polyethylene copolymer that is physically blown using nitrogen. The material shall have properties as indicated in the table 4100-2.

Table 4100-2*: Properties of closed cell foam seal*

Property	*Code*	*Specified value*
Density		41.7 - 51.3 kg/m^3.
Compression set on 25 mm	ASTM D 3575	50% compression samples for 22 hours at 23°C, 2 hour recovery; 13% set.
Working temperature		-70°C to +70°C
Water absorption (Total immersion for 3 months)	ASTM D 3575	0.09766 kg/m^2.
Tensile Strength		0.8 MPa.
Elongation at break	ASTM D 3575	195±20%.

iii) Chemical tests shall be performed on specimens of elastomer and the properties of elastomer shall conform to the values/standards indicated in table 4100-3.

Table 4100-3*: Chemical tests*

Property	*Code*	*Specified value*
Adhesion strength	IS: 3400 Part-14	7 kN/m.
Low temperature stiffness	ASTM D 797	Young's modulus: 70 N/mm^2 (Max).
Ash content	IS: 3400 Part-22	5%.
Polymer identification test (Infrared spectro-photometry)	ASTM D 3677	Comparison of spectra with reference to sample of polychloroprene.

f) The type and application of lubricant cum adhesive material used in bonding the preformed joint seal to the steel nosing and concrete shall be as recommended by the manufacturer/supplier of the seal system.

g) All steel sections shall be protected against corrosion as stated by hot clip galvanizing or any other approved anticorrosive coating with a minimum thickness of 150 micron.

h) The dimension of the joint recess and the width of the gap shall conform to the approved Drawing.

i) Anchoring steel shall be welded to the main reinforcement in the deck maintaining the level and alignment of the joint.

j) The width of the recess shall not be less than 300 mm on either side of the joint. Care shall also be taken to ensure efficient bonding between already cast/existing deck concrete and the concrete in the joint recess.

k) At the time of installation, joint shall be clean and dry and free from spans and irregularities, which might impair a proper joint seal.
l) The lubricant cum adhesive shall be applied to both faces of the joint and joint seal prior to installation in accordance with the manufacturer's instructions.
m) The joint seal shall be compressed to the specified thickness for the rated joint opening and ambient temperature at the time of installation which shall be between 5°C and 35°C.
n) The joint seal shall be installed without damage to the seal. Loose fitting or open joints shall not be permitted.

4104 WORKMANSHIP

a) Expansion joints shall be installed under close supervision of the manufacturer's/supplier's Engineer. Detailed Installation Manual shall be supplied by the manufacturer/supplier.
b) The dimensions of the recess in the deck shall be established in accordance with the Drawings or design data of the manufacturer, taking into account the width of gap for movement of the joint.
c) The pre-setting of expansion joint shall be done by means of an auxiliary construction.
d) The road surfacing/wearing coat shall be laid before commencing installation of joint. Before laying wearing coat, the recess portion shall be filled with sand and wearing coat shall be laid in a continuous manner over the deck slabs and recess portion. Prior to installation of the joints, portion of wearing coat over the recess shall be removed by a suitable method such as saw cutting and the infill sand shall also be removed.
e) The size and form of recess shall suit the geometry of the expansion joint. However, the width shall not be less than the specified value for a particular type of joint. In order to avoid difficulties during installation, the points to be checked and considered are:
    i) Dimension of recess.
    ii) Levels.
    iii) Skew and slope.
    iv) Designed gap between bridge deck and abutment and/or between adjoining decks.
    v) Existing structural reinforcement according to the Drawing.
f) Reinforcing bars that would obstruct the installation of expansion joint shall be bent to accommodate the expansion joint anchorages. Cutting off or removal of interfering reinforcing bars shall only be done after consultation with the Engineer. The recess shall be cleaned thoroughly. If necessary, the surface should be roughened. All loose dirt and debris shall be removed by wire brushing, air blowing and dried with hot compressed air.
g) Shuttering must be used to seal the space between the underside of the joint and the vertical face of the recess. The shuttering must be fitted in such a way that it forms an appropriate seal against the edge of the recess. The recess shall be shuttered in such a way that dimensions shown on the Drawing are maintained. The formwork shall be rigid and firm.
h) Level marks shall be set next to the recess. This enables a controlled levelling of the expansion joint. Lowering the expansion joint/joint construction/insert into

the recess shall be done in such a way that the entire length of the joint is evenly lowered into the recess. Thereafter, the joint/joint construction/insert is precisely levelled and adjusted in the longitudinal, transverse and vertical planes. If required, the joint must also be adjusted to the gradient of the final surface level.

i) The expansion joint/joint construction/insert shall be installed preferably in the early morning when the temperature is distributed almost uniformly over the whole bridge. Immediately before the installation, the actual temperature of the bridge shall be measured. If it is not within the considered tolerance, the preset adjustment shall be corrected. The joint/joint construction/insert shall be lowered in a predetermined position. Following placement of the joint/joint construction/insert in the prepared recess, the joint/joint construction/insert shall be levelled and finally aligned and the anchorage steel on one side of the joint welded to the exposed reinforcement bars of the structure. Upon completion, the same procedure shall be followed for the other side. With the expansion joint/joint construction/insert finally held at both sides, the auxiliary brackets shall be released, allowing it to take up the movement of the structure. After carrying out the final fixing, the protection against corrosion shall be completed.

j) For fully assembled joints with one end fixed and other end movable e.g. modular strip/box seal joint, connection shall be as detailed below:

   (i) *The 1st side*: The fixed side of the assembled joint (either the abutment or the bridge deck side) is designated the 1st side for connecting the joint. The preliminary fixing is made by evenly placing and welding of reinforcing bars over the entire length between the anchor loops and the deck reinforcement. To facilitate concreting, the gap between recess and shuttering is sealed by a grout seam. The seam must be left to dry prior to final concreting. After this, additional reinforcing bars are welded until all anchor loops are firmly connected to the deck reinforcement. The expansion joint shall be considered sufficiently fixed when no vibration is noted when it is lightly tapped. The expansion joint shall not be subjected to any loads that could in any way displace the precise location of this fixing.

   (ii) *The 2nd side*: Depending on the size of the expansion joint and the expected movement during installation. The most suitable time must be determined for fixing of the 2nd (moveable) side. Usually this is the early morning hours with the smallest temperature deviations. The procedure is identical to that for the 1st side. The joint shall be provisionally fixed to the reinforcement as fast as possible.

   (iii) Immediately afterwards, the fixation brackets shall be removed. Thereafter, the gap between recess and shuttering shall be sealed with grout seam and the remaining reinforcing bars welded as described previously.

k) Prior to final concreting, the position of the joint/joint construction/insert must be recorded. The Engineer must give written confirmation of the correct position of the joint and recess concreting. The recess shall be thoroughly watered. Before pouring the concrete the joint construction should be protected by a cover.

l) Controlled concrete having strength not less than that in superstructure subject to a minimum of M35, shall be filled in to the recess. The water cement

ratio shall not be more than 0.4. If necessary, admixtures may be used to improve workability. The concrete must exhibit low shrinkage. The concrete shall be finished flush with the carriageway surfacing. The concrete shall be kept damp until it has cured in order to avoid fissures caused by drying too fast After the concrete has cured, the movable installation brackets and shuttering still in place shall be removed.

m) For modular strip seal joint the space beneath the joint boxes shall be completely filled with concrete. So that traffic loads are safely transmitted into the structure.

n) As soon as the concrete in the recess has become initially set a sturdy ramp shall be placed over the joint to protect it from traffic at site. Expansion joint shall not be exposed to traffic loading before completion of carriageway surfacing.

o) The elastomeric sealing element may be field installed. For strip seal and modular strip seal joints the sealing element shall be in continuous lengths spanning the full carriageway width. Proper fit of the seal of the sealing element must be ensured. The seal shall be installed by suitable methods in such a way that it is not damaged.

4105 SAMPLING AND TESTING

4105.1 Routine tests

This include tests for materials conforming to specifications, carried out by the original manufacturer i.e., in case of imported joints by the foreign manufacturer as part of their quality control procedure for all joints to be supplied by them. Detailed documentation of all the tests and inspection data as per complete quality control procedure shall be supplied by the original manufacturer in the form of Quality control report. Routine tests shall primarily include:

a) *Raw materials inspection:* Test on all raw materials used for the manufacturing of joints as per relevant material standard shall be carried out by the manufacturer.
   i) *Confirmation of the grade of steel:* Grade of the steel for the edge beam shall be confirmed by conducting tests for yield stress, tensile strength and elongation.
   ii) Tests for steel for the anchorage shall conform to IS: 2062.
   iii) Chloroprene seal shall be checked for hardness, tensile strength, elongation at fracture, tear propagation strength, residual compressive strain, change in hardness, change in tensile strength, change in elongation at fracture, ageing in ozone and swelling behaviour in oil. The manufacturers/suppliers shall have in-house testing facilities for conducting these tests.

b) *Process inspection:* Process inspection including inspection of all manufacturing processes adopted to manufacture the joints e.g., welding, corrosion protection, clamping, pre-setting, greasing, bonding by adhesives and riveting, as appropriate, shall be carried out by the manufacturer.

c) *Complete dimensional check:* Complete dimensional check of all components of joint as well as the assembled joint with respect to the approved Drawings and tolerances as per specifications.

4105.2 Acceptance tests

In addition to the routine tests, the manufacturer as well as the local supplier in case of imported joints shall have complete in-house testing facilities for the following tests. The Engineer shall insist upon these tests before acceptance of the joint. The applicability of the acceptance tests shall be as per table 4100-4.

a) *Cyclic motion*: Cyclic motion test may be carried out once on one complete joint assembly *or* one meter sample piece selected at random from the entire lot of supply for each type of joint irrespective of movement capacity. The test sample shall be subjected to 5000 expansion and contraction cycles at minimum 30 cycles per hour. The test movement shall be 10% more than the design expansion/contraction movement. Any sign of distress or permanent set of any component or the assembly due to fatigue, will lead to rejection of entire lot of supply.

b) *Ponding:* Prior to acceptance, 25% of the completed and installed joints, subject to a minimum of one joint, shall be subjected to water tightness test. Water shall be continuously ponded along the entire length for a minimum period of 4 hours for a depth of 25 mm above the highest point of deck. The width of ponding shall be at least 50 mm beyond the anchorage block of the joint on either side. The depth of water shall not fall below 25 mm anytime during the test. A close inspection of the underside of the joint shall not reveal any leakage.

c) *Debris expelling test:* Debris expelling test shall be carried out on one metre sample piece selected at random from the entire lot of supply. The fully open gap shall be filled flush with granular debris and cycled 25 times for full opening and closing. The mass of debris repelled after 25 cycles shall be expressed as the percentage of initial mass. The percentage expelled shall not be less than 75.

d) *Pull-out test*: Pull-out test shall be carried out on one meter sample piece selected at random from the entire lot of supply. The joint shall then be stretched until the sealing element slips off from its housing. The minimum stretching of the joint before slip-off shall be least 150% of the rated movement capacity of the seal.

e) *Vehicular braking/traction test*: This is the only initial acceptance (in-house) test. This test may be carried out once on one complete joint assembly or one metre sample piece selected at random from the entire lot of supply for each type of Joint irrespective of movement capacity. The test sample shall be installed between two blocks of concrete in its mean position. A truck wheel load of 40 kN shall be drawn across the specimen with an engaged ratchet with wheel locked to simulate locked brakes and then rolled back. The cycle shall be repeated for 50,000 times with a period of 2 seconds.

Table 4100-4: *Applicability of acceptance tests*

Performance evaluation tests	*Compression seal joint*	*Single strip/ Box seal joint*
Cyclic motion	Applicable	Applicable
Ponding	Applicable	Applicable
Debris expelling	Applicable	Applicable
Pull-out test	Not applicable	Applicable
Vehicular braking/ Traction test	Not applicable	Applicable

4105 REFERENCES

1. IRC: SP-69 Guidelines and Specifications for Expansion Joints.
2. ASTM D 395 Standard test methods for rubber property - compression set.
3. ASTM D 412 Standard test methods for vulcanized rubber and thermoplastic elastomers - Tension.
4. ASTM D 624 Standard test method for tear strength of conventional vulcanized rubber and thermoplastic elastomers.
5. ASTM D 1043 Standard test method for stiffness properties of plastics as a function of temperature by means of a torsion test.
6. ASTM D 2240 Standard Test Method for Rubber Property—Durometer Hardness.
7. DIN 53508 Accelerated ageing of rubber.
8. DIN 53509 Determination of resistance of rubber to ozone cracking under static strain.
9. DIN 53512 Determining the rebound resilience of rubber using the schob pendulum.
10. DIN 53516 Testing of rubber, elastomers; determination of abrasion resistance.
11. DIN 53517 Testing of rubber and elastomers; determination of compression set after constant strain.
12. DIN 53521 Determination of the behaviour of rubber and elastomers when exposed to fluids and vapours.
13. MoRTH Specifications for road and bridge works (5th revision).

+++++++

SECTION 4200 WEARING COAT AND APPURTENANCES

4201 GENERAL

This part deals with wearing coat and bridge appurtenances such as railing, crash barrier, approach slab, drainage spout and weep holes. The work shall be executed in conformity with details shown in the Drawings and MoRTH Specifications or as approved by the Engineer.

4202 WEARING COAT

4202.1 Bituminous wearing coat

The construction operations and bituminous mixes shall conform to the MoRTH Specifications or as specified in the Contract.

a) Bituminous wearing coat shall generally comprise of following types:
   i) Type 1: Bituminous concrete 50 mm thick laid in single layer.
   ii) Type 2: Bituminous concrete 40 mm thick overlaid with 25 mm thick mastic asphalt.
   iii) Type 3: Stone matrix asphalt 50 mm thick laid in single layer.
   iv) Type 4: Mastic asphalt 50 mm thick laid in single layer.
b) Before laying wearing coat, the deck surface shall be thoroughly cleaned and tack coat shall be applied.

4202.2 Cement concrete wearing coat

a) Cement concrete wearing coat shall be laid separately over the bridge deck as per the Drawing. If the same is not mentioned in the Drawing the following details shall be followed:
   i) The thickness of wearing coat shall be 75 mm. The concrete shall be of minimum M30 grade.
   ii) Steel reinforcement of 8 mm diameter at 150 mm spacing in both directions shall be provided at mid depth of the wearing coat.
   iii) In a length of 1 m near the expansion joint, additional reinforcement of 8 mm diameter bars shall be provided in both directions to make the spacing as 75 mm.
b) Cement concrete and steel reinforcement shall conform to the respective Sections of this Manual.

4202.3 Workmanship

a) Curing of wearing coat shall start as early as possible.
b) All carriageway and footpath surfaces shall have non-skid characteristics.
c) The cross slope in the deck shall be kept as 2.5% or as specified in the Drawing.
d) For the structures with flat deck surface, camber/superelevation in the wearing coat shall be achieved as below:
   i) In bituminous wearing coat provide profile making course before laying wearing coat. The profile making course shall be of the same material as of wearing coat. The thickness of wearing coat at any point shall not be less than that given above.

ii) In case of cement concrete wearing coat provide profile corrective course along with wearing coat in single layer.

e) Overlay on the existing wearing coat on bridge decks shall not be permitted.

f) In case the wearing coat is damaged, it shall be repaired or replaced. The dismantling of wearing coat shall be as per MoRTH Specifications.

4203 RAILING AND CRASH BARRIER

a) Bridge railing/crash barrier includes the portion of the structure erected on and above the kerb.

b) Railing/crash barrier shall not be constructed until the centering false work for the span has been released and the span is self-supporting.

c) For concrete with steel reinforcement, requirements for the items of concrete and reinforcement mentioned under relevant Sections of this Manual shall be applicable.

d) The railing/crash barrier shall be carefully erected true to line and grade. Posts shall be vertical with a tolerance not exceeding 6 mm in 3 m. The pockets left for posts shall be filled with non-shrink mortar.

e) The type of railing/crash barrier to be constructed shall be as shown in the Drawings and shall conform to IRC: 5 and IRC: 6.

f) Care shall be exercised in assembling expansion joints in the railing/crash barrier to ensure that they function properly.

g) The railing/crash barrier shall be of such design as to be amenable to quick repairs.

h) The material of metal railing/crash barrier shall be handled and stored with care, so that it remains clean and free from damage. Railing/crash barrier materials shall be stored above the ground on platforms, skids, or other supports and kept free from grease, dirt and other contaminants.

i) Methods of repairs shall be such that they do not damage the material or protective coating.

4203.1 Metal railing/crash barrier

a) Materials, fabrication, transportation, erection and painting for bridge railing/crash barrier shall conform to the requirements of specifications of structural steel**.**

b) All steel railing elements, pipe terminal sections, posts, bolts, nuts, hardware and other steel fittings shall be galvanised or painted with an approved paint.

c) If galvanised, all elements of the railing/crash barrier shall be free from abrasions, rough or sharp edges, and shall not be kinked, twisted or bent.

d) If straightening is necessary, it shall be done as per method approved by the Engineer.

e) Damaged galvanized surfaces, edges of holes and ends of steel railing/crash barrier cut after galvanising shall be cleaned and re-galvanised.

f) The railing/crash barrier shall be carefully adjusted prior to fixing in place to ensure proper matching at abutting joints and correct alignment and camber throughout its length.

g) Holes for field connections shall be drilled with the railing/crash barrier in place in the structure at proper grade and alignment.

h) Unless otherwise specified in the Drawing, metal railing/crash barrier shall be given one shop coat of paint and three coats of paint after erection, if sections are not galvanised.

i) Railing/crash barrier shall follow the alignment of the deck as per the Drawing.

4203.2 Cast in-situ concrete railing/crash barrier

a) The portion of the railing/crash barrier or parapet which is to be cast in-situ shall be constructed in accordance with the requirements of Section 600 of this Manual.

b) Forms shall be fabricated conforming to the shape of railing/crash barrier shown in the Drawing. It shall be ensured that no form joint appears on plane surfaces. For bridges/viaducts of length more than 500 m horizontal slip forms shall be used for casting of crash barriers.

c) All mouldings, panel work and bevel strips shall be constructed according to the details shown in the Drawing. All corners in the finished work shall be true, sharp and clean-cut and shall be free from cracks, spalls or other defects. Castings of posts shall be done in single pour.

4203.3 Precast concrete railing/crash barrier

a) Precast members for railing/crash barrier shall be of reinforced cement concrete and shall conform to the requirements of Section 600 of this Manual.

b) The maximum size of the aggregate shall be limited to 12 mm and minimum concrete grade shall be M30 for railings and M40 for crash barriers.

c) The precast members shall be removed from the moulds as soon as practicable and shall be kept damp for a period of at least 10 days, during which they shall be protected from sun and wind. Any precast member that becomes chipped, marred or cracked before or during the process of placing shall be rejected.

4204 APPROACH SLAB

a) Reinforced concrete approach slab with 12 mm dia bars at 150 mm c/c in each direction both at top and bottom in M30 grade of concrete covering the entire width of the roadway, shall be provided as per details given in the Drawing or as approved by the Engineer. Minimum length and thickness of approach slab shall be 3.5 m and 300 mm respectively.

b) Reinforced cement concrete and reinforcement shall conform to the requirements of Section 600 of this Manual.

c) The approach slab shall rest on a base of 150 mm thick M15 grade concrete or as shown in the Drawings or as directed by the Engineer.

4205 DRAINAGE SPOUTS

a) Drainage along longitudinal direction shall be ensured by providing sufficient number of drainage fixtures embedded in the deck slab.

b) The spouts shall be of not less than 100 mm in diameter and shall be of corrosion resistant material such as galvanised steel with suitable cleanout fixtures.

c) The spacing of drainage spouts shall not exceed 10 m. The discharge from drainage spout shall be kept away from the deck structure by means of suitable down pipes up to 500 mm above High Flood Level.

d) In case of viaducts in urban areas, the drainage spouts shall be connected with suitably located runners and down pipes to discharge the surface run-off into drains provided at ground level.

e) The galvanised assembly shall be given two coats of bituminous paint before placement. The whole assembly shall be placed in true position, lines and levels as shown in the Drawing with necessary cutouts in the shuttering for deck slab and held in place firmly. Where the reinforcements of the deck are required to be cut, equivalent reinforcements shall be placed at the corners of the cutout.

f) After setting of the deck slab concrete, the shrinkage cracks around the assembly shall be sealed with polysulphide sealant or bituminous sealant as per 1S:1834 and the excess sealant trimmed to receive the wearing coat. After the wearing coat is completed, similar sealant shall be provided to cover at least 50 mm on the wearing coat surface all round the drainage assembly.

4206 WEEP HOLES

a) Weep holes shall be provided on all plain concrete, reinforced concrete, brick masonry and stone masonry structures such as, abutment, wing wall and return walls as shown in the Drawing or as directed by the Engineer to permit water to flow out without building up pressure in the back fill.

b) Weep holes shall be provided with 100 mm diameter AC/PVC/HDPE pipe for structures in plain/reinforced concrete or brick masonry. In case of stone masonry, weep holes shall be of rectangular shape 80 mm wide, 150 mm high or circular with 150 mm diameter.

c) Weep holes shall extend through the full width of concrete/masonry with slope of about 1 vertical to 20 horizontal, towards the draining face.

d) The spacing of weep holes shall be 1 m in either direction or as shown in the Drawings with the lowest at 150 mm above the low water level or ground level whichever is higher or as directed by the Engineer.

4207 REFERENCES

1. IRC: 5 Standard specification and code of practice for road bridges: *General features of design.*
2. IRC: 78 Standard specification and code of practice for road bridges: *Foundations and substructures.*
3. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 4300 RETAINING WALLS

4301 GENERAL

This part covers the quality control requirements and construction of retaining walls. The requirements related to site clearance, setting out of the works, earthworks including rock cutting and blasting operations, stone masonry, brick masonry, plain/reinforced cement concrete, reinforcement etc. shall be as per relevant sections of this Manual.

4302 SOLID RETAINING WALL

a) The solid retaining wall provides stability by virtue of its own weight and shall be built in stone masonry or plain cement concrete.
b) Generally, solid retaining walls shall not be preferred where retaining heights exceeding 3 m.

4303 RCC RETAINING WALL

a) The RCC cantilever wall type retaining structure shall be preferred for heights 6 m to 7 m.
b) The counterfort retaining wall consists of counterforts (Transverse stem supports) which are concealed within the retained earth (On the rear side of the wall) shall be preferred for heights above 7 m.
c) The 'buttress wall' is similar to the 'counterfort wall', except that the transverse stem supports, called buttresses, are located in the front side. The buttresses interconnect the stem with the toe slab and not with the heel slab, as with counterforts.
d) Backfilling of retaining wall shall be applied on heal slab first then toe side filling shall be carried out.
e) Inverted filter shall be provided behind retaining walls to drain off ground water table or rainwater seepage.
f) Special precautions shall be taken to prevent any wedging action against structures and the slopes bounding the excavation for the structure shall be stepped or strutted to prevent such wedging action.
g) Weep holes shall be provided in RR masonry walls at spacing of about 1.5 m centre-to-centre in either direction. The size of weep holes shall be 100 mm to 150 mm PVC (flexible) pipes and shall be sloped towards valley side to effectively drain the water from ground. The weep holes shall be provided above the low water level.
h) In counterfort retaining walls there shall be at least one drain in each pocket between adjacent counterforts.
i) The back fill material shall consist of granular material of GW, GP, SW groups as per IS: 1498 and shall be free of clay and cement.
j) The filter material shall be well packed to a thickness of not less than 600 mm with smaller size towards the soil and bigger size towards the wall and provided over the entire surface to the full height.

k) The drainage layer shall be provided as per the specifications for the reinforced soil retaining wall.

4304 REINFORCED SOIL RETAINING WALL

4304.1 Reinforcing elements

a) The reinforcing element shall be metallic in the form of strips (Aluminium alloy, copper, carbon steel, galvanised steel, stainless steel, ladder) or mats of metal (steel grids, woven and welded steel wire meshes) or synthetic (PET, HDPE, PVA, PP) reinforcement in the form of grid or strip or strap or combination of metallic or synthetic or any other proprietary material which may be approved by the Engineer or as shown in the Drawing.

b) Aluminium alloy strip shall comply with BS: 1470 quality 5454 in the H24 condition.

c) Copper strip shall comply with BS: 2870 quality C101 or C102 in ½ H condition and shall have 0.2% proof stress of not less than 180 N/m^2.

d) Carbon steel strip shall comply with BS: EN10025 or IS: 2062 and have a section content of not more than 0.55%. The fabricated element shall be galvanized in accordance with IS: 4759 and IS: 2629 and the minimum zinc coating weight shall not be less than 1000 gm/m^2.

e) The steel strips with minimum bearing and shear strength of 490 MPa shall comply with the requirements of BS: EN 10025, Grade S 355 JR, or IS: 2062 grade Fe490, except the elongation (on base metal) for which minimum 22% is acceptable.

f) The panel lugs shall be manufactured from hot rolled steel strips with the same steel quality and grades as specified above, except that the minimum zinc coating weight not less than 600 gm/m^2.

g) All permanent metallic connectors (exposed to soil), tie strips and lugs shall be hot dip galvanized. Nuts/bolts (fasteners) shall be galvanized as per requirements of IS: 1367-Part 3 and of grade 10.9.

h) For all metallic components, where holes or penetrations are made through the reinforcing elements to accommodate connection such as bolts, pins, or other, the cross section thickness and/or width of metallic component shall be increased to account for section loss caused by the hole or penetration.

i) Stainless steel strip shall comply with BS:1449 (Part 2) quality 315 S 31 or S/6 S 33 except that the material shall be cold rolled to provide a 0.2% proof stress of not less than 400 MPa and the tensile strength shall not be less than 540 MPa.

j) All metallic components buried in soil shall be of electrolytically compatible materials.

k) High strength high tenacity geo-textile fabrics used as reinforcement in the construction of reinforced slopes or in the base of reinforced soil structure as reinforcement, geotextile fabric used for separation, filtration and/ or drainage shall satisfy all the requirements stipulated for geosynthetic reinforcing elements.

l) The manufacturer of geogrids, geotextiles, geostrips, polymeric strips, polymeric ties or any other geosynthetic material, including any proprietary geo-synthetic material, for use as reinforcing element shall fulfil the following requirements:

i) Shall have ISO (ISO-9001) or CE Certification for manufacturing process and quality control.
ii) The product shall have certification for use as soil reinforcing material from an agency accredited for certifying geo-synthetic reinforcement products.

m) The manufacturer shall provide test reports from an independent laboratory with valid accreditation, for all the tests needed to establish all the reduction factors listed below:

RF_{CR} - Reduction factor for creep.
RF_{ID} - Reduction factor for installation damage.
RF_{W} - Reduction factor for weathering.
RF_{CH} - Reduction factor for chemical/environmental effects.
f_s - Factor for the extrapolation of data.

All the above factors shall be determined in accordance with the provisions of ISO/TR 20432 - Guide to the determination of long strength of geosynthetics for soil reinforcement.

4304.2 Sampling and testing

a) Test for the ultimate tensile strength shall be carried out on a random sample for each grade of reinforcement as per ISO-10319. The test results shall be accompanied by stress-strain curves showing strength at 2% and 5% strain and strain/elongation at failure.
b) Annual average daily temperatures (AADT)/design temperature of the project site shall be worked out and values of reduction factor for creep R_{FCR} and for R_{FCH} shall be provided as per procedures given in ISO/TR-20432.
c) Tests shall be carried out to provide values of:
   i) Pullout coefficient as per ASTM D 6706 "Standard test method for measuring geosynthetic pullout resistance in soil" and
   ii) Coefficient of interaction between reinforced fill soil and geogrids as per ASTM D 5321or IS: 13326: Part 1-1992 for all types of geogrids.
d) One set of project specific tests shall be conducted at third party accredited laboratory or at a reputed institute.
e) Each roll shall have at least one identification label with roll number and product type.

4304.3 Earth fill

a) The fill material in the reinforced soil zone shall have, drained or effective angle of friction not less than 30°, measured in accordance with IS: 2720 (Part 13), by conducting a drained direct shear test. In case the fill material has 25% or more particles of 4.75 mm or larger, drained shear test using large shear box may be conducted (IS: 2720 Part 39).
b) The gradation of fill soil shall be as per table 4300-1.

Table 4300-1: *Requirements for fill soil*

Sieve size	*Percentage passing by weight*
75 mm	100%
425 micron	0-60%
75 micron	Less than 15

c) The plasticity index of fill soil shall be less than or equal to 6.

d) Materials with more than 15% passing 75 micron sieve are acceptable if particles smaller than 15 microns are less than 10%, provided PI is less than 6 and angle of friction is not less than 30°.

e) Properties of fill soil in the reinforced zone, unreinforced zone (or retained/back fill) soil and the foundation soil shall be determined accurately during the construction phase, as per quality assurance plans and directions of Engineer so as to ensure that these are the same as those considered in the design phase. The fill soil in the unreinforced zone shall conform to the requirements specified in the design.

f) Where galvanized steel reinforcement is used, the fill material shall be free draining granular material and shall meet the requirements given in table 4300-2.

Table 4300-2: *Recommended limits of electrochemical properties for reinforced fills with steel reinforcement*

Property	*Code*	*Specified value*
Resistivity	AASHTO T-288	>3000 ohm-cm
pH	AASHTO T-289	>5 and <10
Chlorides	ASTM D 4327	<100 ppm
Sulphates	ASTM D 4327	<200 ppm

g) Where geosynthetic reinforcement is used for reinforcing elements manufactured from polyester yarn, pH value of the fill material shall be between 3 and 9, and for reinforcing elements manufactured from PVA, PP and HDPE, the pH value shall be greater than 3.

4304.4 Facia material

a) The facing system shall be any one of the following:
   i) Precast reinforced concrete panels.
   ii) Precast concrete blocks and precast concrete hollow blocks.
   iii) Gabion facing (See figure 4300-1).
   iv) Wrap around facing using geosynthetics.
   v) Metallic facing, prefabricated in different shapes including welded wire grid and woven steel wire mesh.
   vi) Other proprietary and proven systems.

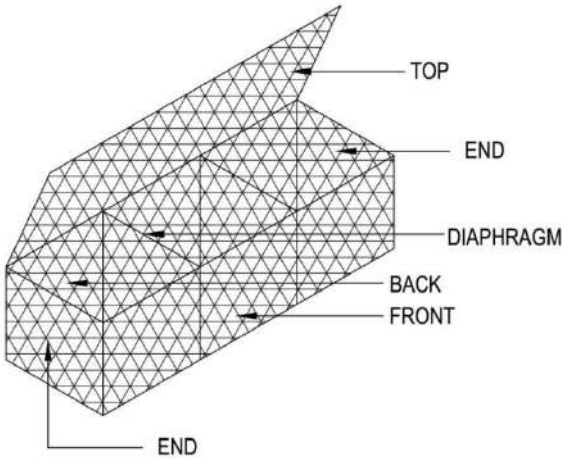


Fig 4300-1: Gabion boxes.

b) Facing shall be sufficiently flexible to withstand any deformation of the fill and foundations.

c) The facia units to be adopted in the project shall be shown in the Drawings and shall be approved by the Engineer.
d) The minimum thickness of precast concrete panels shall be 180 mm including facing textures, logos and embellishments.
e) Precast concrete blocks are dry cast and shall be manufactured from fully automatic block making machines.
f) In case of hollow blocks, the hollow area shall not exceed 40% of the cross sectional area of the block. The outer side of the block shall have minimum thickness of 100 mm.
g) The minimum grade of concrete for pre-cast reinforced concrete or plain concrete panels/blocks shall be M35.
h) Facia panel systems shall have provision of both horizontal and vertical gaps to prevent concrete to concrete contact. The horizontal gap between the facing elements shall be maintained by provision of Ethylene Propylene Diene Monomer (EPDM) pad. Bedding material shall consist of either cement mortar or a durable gasket seating such as resin bonded cork, bitumen bonded cork or EPDM.
i) The joints between the panels shall be covered from inside with non-woven geotextile strips glued to the facing element ensuring full coverage of joints. Synthetic glue shall be used for this purpose. The width of the geo-textile strip shall not be less than 100 mm.
j) Where gabion facia is used, it shall conform to the provisions of BS 8006-1:2010 and EN 14475 and made of mechanically fabricated and selvedged double twisted hexagonal mesh. Wire used for the double twisted mesh shall be hot dip galvanized as per IS: 4826 heavily coated and soft type, with wire and mesh properties in accordance with EN-10223 with minimum Zn or Zn+ alloy coating as per EN-10244 and 0.5 mm thick PVC coating as per EN-10245 and ISO-527.
k) Where geo-synthetics, including geo-grids are used as wrap around facia, these shall form a part of the reinforcing element. The wrap around shall have adequate length to resist pull out and the wrap around length shall be calculated on the basis of safety in pull out. Wrap around facia shall be protected by suitable means, against adverse effects of natural forces.
l) Where steel sheet and steel grids facings are used for facing, the steel for steel sheet shall be as per BS: 1449-Part 1 and the steel grids shall conform to BS: 4482, BS: 4483 and BS: 4489.
m) Where mechanically woven steel wire mesh in wrap around form is used for facing, the steel wire mesh (IS: 4826, IS: 280, IS: 13360, EN: 10218, EN: 10223, EN: 14475) shall be with mechanical selvedging and bottom panel shall continue as an integrated tail mesh.
n) Where welded steel wire mesh units in wrap around form (EN: 10079, EN: 10080, and EN: ISO 1461, EN: 14475) are used as facing, the bottom panel shall continue as an integrated tail mesh.
o) Connection between the facia panels and the reinforcing element shall be by using either nut or bolt, HDPE inserts with bodkin joint, hollow embedded devices, polymeric/steel strips/rods/pipes, fibre glass dowels or any other material shown in the Drawing. The connection between the panel and the

reinforcement shall provide for 100% of the long term design strength of the reinforcing element in continuity.

p) In case of modular block facia and other type of facia such as gabion facia, where the reinforcement is held by friction between the facia block and the reinforcement, the connection strength shall be determined as per ASTM D 6638.

4304.5 Workmanship

a) A strip footing, minimum 350 mm wide and 150 mm thick in M15 grade plain concrete, shall be provided at founding level to receive the facia or the bottom most reinforcement.

b) The depth of embedment below the finished ground level at the foot of the wall shall not be less than 1000 mm. In case rock is met above founding level, the depth of embedment shall be adjusted as per ground conditions.

c) The reinforcing elements shall be placed at right angles to the face of the wall or design axis, with greater cross-sectional dimension in the horizontal plane and the length shall be as shown in the Drawing. Reinforcing elements such as geogrids, shall be stretched and held taut by driving nails or pegs at the farther end.

d) It may be necessary to set facing unit at an additional batter than as provided in the Drawing since there is a tendency for initially positioned units of facia to lean outward as the fill material is placed and compacted. Care and caution shall be taken to accommodate this phenomenon. At the end of the construction, the face may have a slight residual inward batter.

e) Drainage bay shall be provided as shown in the Drawing. The width of the drainage bay shall be 600 mm behind the facing element. The drainage material shall conform to the specifications of the filter media as per MoRTH Specifications.

f) The reinforcing elements shall be laid free from all kinks, damage and displacement during placing, spreading, levelling and compaction of the fill. The program of filling shall be such that no construction equipment moves directly on the reinforcement.

g) All construction equipment having a mass exceeding 1500 kg shall be kept at least 2.0 m away from the face of slope or wall.

h) In areas up to 2.0 m from the face of slope or wall, one of the following equipment shall be used:
   i) Vibratory roller having a weight per metre width not exceeding 1300 kg with total weight not exceeding 1500 kg.
   ii) Vibratory plate compactor of maximum weight 1000 kg.
   iii) Vibro tamper having a weight not exceeding 75 kg.

i) Before allowing the movement of vehicles over the reinforcement, a minimum compacted thickness of 150 mm shall be provided over the reinforcement and the speed of the vehicles shall be restricted to 10 km/hr.

j) During construction of reinforced fill, the retained material beyond the reinforcement at the rear of the structure shall be maintained at the same level as reinforced fill.

k) Fill shall not be placed on surface that contains mud, organic soil or area that have not met compaction requirement.

l) The thickness of compacted layer shall not be more than 200 mm, compacted to 97% of maximum laboratory density measured as per IS: 2720 (Part 8).

4304.6 Tolerances

a) All elements of pre-cast RCC panels shall be manufactured within the tolerances specified in table 4300-3.

Table 4300-3: *Tolerances for faces of retaining walls and abutments*

Property	*Tolerance*
All dimensions	±5 mm.
Evenness of the front face	±5 mm over 1500 mm.
Difference between lengths of two diagonals	5 mm max.
Thickness	+5 mm/-0 mm.
Location of plane of structure	±50 mm - metallic reinforcement. ±75 mm - synthetic reinforcement.
Bulging (Vertical)	±20 mm in 4.5 m template (Metallic).
Bowing (Horizontal)	±30 mm in 4.5 m template (Synthetic).
Steps at joints	±10 mm.

b) Dimensions of modular concrete blocks shall not differ more than ±2.5 mm for length and width and ±1.5 mm in height.

c) Minimum vertical movement capacities required for facing systems to cope with vertical internal settlement of reinforced fill shall be as per table 4300-4.

Table 4300-4*: Minimum vertical movement capacities of facing systems*

Structural form	*Minimum Vertical Movement Capacity of System*
Discrete panels	Joint closure of 1 in 150 relative to panel height.
Full height panels	Vertical movement capacity of connections 1 in 150 relative to panel height.
Semi-elliptical facings	Vertical distortion of 1 in 150 relative to panel height.
Geotextile/geogrid wrap-around facings	No specific limit except for appearance or serviceability considerations.

4305 CONSTRUCTION OF RETAINING WALL IN HILLY TERRAIN

a) The construction of retaining wall in hilly terrain shall be based on IS: 14458 (Part 1 to 3).

b) The construction of retaining/breast walls and gabion structures shall be conforming to the Drawing or as suggested by the Engineer.

c) The foundation bed should be sloped towards the hillside.

d) Resort to stepping up of the foundation bed of retaining walls in stable rocks.

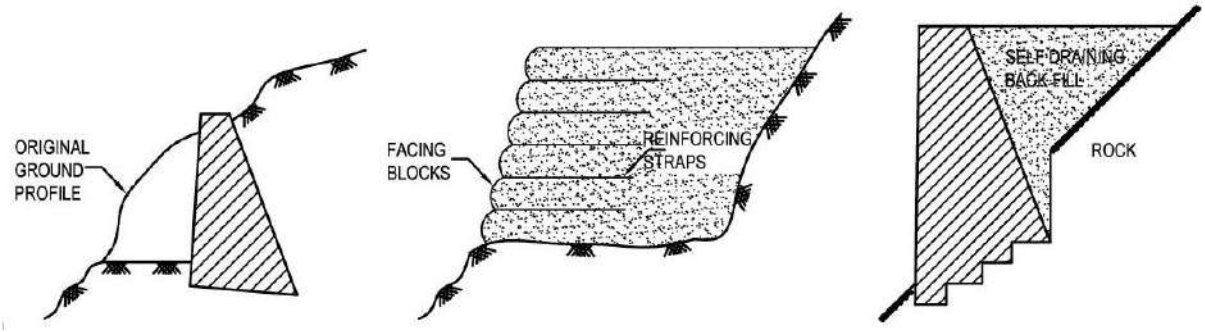
e) Ensure that the top level of the retaining wall matches the adjoining shoulder edge.

f) Ensure that approved filter material is provided behind the wall before back filling. Also ensure that back filling is done only after the masonry work is approved by the Engineer.

g) Do not construct retaining walls, which are having outer curve in plan, especially at hairpin bends.

h) Do not allow construction of retaining walls until proper road geometrics has been achieved in hill cutting otherwise this may lead to excessive heights and quantities of retaining wall masonry, creating unnecessary cost escalation.

i) If the retaining wall is made on rock slope, the foundation shall be stepped as shown in figure 4300-2. In case of steep slopes (>35º), retaining walls with front face nearly vertical and back-face inclined shall be used as it will reduce the height of wall considerably.



a) Gravity wall b) Reinforced soil wall c) Stepping of foundation

Fig. 4300-2: Types of retaining wall in hilly terrain.

4306 REFERENCES

1. IRC: 280 Guidelines for design and construction of river training and control works for road bridges.
2. IS: 2720 Methods of test for soils:
   (Part 8) *Determination of water content-dry density relation using heavy compaction.*
3. IS: 4826 Specification for hot-dipped galvanized coatings on round steel wires.
4. IS: 13326 Method of test for the evaluation of interface friction between geo-synthetics and soil:
   (Part 1) *Modified direct shear technique.*
5. IS: 14458 Retaining wall for hill areas - guidelines.
   (Part 1) *Selection of type of wall.*
   (Part 2) *Design of retaining/breast walls.*
   (Part 3) *Construction of dry stone walls.*
   (Part 4) *Construction of banded dry stone walls.*
   (Part 5) *Construction of cement stone walls.*
   (Part 6) *Construction of gabion walls.*
   (Part 7) *Construction of RCC crib walls.*
   (Part 8) *Construction of timber crib walls.*
   (Part 9) *Design of RCC cantilever wall/buttressed wall & L-type walls.*
   (Part 10) *Design and construction of reinforced earth retaining walls*.
6. ASTM D5321 Standard test method for determining the coefficient of soil and geosynthetic or geosynthetic and geosynthetic friction by the direct shear method.
7. ASTM D6638 Standard method of test for determining connection strength between geo-synthetic reinforcement and segmental concrete units.
8. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

SECTION 4400 RIVER PROTECTION WORKS

4401 GENERAL

River training and protection works shall include construction of guide bunds, guide walls, spurs, groynes, bank protection, flooring, cut-off walls, apron and approach embankment protection, as required for ensuring safety of the bridge structure and its approaches against damage due to flood/flowing water. Construction of various components shall conform to IRC: 89 and MoRTH Specifications or as directed by the Engineer.

4402 GUIDE BUND

a) This work shall consist of construction of embankment of guide bund in accordance with Clause 2502 of MoRTH Specifications or as directed by the Engineer.
b) The provision of apron and toe protection and pitching/revetment on slopes, etc shall be as indicated in the Drawings and constructed in accordance with Clauses 2503 and 2504 of MoRTH Specifications.
c) The alignment and layout of guide bund shall be as indicated in the Drawing or as approved by the Engineer.
d) The construction of embankment for guide bund shall conform to provisions of Section 2100 of this Manual.
e) Guide bunds shall be made of locally available materials. Trial pits shall be taken in borrow areas to examine suitability of soil for construction and also to decide the types of earth moving machinery to be used. No borrow pits should be dug on the river side of the guide bunds.
f) Construction of guide bund shall be taken in hand along with the construction of the bridge and to complete the work of the guide bund in one working season.
g) Sufficient area along the side of the guide bund shall be ready within one to two months of commencement of work, so that the placing of stones in the apron and in the slope pitching can be commenced.
h) Earth work shall be completed within 80% of the working season and about 70% of the working season shall be available for laying apron and pitching.
i) No portion of the guide bund should be left incomplete below high flood level before the onset of the monsoon.
j) The methodology for transport of stones from the quarries to the site of work including the quantities of stone to be transported every day, mode of transport to be used (train, truck, ferry, boats), labour for loading, unloading and laying etc. shall be furnished by the Contractor for approval by the Engineer.
k) Adequate reserve of stones should be maintained for major works as decided by the Engineer. The reserve stones shall be stacked away from the main channel of the river.
l) Where the alignment of guide bund or the approach embankment crosses branch channel of the river, the branch channel shall be either diverted to the main channel of the river with the help of spurs, groynes etc. or closed by a

properly designed closing dyke or closure bund, before taking up construction of guide bund.

4403 APRON

This work shall consist of laying boulders directly or in wire crates on the bed of rivers for protection against scour. The detailed specifications and construction procedures are given under clause 2503 of MoRTH Specifications.

a) The stones used in apron shall be sound, hard, durable and fairly regular in shape.
b) Stones subjected to marked deterioration by water or weather shall not be used.
c) Quarry stones having angular shapes shall be preferred to round boulders.
d) The size of stones for boulder aprons shall conform to relevant clause of IRC: 89.
e) Where the stones of required size are not economically available, cement concrete blocks in minimum M15 grade conforming to Section 3300 of this Manual or stones in wire crates shall be used.
f) Requirements of wire crates and mattresses for apron shall be as per clause 2503 of MoRTH Specifications.

4404 PITCHING/REVETMENT ON SLOPES

This work shall consist of covering the river side slopes of guide bunds, training works and road embankments with stone, boulders, cement concrete blocks or stones in wire crates over a layer of granular material which will act as a filter. The rear slopes, not subjected to direct attack of the river, may be protected by 300 mm to 600 mm thick cover of clayey or silty earth and turfing.

a) The pitching shall be provided with stones of thickness and shape as indicated in the Drawings. The size and weight of stones shall conform to IRC: 89. No stone weighing less than 40 kg shall be used.
b) The stones shall be obtained from quarries and shall be sound, hard, durable and fairly regular in shape. Round boulders shall not be allowed. Stones showing marked deterioration by water or weather shall not be accepted.
c) Where the stones of required size are not economically available, cement concrete blocks in minimum M15 grade concrete conforming to Section 3300 of this Manual or stones in wire crates, shall be used.
d) Geosynthetics, if used in pitching, shall conform to Section 2600 of this Manual.
e) The material for the filter shall consist of coarse sand, gravel or stone. One or more layers of graded materials, to act as a filter medium, shall be provided underneath the pitching, to prevent loss of the embankment material and build up of uplift head on the pitching. The gradation of the filter material shall conform to IRC: 89 and MoRTH Specifications.
f) Construction operations of pitching on slopes shall be carried out conforming to MoRTH Specifications.

4405 TOE PROTECTION

a) A toe wall shall be provided at the junction of slope pitching and launching apron of a guide bund so as to prevent the slope pitching from sliding down.

b) The toe wall shall be in dry rubble masonry (Un-coursed) conforming to MoRTH Specifications or in cement concrete of M15 grade.

4406 RUBBLE STONE FLOORING

a) Where specified, provide rigid flooring under culverts and extend for a minimum distance of 1.5 m on upstream side and 3.0 m on downstream side or as shown in Drawings.
b) Excavate trench for laying foundation of bed protection and lay 300 mm thick cement concrete of M15 grade (Unless not specified in the Drawing), so as to commence paving work.
c) There shall be no loose materials or pockets in the trench. The bed shall be compacted level and even. All concrete and other elements are laid in dry bed.
d) Flooring is done with 150 mm flat stones/cement concrete block M15 grade thick, which are bedded on a 25 mm thick layer of 1:3 cement mortar. Fill the joints with cement mortar and finish neatly.
e) Keep the top of flooring 300 mm below the lowest bed level and extend the flooring up to the line connecting the end of splayed wing walls on either side of the culvert/bridge.
f) Adopt dry rubble stone where the velocity of flow is less than 1.5 m/sec by keeping the top of flooring 300 mm below the low bed level.
g) Lay the rubble stones closely, breaking joints, and fill all joints with spalls of proper size, wedged in with rammers to ensure tight packing.
h) Before laying the foundation and protection walls, the excavated trenches shall be inspected by the Engineer to ensure that:
    i) There are no loose pockets and unfilled depressions left in the trench.
    ii) The soil at the founding level is properly compacted to true lines and level so as to have even bedding.
    iii) All concrete and other elements are laid in dry bed.

4407 CURTAIN WALL AND FLEXIBLE APRON

a) The rigid flooring shall be enclosed by curtain walls (Tied to the wing walls) with minimum depth below floor level of 2 m on upstream side and 2.5 m on downstream side.
b) The curtain wall shall be in cement concrete M15 grade or stone masonry in cement mortar 1:3.
c) Beyond curtain walls, flexible apron 1.0 m thick comprising loose stone boulders (Weighing not less than 40 kg) shall be provided for a minimum distance of 3.0 m on upstream side and 6.0 m on downstream side.
d) The work of floor protection shall be simultaneously completed along with the work on bridge foundations.

4408 QUALITY CONTROL

a) The size and weight of stones for laying boulder apron and pitching on slopes shall conform to the requirement given in IRC: 89.
b) The galvanising coating shall conform to IS: 4826 and that of annealed steel wire for wire crates shall conform to IS: 280.
c) Size and weight of stones in apron/slope/flooring etc. shall be checked at quarry site before procurement.

d) Wire crates (Size and mesh size) and cement concrete blocks (Weight and size) shall be checked before procurement.
e) Gradation of filter media shall be checked for specifications in IRC: 89.
f) The tests to be carried out during construction are indicated in table 4400-1.

Table 4400-1: *Tests during construction*

Sl. No.	*Test/check*	*Frequency*
1	Laying of filter granular material	Daily check for workmanship.
2	Laying boulders for - Apron - Pitching on slopes - Toe protection - Wire crates	Daily check for uniformity in workmanship.
3	Mortar for joints - Mix proportions (control on quality of cement by weight) - Consistency and water retentivity (IS: 2250) - Compressive strength (IS:2250)	Each batch. As required. On a set of 3 cubes, where specified.
4	Laying of stones in flooring	Daily check for workmanship.
5	Curtain wall	Daily check for workmanship.

4409 REFERENCES

1. IRC: 89 Guidelines for design and construction of river training and control works for road bridges.
2. IS: 280 Mild steel wire for general engineering purposes.
3. IS: 10751 Planning and design of guide banks for alluvial rivers – guidelines.
4. MoRTH Specifications for Road and Bridge works (5th revision).

+++++++

INDEX

INDEX

Word/phrase	*Page*
Part A: BUILDINGS	
Admixture	63-65
Aggregates	60, 61
Air bath	217
Aluminium composite panel cladding	122, 123
Aluminium fabrication	124
Aluminium paint	110
Aluminium partitions	120
American Society for Testing and Materials (ASTM)	12
Anchor bolts	182
Anti corrosive bitumastic paint	110
Anti termite treatment	22
Bath tubs	217
Bench mark	15
Bib tap/cock	219
Bidet	216
Blasting	18
Bolted connection	180
Bored cast-in-situ piles	28, 29
Bore well	224
Brick masonry	38
British Standards (BS)	94, 124
Bureau of Indian Standards (BIS)	11, 12
Cast iron pipes	196
Ceiling	147
Fibre insulating building boards	148
Gypsum board	151
Particle board/ multipurpose cement board	150
Plain/ semi perforated particle board tiles	150
Plaster of paris	152
PVC	151
Translucent white acrylic plastic (PMMA) sheet	152
Wooden	147
Cement	57, 58, 59
Cement concrete	24, 25, 27, 63, 134, 159-163, 166, 170, 175, 196, 197, 199, 200
Cement concrete pipes	196
Cement paint	107
Cement plaster	103, 160
Cement primer	106
Cement water proofing compound	104
Central Public Works Department (CPWD)	11
Centrifugally cast (Spun) iron pipes	207
Chequered plates	183
Chlorinated polyvinyl chloride (CPVC) pipes	213-215
Coal tarring	108
Coir veneer board	119
Colour washing	105

Compaction	16, 21, 22, 23, 79
Compressive strength	27, 35, 38-45, 47, 49-51, 59, 62, 72, 81, 85, 88,143,152, 156, 190
Concealed diverter	220
Concrete	24-32, 71
Proportioning	71, 72, 83
Hand mixing	76
Placing	78
Plant Batching and mixing	73
Transportation	76
Volume batching	73
Concrete block masonry	43
Conduit	88
Consistency	35, 37, 38, 43, 49, 185
Core test	85
Curing	37, 81, 82, 160
Distempering	106
Door closers	99
Doors and windows	90
Aluminium	97
PVC/UPVC	96
Steel	93
Timber	90
Door stopper	99
Drainage pipes	196, 197
Earth filling	21
EPDM gaskets	121
Excavation	15, 16, 17
Ordinary/hard rock	18
Soil	17
Underwater	19
Expansion fasteners	184
Exposed diverter - mixers	220
Fabrication	93, 94, 97, 123, 138, 139, 178, 180, 182, 183, 185
Fibre glass reinforced plastic (FRP) doors	98
Fittings	56, 98, 99, 196, 200, 205
Float glass	121
Flooring	159
Acid or alkali resistant tile	167
Cement concrete	159
Chequered tile	166
Crazy marble stone	162
Granite	174
Kota stone	173
Marble stone	171
Pressed ceramic tile	168
Terazzo (Marble chips)	161, 163
Vitrified tile	170
Wooden	175
Floor trap	204
Flush door shutters	92
Flushing cistern	201
Flush valve	204
Footings	25, 26
Form work	86

Foundation	24
Deep foundation	27
Shallow foundation	24
Frames	90
French polishing	110
Galvanised iron (GI) pipes	207
Glazed stoneware pipes	196
Gratings	184
Grouting	190
Gully chamber	199
Gully trap	200
Hand shower	221
Health faucet	222
High density polyethylene (HDPE) pipes	210-212
Hinges	99
Home pressure booster pump	222
Initial load test	32
Laterite Masonry	49
Manholes	198, 199
Masonry Mortar	34
Medium density polyethylene (PE) pipes	210
Metal inserts	183
Mirror	204
Moisture content	23, 90, 114, 115, 116
Mortice locks	100
National Building Code of India	11
Non-asbestos fibre board	118
Non-destructive tests	85
Non structural members	182
Open surface drain	199
Painting	107-110, 190, 205
Panelling	113
Particle board	116, 117, 118
PE-AL-PE pipes	215, 216
Pile foundation	27
Pillar taps	216
Placing of reinforcement	67
Planking	20
Plastic emulsion paint	108
Plywood	113, 114, 115
Pointing	105
Polishing	110
Polypropylene random co-polymer (PP-R) pipes	212
Primer	94, 95, 106-109, 123, 128, 129, 137, 141,142,150-152, 191, 192
Protective coating	191
Pumped concrete	77
PVC/UPVC pipes	197, 208-210
Ready Mixed Concrete	83
Reflective glass	122
Reinforcement	65
Reinforcing bars	65-70
Roofing	126
Galvanised steel sheet roofing	126
Aluminium roofing sheets	142

Asphaltic roofing 146
Fibre-reinforced plastic sheets 144
Galvalume/zincalume and colour coated sheets 137
Non-asbestos high impact poly propylene reinforced cement corrugated sheet roofing 130, 133
Plastic translucent sheets 139
Polycarbonate (PC) sheets 138
Polyvinyl chloride roofing sheets 144
Prepainted galvanised steel sheets 141
Sandwich polyurethane foam panels 143
Unpalsticized polyvinyl chloride sheets 145
Routine load test 33
Sand 34-38
Sanitary installations 200
Sauna 218
Scaffoldings 53
Double 54
Single 53
Steel 54
Timber/Bamboo 53
Sealant 122
Seasoning of timber 91
Septic tank 200
Setting out 14, 15
Shower panel 221
Shower rose 216
Shutters 90
Single lever basin mixer 220
Site clearance 14
Solid PVC foam profile doors 98
Spout 220, 221
Steam bath 218
Steel fabrication 183
Stone masonry 46
Stripping of formwork 88
Structural fasteners 178, 180
Structural members 179
Structural steel work 178
Strutting 20
Surface box 222
Surface preparation 178, 190, 192
Synthetic enamel paint 108, 109
Table mounted mixers 220
Testing of concrete 85
Thermal insulation 153, 154, 155
Tie wire 66
Tube well 223
Tubular hand railing 184
Under-reamed piles 30, 31
Urinals 205
Valves 218, 219
Varnishing 110
Wall mounted mixers 220
Wash basin/sink 204
Water 62

Water closet	200
Water meter	222
Water retentivity	35, 43, 49
Water storage tank	223
Water supply	205-207
Water supply pipes and specials	207, 208, 210, 212, 213, 215
Welded connection	181
Welded joints	67
Welded steel wire fabric	66
Welding	187, 188
Whirl pool	217
White washing	105
Wire cloth	118
Wooden panelling	113

Part B: ROADS

AASHTO	227-28, 271, 274-75, 278, 280-81, 283, 285, 291, 295, 297-99, 300, 304, 346
Aggregate drain	325, 335-36
Anchor blanket	327-28
Arterial streets	229
ASTM	227-28, 264, 272
Backfill	234, 236-37, 334-35
Band drain	244, 320, 325
Base course	231, 247-48, 259, 268, 279
Binder course	247, 277, 294, 303
Bituminous concrete (BC)	232, 268, 291-92, 295
Bituminous macadam (BM)	230-32, 268, 270, 272-74, 292, 299
Blasting	234-35
British Standard (BS)	227-28, 321, 345-46
Bullock-cart traffic	314
Bureau of Indian Stanards (BIS)	227
Butt joint	288
California bearing ratio (CBR)	231, 237-38, 252-56, 318, 322-24
Carriageway	230, 236, 239-40, 247-48, 250, 307-09, 342, 345, 349
Cellulose fibre	297
Cement concrete pavement	232, 247-48, 269-70, 306, 313, 347
Central Public Works Department(CPWD)	227
Chanelled traffic	314
Classification	228, 230, 232-35, 237, 249, 250, 306, 310, 337, 341
Clearing width	230
Close-graded premix	268, 284
Coarse aggregates	249, 257, 261, 265, 271, 274, 282, 284, 291, 296, 298, 300, 312
Cold joints	269
Collector streets	229
Commercial	229, 242, 286, 343
Composite pavement	230
Construction joint	307
Construction limits	230
Construction traffic	262
Continuous traffic	311
Contraction joint	307, 318
Corrugation	311, 314-15, 331
Cracking	269, 289, 312-13, 340, 346, 350
Cracks	252, 254, 256, 286, 288, 298, 307, 310, 312-14,

316, 329, 346
Crazing 312
Cross-traffic 228
Curing 232, 252, 254, 262-64, 266, 308, 347, 351
Cut back 268-70, 280, 283, 317, 333
Dense-bituminous macadam (DBM) 268, 273, 299
Deterioration 232, 310, 313
Drainage 231-33, 235, 239, 244, 310, 313, 316, 320-22, 325, 331-34
Drainage layer 250, 262-63
Drainage system 233, 324, 331-32, 335
Dry lean concrete (DLC) 232, 247, 260, 262-66, 307
Ductility 273, 278-79, 281, 283, 290, 295, 299, 304, 350
Earthen shoulder 232, 236, 240, 318
Earthwork 230, 232, 234
Economical 231
Embankment 230, 232, 234, 236-41, 244-45, 310, 317, 333
Erosion control 232, 320, 321, 323, 326-27
Evaluation 232
Existing traffic 288
Expansion joint 294, 303, 306-07, 318
Expressways 228-29, 248, 338-39, 341
Fast traffic 314, 316-17
Field Engineer 236
Fine aggregates 258, 265, 267, 271, 276, 282, 284, 291, 296, 300, 319
Flexible pavement 230, 247, 288, 306, 323
Fly ash 230, 237, 261-62, 296
Formation 230, 235, 312, 314, 334, 336
Formation width 230
Frost 231, 316
Geosynthetics 232, 250, 320-21
Glass beads 345-48
Glass grids 320-21, 28
Granular subbase (GSB) 232, 247-48, 255-56, 262-63, 306, 334, 374
Ground improvement 232, 245-46
Heavy traffic 315
Indian Roads Congress (IRC) 227
Industrial 228-29
Internal reflection 350
Investigation 233, 237, 261, 312, 331-32
ISO 228, 321, 323, 325
Job mix formula 276, 277, 292, 293
Joints 232, 242, 263-64, 269, 273, 277, 299, 307, 309, 312, 333
Levelling course 231, 329
Liquid limit (LL) 237, 249, 259-60
Local streets 229
Locally available material 231, 253
Longitudinal joint 263, 273, 288, 294-95, 303-04, 307, 318
Maintenance of road 232, 310
Major District Roads (MDR) 228, 337
Micro-prismatic 339, 343-44
Micro-surfacing 268, 289-90
Mitigation 231
Mix design 232, 262, 264, 275-76, 287, 290, 298, 305, 307, 311, 314
Mixing and placing 232, 308
MoRTH 227
Mud pumping 231, 314

National Building Code (NBC)	227
National Highways (NH)	228, 248, 337
National Standard Body	228
Non-urban Roads	228
Open-graded premix	268, 282
Other District Roads (ODR)	228, 337
Paint	342, 345, 347-48, 349, 351
Parking	228-29, 337-38, 342, 345
Pavement marker	350-51
Pavement strengthening	232, 327
Pavement strengthening	232, 328
Pavement structure	231, 314
Paving fabric	244, 320-21
Plastic	233, 237, 278, 296, 307, 308, 315, 321, 339, 350, 353-356
Plasticity index (PI)	237-38, 249, 251-53, 273, 278-79, 291, 295, 299, 301, 304
Poly vinyl chloride	334, 353-54
Portland	232, 261, 287, 290
Potable water	290
Potholes	280, 294, 303, 315, 329, 331
Practical	231
Precaution	236, 295, 304, 317
Premix	232, 268, 282-85, 293-95 ,303-04, 311-15, 317, 353, 355
Prime coat	232, 268-69, 272, 277, 280, 312, 314
Prismatic	338-41, 343-44, 350
Pumping	231, 234-35, 314
Rain cuts	232, 317
Raveling	296, 310, 312, 317
Residential	229
Retro-reflective	233, 338-341, 343-45, 348-50
Right of Way (RoW)	230
Rigid pavement	230-31, 306
Road cross section	230
Road drainage	232-33, 331-32
Road marker	348, 350-51
Road markings	233, 337, 345, 349
Road stud	233, 341, 344-45, 351
Roadway	228, 236, 239, 247, 269, 332, 337, 343
Rollers	239, 260, 294-95, 303, 304, 312, 316
Sampling and testing	349, 351
Sand bitumen	232, 268, 278-80
Sand blanket	244, 246, 325
Seal coat	232, 268, 283-85, 311, 316-17
Semi-dense bituminous concrete	268, 299, 301
Semi-rigid	230
Settlement	236, 245, 313, 316
Shear stress	231
Shoulder	230, 234-37, 248, 250, 263, 310, 312-13, 317-18, 331-33, 335, 343
Shoulder drain	332, 333
Shredded plastic	233, 353-55
Slippage	269,314
Slow traffic	285
Slurry seal	232, 268, 285-91, 312, 317
Solar studs	350-51
Stabilised soil	230-32, 252, 254-55, 268, 333
State Highways (SH)	228, 337

Stockpile	235-36, 250
Stripping	271, 273-74, 278, 281, 283, 285, 291, 295, 299,300, 303, 315-16, 352
Structural capacity	231-32, 269
Structural stability	231
Structural support	231
Sub-arterial streets	229
Subbase	231, 247, 249, 254-55, 259-60, 262, 268, 272, 278, 307, 323, 332, 336
Subgrade	231, 237, 239-40, 247, 250, 261, 268, 279, 313, 316, 322, 331, 334
Subsoil	244, 245, 325, 336
Subsurface	233, 322, 331, 334-36
Surface defects	232, 311
Surface drain	233, 313, 322, 331-32, 334-336
Surface dressing	232, 268, 280-81, 283-85, 311-14, 316-17
Surface irregularities	232, 235, 248, 253-256, 259, 273, 280, 283-84
Tack coat	232, 268-70, 272, 277, 283, 288, 293-94, 302-03, 311, 314-15, 329
Terrain	236, 240, 332, 337
Thermoplastic	338, 345 ,346 ,353, 355
Top soil	234-35, 239, 242-43
Traffic	228, 232, 244, 248, 254, 258, 269, 273, 277, 280-81, 283-84, 291, 295-96, 299, 304, 318, 330, 343-45, 348
Traffic arrangement	264
Traffic condition	314
Traffic Engineering	337
Traffic flow	229
Traffic intensity	229
Traffic lanes	248, 288
Traffic signs	233, 337-38, 340, 342
Traffic volume	292, 301
Transverse joint	263, 307, 308
Turfing	232, 241-42, 326, 333
Ultraviolet (UV)	244, 320-23, 325-27,
Unsuitable	235-38, 333
Vehicular traffic	230, 309, 342
Village Roads	228, 337
Visual rating	310
Volume changes	231
Water cement ratio	307
Water logged	236, 246
Water-proof	244, 262, 294, 303, 339
Wearing course	231-32, 247-48, 294, 297, 302-03, 317, 353
Wet stripping	286-87, 290
Wet weather	231, 241
Wheel load	231, 310, 314, 316
Workability	307, 317

Part C: BRIDGES AND CULVERTS

Abutment cap	418
Abutments	362, 369, 375, 404, 405, 417, 418, 457
Acceptance criteria	379, 400, 431
Admixtures	358, 363-367, 377, 385-388, 408, 444
Aggregate	362, 365, 376, 377, 388, 449
Anchorages	362, 373, 381, 384, 385, 388, 437, 442

Approach slab	358, 359, 447, 449
Arches	392
ASTM	357, 379, 380, 387, 388, 412, 416, 426, 436, 438, 439, 441, 446, 453-455, 458
Backfill	407, 418
Bar bending schedule	371
Batching	358, 370, 373, 376-378
Bearings	359, 393, 395, 396, 418, 421-426, 428-436
Bedding	402, 403, 404, 434, 435, 461
Bolts	375, 389, 390, 391, 397, 398, 418, 434, 448, 452
Boreholes	410
Boulders	402, 407, 413, 460-462
Bow string	423, 424
Box girders	369, 396, 400, 422, 424, 425
Bracings	370, 371
Bridges	357-360, 380, 388, 389, 393, 401, 405, 416, 417, 419, 420, 425, 426, 436, 437, 449, 450, 458, 462
Capacity of the piles	411
Cast in-situ	408-410, 423, 424, 428, 449
Casting	370, 372, 389, 397, 415, 421-425, 435, 449
Cement	358, 361-367, 369, 374-377, 386, 388, 403, 405, 407, 408, 410, 418, 421, 444, 447, 449, 451, 455, 458, 460-462
Centering	370, 374, 448
Characteristic strength	364, 368, 373
Clear distance	362, 415
Coarse aggregate	358, 362, 367, 372
Compaction	358, 363, 369, 374, 406, 440, 456, 458
Composite	423, 434
Compressive strength	364, 366, 377-379, 387, 424
Concrete	358, 361-380, 383, 385, 387, 388, 402-410, 412-414, 417, 418, 420-425, 428, 435, 438, 440-442, 444, 445, 447-451, 454-458, 460, 461
Consistency	363, 369, 375, 385, 386
Construction joint	377, 379, 405, 406, 414, 418, 421-423, 425
Cooling	377, 390
Corrosion	370, 384, 390, 438, 441, 443, 444, 449
Couplers	384, 414
Cover blocks	372
Crash barrier	359, 447, 448, 449
Culverts	357-360, 369, 402, 404, 405, 417, 420, 461
Curing	363, 366, 370, 374, 377, 378, 380, 384, 405, 407, 417, 420, 425
Cutting edge	413, 416
Deck slab	358, 369, 422-425, 449, 450
De-shuttering	366, 374
Dewatering	405, 406, 415
Dimensions	360, 370, 371, 402, 404-407, 410, 411, 419, 429, 430, 432, 442, 443, 457
Dirt wall	357, 358, 402, 418
Drainage	357, 359, 402, 404, 405, 447, 449-452, 456
Dynamic tests	411
Earth pressure	418
Earthwork	360
Elastomeric	426-428, 437, 444
Elongation	382, 387, 427, 433, 439, 444, 452, 453
Embankment	359, 402, 416, 418, 459, 460

Equipment	360, 373, 376, 377, 381, 384, 386, 387, 402, 403, 408, 409, 411, 416, 423, 425, 430, 456
Excavation	360, 374, 402, 405-407, 414, 451
Expansion joints	359, 421-423, 437, 448
Exposure conditions	365
Fabrication	389, 391-393, 395, 397, 398, 400, 401, 414, 448
Fine aggregate	358, 362, 375
Formwork	358, 369-372, 374, 375, 378, 405-407, 413, 420, 425, 435, 443
Foundation	358, 360, 365, 403-410, 412, 415, 418, 453, 457, 458, 461
Gabion walls	458
Geotextiles	452
Girders	358, 369, 374, 375, 387, 389, 390, 392-394, 396, 399, 400, 420-425
Grade of concrete	364-366, 375, 408, 449
Green concrete	374, 409, 435
Grouting	383-386
Honeycombing	375
Indian roads congress	357
Jacking	382, 384, 385, 426, 436
Joints	359, 370, 373, 375, 377, 383, 391, 392, 395-399, 403, 413, 417, 421-423, 437-439, 442-445, 448, 455, 457, 461, 462
Laminations	397
Launching	370, 423, 460
Levelling course	406
Load test	411, 425
Lubrication	389
Maintenance	357, 426, 432, 436
Marine clay	409
Mark number	389, 397
Masonry	358, 361, 404, 405, 418, 450, 451, 457, 460, 461
Mean strength	366-369
Minimum cement content	365, 408
Minimum grade	365, 455
Misalignment	395, 429
Mix design	363, 367, 368, 376, 380
Mixing	358, 363, 370, 373, 376-378, 385
Mortar	361, 372, 375, 380, 384, 403, 428, 435, 448, 455, 461
MoRTH	357, 359-363, 373, 374, 380, 381, 388, 393, 401, 402, 405, 406, 408, 414, 416, 419, 425, 431, 436, 437, 438, 441, 446-448, 450, 456, 458-460, 462
Nominal mix	365
Non-destructive	399, 412
Overlapping bars	372
Painting	393, 400, 448
Parapets	404, 405
Pedestals	418
Pier cap	418
Piers	362, 369, 375, 405, 417, 418
Pile	358, 362, 408, 409, 410, 411, 412, 416, 418
Pile cap	358
Piles	362, 408, 409, 410, 411, 413, 416
Pipes	402, 403, 404, 405, 414, 449, 451, 455
Pitching	404, 459, 460, 461
Plasticizers	363, 367

Plugging	412
Pneumatic	391, 402, 415
Porosity	365, 399, 400
Pot bearings	433
Precast	387, 408, 420, 423, 424, 425, 428, 435, 449, 454
Prestressed concrete	388, 420, 421
Prestressing	358, 366, 381, 383, 384, 387, 388
Proof load	382
Props	371, 375
Protection works	359, 459
PTFE	426, 433, 434, 436
Quality control	358, 359, 362, 363, 373, 374, 381, 388, 389, 404, 431, 444, 451, 452
Railing	358, 359, 404, 405, 421, 447-449
References	360, 361, 380, 388, 401, 405, 416, 419, 425, 436, 446, 450, 458, 462
Reinforced concrete	380, 405, 406, 420, 421, 450, 454, 455
Reinforcement	363-365, 369, 371-373, 379, 380, 405, 409, 421, 438, 440-443, 447-449, 451-458
Retaining walls	359, 451, 457, 458
Return walls	404, 405, 450
River training	359, 458, 462
Riveted	370, 389, 391, 398
Saline	374
Sampling	357, 362, 363, 376, 378, 380, 417, 420
Sampling and testing	377, 388, 416, 419, 444
Scour	404, 406, 409, 411, 413, 415, 460
Seal joint	437, 440, 443-445
Setting time	366, 378, 387, 435
Shear connectors	392, 400
Site clearance	358, 451
Slump	363, 369, 376, 406, 408, 409
Socket	409
Soil reinforcing	452
Solid slab	420, 421
Span	357, 370, 372, 393, 395, 421, 424, 425, 448
Specimens	378, 388, 398, 441
Splicing	372
Steel liner	409
Steel reinforcement	363, 420, 447, 448, 454
Steining	362, 369, 413-416
Strands	362, 381, 382, 384, 388
Strength	364-366, 368, 369, 372-375, 377-380, 382, 384, 385, 387, 389-392, 397, 398, 413, 423, 424, 427, 431, 433-435, 438-441, 444, 446, 452, 453, 455, 458, 462
Stripping time	375
Studs	392, 400, 440
Substructures	359, 404, 416, 417, 419, 450
Sump	415
Superstructures	359, 420, 424
Tendons	362, 381, 383, 385-387
Tensioning	384, 385, 387, 388
Testing	362, 363, 368, 376-378, 397-399, 404, 405, 411, 416, 425, 427, 428, 430, 431, 436, 444, 445, 453
Tilt	414-416
Tolerances	360, 370, 377, 379, 387, 388, 393-396, 400, 403, 404, 407, 410, 416, 419, 424, 425, 429, 445, 456

Transportation	358, 363, 373, 400, 417, 420, 448
Tremie	369, 407, 409, 410
Trusses	370
Ultrasonic	397, 399
Vent way	402
Ventway	357
Void formers	421
Voided slab	421
Washers	390, 391, 397
Water-cement ratio	365
Wearing coat	359, 362, 421, 440, 442, 447, 448, 450
Weep holes	359, 405, 418, 447, 450, 451
Welding	372, 373, 380, 391, 392, 397, 398, 401, 413, 438, 443, 444
Well cap	358, 369, 412, 415, 416, 418
Well curb	369, 413, 415
Well foundation	358, 412, 413, 415, 416
Well sinking	413, 415
Wells	413-416
Wing walls	405, 418, 461
Wires	362, 363, 372, 381, 382, 458
Workmanship	370, 384, 389, 417, 420, 442
Wrenches	391

APPENDIX

CHECK LIST FOR QUALITY CONTROL MONITORING

(*To accompany the bill for making payment*)

Name of work					
Division		Sub Division		Section	
Agreement No.				Date	
Contract amount	Rs		Contract period		
Date of commencement			Date of completion		
Extended date of completion			Contractor		

SUMMARY OF QUALITY CONTROL TESTS DONE ON BUILDING & OTHER STRUCTURES

Sl. No.	*Item*	*First-tier tests done*			*Second-tier tests done*			*No of tests failed*
		This bill	*Previ-ous*	*Total*	*This bill*	*Previ-ous*	*Total*	
1.	Cement							
2.	Steel							
3.	Bricks							
4.	Cement blocks							
5.	Fine aggregate							
6.	40 mm aggregate							
7.	20 mm aggregate							
8.	Water							
9.	Paver blocks							
10.	Flooring tiles							
11.	Wall tiles							

Items for which, manufacturer's certificate obtained:

RECTIFICATION REPORT ON FAILED TESTS

Sl. No.	*Test/material failed*	*Date*	*Result obtained*	*Date of re-test*	*Result obtained*	*Re-test done by*

Action taken on failed items:

Name & signature	Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Submitted*)	Overseer (*Verified*)	Assistant Engineer (*Accepted*)	Asst. Exe. Engineer (*Recommended*)	Exe. Engineer (*Approved*)

CHECK LIST FOR QUALITY CONTROL MONITORING

(*To accompany the bill for making payment*)

Name of work					
Division		Sub Division		Section	
Agreement No.				Date	
Contract amount	Rs		Contract period		
Date of commencement			Date of completion		
Extended date of completion			Contractor		

SUMMARY OF QUALITY CONTROL TESTS DONE ON ROAD WORKS

Sl. No.	*Item*	*First-tier tests done*			*Second-tier tests done*			*No of tests failed*
		This bill	*Previ-ous*	*Total*	*This bill*	*Previ-ous*	*Total*	
1.	Paving bitumen							
2.	Bituminous primer							
3.	Aggregate grading							
4.	Aggregate properties							
5.	Filler material							
6.	Marshall test							
7.	Binder content							
8.	Mix specific gravity							
9.	Layer density							
10.	Cement							
11.	Steel							
12.	Water							
13	Paver blocks							

Items for which, manufacturer's certificate obtained:

RECTIFICATION REPORT ON FAILED TESTS

Sl. No.	*Test/material failed*	*Date*	*Result obtained*	*Date of re-test*	*Result obtained*	*Re-test done by*

Action taken on failed items:

Name & signature	Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Submitted*)	Overseer (*Verified*)	Assistant Engineer (*Accepted*)	Asst. Exe. Engineer (*Recommended*)	Exe. Engineer (*Approved*)

CHECK LIST FOR CONCRETE POUR MONITORING

(To be prepared by the Overseer in charge of the concrete work)

Name of work							
Division		Sub Division			Section		
Agreement No.				Date of pour			
Contractor				Date of last pour			
Structure				Component			
Quantity to be poured		m^3		Location			
Concrete class		Lines & levels checked by					
Time of inspection	……*am/pm*	Weather	*Hot & humid/Rainy/Cloudy/Windy*				
1. Cement	*Tested /Not tested*		Quantity required		….*bags*	Brand	
2. Steel reinforcement	Dia of bars	….. *mm*	…. *mm*	…..*mm*	….. *mm*	… *mm*	….*mm*
Weight of bars per metre in gm							
3. Sand/crushed sand	Source			Grading checked		*Yes*	*No*
4. Water	Source			Tested on			
5. Scaffolding	Not satisfactory	Approved		Formwork approved			*Yes*
6. (a) Aggregate grading approved		….. *mm*	*Yes*	…. *mm*	*Yes*	….*mm*	*Yes*
(b) Physical properties tested		….. *mm*	*Yes*	…..*mm*	*Yes*	….*mm*	*Yes*
7. Manufacturer's certificates submitted for:			*Cement*		*Steel*	Others	
8. Concrete mixer available		*Yes*	*No*	Cleaning of forms			*Done*
9. Plant & equipment condition		*Satisfactory*			*Not satisfactory*		
10. Labours	*Sufficient*	*Not sufficient*		Supervisor competent			*Yes*
11. QC testing arranged	*Yes/No*	No of cube moulds			Slump cone available		*Yes*
12. Curing arrangement	By ponding	Wet gunny bags			Curing compound		

RECTIFICATION REPORT ON ITEMS NOT IN ORDER/NOT APPROVED

Sl. No.	*Item*	*Defect noted*	*Rectification done*

Concrete pour started at	……*am/pm*	Concrete pour ended at	……*am/pm*

Remarks:

Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Accepted*)	Overseer (*Prepared*)	Assistant Engineer (*Verified*)	Asst. Exe. Engineer (*Approved*)

CHECK LIST FOR EARTHWORK MONITORING

(To be prepared by the Overseer in charge of the earthwork operations)

Name of work					
Division		Sub Division		Section	
Agreement No.			Date of earthwork		
Contractor			Date of last operation		
Layer #	*Fill*	*Backfill*	*Original ground*	*Subgrade*	
Location	From: km .....+..... to km .....+.....				
LHS / RHS		Lines & levels checked by			
Time of inspection	.....*am/pm*	Weather	*Hot & humid/Rainy/Cloudy/Windy*		
1. Quarry name			Distance from site	.....km	
2. Quarry approved by:			Quantity to be extracted	.....m^3	
3. Material properties:	MDD	*gm/cm3*	OMC	*%*	
	Liquid limit		Plasticity index	CBR	
4. Water	Source		Tested on		
5. Clearing & grubbing	Not done	Approved	Topsoil removed	*Yes*	*No*
6. Soil to be stabilised:	*Yes/No*	Additive:	*Cement*	*Lime*	Others
7. Plant & equipment engaged for work at site	Trucks		Grader		Bulldozer
	Rollers		Mixer		Water trucks
8. Labours	*Sufficient*	*Not sufficient*	Supervisor competent	*Yes*	
9. QC testing arranged	*Yes* / *No*	Layer density by	*Sand replacement/Using Gauge*		
10. Field moisture determination		*By oven drying*	*Moisture meter*	*Carbide bottle*	

RECTIFICATION REPORT ON ITEMS NOT IN ORDER/NOT APPROVED

Sl. No.	*Item*	*Defect noted*	*Rectification done*

Layer work started at	.....*am/pm*	Layer work ended at	.....*am/pm*

Remarks:

Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Accepted*)	Overseer (*Prepared*)	Assistant Engineer (*Verified*)	Asst. Exe. Engineer (*Approved*)

CHECK LIST FOR NON-BITUMINOUS SUBBASE/BASE LAYERS

(To be prepared by the Overseer in charge of the subbase/base layer operations)

Name of work									
Division			Sub Division			Section			
Agreement No.					Date of paving				
Contractor					Date of last paving				
Layer type	*GSB*	*WMM*	*WBM*	*CRM*	*Stabilised soil*				
Location	From km ……+…… to km ……+……						LHS	RHS	
Time of inspection	……*am/pm*		Lines & levels checked by						
Air temperature	……. °C		Weather	*Hot & humid/Rainy/Cloudy/Windy*					
1. Aggregate quarry					Distance from site		……km		
2. Quarry approved by:					Quantity to be extracted		……m^3		
3. Cement/Lime used	*Yes/No*		Cement/Lime tested			*Yes*	*No*		
4. Aggregate tested	*Yes/No*		Grading:	*Not checked*			*Approved*		
5. Aggregate properties	AIV/LAA				Water absorption		……%		
	Stripping				FI & EI combined				
6. Base layer primed:	*Yes/No*		Primer used			Primed on			
7. Plant & equipment engaged for work at site	Tipper trucks				Sensor paver				
	Smooth wheeled roller				Mechanical broom				
	Pneumatic tyred roller				Compressor air jet				
	Vibratory roller				Grader				
8. Labours	*Sufficient*		*Not sufficient*		Supervisor competent		*Yes*		
9. QC testing arranged	*Yes*	*No*	Layer density by		*Sand replacement/Using Gauge*				
10. Field moisture determination			*By oven drying*		*Moisture meter*		*Carbide bottle*		

RECTIFICATION REPORT ON ITEMS NOT IN ORDER/NOT APPROVED

Sl. No.	*Item*	*Defect noted*	*Rectification work done*

Paving started at	……*am/pm*	Paving ended at	……*am/pm*

Remarks:

Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Accepted*)	Overseer (*Prepared*)	Assistant Engineer (*Verified*)	Asst. Exe. Engineer (*Approved*)

CHECK LIST FOR MONITORING BITUMINOUS WORKS

(To be prepared by the Overseer in charge of the paving operations)

Name of work							
Division		Sub Division			Section		
Agreement No.				Date of paving			
Contractor				Date of last paving			
Layer	*BM*	*Premix surfacing*		*Seal coat*	*SMA*	*BC*	*SD*
Location	From km ……+…… to km ……+……					LHS	RHS
Time of inspection	……*am/pm*	Lines & levels checked by					
Air temperature	…… °C	Weather	*Hot & humid/Rainy/Cloudy/Windy*				
1. Aggregate quarry				Distance from site		……km	
2. Quarry approved by:				Quantity to be extracted		……m^3	
3. Bitumen grade	VG……	Bitumen tested			*Yes*	*No*	
4. Aggregate tested	*Yes/No*	Grading:	*Not checked*			*Approved*	
5. Aggregate properties	AIV/LAA		Water absorption			……%	
	Stripping		FI & EI combined				
6. Base layer primed:	*Yes/No*	Primer used			Primed on		
7. Tack coat applied:	*Yes/No*	Material			*Time applied……*		
8. Plant & equipment engaged for work at site	Tipper trucks			Sensor paver			
	Bitumen sprayer			Mechanical broom			
	Pneumatic tyred roller			Compressor air jet			
	Smooth wheeled roller			Vibratory roller			
9. Labours	*Sufficient*	*Not sufficient*		Supervisor competent		*Yes*	
10. QC testing arranged	*Yes*	*No*	Layer density by	*Coring/Using Gauge/NA*			

RECTIFICATION REPORT ON ITEMS NOT IN ORDER/NOT APPROVED

Sl. No.	*Item*	*Defect noted*	*Rectification work done*

Paving started at	……*am/pm*	Paving ended at	…….*am/pm*

Remarks:

Name & signature	Name & signature	Name & signature	Name & signature
Contractor (*Accepted*)	Overseer (*Prepared*)	Assistant Engineer (*Verified*)	Asst. Exe. Engineer (*Approved*)