Kerala Public Works Department

QUALITY CONTROL LABORATORY MANUAL

July 2015

GOVERNMENT OF KERALA

KERALA PUBLIC WORKS DEPARTMENT
QUALITY CONTROL LABORATORY MANUAL

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PREFACE

The Kerala Public Works Department is involved in the infrastructure development of the State in the field of Buildings, Roads and Bridges. For ensuring quality in construction works carried out by PWD, Government introduced a new three tier system through the revised PWD Manual 2012. Subsequently Quality Control laboratories were established in all the 14 districts with necessary equipment and staff, which started functioning from October 2013 onwards.

This QC laboratory manual is intended to provide guidelines to the quality control team of PWD, comprising of Engineers and Overseers (Technicians). The manual has been prepared based on available standards/codes published by BIS, BS, ASTM, AASHTO and IRC. As listed below, this manual is divided into 5 parts along with appendices:

Part I - *Aggregates testing*
Part II - *Cement, concrete and steel testing*
Part III - *Soils testing*
Part IV - *Bituminous materials testing*
Part V - *Building materials testing*
Appendix A - *Bituminous mix design*
Appendix B - *Concrete mix design*
Appendix C - *Load test on piles*

The team of Engineers who prepared this Manual has made efforts to explain the various tests in a simple manner, for easy understanding by the technical staff in the QC Wing. Hope this Manual will assist in ensuring uniformity in testing procedures and reporting results prepared by the QC laboratories across the State.

I express my appreciation and gratitude to all the Engineers directly or indirectly associated with the compilation of this Manual.

Any errors, omissions or variations from the standards prescribed by the codes 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.

The Technical Committee constituted by the Government vide G.O (Rt) No. 1784/2012/PWD dated 20-10-2012 for the rectification of anomalies in the revised PWD Manual 2012 took initiative to prepare a QC Manual for PWD. During the developing stage of the QC Manual, it was decided to make a separate Manual for the QC tests which resulted in the outcome of this publication.

The following officers/experts of the department were the key personnel entrusted with the task of preparation of this Quality Control Laboratory Manual.

(i) Er. Santhosh Kumar T, Director, I&QC (Rtd)
(ii) Er. Sushama P. R, Executive Engineer, NH
(iii) Er. Biju P. B, Assistant Director, Computer Cell
(iv) Er. Indu G. S, Assistant Engineer, NH

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 the Convener of the Technical Committee.

The Department wishes to record the appreciation on the dedicated effort taken by the above team of Engineers in the preparation of this Quality Control Laboratory Manual. The Department also appreciates the assistance rendered by Er. P.K. Rajeev, Superintending Engineer (Rtd) and former Special Officer, PWD Manual Revision, Er. V. G. Hari, Director (I&QC) and Er. S. Saju, Joint Director, Highways Design in compiling this Manual. The Engineers from the field who provided valuable suggestions also deserve appreciation.

It is expected that this first edition of the PWD Quality Control Laboratory Manual be a useful and valuable guidance to the officers associated with Quality Control testing in the Public Works Department.

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

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Part - I

AGGREGATES TESTING

METHODS FOR SAMPLING OF AGGREGATES

IS: 2430

1. Introduction

Sampling is of equal importance as testing. Hence every precaution shall be taken to obtain samples which represent the true nature and condition of the material tested.

The terms associated with sampling process of aggregates are given below:

a) *Increment*: The quantity of aggregate obtained by the sampling device at a time.

b) *Lot*: The quantity of the material of the same class, nominal size, source inspected for testing is called a lot.

c) *Sub-lot*: Before sampling, a lot is divided into a number of sub-lots of equal size.

d) *Unit sample*: It is the quantity of aggregates collected at one point in sectional sampling or at one time from the conveyor.

e) *Gross sample*: The unit samples or increments collected from sub-lots constitute gross sample.

f) *Laboratory sample*: The gross sample is reduced using sample dividers or by quartering to obtain samples for laboratory testing.

g) *Aggregates*: This includes crushed stone, crushed boulders, gravel, sand, industrial by-products or such inert materials.

h) *Coarse aggregates*: Aggregates retained on 4.75 mm IS sieve.

i) *Fine aggregates*: Aggregates passing 4.75 mm IS sieve is classified as fine aggregates. Fine aggregates may be natural sand, crushed hard stone (M-sand etc) or crushed natural gravel.

j) *All-in aggregates*: A mixture of coarse and fine aggregates is termed as all-in aggregates.

k) *Road side production*: It is the production of materials with a portable or semi-portable crushing, screening or washing plants established or re-opened in the vicinity of a work or project.

l) *Bank run sand*: This includes previously worked pits or potential sources discovered through aerial photography or geo-physical exploration.

Sampling is required for the following purposes:

(i) Preliminary investigation for establishing a source of supply.
(ii) Inspection of materials in shipments like truck, wagon, boat etc.
(iii) Inspection of materials delivered at work site.

The general procedures to be followed in each of the above cases are briefly explained in this method. However, it is recommended to refer IS: 2430 for details.

2. Sampling for establishing a source of supply

a) The ledge or quarry face is inspected and colour, texture, pattern etc of various strata is noted.

b) Separate stone samples of at least 25 kg mass shall be taken from each strata or type. Weathered material not useful for the project/work should not be included in the samples.

c) Samples from field stones or boulders should include all classes of stones suitable for use on visual observation.

d) If the bank or pit deposit is worked as an open-face, sampling shall be carried out by channeling vertically top to bottom so as to represent all the materials suitable for use. Overburden or disturbed material shall not be used for sampling.

e) Trials pits shall also be dug at selected points of the deposit and individual samples collected from various layers of the material. An estimate of the quantity of each type of material shall also be prepared.

f) Samples from open-face and trial pits shall not be mixed together.

g) For sand or gravel deposits, the quantity of individual samples shall be 25 kg for sand and 35 kg for materials containing appreciable amount of coarse aggregates.

3. Sampling for inspection of a shipment of materials

This procedure of sampling is applicable where the aggregates are manufactured.

a) Samples shall be selected from each lot separately.

b) Wherever possible, samples shall be obtained when aggregates are in motion, like from conveyor belts or during loading and unloading.

c) Sampling from a lot is carried out from sub-lots of approximately equal size as given in table 1.

Table 1: *Number of sub-lots recommended for different lot sizes.*

Sl. No.	*Lot size in m^3*	*No of sub-lots*
1	101 to 500	3
2	501 to 1500	5
3	1500 to 5000	7
NOTE: If the lot to be sampled is less than 101 m^3, the number of lots to be sampled shall be decided by the Engineer.		

d) A representative gross sample is collected from each of the sub-lots and kept separately.

e) The weight of gross sample depends on the maximum nominal size of the aggregate as indicated in table 2. This weight of gross sample shall be obtained from 10 increments each not less than 1 kg.

Table 2: *Minimum weight of gross sample for various aggregate sizes.*

Sl. No.	*Max nominal size of aggregate in mm*	*Minimum weight of gross sample in kg*
1	2.36	10
2	4.75	10
3	9.5	10
4	10	10
5	12.5	15
6	13.2	15
7	16	20
8	19	25
9	20	25
10	25	50
11	37.5	75
12	40	80
13	50	100
14	63	125
15	75	150
16	80	160
17	90	175

NOTE:
(i) For aggregates, the maximum nominal size of particles is the largest sieve upon which any material is permitted to be retained.
(ii) For all-in aggregates, the minimum weight of gross sample shall be the above prescribed minimum mass of coarse sample plus 10 kg.

f) When the aggregates are in motion, sample increments shall be taken direct from the point where the material is discharged from the conveyor belt.

g) The sample shall be collected from full width of the aggregate stream, without over flowing the sampling pan or any other collecting device.

h) If sampling is not possible at the discharge point, samples may be obtained from the moving belt. Using a scoop, samples are taken from centre and the left and right side of the moving stream along the same width.

i) The samples collected from a sub-lot are combined and mixed together to make a gross sample.

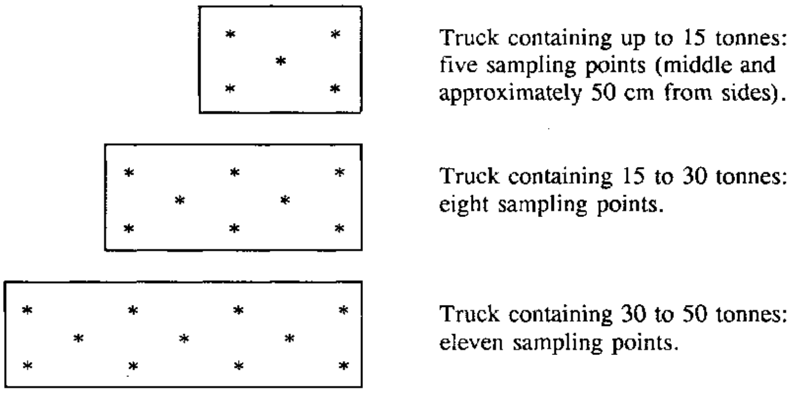
4. Sampling from wagons or trucks

For the purpose of sampling, all the carriers' viz., wagons, trucks or boats in a lot shall be divided into convenient sub-lots of approximately equal size.

a) A representative gross sample is collected from each of the sub-lots and kept separately.

b) A minimum of 25% of the carriers is selected from the sub-lot for sampling.

c) If 10 increments of samples are to be collected from a loaded carrier, an equal number of points are selected at random on the surface of the aggregate. From each selected point, sample increments are collected by sectional sampling.



Truck containing up to 15 tonnes: five sampling points (middle and approximately 50 cm from sides).

Truck containing 15 to 30 tonnes: eight sampling points.

Truck containing 30 to 50 tonnes: eleven sampling points.

d) Power equipment may be used to expose the material at various levels and random locations. Sectional sampling may be resorted to if power equipment is not available.

NOTE: In sectional sampling, from each point on the surface of the aggregate, all the materials from top to bottom over an area of 20 cm diameter are collected for aggregates more than 20 mm nominal size. Initially aggregates for a depth of about 45 cm are collected. The bottom of the hole is then covered with a plate. The aggregates from the sides are then removed up to the plate so that the material from sides will not fall into the hole. The plate is then removed and the process repeated till the bottom is reached. For aggregates up to 20 mm size, a sampling auger can be used inside a 15 cm casing pipe of height more than the height of material. The pipe is then pushed down till it reaches the bottom. The material inside the pipe is removed by the auger to give an increment.

5. Sampling from materials stockpiled at site

a) For coarse or all-in aggregates, any power equipment may be used make a small sampling pile of materials taken from different levels and locations of the main stockpile.

b) Increments are then taken from the sampling pile and combined to make the gross sample.

c) To check if non-uniformity exists within the main pile, separate samples shall be drawn from different points in the stockpile.

d) Where power equipment is not available, the required number of increments shall be made from top third, middle and bottom third of the volume of the pile.

e) In sampling stock piles, the segregated outer layer shall be removed and samples taken from the inside material.

f) For the purpose of sampling, the aggregates in the stack shall be divided into convenient sub-lots of equal size and increments made from each sub-lot.

g) A representative gross sample is collected from each of the sub-lots and kept separately.

h) A minimum of 10 increments shall be taken from a sub-lot for making up a gross sample. The weight of gross sample shall be as indicated in table 2.

i) If it is necessary to sample a stationery stack, trench sampling method may be adopted provided the height of stack is not more than 1.5 m.

NOTE: In trench sampling, a trench is cut right down to ground level. Sample of aggregates are collected from the exposed sides of the trench using a suitable scoop. For large stacks, sides of the piles also may be opened up to expose the aggregates down to the bottom and sample increments collected.

6. Packing and marking of samples

a) Samples are to be packed separately and carried to the laboratory for testing.

b) Proper care shall be ensured to prevent loss of any fine material.

c) Coarse aggregate shall be packed in secure containers or sample bags.

d) Fine aggregates and all-in aggregates shall be packed in tight containers, thick polythene bags or closely woven bags so that there is no loss of finer particles.

e) Each container or bag shall contain an identification card, well protected from moisture and abrasion, containing the following information:

   (i) Name, nature and location of the quarry.
   (ii) Reference to the work/project sampled.
   (iii) Type of material and stock pile identification.
   (iv) Chainage of sampling with date and time.
   (v) Size of material and proposed use in the work.

7. Reduction of gross sample

a) Each gross sample shall be reduced separately.

b) The process of reduction of gross sample shall be continued till the laboratory samples of suitable size to carry out each test as specified in IS: 2386 Pat 1 to 8 are obtained.

c) *Reduction by Riffle Divider*: The aggregate shall be well mixed and poured into riffle boxes. The process shall be repeated using different riffle boxes according to the size of the aggregates to be tested.

d) *Method of quartering*: If riffle boxes are not available, the method of quartering shall be adopted. The aggregates are thoroughly mixed and heaped into a cone shaped pile using a scoop. The cone is then flattened and cut into 4 quarters by making two deep lines at right angles. The bulk of the sample is reduced by rejecting one set of opposite quarters. The process is repeated if the sample is large for testing.

8. Tests on aggregate samples

Samples are tested for compliance with the properties stipulated in the specifications. All the aggregate tests are covered in IS: 2386 Part 1 to 8. The titles of various parts of IS: 2386 are given in table 3 below:

Table 3: *Titles of various parts of IS: 2386 for aggregate testing.*

Code & part number	*Title*
IS: 2386 Part 1 -1963	Methods of test for aggregates for concrete: Part 1 - Particle size and shape.
IS: 2386 Part 2 -1963	Methods of test for aggregates for concrete: Part 2 - Estimation of deleterious materials and organic impurities.
IS: 2386 Part 3 -1963	Methods of test for aggregates for concrete: Part 3 - Specific gravity, density, voids, absorption and bulking.
IS: 2386 Part 4 -1963	Methods of test for aggregates for concrete: Part 4 - Mechanical properties.
IS: 2386 Part 5 -1963	Methods of test for aggregates for concrete: Part 5 - Soundness.
IS: 2386 Part 6 -1963	Methods of test for aggregates for concrete: Part 6 - Measuring mortar making properties of fine aggregates.
IS: 2386 Part 7 -1963	Methods of test for aggregates for concrete: Part 7 - Alkali aggregate reactivity.
IS: 2386 Part 8 -1963	Methods of test for aggregates for concrete: Part 8 - Petro-graphic examinations.

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SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

IS: 2386 - Part I

1. Introduction

This method covers the procedure to determine the gradation of fine and coarse aggregates by sieving.

2. Apparatus

- (i) IS sieves required for the specified grading or purpose.
- (ii) A mechanical sieving device is recommended if the sample size is more than 20 kg and may be used for even smaller samples.
- (iii) A balance of suitable capacity readable to 0.1 percent of the mass.
- (iv) A thermostatically controlled oven capable of maintaining temperatures of 110±5°C.

3. Sample size

The recommended mass of coarse aggregate samples to be collected shall be as given in the table below:

Nominal maximum size mm	*Minimum mass of sample kg*
6.3	3
10	6
12.5	12
16	25
20	25
25	50
40	50
50	100
63	100
75	100
90	100
100	150
125	300

The sample is thoroughly mixed and reduced to the amount required for testing. The reduction of the sample to the exact predetermined mass is not permitted. The minimum test sample of fine aggregates after drying shall be 300 gm.

4. Procedure for coarse and fine aggregates

- a) Dry the test sample to a constant mass and air dry condition at a temperature of 110±5 °C.
- b) Clean the selected sieves.
- c) Arrange the sieves in the sieve shaker in such a way that largest size sieve is at the top.
- d) Always ensure that the bottom pan is not omitted.
- e) Mechanical sieving using a sieve shaker shall be done for a minimum period of ten minutes.
- f) In the case of manual sieving, each sieve shall be

shaken separately for minimum two minutes.

g) The shaking shall be done in varied motion so that the material continuously moves over the sieve surface.

h) Material shall not be forced by pressure except for particle size more than 20 mm where placing by hand is permitted.

i) Lumps of fine materials may be broken by pushing to the side of the sieves with fingers.

j) A soft brush can be used to brush underside of the sieve to clear the openings.

k) For 150 and 75 micron sieves, fine camel hair brush shall be used to push the materials down, without applying any pressure.

l) On completion of sieving, the material retained in each sieve is taken out and weighed accurately.

m) Overloading of the test sieves should be avoided. After completion of sieving, the weight retained in sieves shall not exceed the weights given below.

IS sieve designation	*Coarse aggregates*		*Fine aggregates*
	Maximum weight in 45 cm dia sieves	*Maximum weight in 30 cm dia sieves*	*Maximum weight in 20 cm dia sieves*
50 mm	10 kg	4.5 kg	-
40 mm	8 kg	3.5 kg	-
31.5/25 mm	6 kg	5.5 kg	-
20 mm	4 kg	2.0 kg	-
16/12.5 mm	3 kg	1.5 kg	-
10 mm	2 kg	1.0 kg	-
6.3 mm	1.5 kg	0.75 kg	-
4.75 mm	1.0 kg	0.50 kg	-
3.35 mm	-	0.30 kg	-
2.36 mm	-	-	200 gm
1.18 mm	-	-	100 gm
600 micron	-	-	75 gm
300 micron	-	-	50 gm
150 micron	-	-	40 gm
75 micron	-	-	25 gm

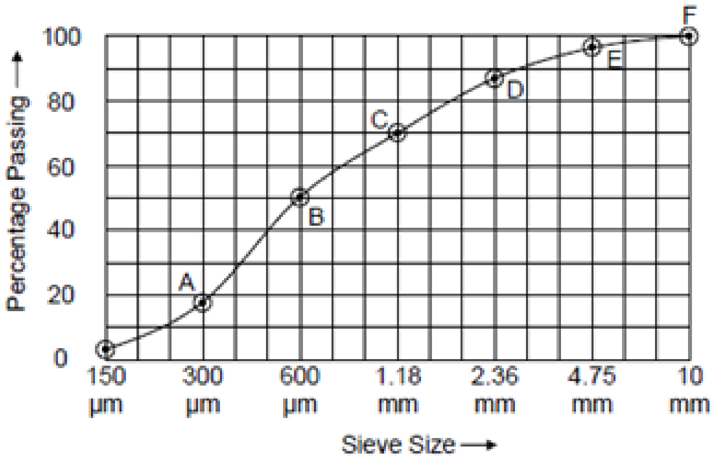
5. Procedure for sieving fine and coarse aggregate mix

The weight of sample for testing shall be as given below, prepared from large samples collected from stockpile.

IS sieve designation	*Minimum weight of sample for sieve analysis*
63 mm	50 kg
50 mm	35 kg
40/31.5 mm	15 kg
25 mm	5 kg
20/16 mm	2 kg
12.5 mm	1 kg
10 mm	500 gm
6.3 mm	200 gm
4.75 mm	200 gm
2.36 mm	100 gm

To avoid heavy loading of the sieves, the test shall be carried out by splitting the sample into several parts. Also the aggregate mix shall be initially separated into coarse and fine aggregates using a 3.35 mm or 4.75 mm sieve before sieving is commenced.

6. Calculations



The cumulative percentage passing by weight for each sieve is determined and reported to the nearest whole number. For material retained the weight is recorded to the nearest 0.1 gm. The results of the sieve analysis shall be also represented in a graphical method, with cumulative percentage passing on the Y-axis expressed linearly and sieve diameter on the X-axis plotted in a logarithmic scale.

A sample format for recoding the sieve analysis data is attached for guidance.

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-G1/2015
	QUALITY CONTROL WING	

Grain size analysis by dry sieving **IS: 2386 – Part 1**	Report No.	Date:

REGIONAL LABORATORY……………………………..	**DISTRICT LABORATORY………………………………..**

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TYPE:		Date of testing:

LAYER:	Concrete	Subbase	WBM	WMM	BM/DBM	BC/SMA

IS Sieve designation	Weight. retained in gm	% weight retained	Cumulative % retained	Percentage finer	***Required value***
Pan					

Remarks:

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

AMOUNT OF FINES PASSING 75 MICRON SIEVE BY WET SIEVING

IS: 2386 - Part I

1. Introduction

Materials finer than 75 mic (No. 200) can be separated from larger particles much more efficiently and completely by wet sieving. When accurate determination of such fraction in the aggregate is required, this method is used prior to dry sieving. Plain water is adequate for washing. Dispersing agents like liquid dish washing detergents may be used if clay coatings and coatings on extracted aggregate are to be removed*.*

2. Apparatus

(i) A balance of suitable capacity with accuracy of 0.1 percent of the test sample.
(ii) IS test sieves 75 mic and 1.18 mm.
(iii) A container or pan to soak the sample and of size large enough to agitate the soaked material without loss of water or sample.
(iv) A thermostatically controlled oven capable of maintaining temperatures of 110±5°C.
(v) Wetting agent etc.

3. Sample preparation

The test sample shall be prepared from thoroughly mixed material containing sufficient moisture to prevent segregation. The weight of test sample shall be as given in the table below.

Nominal maximum size mm	*Minimum mass of test sample gm*
4.75	500
10	2000
20	2500
40 or above	5000

4. Procedure using water for washing

a) Dry the sample to constant weight at 110±5°C and find the weight (A) after cooling.
b) Place the sample in the container, pour water and agitate the sample vigorously to separate the fine particles from the coarse particles.
c) Immediately pour the wash water over the sieves arranged with the coarser sieve the top.
d) Add similar increments of water to the aggregate in the container and repeat the process till the wash water is clean*.*
e) Rinse the sieves with a spray nozzle or a small hose.
f) Return all materials retained on the sieves to the washed sample in the container.
g) Dry the washed aggregate in the container to constant weight (B) in the oven at a temperature not exceeding 110°C.

NOTE: Use of mechanical apparatus for washing is not recommended.

5. Procedure using a wetting agent for washing

a) After drying and determining the weight place the test sample in a container.
b) Add sufficient water to cover the sample and add the wetting agent.
c) Agitate the sample vigorously to separate the fine particles from the coarse particles.
d) Immediately pour the wash water over the sieves arranged with the coarser sieve the top.
e) Add another charge of water without wetting agent and repeat the process.

f) Continue till the wash water is clean.
g) Dry the washed aggregate in oven and find the weight.

6. Calculation

Calculate the amount of material passing 75 micron sieve from the equation:

[(A-B)/A] x 100, where
A = Original dry weight of the sample in gm.
B = Dry weight in gm after washing.

Report the percentage of material finer than 75 mic sieve by washing to the nearest 0.1 percent.

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DETERMINATION OF BULK DENSITY AND VOIDS OF AGGREGATES

IS: 2386 - Part III

1. Introduction

This method of test is prescribed to determine the bulk density (Unit weight) and voids of aggregates. Unit weight is the traditional terminology used to describe the property which is weight per unit volume (More precisely, mass per unit volume). The bulk density of the aggregate determined by this procedure is measured in kilograms per litre.

This test is intended to compare the properties of different aggregates. It is not generally suitable for use as a basis for quoting mix design conversion factors.

2. Apparatus

(i) A cylindrical metal measure with handle. It shall be watertight, with sufficient rigidity for rough use. The capacity required for the different sizes of aggregates are given in the table below:

Table 1: *Sizes of containers for bulk density test*

Size of largest particles	*Nominal capacity (in litres)*	*Inner dia in cm*	*Inside height in cm*	*Wall thickness in mm*
4.75 mm or less	3	15	17	3.15
4.75 mm to 40 mm	15	25	30	4.00
More than 40 mm	30	35	51	5.00

(ii) A balance of suitable capacity sensitive to 0.5% of the weight of the sample to be weighed.

(iii) A straight metal tamping rod of cylindrical cross-section, 16 mm in diameter and 60 cm long, rounded at one end.

3. Calibration of the container

The measure shall be calibrated by determining the weight of water at 27°C required to fill it such that no meniscus is present above the rim of the container. The capacity in litres shall be obtained by dividing the weight of water in kilograms required to fill the container at 27°C by the weight of water in one litre at 27°C, which may be taken as one kilogram.

4. Procedure

Dry material shall be used for determining the voids. Material with the given percentage of water shall be chosen while determining bulking of aggregates.

4.1 *Procedure by rodded or compacted weight*

a) Fill the measure one-third with thoroughly mixed test sample.

b) Tamp the layer of aggregate 25 times with the round end of the tamping rod ensuring the strokes evenly distributed over the surface. Do not allow the tamping rod to touch the bottom of the measure.

c) Fill the measure up to two thirds full and tamp again 25 times vigorously but without penetrating the layer below.

d) Fill the measure overflowing and tamp 25 times vigorously. Level the surface with a straight edge in such a way that the projections of aggregate balance with the larger voids on the aggregate surface.

e) Determine the mass of the measure plus contents. Determine the empty weight of the measure. Calculate the bulk density of the aggregate from the weight of aggregate and volume of the measure determined earlier.

4.2 *Procedure by loose weight*

a) Fill the measure to over flowing using a shovel or scoop. Discharge the aggregates from a height of 50mm above the top edge of the measure exercising enough care to prevent segregation of the particles.

b) Level the surface with straight edge in such a way that the projections of aggregate balance with the larger voids on the aggregate surface.

c) Determine the mass of the measure plus contents and measure alone and record in kilogram per liter.

d) Determine the mass of the measure plus contents. Determine the empty weight of the measure. Calculate the bulk density of the aggregate from the weight of aggregate and volume of the measure determined earlier.

5. Calculation

a) Calculate the bulk density of the aggregates as below:

Bulk Density, γ= [M_2-M_1]/V in kg/liter where
M_2= Weight of the aggregate plus measure in kg
M_1= Weight of the measure in kg and
V= Volume of the measure in liter obtained from calibration

If the volume V is expressed in m3, the bulk density can be obtained in kg/m3.

b) The percentage of voids shall be calculated as follows:

Percentage of voids = [G_s-γ] / G_s x 100
G_s = Specific gravity of the aggregate and
γ = Bulk density in kg/litre.

6. Report

The report shall include the following:

(i) The bulk density shall be reported in kg/litre or kg/m3 to the nearest 0.01 kg.
(ii) The voids shall be reported as a percentage to the nearest whole number.
(iii) The condition of aggregate at the time of test shall be stated, that is (a) oven dry (b) saturated and surface dry or (c) with a given percentage of moisture.

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SPECIFIC GRAVITY AND WATER ABSORPTION OF AGGEGATES

IS: 2386 - Part 3

1. Introduction

The specific gravity of a solid substance is the ratio of the weight of a given volume of material to the weight of an equal volume of water (at 20°C). In effect, it tells how much heavier (or lighter) the material is than water. A change in aggregate mineral or physical properties can result in a change in specific gravity.

Aggregate specific gravity is needed to determine weight-to-volume relationships in the design of concrete and bituminous mixes. In bituminous mix design specific gravity is needed to calculate various volume-related quantities such as voids in mineral aggregate (VMA), and voids filled by bitumen (VFB). Absorption is an indicator of aggregate durability as well as the volume of the bituminous binder it is likely to absorb. It shall be noted that water absorption test results will not be consistent in the case of highly porous aggregates.

Based on the size of aggregates, three main methods are specified for determining specific gravity and water absorption are included.

(i) Method I - The size of the aggregate is large than 10 mm.
(ii) Method I or II - The size of aggregates is between 40 mm and 10 mm.
(iii) Method III - The size of the aggregate is smaller than 10 mm.

2. Method I – Aggregate larger than 10 mm

2.1 Apparatus

(i) A balance or scale of capacity not less than 3 kg, readable and accurate to 0.5 g suitable to suspend the basket containing the aggregate sample to be suspended for weighing in water.

(ii) A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110°C.

(iii) A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size, preferably chromium plated and polished, with wire hangers not thicker than 1 mm for suspending it from the balance.

(iv) A stout watertight container in which the basket may be freely suspended.

(v) Two dry soft absorbent cloths each not less than 75 cm x 45 cm.

(vi) A shallow tray of area not less than 650 cm^2.

(vii) An airtight container of capacity similar to that of the basket.

2.2 Procedure

a) A sample of aggregates not less than 2000 gm is taken for the test. Two tests shall be made and it is recommended that the two samples should not be tested concurrently. Aggregates, artificially heated, are not normally tested.

b) The test sample is washed thoroughly, drained and then placed in the wire basket.

c) The basket with sample is immersed in distilled water in the container at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket.

d) Remove the entrapped air from the sample by lifting the basket 25 mm from the base of the container and allowing it to drop 25 times at the rate of about one drop per second.

e) The basket and aggregate is kept completely immersed during the operation and for a period of 24±½ hours afterwards.

f) The basket and the sample are then jolted and weighed (Weight A1) in water at a temperature of 22 to 32°C.

g) If it is necessary to transfer the basket with aggregates to a different tank for weighing, it is jolted 25 times in the new tank before weighing (Weight A1).

h) The basket with the aggregates is removed from the water and allowed to drain for a few minutes.

i) Thereafter, empty the aggregates from the basket on to one of the dry clothes, and the empty basket returned to the water, jolted 25 times and weighed in water (Weight A2).

j) The aggregate placed on the dry cloth is gently surface dried with the cloth. Transfer it to the second dry cloth when the first will remove no further moisture. It shall then be spread out not more than one stone deep on the second cloth, and air dried keeping away from direct sunlight or any other source of heat for not less than 10 minutes.

k) After the aggregates are completely surface dry (which with some aggregates may take an hour or more) it shall then be weighed (Weight B).

l) During the period of air drying, the aggregates must be turned over at least once and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregates.

m) The aggregate is then oven dried in the shallow tray, at a temperature of 100 to 110°C for 24±½ hours.

n) After 24 hours, the sample is removed from the oven, cooled in the airtight container and weighed (Weight C).

2.3 Calculation

Specific gravity (Bulk), apparent specific gravity and water absorption are calculated as follows:

Specific gravity (Bulk) = C/ (B-A)

Apparent specific gravity = C/ (C-A)

Water absorption (% of dry weight) = 100(B-C)/ C where

A= Weight of the saturated aggregate in water (A1-A2), gm.

B = Weight of the saturated surface-dry aggregate in air, gm.

C = Weight of oven-dried aggregate in air, gm.

2.4 Reporting of results

The individual and mean of the two results are reported to three decimal places. The size of material tested, and if artificial heating has been done shall also be stated.

3. Method II – Aggregate between 40 mm and 10 mm

3.1 Apparatus

(i) A balance or scale of capacity not less than 3 kg, readable and accurate to 0.5 g suitable to suspend the basket containing the aggregate sample to be suspended for weighing in water.

(ii) A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110°C.

(iii) A wide mouthed glass jar of about 1.5 litres capacity with flat round lip and a plane disc of ground glass plate to close the jar water tight.
(iv) Two dry soft absorbent cloths each not less than 75 cm x 45 cm.
(v) A shallow tray of area not less than 650 cm^2.
(vi) An airtight container of capacity large enough to hold the sample.

3.2 Procedure

a) A sample of aggregates about 1000 gm is taken for the test. Two tests shall be made and it is recommended that the two samples should not be tested concurrently. Aggregates, artificially heated, are not normally tested.
b) The test sample screened on a 10 mm sieve is washed thoroughly, drained and then immersed in distilled water in the glass jar.
c) The sample is kept immersed in distilled water in the jar at a temperature between 22°C and 32°C.
d) Immediately after immersion, remove the entrapped air from the sample by hand rotation of the jar in clockwise and anti-clockwise directions. Repeat this after the end of soaking period.
e) The sample in the jar is kept completely immersed during the operation and for a period of 24±1/2 hours afterwards.
f) The jar is overfilled with distilled water and the plane ground glass is placed over the lip of the jar, ensuring that no air is entrapped in the jar. The jar is dried outside and the weight taken (Weight A).
g) Thereafter, drain the jar and transfer the aggregates on to one of the dry clothes. Fill the jar with water and weigh (Weight B).
h) The aggregate placed on the dry cloth is gently surface dried with the cloth. Transfer it to the second dry cloth when the first will remove no further moisture. It shall then be spread out not more than one stone deep on the second cloth, and air dried keeping away from direct sunlight or any other source of heat for not less than 10 minutes.
i) After the aggregates are completely surface dry (which with some aggregates may take an hour or more) it shall then be weighed (Weight C).
j) During the period of air drying, the aggregates must be turned over at least once and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregates.
k) The aggregate is then oven dried in the shallow tray, at a temperature of 100 to 110°C for 24±½ hours.
l) After 24 hours, the sample is removed from the oven, cooled in the airtight container and weighed (Weight D).

3.3 Calculation

Specific gravity (Bulk), apparent specific gravity and water absorption are calculated as follows:

$$\text{Specific gravity (Bulk)} = D/\,[C - (A-B)]$$

$$\text{Apparent specific gravity} = D/\,[D - (A-B)]$$

$$\text{Water absorption (\% of dry weight)} = 100(C-D)/\,D$$ where

A= Weight of the jar and aggregate filled with water, gm.
B= Weight of jar filled with distilled water, gm.
C = Weight of the saturated surface-dry aggregate in air, gm.
D = Weight of oven-dried aggregate in air, gm.

3.4 Reporting of results

The individual and mean of the two results are reported to three decimal places. The size of material tested, and if artificial heating has been done shall also be stated.

4. Method II – Aggregate smaller than 10 mm

4.1 Apparatus

(i) A balance or scale of capacity not less than 3 kg, readable and accurate to 0.5 g suitable to suspend the basket containing the aggregate sample to be suspended for weighing in water.

(ii) A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110°C.

(iii) A glass pycnometer of about 1litre capacity with a metal conical screw top with a 6 mm diameter hole at the apex or a wide mouthed glass jar of about 1.5 litres capacity with flat round lip and a plane disc of ground glass plate to close the jar water tight.

(iv) A hair drier or so for supplying a current of warm air.

(v) A shallow tray of area not less than 325 cm^2.

(vi) An airtight container of capacity large enough to take the sample.

4.2 Procedure

a) A sample of aggregates about 1000 gm for 4.75 mm to 10 mm size or 500 gm if finer that 4.75 mm is taken for the test. Two tests shall be made and it is recommended that the two samples should not be tested concurrently. Aggregates, artificially heated, are not normally tested.

b) The test sample passing a 10 mm sieve is placed in a tray and kept immersed in distilled water at a temperature between 22°C and 32°C.

c) Immediately after immersion, remove the entrapped air from the sample by gentle agitation with a rod.

d) The sample is kept completely immersed for a period of 24±1/2 hours.

e) The water is drained from the sample by decantation through a filter paper. The aggregate retained on filter paper is exposed to a gentle current of warm air. Ensure uniform drying by stirring till the material just attains a free running condition. Avoid over drying of the material. The weight of the saturated surface dry (SSD) aggregate is taken (Weight A).

f) Transfer the aggregates to the pycnometer and fill it with water. Remove the entrapped air from the sample by rotating the pycnometer on its side while the hole in the apex of the cone is covered with a finger. Top up the pycnometer up to the hole with distilled water ensuring that any froth on the surface is removed.

g) The pycnometer is dried outside and the weight taken (Weight B). Thereafter, drain the pycnometer and transfer all the aggregates into the tray.

h) The pycnometer is refilled with distilled water to the same level as before, dried out side and weight taken (Weight C). The difference in temperature of water in the pycnometer shall not vary more than 2°C.

i) The saturated surface dry aggregate is then oven dried in the shallow tray, at a temperature of 100 to 110°C for 24±½ hours. During this period, the aggregates are stirred to facilitate drying.

j) After 24 hours, the sample is removed from the oven, cooled in the airtight container and weighed (Weight D).

NOTE: *Instead of pycnometer if glass jar is used, the procedure is the same except that the jar is filled to overflowing and the glass plate slid over to exclude any air bubbles.*

4.3 Calculation

Specific gravity (Bulk), apparent specific gravity and water absorption are calculated as follows:

Specific gravity (Bulk) = D/ [A - (B-C)]
Apparent specific gravity = D/ [D - (B-C)]
Water absorption (% of dry weight) = 100 (A-D)/ D where

A= Weight of the saturated surface dry sample in gm.
B= Weight of the pycnometer or glass jar and sample filled with distilled water in gm.
C = Weight of the pycnometer or glass jar filled with distilled water in gm.
D = Weight of oven-dried aggregate in air in gm.

4.4 Reporting of results

The individual and mean of the two results are reported to three decimal places. The grading of material shall be stated.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-G2/2015

Specific Gravity and Water Absorption of aggregates **IS: 2386 - Part III**	Report No.	Date:

REGIONAL LABORATORY……………………………...	**DISTRICT LABORATORY……………………………......**

Name of work:		
Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

MATERIAL:	Crushed stone aggregate 20 mm/ 13.2 mm/19 mm/40 mm/11.2 mm/6.7mm	Date of testing:	

LAYER:	Concrete	Subbase	WBM	WMM	BM/DBM	BC/SMA

Specific Gravity and Water Absorption determination using wire basket

Determinations	*Trial 1*	*Trial 2*	Mean value
Weight of saturated aggregate and wire basket = A_1 gm			
Weight of wire basket in water = A_2 gm			
Weight of saturated aggregate in water (A_1-A_2) = A gm			
Weight of saturated surface dry aggregates in air = B gm			
Weight of oven dry aggregates in air = C gm			
Specific Gravity (Bulk) = C/(B-A)			
Specific Gravity (Apparent) = C/(C-A)			
Water Absorption (% of dry weight) = 100 x (B-C)/C			

RESULTS:

Mean value of Specific gravity =	***Required value***
Mean value of Water Absorption = %	***Required value*** %

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF FLAKINESS INDEX OF COARSE AGGREGATE

IS: 2386 - Part 1

1. Introduction

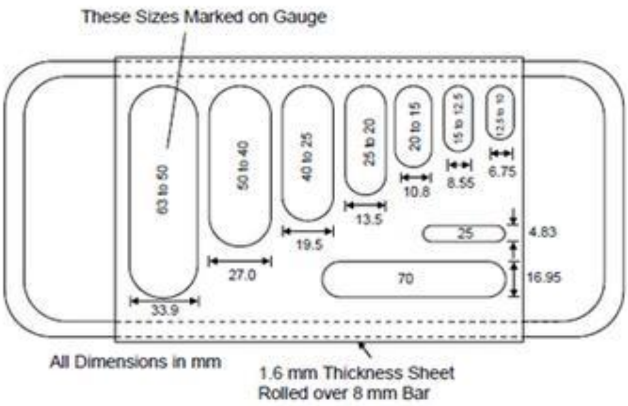
This method of test covers the procedure for determining the Flakiness Index of coarse aggregate in the size range from 63 mm to 6.3 mm.

2. Apparatus

(i) Metal gauge of the pattern shown in the figure.

(ii) A balance of sufficient capacity and sensitivity with accuracy of at least 0.1 percent of the total weight of the sample tested.

(ii) IS test sieves of sizes shown in the table 1 below for sieving the aggregates.



3. Sample preparation

Sufficient quantity of aggregate shall be taken to provide a minimum number of 200 pieces of each fraction for gauging.

Table 1: *Recommended IS sieves for Flakiness test*

Passing IS sieve mm	*Retained on IS sieve mm*	*Thickness of gauge mm*
63	50	33.90
50	40	27.00
40	31.5	21.50
31.5	25	16.95
25	20	13.50
20	16	10.80
16	12.5	8.55
12.5	10	6.75
10	6.3	4.89

4. Procedure

a) The sample shall be first sieved through the required sieves given in the table 1 above. The dimension of the thickness gauge to be used to test aggregate of each size range is also indicated in the table.

b) The weight of each fraction retained in the sieves, W_1, W_2, W_3 .....etc is determined. The sum of these will be the weight of sample tested (W).

c) The fraction retained in each sieve is then gauged through the appropriate slot of the thickness gauge, one by one.

d) The weight of material passing each slot is determined as Y_1, Y_2, Y_3 etc, which constitute the flaky particles.

e) In case where sieves with slots are used in place of gauge, the fraction of the sample retained on each sieve is sieved through each of the slotted sieves in full, instead of checking the aggregate pieces individually.

5. Calculation

a) The percentage by weight retained on each sieve, x_1, x_2, x_3 ….etc of the total weight of the aggregates tested (W) are then calculated to the accuracy of 0.1 percent of the weight of test sample.
i.e., $x_1 = W_1/W$, $x_2 = W_2/W$, $x_3 = W_3/W$…. etc. The sum of this should be 100%.

b) The percentage of particles passing each slot say, y_1, y_2, y_3 ….etc are then calculated.
i.e., $y_1 = Y_1/W_1$, $y_2 = Y_2/W_2$, $y_3 = Y_3/W_3$…. etc

c) The weighted % of aggregates passing each slot is determined by multiplying x_1 by y_1, x_2 by y_2….etc

d) The Flakiness Index is the % total weighted mass of the material passing the gauges or sieves expressed as a percentage of the total weight of the sample tested.

$$\text{Flakiness Index in percentage} = (x_1y_1 + x_2y_2 + x_3y_3 \ldots\ldots)/100.$$

6. Combined Flakiness and Elongation Indices

Some specifications insist on combined Flakiness and Elongation Indices (Total). This combined value is determined as follows:

a) The Flakiness Index of the sample passing 63 mm IS sieve and retaining on 6.3 mm IS sieve is first determined.

b) The flaky particles are then separated out from the sample.

c) From the remaining non-flaky material, elongated particles are separated.

d) The Elongation Index is then calculated from the weight of the non-flaky part.

e) The value of Flakiness Index and Elongation Index thus computed is added up to give the combined Flakiness and Elongation Indices (Total).

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-G3/2015
Aggregate Flakiness & Elongation Index **IS: 2386 - Part I**	Report No.	Date:
REGIONAL LABORATORY…………………………….…..	**DISTRICT LABORATORY………………………………..…..**	

Name of work:		
Division:	Subdivision:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TESTED:	Crushed aggregate 20 mm/ 40 mm/ graded	Date of testing:

LAYER:	Concrete	Subbase		WBM		WMM		BM/DBM		BC/SMA	
Grading IS sieve mm	Passing	63	50	40	31.5	25	20	16	12.5	10	Total
	Retained	50	40	31.5	25	20	16	12.5	10	6.3	
Flakiness Index determination											
Weight of particles in each range W_1, W_2, W_3 …… etc gm											
% weight of particles in each sieve of the total sample, x_1, x_2, x_3 …..etc											
Weight passing, each slot, Y_1, Y_2, …… etc gm											
% weight passing of each range, y_1, y_2, y_3 …..etc											
Flakiness Index = $\Sigma xy/100$ = %						Weight of test sample = gm					
Elongation Index determination : Whole sample/non-flaky portion											
Weight of sample in each range W_1, W_2, W_3 …… etc gm		--			--						
% weight of particles in each sieve of the total sample, w_1, w_2, w_3 …..etc											
Weight not passing each slot, Y_1, Y_2, …etc gm		--			--						
% weight passing of each range, y_1, y_2, y_3 …..etc		--			--						
Elongation Index = $\Sigma wy/100$ = %						Weight of test sample = gm					

RESULTS:	***Required value***	
Flakiness Index = % Elongation Index = % Combined Flakiness & Elongation Index = %	Flakiness Index = %	Elongation Index = %
	Flakiness & Elongation Index (Combined) = %	

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved*: Asst. Exe. Engineer (QC)

DETERMINATION OF ELONGATION INDEX OF COARSE AGGREGATE

IS: 2386 - Part 1

1. Introduction

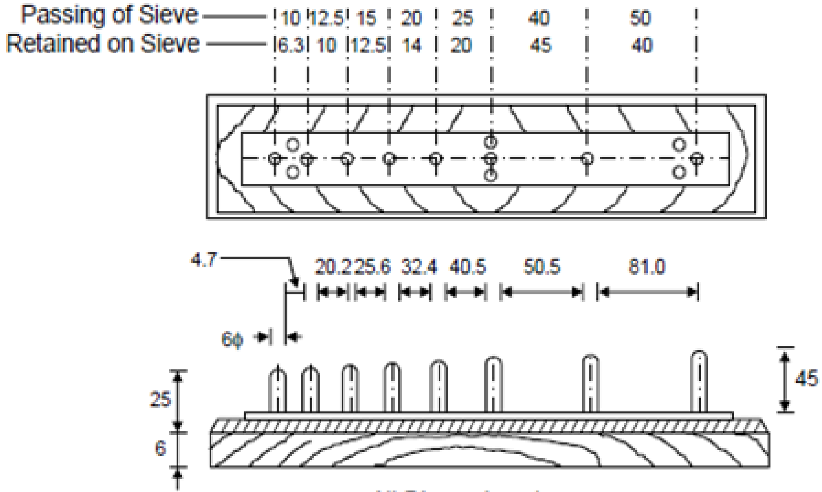
This method of test covers the procedure for determining the Elongation Index of coarse aggregate. Elongation index is not applicable to aggregate size smaller than 6.3 mm.

2. Apparatus

(i) Metal gauge of the pattern shown in the figure.

(ii) A balance of sufficient capacity and sensitivity with accuracy of at least 0.1 percent of the total weight of the sample tested.

(iii) IS test sieves of sizes shown in the table below for sieving the aggregates.



All Dimensions in mm

3. Sample preparation

Sufficient quantity of aggregate shall be taken to provide a minimum number of 200 pieces of each fraction for gauging.

Passing IS sieve mm	*Retained on IS sieve mm*	*Length of gauge mm*
50	40	81.0
40	25	58.5
25	20	40.5
20	16	32.4
16	12.5	25.6
12.5	10	20.2
10	6.3	14.7

4. Procedure

a) The sample shall be first sieved through the required sieves given in the table above. (The dimension of the thickness gauge for each size of aggregate is also indicated in the table).

b) The weight of each fraction retained, W_1, W_2, W_3…etc are determined to the accuracy of 0.1% of the total weight of the test sample. The sum of these will be the total weight of the test sample (W).

c) W_1, W_2, W_3… etc are then gauged through the appropriate slot of the length gauge, one by one.

d) The weight of the aggregates not passing each slot (Elongated particles) Y_1, Y_2….etc are determined.

e) In case where sieves with slots are used in place of gauge, the fraction of the sample retained on each sieve is sieved through the slotted sieves in full, instead of checking the aggregate pieces individually.

5. Calculation

e) The percentage by weight of particles retained on each sieve, w_1, w_2, w_3 ….etc of the total weight of the aggregates tested (W) are then calculated to the accuracy of 0.1 percent of the weight of test sample.

i.e., $w_1 = W_1/W$, $w_2 = W_2/W$, $w_3 = W_3/W$…. etc. The sum of this should be 100%.

f) The % by weight of particles not passing each slot (Elongated particles) say, y_1, y_2, y_3 ….etc are then calculated.

i.e., $y_1 = Y_1/W_1$, $y_2 = Y_2/W_2$, $y_3 = Y_3/W_3$…. etc

g) The Elongation Index is the total weighted fraction of the material retained on the slots or sieves, expressed as a percentage.

Elongation Index in percentage = $(x_1y_1 + x_2y_2 + x_3y_3 \ldots\ldots)/100$.

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DETERMINATION OF AGGREGATE IMPACT VALUE

IS: 2386 - Part 4

1. Introduction

The aggregate impact value (AIV) indicates a relative measure of the resistance of the aggregate to sudden impact or shock, which differs from its resistance to slow compressive load. This method covers the procedure for determining the aggregate impact value of coarse aggregate.

2. Apparatus

(i) Aggregate Impact Testing machine which consists of a heavy metal base, detachable cylindrical steel cup 10. 2 cm dia and 5.0 cm height which can be secured to the base, a metal hammer of weight 13.5 kg to 14.0 kg, moving between vertical guides with lower end cylindrical in shape which can fall freely into the cup. There is arrangement to raise the hammer and drop from a height of 38±0.5 cm. A key is provided to lock the hammer while fastening or removing the cup.

(ii) A cylindrical metal measure having internal dia 7.5 cm and depth 5.0 cm for measuring the required quantity of test sample.

(iii) A straight metal tamping rod of circular cross section, 1.0 cm in dia and 23.0 cm long, rounded at one end.

(iv) IS sieves of sizes 12.5 mm, 10.0 mm and 2.36 mm for sieving aggregates.

(v) A balance of capacity not less than 500 gm with sensitivity of 0.1 gm.

(vi) Drying oven, thermostatically controlled, capable of maintaining temperatures of 100°C to 110°C.

3. Procedure

a) Test samples of aggregate passing 12.5 mm and retaining on 10.0 mm sieve is dried in the oven for four hours at 105±5°C and cooled to room temperature.

b) The measuring cup is filled with the sample aggregates to one-third full and given 25 tamping with the tamping rod.

c) Another layer to reach up to two-third of the cup is filled and given 25 tamping.

d) The measure is then filled to over flow and tamped 25 times. Struck off the excess aggregates using the tamping rod as straight edge.

e) The net weight of the aggregate is determined and the same weight of aggregate is used for the duplicate test.

f) The steel cup is now clamped to the base and the whole sample in the measure is transferred to the steel cup.

g) 25 tamping are given to the sample in the steel cup.

h) The hammer is raised, until its lower face is 380 mm above the above the upper surface of the aggregate sample in the cup, and allowed to fall freely on the aggregates.

i) The test sample is subjected to a total number of 15 such blows and each delivered at an interval of not less than one second.

j) The crushed aggregate is removed from the steel cup and sieved through 2.36 mm sieve till no significant amount of material pass.
k) The fraction passing the sieve is weighed accurately to the nearest 0.1 gm. The weight retained is also determined and the total should agree with the weight of sample taken for test. If the difference is more than 1.0 gm, the sample is discarded and test shall be repeated.
l) Another sample of similar weight is taken and the test is carried on this second sample also.

4. Calculations

The aggregate impact value is expressed as a percentage of the fines formed against the weight of sample tested.

Let the weight of sample taken = W_1 gm.
Weight of material passing 2.36 mm sieve = W_2 gm.
Aggregate impact value = $(W_2/W_1) \times 100$ percent.

The mean of the 2 results rounded to the nearest whole number is reported as the aggregate impact value (AIV) of the tested material.

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-G4/2015
	QUALITY CONTROL WING	

Aggregate Impact Value test (AIV) **IS: 2386 - Part 4**	Report No.	Date:

REGIONAL LABORATORY……………………………….	**DISTRICT LABORATORY………………………………..**
Name of work:	

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TESTED:	Crushed aggregate 20 mm/ 40 mm/ graded	Date of testing:

LAYER:	Concrete	Subbase	WBM	WMM	BM/DBM	BC/SMA	

Impact Value determination

Trial number	*1*	*2*
Weight t of dry sample filling the cylindrical measure = W_1 gm		
Wt of aggregate passing 2.36 mm after the test = W_2 gm		
Aggregate Impact Value =100 x (W_2/ W_1) %		
Average		

RESULTS:	***Required value***
Aggregate Impact Value = %	%

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved*: Asst. Exe. Engineer (QC)

DETERMINATION OF LOS ANGELES ABRASION VALUE

IS: 2386 - Part 4

1. Introduction

The Los Angles abrasion test is a common test method used to indicate the toughness and abrasion characteristics of aggregates. The abrasion characteristics of aggregates are important because the durability of bituminous mix depends on the resistance of the aggregate to crushing, degradation and disintegration.

This method covers the procedure for determining the resistance to degradation of aggregates using Los Angeles Abrasion testing machine.

2. Apparatus

(i) Los Angeles machine which consists of a hollow cylindrical drum closed at both ends with an inner dia of 700 mm and inside length 500 mm, capable of rotating about its horizontal axis.

The cylinder shall be supported on sides by stub shafts but not entering inside.

NOTE: *The shaft bearing shall be mounted on concrete or any rigid support*.

The drum shall rotate along a horizontal axis. An opening is provided on the drum to introduce sample inside. A suitable dust-tight lid keeps the opening closed while drum is rotating.

A removable steel shelf of depth 88 mm and suitable thickness preferably made with wear resistant steel, extending to the full length of the drum and projecting inward is mounted on the interior cylindrical surface. The steel shelf is fixed rigidly to the inside of the drum.

The position of the shelf is such that sample and spheres shall not impact on the lid of the opening or be near it. If the shelf is found bent in either direction, it shall be replaced.

NOTE: *The suggested power for motor is 1 HP*.

(ii) A straight metal tamping rod of circular cross section, 1.0 cm in dia and 23.0 cm long, rounded at one end.

(iii) IS test sieves of sizes 40 mm, 25.0 mm, 20 mm, 12.5 mm, 10 mm, 6.3 mm, 4.75 mm, 2.36 mm and 1.70 mm.

(iv) A balance of capacity not less than 6000 gm with sensitivity of 0.1 gm.

(v) The charge consisting of steel spheres of approximately 48 mm dia and having a mass between 390 and 445 g. Six to twelve balls are required for the test.

(vi) Drying oven, thermostatically controlled capable of maintaining temperatures of 110±5°C.

3. Preparation of sample for testing

a) The aggregate samples are prepared in four grading as given below depending upon the maximum size of aggregate.

IS sieve size mm		*Mass required in gm for each grading*						
Passing	*Retaining*	*A*	*B*	*C*	*D*	*E*	*F*	*G*
80	63					2500±50		
63	50					2500±50		
50	40					5000±100	5000±100	
40	25	1250					5000±100	5000±100
25	20	1250						
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

b) The amount of charge to be added to the aggregate depending on the grading of the sample is given below:

Grading	*No of spheres*	*Total weight of the charge*
A	12	5000±25
B	11	4584±25
C	8	3330±20
D	6	2500±15
E	12	5000±25
F	12	5000±25
G	12	5000±25

4. Procedure

a) Wash and oven dry the test samples of aggregate to constant mass at 110±5°C and cool to room temperature.

b) Separate into different fraction and combine to get the required grading.

c) Place the aggregate and the required charge inside the Los Angeles testing machine and rotate at a speed of 30 to 33 revolutions per minute.

d) For grading A, B, C and D, machine shall be rotated for 500 revolutions and for E, F and G it shall be rotated for 1000 revolutions.

e) After completion of the revolutions, make a preliminary separation using 1.70 mm IS sieve.

f) Wash the material retained on 1.70 mm sieve and dry to constant mass in an oven at 110±5°C. Find the weight to the nearest 1 gm.

NOTE: *Elimination of washing seldom varies the result by more than 0.2% of the original sample mass*.

NOTE: *The test may be carried out in two stages*:

(i) After 100 revolutions, the sample is taken out and sieved in 1.70 mm sieve without washing to determine the amount of degradation.

(ii) The sample including all fines is carefully collected, returned to the machine and for the remaining 400 revolutions required to complete the test.

It is observed that the ratio of loss at 100 revolutions to 500 revolutions should not greatly exceed 0.2 for material of uniform hardness.

5. Calculations

The Los Angeles Abrasion value is expressed as a percentage of the loss of weight against the weight of sample tested.

Let the weight of sample taken = W_1 gm.
Weight of material retained in 1.70 mm sieve = W_2 gm.
Loss of material due to abrasion = $W_1 – W_2$
Los Angeles abrasion value = $(W_1 – W_2/W_1)$ x 100 percent.
The result is reported to the nearest 1% by mass.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-G5/2015

Los Angeles Abrasion Value test (LAAV) **IS: 2386 - Part IV**	Report No.	Date:

REGIONAL LABORATORY……………………………….	**DISTRICT LABORATORY………………………………..**

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TESTED:	Crushed aggregate 20 mm/ 40 mm/ graded	Date of testing:

LAYER:	Concrete	Subbase	WBM	WMM	BM/DBM	BC/SMA	

Los Angeles Abrasion Value determination

Trial number	*1*	*2*
Weight of aggregate sample = W_1 gm		
Weight of aggregate retained on 1.70 mm IS sieve = W_2 gm		
Los Angeles Abrasion value =100 x (W_1-W_2)/W_1 %		
Average		

RESULTS:	***Required value***
Los Angeles Abrasion Value = %	%

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved*: Asst. Exe. Engineer (QC)

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DETERMINATION OF AGGREGATE CRUSHING VALUE

IS: 2386 - Part 4

1. Introduction

The aggregate crushing value (ACV) gives a relative measure of the resistance of an aggregate to crushing under a gradually applied load. If the ACV is greater than or equal to 30, the result may be anomalous, and in such cases the 'ten percent fines value (TFV)' should be determined instead. The standard aggregate crushing test shall be made on aggregates passing through 12.5 mm IS sieve and retained on a 10 mm IS Sieve. If the standard size is not available, other sizes up to 25 mm may be tested.

2. Apparatus

(i) A 15 cm diameter open-ended steel cylinder, with plunger and base-plate.
(ii) IS Sieves of sizes 12.5, 10 and 2.36 mm.
(iii) A compression testing machine capable of applying a load of 40 tonnes.
(iv) Tamping rod.
(v) Balance.
(vi) Cylindrical measure.

3. Procedure

a) Aggregate passing 12.5 mm IS Sieve and retained on 10-mm IS Sieve, are oven-dried at a temperature of 100 to 110°C and then cooled to room temperature before testing.
b) The required quantity of test sample is obtained by filling the cylindrical measure in 3 equal layers and tamping each layer 25 times with the tamping rod. The top is levelled using the tamping rod as a straight edge.
c) The weight of the test sample should be determined (Weight A) and the same weight of sample shall be taken for the repeat test.
d) The test sample is transferred into the cylinder of the test apparatus in 3 layers and each layer is tamped with 25 strokes of the tamping rod.
e) The surface of the aggregates is then leveled and the plunger inserted.
f) The apparatus with the test sample and plunger in position is then placed in the compression testing machine and loaded at a uniform rate so as to achieve 40 tonnes load in 10 minutes. After this, the load is released.
g) The sample is then sieved through a 2.36 mm IS Sieve and the fraction passing through the sieve is weighed (Weight B).

4. Calculation

The ratio of the weight of fines formed after applying the standard load to the total sample weight in each test shall be expressed as a percentage. The result must be recorded to the first decimal place.

Aggregate crushing value = [B/A] x100, where
B = Weight of fraction passing the appropriate sieve.
A = Weight of oven dry sample.

5. Reporting of results

The mean of the two results shall be reported to the nearest whole number as the 'aggregate crushing value'. The size of material tested, shall also be stated.

	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-G6/2015
	QUALITY CONTROL WING	

Aggregate Crushing Value (ACV) & Ten percent fines Value (TFV)

IS: 2386 – Part 4

Report No.	Date:
REGIONAL LABORATORY…………………………	**DISTRICT LABORATORY…………………………………**

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

MATERIAL:	Crushed aggregate 20 mm/ 40 mm/ graded	Date of testing:	

LAYER:	Concrete	Subbase	WBM	WMM	BM/DBM	BC/SMA

Test No.	Weight of specimen A gm	Weight retained in 2.36 mm sieve gm	Weight passing 2.36 mm sieve B gm	Difference in weight before and after test gm	Aggregate Crushing Value % = B/A x 100
1(a)					
1(b)					
1(c)					
				Average	

	Weight of specimen, A gm	Weight retained in 2.36 mm sieve gm	Weight passing 2.36 mm sieve, B gm	Difference in weight before and after test gm	% fines, Y = B/A x 100	Load applied, X in tonnes to obtain % fines 7.5 to 12.5
2(a)						
2(b)						
2(c)						
				Average		

RESULTS:

Average aggregate crushing value (ACV = B/A x 100) = %	***Required value*** %
Average ten percent fines value (TFV = 14X/(Y+4)) = %	***Required value*** %

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF TEN PERCENT FINES VALUE

IS: 2386 - Part 4

1. Introduction

The ‘ten percent fines’ value gives a measure of the resistance of an aggregate to crushing, that is, applicable to all aggregates. This method illustrates the procedure to determine the ‘ten percent fines’ value of coarse aggregates.

2. Apparatus

(i) A 15 cm diameter open-ended steel cylinder, with plunger and base-plate.
(ii) IS Sieves of sizes 12.5 mm, 10 mm and 2.36 mm.
(iii) A compression testing machine capable of applying a load up to 50 tonnes in a period of 10 minutes.
(iv) Tamping rod 16 mm diameter, 45 cm to 60 cm long with one end rounded.
(v) Balance of capacity 3 kg readable and accurate to 1 gm.
(vi) Cylindrical measure of internal diameter 115 mm and 180 mm height, for measuring the sample.
(vii) Dial gauge.

3. Procedure

a) Aggregate passing 12.5 mm IS Sieve and retained on 10 mm IS Sieve, are oven-dried at a temperature of 100 to 110°C and then cooled to room temperature before testing.
b) The required quantity of test sample is obtained by filling the cylindrical measure in 3 equal layers and tamping each layer 25 times with the tamping rod. The top is levelled using the tamping rod as a straight edge. The quantity of aggregate shall be such that the depth of material in the cylinder, after tamping shall be 10 cm.
c) The weight of the test sample should be determined (Weight A) and the same weight of sample shall be taken for the repeat test.
d) The test sample is transferred into the cylinder of the test apparatus in 3 layers and each layer is tamped with 25 strokes of the tamping rod.
e) The surface of the aggregates is then leveled and the plunger inserted.
f) The apparatus, with the test sample and plunger in position is then placed in the compression testing machine and loaded at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about:
    (i) 15.0 mm for rounded or partially rounded aggregates (for example, uncrushed gravels),
    (ii) 20.0 mm for normal crushed aggregates, and
    (iii) 24.0 mm for honeycombed aggregates (for example, expanded shale and slag).

NOTE: *These figures may be varied according to rounding or honey combing*.

g) The sample is then sieved through a 2.36 mm IS Sieve and the fraction passing through the sieve is weighed (Weight B) and is expressed as a percentage of the weight of the test sample.

NOTE: *Normally, this percentage will fall within the range 7.5 to 12.5. If it does not, a further test shall be made at a load adjusted to bring the percentage fines within the range of 7.5 to 12.5.*

4. Calculation

Load required for 10 percent fines = (14 x A)/(B+4) where

A = load in tonnes and

B = mean percentage fines from two tests at ‘A’ tonnes load.

5. Reporting of results

For loads greater than 10 tonnes, the load required to produce 10 percent fines shall be reported to the nearest whole number and for loads less than 10 tonnes the result shall be expressed to the nearest 0.5 tonne.

****

DETERMINATION OF SOUNDESS OF AGGREGATES

IS: 2386 - Part 4

1. Introduction

This test furnishes information helpful in judging the performance of aggregates against weathering action, particularly when adequate information is not available from service records of the material exposed to actual weathering conditions. In soundness test, the resistance to disintegration of aggregates by saturated solutions of sodium sulphate or magnesium sulphate is determined.

2. Apparatus

(i) A balance or scale of capacity not less than 500 gm, readable and accurate to 0.1 gm for weighing fine aggregates.

(ii) For weighing coarse aggregates a balance or scale of capacity not less than 5000 gm, readable and accurate to 1 gm.

(iii) Suitable means to regulate the temperature of the samples immersed in sodium sulphate or magnesium sulphate solutions.

(iv) A well ventilated oven, thermostatically controlled, to maintain a temperature of 105 to 110°C with average rate of evaporation of 25 gm/hr for 4 hours.

(v) Baskets made of suitable wire mesh or sieves with suitable openings for immersing the samples of aggregate in the solution.

(vi) IS test sieves given in table 1.

Table 1 - *Recommended IS test sieves for soundness test*.

No.	*For fine aggregates*	*For coarse aggregates*
1	150 microns	8.0 mm
2	300 microns	10 mm
3	600 microns	12.5 mm
4	1.18 mm	16 mm
5	2.36 mm	20 mm
6	4.00 mm	25 mm
7	4.75 mm	31.5 mm
8	-	40 mm
9	-	50 mm
10	-	63 mm
11	-	80 mm

3. Preparation of Sodium Sulphate solution

a) Saturated solution of sodium sulphate is prepared by dissolving sodium sulphate, technical grade conforming to IS: 255-1950 in water at a temperature of 25°C to 30°C.

b) The mixture is thoroughly stirred during the addition of the salt and the solution is stirred at frequent intervals until used. Sufficient salt is added till excess crystals are present in the solution ready for testing.

c) Normally 350 gm of anhydrous salt or 1150 gm of decahydrate salt per litre of water is sufficient produce saturation at 28°C. Since excess crystals are to be present, this may be increased to 420 gm and 1300 gm respectively.

d) The solution is cooled to a temperature at 27±2°C and maintained at this temperature at least for 48 hours before use.

e) The grade of sodium sulphate mostly available as dried powder can be conveniently used for the preparation of solution.

f) The specific gravity of the solution is determined immediately before using for the test. The specific gravity shall not less than 1.151 and not more than 1.174.

g) Discoloured solution is discarded.

4. Preparation of Magnesium Sulphate solution

a) Saturated solution of magnesium sulphate is prepared by dissolving magnesium sulphate, technical grade conforming to IS: 257-1950 in water at a temperature of 25°C to 30°C.

b) The mixture is thoroughly stirred during the addition of the salt and the solution is stirred at frequent intervals until used. Sufficient salt is added till excess crystals are present in the solution ready for testing.

c) Normally 400 gm of anhydrous salt or 1400 gm of heptahydrate salt per litre of water is sufficient to produce saturation at 28°C. Since excess crystals are to be present, 1600 gm of heptahydrate salt per litre of water is recommended for use.

d) The solution is cooled to a temperature at 27±1°C and maintained at this temperature at least for 48 hours before use.

e) The grade of sodium sulphate mostly available as dried powder can be conveniently used for the preparation of solution.

f) The specific gravity of the solution is determined immediately before using for the test. The specific gravity shall not less than 1.295 and not more than 1.308.

g) Discoloured solution is discarded.

5. Sample preparation

5.1 *Fine aggregates*

a) The fine aggregates for the test shall pass through 10 mm IS sieve.

b) Samples of the size ranges indicated in table 2 are prepared with each size not less than 100 gm.

Table 2 – *Recommended sizes of samples for fine aggregates.*

Passing IS sieve	*Retained on IS sieve*
600 mic	300 mic
1.18 mm	600 mic
2.36 mm	1.18 mm
4.75 mm	2.36 mm
10 mm	4.75 mm

c) The sample of fine aggregates is washed on a 300 micron sieve, dried to constant weight at 105°C to 110°C and separated into different sizes mentioned in the table above.

d) Samples of 100 gm is weighed after final sieving from each fraction and kept in separate containers for test.

5.2 *Coarse aggregates*

a) Coarse aggregate samples are prepared for the test after removing the fraction finer than 4.75mm IS sieve.

b) The sample size shall not be less than the amounts given in the table 3 and in excess of 5% or more.

c) The sample of coarse aggregates is thoroughly washed, dried to constant weight at 105°C to 110°C and separated into different sizes mentioned in the table 3.

d) Samples of required weight is weighed after final sieving from each fraction and kept in separate containers for test.

e) In case of fractions coarser than 20 mm size, the total number of pieces shall also be counted and recorded.

Table 3 - *Quantity of coarse aggregate sample required for soundness test.*

IS sieve size (Square-hole sieves)	*Required quantity/fraction*
10 mm to 4.75 mm	300 gm
20mm to 10mm Consisting of: 12.5 mm to 10 mm 20 mm to 12.5 mm	1000 gm 33% 67%
40 mm to 20 mm Consisting of: 25 mm to 20 mm 40 mm to 25 mm	1500 gm 33% 67%
63 mm to 40 mm Consisting of: 50 mm to 40 mm 63 mm to 50 mm	3000 gm 50% 50%
80 mm and large sizes - each fraction	3000 gm

5.3 *All-in aggregates*

a) All-in aggregates shall be separated into two major fractions, finer than 4.75 mm and coarser than 4.75 mm.

b) If the samples contain less than 5% in any of the size range, the same need not be tested. However, the test result of such fraction will be taken as the average of the value obtained for sizes above and below the fraction found to be less than 5%.

6. Procedure

a) The sample of aggregates in the container is immersed in sodium or magnesium sulphate solution at a temperature of 27±1°C with a cover of at least 15 mm of the solution above the top of the aggregates.

b) The containers are covered to reduce evaporation and accidental addition of extraneous materials.

c) The samples are immersed for a period of not less than 16 hours and not more than 18 hours.

d) After the immersion period, the sample is removed from the solution, permitted drain for 15±5 minutes and kept in the oven at 105°C to 110°C.

e) The sample is dried to constant weight at 105°C to 110°C. The sample is taken out of the oven, cooled to room temperature and weight determined every 4 hours till constant weight is achieved.

f) Constant weight is considered to be achieved when two successive weights do not differ by 0.1 gm in the case of fine aggregates and 1 gm in the case of coarse aggregates.

g) After constant weight is achieved, the sample is again immersed in the prepared solution.

h) This process is repeated for the prescribed number of cycles.

i) After the end of the final cycle, the sample is washed free from solutions. This is ascertained by the reaction of the wash water with $BaCl_2$.

j) The each sulphate free fraction is dried to constant weight at 105°C to 110°C and the weight recorded.

k) The fine aggregates are sieved through the sieves on which it was retained before test. Coarse aggregates are sieved through sieves mentioned in table 4.

l) The fraction coarser than 20 mm is examined qualitatively and quantitatively. In qualitative examination, the amount of disintegration, splitting, crumbling, cracking, flaking etc are noted and recorded. The numbers of particles affected are also counted.

Table 4 – *Recommended sieves for determining loss for coarse fraction.*

Size of aggregates	*Sieve to determine loss*
63 mm to 40 mm	31.5 mm
40 mm to 20 mm	16 mm
20 mm to 10 mm	8.0 mm
10 mm to 4.75 mm	4.0 mm

m) The fraction coarser than 20 mm is examined qualitatively and quantitatively. In qualitative examination, the amount of disintegration, splitting, crumbling, cracking, flaking etc are noted and recorded. The numbers of particles affected are also counted.

7. Reporting of results

The report shall include the following data:

(i) Weight of each fraction of each sample before test.

(ii) Weight of fraction passing each sieve after test, expressed as a % of the original weight.

(iii) Weighted average of the percentage loss obtained from the product of percentage of each fraction multiplied by the % passing the finer sieve after test. In these calculations, sizes finer than 300 micron IS sieve is assumed as to have zero % loss.

(iv) For particles above 20 mm size, indicate the number of pieces before test and the number of particles affected by test.

(v) The solution used viz., Sodium sulphate or Magnesium sulphate.

Typical formats for recording soundness test data for coarse and fine aggregates are given in tables 5 and 6 below:

Table 5 - *Soundness test data for coarse aggregates*

IS sieve passing mm	*sieve retained mm*	*Grading % of the original sample*	*Weight of test fraction before test*	*% passing the finer sieve after test*	*Weighted average*
150 mic	-	5.0	-	-	-
300 mic	150 mic	11.4	-	-	-
600 mic	300 mic	26.0	100	4.2	1.09
1.18 mm	600 mic	25.2	100	4.8	1.21
2.36 mm	1.18 mm	17.0	100	8.0	1.36
4.75 mm	2.36 mm	10.8	100	11.2	1.21
10 mm	4.75 mm	4.6	-	11.2*	0.52
TOTAL		100	400	-	5.39

NOTE: **The percentage passing for the size is taken as the % passing for the next smaller size since the percentage of this fraction in the test sample is less than %.*

Table 6 - *Soundness test data for fine aggregates*

IS sieve passing mm	*sieve retained mm*	*Grading % of the original sample*	*Weight of test fraction* before test*	*% passing the finer sieve after test*	*Weighted average*
63 mm	40 mm	20.0	3000	4.8	0.96
40 mm	20 mm	45.0	1500	8.0	3.60
20 mm	10 mm	23.0	1000	9.6	2.20
10 mm	4.75 mm	12.0	300	11.2	1.34
TOTAL		100	5800	-	8.10

NOTE: **The sample taken is the minimum specified but larger samples can be used.*

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BULKING OF FINE AGGREGATE (FIELD METHOD)

IS: 2386 - Part 3

1. Introduction

Sand brought on to a site or works may contain some amount of moisture. Due to this, when loosely filled into a container, it will occupy a larger volume than if it is dry. If the sand is measured by loose volume, it is necessary in such a case to increase the measured volume of sand, in order that the amount of sand put into the concrete may be the amount intended for nominal mix used, based on dry sand. It will be necessary to increase the volume of sand by the 'percentage bulking'. The procedure to be adopted may be varied, but two methods are used.

2. Apparatus

(i) A measuring cylinder, 250 ml.
(ii) Two containers to hold test sand.
(iii) One steel rule.

3. Procedure for method I

a) Put sufficient quantity of the sand loosely into a container until it is about two-third full and level off the top of the sand.
b) Push a steel rule vertically down through the sand at the middle to the bottom and measure the height, h cm.
c) Empty the sand out of the container into another container where none of it will be lost.
d) Half fill the first container with water
e) Put back about half the sand and rod it with a steel rod, about 6 mm in diameter, so that its volume is reduced to a minimum.
f) Then add the remaining sand and rod it in the same way.
g) Smooth and level the top surface of the inundated sand and measure its depth at the middle with the steel rule, h' cm.

4. Calculation

The percentage of bulking of sand due to moisture is calculated from the below formula:

$$\text{Percentage bulking} = [(h/h')-1] \times 100$$

5. Procedure for method II

a) Pour the damp sand (consolidated by shaking) into a 250 ml measuring cylinder, until it reaches the 200 ml mark.
b) Then fill the cylinder with water and stir the sand well. (The water shall be sufficient to submerge the sand completely).
c) It will be seen that the sand surface is now below its original level. Suppose the surface is at the mark y ml.

6. Calculation

The percentage of bulking of sand due to moisture is calculated from the formula below:

$$\text{Percentage bulking} = [(200/y) -1] \times 100$$

7. Reporting of results

Report the percentage bulking of the sand to the nearest whole number.

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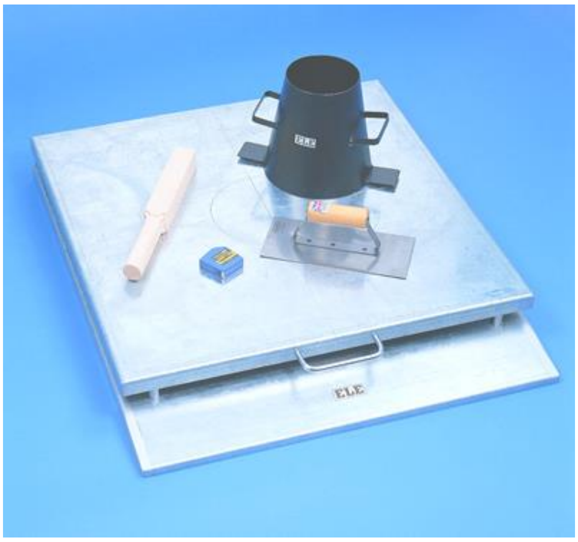
MEASURING THE MORTAR MAKING PROPERIES OF FINE AGGREGATES

IS: 2386 - Part 6

1. Introduction

The mortar-making properties of fine aggregate for concrete are measured by casting cubes in 7.06 cm cube moulds with mortar of a plastic consistency and gauged to a definite water-cement ratio. The cubes tested in a compression testing machine of required capacity and average crushing strength determined. The fine aggregate is compared by testing mortar cubes made using sand treated with 3 percent solution of Sodium Hydroxide and mortar cubes made using sand without treatment.

2. Apparatus



(i) Flow table and flow mould conforming to the requirements specified in 12 of IS: 1727-1960 Methods of test for Pozzolanic materials.

(ii) A tamper of 12.5 mm x 25 mm cross section 12.5 to 15 cm long of a non-absorptive, non-abrasive material.

(iii) A trowel having a steel blade 100 to 150 mm long with straight edges.

(iv) Steel moulds of 7.06 cm size.

(v) Tamping rod shall be 10 mm diameter with one end with hemispherical tip, 300 mm long.

(vi) A compression testing machine of suitable capacity.

3. Treatment of sand

a) The sand for preparing mortar is washed with 3 percent of solution of Sodium Hydroxide followed by through rinsing with water.

b) The treatment process shall be repeated till the washed material produces a colour lighter than that of the standard solution described in IS: 2386 (Part 2) - Methods of test for aggregates for concrete: Estimation of deleterious material and organic impurities.

c) Ensure that no fines are lost while washing with sodium hydroxide solution.

d) The rinsed aggregate may be tested using litmus or phenolphthalein to assure that all traces of sodium hydroxide is removed from the sand before preparing mortar.

4. Preparation of mortar

a) Take cement and water in a vessel to get a water-cement ratio of 0.6 by weight. Permit the cement to absorb water by keeping for one minute.

b) Mix with a spoon to make a smooth paste.

c) Add a known weight of sample sand at saturated surface-dry condition to this paste and mix thoroughly to get the desired consistency (Flow 100±5).

d) After mixing for another 30 seconds, determine flow as given in para 5 below.

5. Determination of flow

a) Place the flow mould on the carefully cleaned surface of the flow table.

b) Immediately after mixing of the mortar, place a layer 25 mm thick and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling inside the mould.
c) Fill the mould fully in the same manner as first layer. Cut off the excess mortar from the top of the mould using the straight edge of the trowel.
d) Clean the flow table surface, free of water and spilled mortar.
e) Lift the mould after one minute after completing the mixing. Drop the table 10 times in 6 seconds through a height of 12.5 mm.
f) Measure the dia of the spread mortar mass in four directions and find the average. This expressed as a percentage of the original diameter will give the flow.
g) If the flow is more, add more sand and repeat the process to get a flow of 100±5.
h) If more than two trials are required to get a flow of 100±5 consider it as a trial mortar. Prepare test specimens from a new batch.

6. Moulding test specimens

a) Immediately after completing the flow test, place the mortar in 7.06 cm cubes in 2 layers, each layer rodded 25 times with tamping road.
b) After rodding is completed, fill the moulds to overflow. Place the moulds in a moist chamber for curing.
c) After 3-4 hours, strike off the excess mortar to make a smooth surface.
d) Remove the specimens from the mould after 20-24 hours and keep in water until tested.
e) The temperature of mixing water, moist closet and water in the curing tank shall be kept at 27±2°C.

7. Testing of specimens

a) Remove the specimens from moist closet (24 hours testing) or from curing tank after the specified period.
b) Surface dry each specimen.
c) Remove any sand particles adhering to the faces. Use soft instruments to clean the cubes.
d) Apply load to the face of the specimen which is in contact with plane surface of the mould.
e) Rate of loading shall be adjusted such that the failure occurs only after 20 seconds but within 80 seconds.

8. Calculation

a) Calculate the average crushing strength of minimum three specimens prepared with the sand sample.
b) Similarly find out the crushing strength of specimens prepared with treated sand.
c) Report the crushing strength of specimens prepared with untreated sand as a percentage of the average crushing strength of specimens made with treated sand.

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DETERMINATION OF STRIPPING VALUE OF ROAD AGGREGATES

IS: 2386 - Part 4

1. Introduction

Some types of aggregates have lesser affinity towards bitumen than water. The phenomenon of stripping is observed when the pavement layer is subjected to prolonged soaking under water. In the state of Kerala where long periods of rain prevail, this property of the aggregate is very relevant. Hence to assess the suitability of aggregates for bituminous construction, the stripping characteristics of the binder from the aggregates by water is determined by various tests. Several anti-stripping agents are available in the market which when added to the bituminous mix is found to reduce stripping. The procedure for determining stripping value of road aggregates with bitumen or tar binders by static immersion method is explained below.

2. Apparatus

(i) Thermostatically controlled water bath.
(ii) Oven to heat aggregate.
(iii) Sieves of sizes 20 mm and 12.5 mm.
(iv) Beaker of 500 ml capacity.
(v) Mixer to mix aggregate and bitumen.

3. Procedure

a) Take 200 gm of clean and dry aggregate passing 20 mm IS sieve and retained on 12.5 mm sieve in a mixer or heating pan.
b) The dried, clean aggregates are heated up to 150°C and mixed with bitumen binder amounting to 5% by weight of aggregate heated to 160°C.
c) The aggregate and binder are mixed thoroughly till they are completely coated and mixture is transferred to the beaker.
d) The mix is then allowed to cool at room temperature for about 2 hours.
e) Distilled water is then added to immerse the coated aggregates. The beaker is covered and kept in a water bath maintained at 40°C.
f) After 24 hours, the beaker is taken out and the extent of stripping is visually estimated while the specimen is still immersed in water.

4. Result

Figure 1: *Bitumen coating stripped*.

Figure 2: *Film of bitumen not stripped*.

a) The stripping value of the aggregate is the area bitumen stripped measured by visual observation expressed as a % of the total surface area of the sample mix.
b) A comparison, of aggregates with bitumen coating stripped off and remaining intact, can made from the figures (1) and (2) given above.

$$\text{Stripping Value} = \frac{\text{Uncovered area observed visually}}{\text{Total area of the aggregates (100\%)}}$$

The mean of the three results shall be reported as stripping value of the tested material and shall be expressed to the nearest whole number.

****

DETERMINATION OF POLISHED STONE VALUE

BS 812: Part 114

1. Introduction

The polished stone value (PSV) gives a measure of the resistance of road stone to the polishing action of vehicle tyres under conditions similar to those occurring on the surface of a road. This test is conducted in two stages. In the first stage the sample of stone aggregates placed in a mould is subjected to a polishing action in an accelerated polishing machine, under standard set of test conditions. In the second stage, the polished sample is subjected to friction test using a pendulum type skid resistance tester to determine the coefficient of friction expressed as percentage or the 'Polished Stone Value'.

2. Apparatus

(i) Accelerated Polishing Machine (With a road wheel with a flat periphery to fix 14 specimens of stone aggregates, 2 solid rubber tyred wheels 200 mm dia, and two feeding mechanism for abrading sand and emery powder) rigidly mounted on a level, firm, concrete base.

(ii) IS test sieves of size 10, 8, 0.425, 0.300, 0.212 and 0.150 mm.

(iii) Mould of size 90.6 mm x 44.5 mm for the preparation of test specimen of stone aggregate.

(iv) Release agent or liquid car polish.

(v) Abrading sand passing 425 micron, 85-100% passing 300 micron, 20-50% passing 212 micron and 0-5% passing 150 micron IS sieve.

(vi) Emery powder 100% passing 60 micron sieve and more than 70% passing 2 micron IS sieve.

(vii) Polyester resin and hardener.

(viii) Clean flexible plastic sheets for cutting strips to fix the samples to the polishing machine.

(ix) Pendulum type friction tester.

3. Preparation of test specimen

a) About 3 kg of clean stone aggregate sample, all passing through 10 mm and retained on 8 mm IS test sieves which are not flaky or elongated is collected for the preparation of the test specimen.

b) Prepare a stiff paste of cement mortar with equal proportion of cement and sand of similar grading as the abrading sand.

c) Place a thin layer of this mortar inside the specimen mould.

d) Carefully place the selected particles of the aggregate sample over the mortar in a single layer, as closely as possible and to cover an area of 90.6 x 44.5 mm, with flat surface of the aggregates lying on the bottom of the mould.

e) Fill the space between the particles up to 3 quarters of its depth with fine sand (Passing 0.212 mm sieve) and level it with fine haired brush.

f) The exposed internal faces and top edges of the metal moulds shall be lightly coated with release agent, using a fine haired brush.

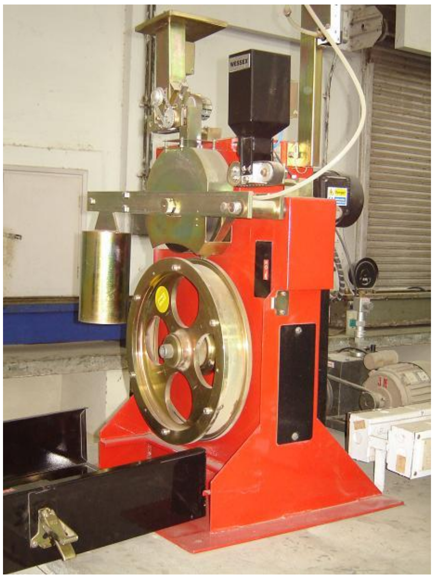
g) Mix the hardener with resin and fill the mould to over flowing with mixed resin. The excess resin can be trimmed off using a knife after 5 to 10 minutes.

- h) After the resin has completely set (About 30 minutes from mixing), remove the specimen from the mould, brush off the loose sand and subject to polishing after a further 30 minutes.
- i) Clean the moulds, tools etc with solvent.
- j) The mould as well as the prepared sample is flat across the width 44.6 mm but these are curved along the length 90.5 mm as an arc of a circle diameter 406 mm.
- k) A minimum of two such test specimens are prepared using each sample of stone aggregates.

4. Accelerated polishing test procedure

The rim of the road wheel can accommodate 14 test specimens which can be simultaneously subjected to accelerating polishing. Therefore it is possible to conduct polishing test simultaneously on different aggregate samples.

- a) The test specimens are clamped around the rim of the road wheel with the help of strips of polythene sheet beneath and in between the adjoining test specimens.
- b) The rubber tyred test wheel is lowered until it rests on the surface of the test specimens fixed around the road wheel.



- c) The required weight is added at the end of the lever so that a total effective load of 40 kg is applied on the road wheel.
- d) The motor is switched on and the road wheel rotated to a speed of 320±5 rpm.
- e) Abrading sand and water are released at a rate of 27±7 gm/min and these are uniformly spread over the surface of the test specimen and the tyre of the test wheel where they are in contact.
- f) The machine is operated for a further period of three hours after releasing the emery powder and water at the specified rate.
- g) The test is interrupted after 1 and 2 hours to remove any excess sand collected at the base.
- h) After the three hours period, the machine is stopped and the test specimens and the machine are cleaned by washing.
- i) The whole procedure is then repeated with emery powder as abrading agent added at a rate of 3±1g/min. Feed water at twice the rate of emery powder.
- j) After the three hours of polishing with emery powder, the machine is stopped and the test specimens and the machine are cleaned by washing.
- k) The polished set of specimens is now ready for determination of the friction coefficient/skid number or the polished stone value.

5. Measurement of friction of polished specimen

Pendulum type friction tester is used to determine the coefficient of friction or the skid resistance value of the test specimen.

- a) Keep the friction test apparatus and slider in a room where the temperature is controlled at 20±2°C for at least 2 hours before the test begins and for duration of the test.

b) Keep the friction tester on a firm level surface and adjust the leveling screws such that the column is vertical.

c) The hinge of the pendulum unit is raised and fixed on the column such that the rubber slider does not touch the ground surface and the pendulum can swing freely.

d) The pendulum arm is released from the horizontal rest position by pressing the button and the pendulum is allowed to swing freely, moving the dead pointer along.

e) If the pointer reads zero of the graduated scale, the calibration is with zero error. If not, the friction adjustment screw head at the hinge is adjusted by tightening or loosening as required, until repeat trial of free swing of the pendulum results in pointer showing zero reading on the graduated scale.

f) One of the specimens of aggregate which was subjected to accelerated polishing is rigidly fixed in the slot provided with its longer side lying in the track of the pendulum swing.

g) The hinge of the pendulum is adjusted such that the sliding length of the rubber shoe along the specimen is 75 mm. The hinge of the pendulum unit is fixed in this position by tightening the fixing head.

h) The surfaces of the specimen and the rubber shoe are copiously wetted with clean water.

i) The pendulum and the pointer are released from the horizontal position by pressing the button. The pointer reading from the graduated scale is recorded to the nearest whole number and is noted as the ‘Skid Number’ or the Polished Stone Value.

j) Perform this operation 5 times, each time wetting the specimen. Record the mean of the last three readings to the nearest 0.1.

k) After this test, the sample is removed from the slot and the process repeated with the second sample is fixed in position. If the mean value of the two specimens of the same material differs by more than 3%, the result is discarded and test is repeated with fresh specimens. This procedure may be repeated a number of times using new specimens until two values are within this limit.

l) The samples are tested in the order 13, 1, 10, 3, 5, 12, 8, 7, 11, 6, 4, 9, 12, 14.

6. Report

The mean of the two values of the skid number or coefficient of friction expressed as percentage, is reported as the Polished Stone Value (PSV) of the stone aggregate to the nearest whole number.

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Part - II

CEMENT, CONCRETE & STEEL TESTING

METHODS OF SAMPLING OF CEMENT

IS: 3535

1. Introduction

With the substantial production and use of cement, it is imperative that due consideration is given to sampling procedures which will ensure proper evaluation of the characteristics of the cement. Sampling procedures of cement from bags, bulk storage, wagons, conveyors etc recommended in IS: 3535 are explained below.

The terms associated with sampling process of cement are given below:

- (i) *Hydraulic cement*: Finely ground material which on addition of water is capable of hardening both under water and in air, by the chemical action of its constituents with water and also capable of binding together appropriate materials.
- (ii) *Increment*: The quantity of cement obtained by the sampling device at a time.
- (iii) *Lot*: The quantity of the cement of the same manufacturer or source not exceeding 2000 tonnes, inspected for testing is called a lot.
- (iv) *Sub-lot*: Before sampling, a lot is divided into a number of sub-lots of equal size.
- (v) *Gross sample*: The unit samples or increments collected from sub-lots constitute gross sample.
- (vi) *Laboratory sample*: The gross sample is reduced by specified procedures to obtain samples for laboratory testing.
- (vii) *Composite sample*: It is the quantity of cement obtained by mixing together equal quantity of cement from the laboratory samples representing the sub-lots.

In drawing, preparing and handling test samples, the following precautions shall be taken:

- a) The sampling device shall be clean and dry when used.
- b) Contamination of the sample, sampling device or container shall be eliminated.

- c) The sample containers shall be selected that it is almost fully filled with the sample.
- d) The sample containers shall be sealed air-tight after sampling and particulars of sample, date of sampling etc marked on it.
- e) The sample shall be stored at a normal temperature.
- f) The location of sampling shall be clean, dry and free from breeze.
- g) The interval of drawing the increments shall be uniform in terms of the mass of the lot or sub-lot. If the rate of the quantity handled is uniform, increments may be taken based on time interval.

2. Sampling from conveyors

- a) Wherever possible, cement samples shall be obtained when it is in motion, like from conveyor belts or during loading and unloading.
- b) For the purpose of sampling, a lot while it is being discharged over a conveyor shall be divided into a number of sub-lots in accordance with table 1.
- c) A representative gross sample is collected from each of the sub-lots and kept separately.
- d) When the cement is in motion, sample increments shall be taken direct from the point where the material is discharged from the conveyor belt.

Table 1: *Number of sub-lots recommended for different lot sizes.*

Sl. No.	*Weight of tot size in tonnes*	*No of sub-lots*
1	Up to 100	2
2	101 to 200	3
3	201 to 300	4
4	301 to 500	5
5	501 to 1000	6
6	1001 to 2000	7

e) The sample shall be collected from full width of the stream, without over flowing the sampling pan or any other collecting device.
f) If sampling is not possible at the discharge point, samples may be obtained from the moving belt.
g) Using a scoop, samples are taken from centre and the left and right side of the moving stream along the same width. For this, the conveyor belt may be stopped, if possible.
h) The increments from sub-lots are placed directly in moisture-proof, air-tight containers to avoid moisture absorption and aeration of the sample.
i) One increment is taken from every 10 tonnes or part thereof from the material discharged and the weight of one increment shall not be less than 2 kg.
j) If the increments are placed in cans, the cans are filled completely and sealed immediately.
k) Moisture proof multiple wall paper bags or plastic bags may be used if they are strong enough to avoid breakage.
l) Sealing of paper bags or plastic bags may be done immediately after filling, to eliminate excess air in the bag and avoid moisture absorption and aeration of the sample.
m) The sample containers or bags shall carry suitable identification marks so that they can be related back to the particular sub-lot from where the sample was obtained.

3. Sampling from wagons

This is applied when loose cement is received in wagons. For the purpose of sampling, all the wagons shall be divided into convenient sub-lots of approximately equal number of wagons as given in table 1.

a) A representative gross sample is collected from each of the sub-lots and kept separately.
b) A slotted tube sampler 60 cm long is used for obtaining sample increments. Samples are to be collected from at least six points in each selected wagon.

c) From each selected wagon, approximately equal number of increments is taken and the weight of one increment shall not be less than 2 kg.
d) If the increments are placed in cans, the cans are filled completely and sealed immediately.
e) Moisture proof multiple wall paper bags or plastic bags may be used if they are strong enough to avoid breakage.

f) Sealing of paper bags or plastic bags may be done immediately after filling, to eliminate excess air in the bag and avoid moisture absorption and aeration of the sample.
g) The sample containers or bags shall carry suitable identification marks so that they can be related back to the particular sub-lot from where the sample was obtained.

4. Sampling from bulk storage (Silos)

For the purpose of sampling, the quantity of cement in the bulk storage shall be divided into convenient sub-lots depending on the weight of the lot, as given in table 1.

a) The gross sample from a sub-lot is obtained by taking increments at regular intervals when the cement is being discharged into the bulk storage or discharged from it.
b) One increment is taken from every 10 tonnes or part thereof from the material discharged and the weight of one increment shall not be less than 2 kg.
c) If the increments are placed in cans, the cans are filled completely and sealed immediately.
d) Moisture proof multiple wall paper bags or plastic bags may be used if they are strong enough to avoid breakage.
e) Sealing of paper bags or plastic bags may be done immediately after filling, to eliminate excess air in the bag and avoid moisture absorption and aeration of the sample.
f) The sample containers or bags shall carry suitable identification marks so that they can be related back to the particular sub-lot from where the sample was obtained.
g) It shall be ensured that the cement sample collected is sufficient for all the required tests.
h) A representative gross sample is collected from each of the sub-lots and kept separately.

5. Sampling from bags

For the purpose of sampling, the quantity of cement in the lot shall be divided into a number of sub-lots depending on the weight of the lot, in accordance with table 1.

a) The sub-lots shall be approximately equal number of bags.
b) For getting a representative gross sample from a sub-lot, at least 2% of the bags subject to a minimum of 5 bags shall be sampled. In case fractional number is obtained, it shall be rounded to the next higher number.
c) The bags are selected at random from the sub-lots. For details of random sampling, IS: 4905 may be referred.
d) A sampling tube is inserted into the bag and sample of cement collected in two or three operations.
e) Equal number of increments is taken from each selected bag and the weight of each increment shall not be less than 2 kg.
f) If the increments are placed in cans, the cans are filled completely and sealed immediately.
g) Moisture proof multiple wall paper bags or plastic bags may be used if they are strong enough to avoid breakage.
h) Sealing of paper bags or plastic bags may be done immediately after filling, to eliminate excess air in the bag and avoid moisture absorption and aeration of the sample.

i) The sample containers or bags shall carry suitable identification marks so that they can be related back to the particular sub-lot from where the sample was obtained.

j) It shall be ensured that the cement sample collected is sufficient for all the required tests.

6. Reduction of gross sample

a) Each gross sample shall be reduced separately.

b) The material of the gross sample is thoroughly mixed, breaking lumps and removing foreign matters.

c) The cement sample is then passed through 850 micron IS sieve. Hardened lumps and foreign matters are discarded.

d) Equal quantities of material from lot samples may be taken and mixed together to form a composite sample representing the whole lot.

e) *Reduction by Riffle Divider*: The gross sample shall be well mixed and poured into riffle boxes. The process shall be repeated till test sample of suitable size is obtained.

f) *Method of quartering*: The method of quartering can be adopted for sample reduction. The cement is thoroughly mixed and heaped into a cone shaped pile using a scoop. The cone is then flattened using the smooth surface of the scoop. The flattened cone is cut into 4 quarters by making two deep lines at right angles. The bulk of the sample is reduced by rejecting one set of opposite quarters.

g) The process of reduction of gross sample shall be continued till 11 kg of the material, required to carry out the specified tests, is obtained.

h) The laboratory sample and composite sample are divided into three equal parts, one for the Client, one for the Contractor and one for third party testing in case of disputes.

7. Tests on cement samples

The laboratory samples of cement are subjected to chemical and physical requirement tests given below:

(i) Total sulphur content as sulphuric anhydride.

(ii) Fineness.

(iii) Setting time.

(iv) Strength.

(v) Soundness.

If three or more test results are obtained the compliance to specification is verified statistically by calculating ($x \pm 0.5R$) which shall be within the limits prescribed.

Where,

x = Average = Sum of all the test results/number of tests.

R = Range = Difference between the maximum and minimum values of the test results.

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DETERMINATION OF FINENESS OF CEMENT BY DRY SIEVING

IS: 4031 - Part 1

1. Introduction

This test method covers the determination of the fineness of cement by sieving it on standard sieve.

2. Apparatus

(i) IS sieve 90 micron with tray fitting beneath the sieve frame and a lid fitting above it shall be provided to avoid loss of material during sieving.
(i) A balance capable of weighing up to 10 gm to the nearest 10 mg.
(ii) A brush for cleaning the sieve.

3. Procedure

a) Shake the sample of cement to be tested for 2 minutes in a closed jar to disperse agglomerates. Wait for 2 minutes.
b) Stir the resulting powder gently using a clean dry rod.
c) Weigh approximately 10 gm of cement and place it on the 90 micron sieve with the tray under the sieve.
d) Break down any air set lumps in the cement sample with fingers. Fit the lid over the sieve.
e) Sieve the sample continuously by swirling, planetary and linear movements until no more fine material passes through it.
f) Weigh the residue and express its mass as a percentage R_1 of the quantity first placed on the sieve to the nearest 0.1%.
g) Repeat the whole procedure using a fresh 10 gm sample to obtain R_2.
h) Then calculate the residue of the cement R as the mean of R_1 and R_2 as a percentage, expressed to the nearest 0.1%.
i) If the results differ by more than 1%, then carry out a third sieving and calculate the mean of the three values.
j) In case where correction factor (F) is to be applied, then the residue R shall be corrected by multiplying by F.

4. Checking the sieve

a) The sieve should be checked after every 100 sievings.
b) For this, the above procedure should be repeated and two values of residue of cement should be found.
c) Let this be $P_1$and P_2 expressed to the nearest 0.1%. For a satisfactory sieve the two values of P_1 and P_2 should not differ by more than 0.3%.
d) The mean value is taken as P.
e) Get a reference sample with known residue (M) on the 90 micron sieve.
f) Calculate M/P as the sieve factor, F, expressed to the nearest 0.01.
g) The residue R is multiplied by F which may have a value of 1.0±0.2.

5. Reporting of results

Report the value of R, to the nearest 0.1%, as the residue on the 90 micron sieve for the cement tested.

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DETERMINATION OF FINENESS OF CEMENT USING BLAINE'S AIR PERMEABILITY APPARATUS

IS: 4031 - Part 2

1. Introduction

This test method covers the determination of the fineness of hydraulic cement using the Blaine air permeability apparatus. The variable flow type air permeability apparatus (Blaine type) and the accessories shall conform to IS: 5516.

The fineness of cement is indicated in terms of specific surface and is expressed as the total surface area in square centimeters per gram or square meter per kilogram of cement.

2. Apparatus

(i) The Blaine air permeability apparatus consists essentially of an arrangement to draw a definite quantity of air through a prepared bed of cement of definite porosity. The rate of air flow through the bed depends on the number and size of the pores in the cement bed which is a function of the particle size of the cement tested.

(ii) The permeability cell shall consist of a rigid cylinder 12.7±0.1 mm inside diameter, constructed with austenitic stainless steel with interior finish of 0.81 µm. The bottom of the cell must be able to form an air tight fit with the upper end of the manometer. A ledge 0.5 to 1.0 mm shall be fitted at 55 ± 10 mm from top of the cell to support the perforated metal disc.

(iii) The disc shall be constructed of non-corrodible metal 0.9±0.1 mm thick, perforated 30 to 40 holes 1 mm diameter equally distributed over its area. Inscribe a suitable mark on one side of the disc to ensure that this face is always on the down side.

(iv) The plunger shall be made with austenitic stainless steel and shall fit inside the cell with clearance not more than 0.1 mm. The bottom of the plunger shall sharply meet the lateral surfaces. An air vent 3.0±0.3 mm wide shall be provided on one side of the plunger. The plunger is provided with a collar at the top which will rest on the top of the cell such that the gap between the bottom of the plunger and top of the perforated plate shall be mm 15 ± 1 mm.

(v) Circular discs of filter paper of medium porosity (Mean pore dia 7 mic) having a smooth circumference adapted to the dimensions of the cell.

(vi) The standard glass-wall U-tube manometer shall have a nominal outside diameter of 9 mm. The top of one arm should form an air tight connection with the permeability cell. A side out let for evacuation shall be provided at 250 to 305 mm above the bottom of the manometer. The manometer shall be etched with a line 125 to 140 mm below the outlet and three other lines at 15±1 mm, 70±1 mm and 110±1 mm above this line. A positive air tight valve shall be connected to the side out let not more than 50 mm away from the arm of the manometer. The manometer shall be mounted firmly such that the arms are vertical.

(vii) Non-volatile, non-hygroscopic liquid of low viscosity and density like Dibutyl phthalate or light grade mineral oil as manometer liquid.

(viii) Mercury of reagent grade or better.

(ix) Light grease for ensuring an airtight joint between cell and manometer and in the stopcock.

(x) Pyknometer or other convenient means of determining the density of cement.

(xi) Time with starting and stopping mechanisms and to read to the nearest 0.2 seconds.

(xii) Standard weights.

3. Preparation of compacted bed of cement

a) Samples of cement for testing shall be taken in accordance with the requirements of IS: 3535 and the relevant standard specification for the type of cement tested.

b) Agitate the sample for 2 minutes in a stoppered jar to disperse agglomerates. Stir the powder with a clean dry rod to distribute the fines uniformly.

c) Determine the density of cement sample using Pyknometer or Le-chatelier flask. Use a non-reactive liquid such as kerosene for the test. Calculate the density of cement ρ to the accuracy of 0.01 gm/cm^3 from the mean of two determinations.

d) The weight of cement m_1 required to produce a porosity $e = 0.500$ is calculated from the formula:

$$m_1 = 0.500\ \rho\ V$$ where V= volume of the cement bed for testing.

e) Place the perforated disc on the ledge at the bottom of the cell. Place a new filter paper disc flat on it. Weigh the calculated quantity of cement and place it in the cell without any loss. Gently tap the cell to level the cement. Place a new filter paper on the top of the cement.

f) Insert the plunger to make contact with the disc. Press gently until the lower face of the cap is in contact with the cell. Slowly lift the plunger for about 5 mm, rotate for 90° and press the cement bed firmly until the plunger cap is in contact with the cell. Avoid exerting too much pressure on the sample bed. The bed is now ready for permeability test. Slowly withdraw the plunger.

4. Calibration of the apparatus

The testing and calibration of the apparatus shall be made at a laboratory temperature of 27±2°C and relative humidity not exceeding 65%.

4.1 *Bulk volume of compacted bed of powder by mercury displacement*

a) Apply a thin film of light mineral oil to the cell interior.

b) Place the perforated disc on the ledge in the cell. Place two filter paper disks on the perforated disc. Push them with a rod until they are placed flat on the perforated metal disk.

c) Fill the cell with mercury without any air bubbles. Use tong when handling the cell.

d) Press the top of mercury with a glass plate and flush the surface with the top edge of the cell. Ensure that no air bubbles or voids exist between the mercury and the glass plate.

e) Remove the mercury from the cell and record its mass m_2 to the nearest 0.01 gm. Record the temperature also.

f) Remove one filter disc from the cell and form a compacted bed of cement as described earlier. Place a new paper disc and compress the cement.

g) Pour mercury over the filter disc till the space left in the cell is filled up. Remove the entrapped air and level off the mercury as before.

h) Remove the mercury and record its mass m_3 to the nearest 0.01 gm, noting the temperature also.

i) Calculate the volume V of cement bed as follows:

$V = (m_2 – m_3)/D$ cm^3) where,

m^2 = Mass of mercury required to fill the cell without cement bed, in gm.

m^3 = Mass of mercury in gm required to fill above the cement bed in the cell in gm and

D = Density of mercury at the time of test in gm/cm^3.

j) The density of mercury at the test temperature may be taken from table 1 given below:

Table 1: *Temperature Vs Density of mercury D, Air viscosity (μ) and* $\sqrt{0.1\mu}$

Temperature	*Density of mercury gm/cm3*	*Viscosity of air, μ Pa.S*	$\sqrt{0.1\mu}$
16	13.56	0.00001788	0.001337
18	13.55	0.00001798	0.001341
20	13.55	0.00001808	0.001345
22	13.54	0.00001818	0.001348
24	13.54	0.00001828	0.001352
26	13.53	0.00001837	0.001355
28	13.53	0.00001847	0.001359
30	13.52	0.00001857	0.001363
32	13.52	0.00001867	0.001366
34	13.51	0.00001876	0.001370

NOTE*: Intermediate value shall be obtained by linear interpolation*

k) Take average of at least two determinations of bulk volume of cement bed agreeing within ±0.005 cm^3 and record this as V.

l) Note the temperature in the vicinity of the cell at the beginning and end of determination.

m) Adjust the volume of cement to get the required porosity.

NOTE: *Care should be taken to avoid splashing or spilling of mercury and contact with the skin of the technician*.

4.2 Air permeability test

a) Attach the permeability cell to the socket at the top of manometer tube ensuring an airtight connection without disturbing the cement bed.

b) Apply a little grease if required.

c) Open the stopcock and slowly evacuate the air in one arm of the manometer tube until the liquid reaches the top mark. Close the stopcock.

d) If the level of liquid falls, improve the sealing till the level is maintained steady.

e) Remove the top plug. The manometer liquid will begin to fall.

f) Start the timer when the bottom meniscus of the manometer liquid reaches the second mark and stop when it reaches the third mark (next to the bottom).

g) Note the time interval *t* to the nearest 0.2 seconds and test temperature to the nearest °C.

h) Repeat the procedure with the same bed to get additional values of time and temperature.

i) Carry out the permeability test on a second cement bed, two times.

NOTE: *The calibration and fineness shall be determined by the same technician*.

The specific surface S is given by the equation $S = (K/\rho) \times \sqrt{e^3}/(1-e) \times [\sqrt{t}/\sqrt{0.1\mu}]$.

5. Procedure

a) The cement sample shall be at room temperature when used.

b) The mass of sample shall be the same as that used in the calibration test on the standard sample.

c) However for cements other than Ordinary Portland cement, the test bed may be prepared for a porosity of 0.530±0.005.

d) The preparation of bed is done as described in 3 above.

e) Carry out the permeability tests in accordance with the method described in 4.2 above. Only one time of flow determination is made on each bed.

6. Calculation

Calculate the specific surface values with the following equation:

$S = (K/\rho) \times \sqrt{e^3}/(1-e) \times [\sqrt{t}/\sqrt{0.1\mu}]$ where

K = Apparatus constant

ρ = Density of cement in gm/cm^3

e = Porosity of cement

t = Time in seconds

μ = Viscosity of air at the test temperature (From table 1)

When porosity is specified as 0.500, the equation simplifies to

$S = [521.08\ K\sqrt{t}\ ]/\ \rho$ cm2/gm at temperature 27±2°C and

$S = [524.2\ K\sqrt{t}\ ]/\ \rho$ cm2/gm at temperature 20±2°C.

The specific surface values of cm^2/gm are rounded to the nearest 10 units and values in m^2/kg to the nearest unit.

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DETERMINATION OF CONSISTENCY OF STANDARD CEMENT PASTE

IS: 4031 - Part 4

1. Introduction

This test method covers the determination of quantity of water required to produce a cement paste of standard consistency. The standard consistency of a cement paste is defined as that consistency which will permit the Vicat plunger having 10 mm diameter and 50 mm length to penetrate up to a depth of 5 to 7 mm from the bottom of the Vicat mould.

2. Apparatus

(i) The Vicat apparatus, conforming to IS: 5513-1976, consisting of a frame having movable rod with a platform at one end with the following that can be attached at the other end:
  - Needle for determining the initial setting time.
  - Needle for determining the final setting time.
  - Plunger with a diameter of 10±0.05 mm and a length of 50±1mm, for determining the standard consistency.

(ii) A balance with permissible variation at a load of 1000 gm shall be ±1.0 gm.

(iii) Standard weights for weighing cement.

(iv) Gauging trowel.

3. Procedure

a) Prepare a paste of weighted quantity of cement with a weighed quantity of potable or distilled water taking care that the time of gauging is 3-5 minutes, and the gauging shall be completed before any sign of setting occurs.

b) The time counted from the time of adding water to the dry cement until commencing to fill the mould is called gauging time.

c) Fill the Vicat mould with this paste, the mould resting upon a non-porous plate.

d) After completely filling the mould, smoothen the surface of the paste, making it level with the top of the mould.

e) Shake the mould to expel the air.

f) Place the test block in the mould along with the non-porous resting plate, under the rod bearing the plunger.

g) Lower the plunger gently to touch the surface of the test block, and quickly release, allowing it to shrink into the paste by its own weight.

h) This operation shall be carried out immediately after filling the mould.

i) Take the reading from the indicator of the un-penetrated depth by the plunger.

j) Similarly conduct trials with varying percentages of water as described above until the amount of water necessary for making up the standard consistency is obtained.

4. Result

Express the amount of water as a percentage by mass of the dry cement to the first place of decimal.

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DETERMINATION OF INITIAL AND FINAL SETTING TIME OF CEMENT

IS: 4031 - Part 5

1. Introduction

This test method determine the time of setting of cement by means of the Vicat's needle. The initial setting time is the interval between the addition of water to cement and the stage at which needle stops to penetrate at 5+0.05mm from the bottom. The final setting time is the period elapsing between the time when water is added to the cement and time at which the circular cutting edge fails to make an impression on the surface of the test block.

2. Apparatus

(i) The Vicat apparatus (conforming to IS: 5513-1976) shall consist of a frame having a movable rod with a platform at one end and the following which can be attached at the other end:
  - (a) Needle C for determining the initial setting time.
  - (b) Needle for determining the final setting time.
  - (c) Plunger G with a dia of 10+0.05 mm and a length of 50+1 mm, for determining the standard consistency.

(ii) A balance with permissible variation at a load of 1000 gm shall be +1.0 gm.

(iii) Standard weights for weighing cement.

(iv) Gauging trowel.

3. Temperature and humidity

a) The temperature of moulding room, dry materials and water shall be maintained at 27+2°C.

b) The relative humidity of the laboratory shall be 65%.

c) The moist room shall be maintained at 27±2°C and at a relative humidity of not less than 90%.

4. Standard Consistency

The Standard Consistency of a cement paste is defined as that consistency which will permit a Vicat Plunger 10 mm dia and 50 mm long will penetrate to a depth of 33-35 mm from top of the mould. The equipment used to determine the Standard Consistency (Usually denoted as 'P) is called Vicat's Apparatus. Standard Consistency is sometimes referred as normal consistency.

5. Preparation of sample

a) Prepare a paste of 500 gm of cement with 0.85 times the water required for to make a cement paste of Standard Consistency.

b) The gauging time counted from the time of adding water to the dry cement until commencing to fill the mould is 3-5 minutes.

c) Potable or distilled water shall be used in preparing the paste.

d) Fill the Vicat mould with a cement paste gauged as above with the mould resting on a non-porous plate.

e) Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

f) Immediately after moulding, place the test block in the moist closet or moist room and allow it to remain there except when determinations of time of setting are being made.

g) Keep all apparatus free from vibrations during the test and keep the Vicat needle clean and straight.

6. Procedure for determining initial setting time

a) Place the test block, under the rod bearing the needle.
b) Lower the needle gently until it comes in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block.
c) In the beginning, the needle will completely pierce the test block. Repeat this procedure until the needle, fails to pierce the block beyond 5.0±0.5 mm measured from the bottom of the mould.
d) The elapsed time when water is added to the cement and the time at which the needle fails to pierce the test block to a point 5.0±0.5 mm shall be the initial setting time.

7. Procedure for determining final setting time

a) Replace the rod bearing needle of the Vicat apparatus by the needle with circular attachment.
b) Lower the needle gently to the surface of the test block.
c) The cement shall be considered as finally set, when the needle makes an impression, while the attachment fails to do so.
d) The elapsed time when water is added to the cement and the time at which the needle makes an impression on the surface of test block while the attachment fails to do so shall be the final setting time.
e) In the event of a scum forming on the surface of the test block, use the underside of the block for the determination.

8. Reporting the result

The results of initial and final setting time shall be reported to the nearest five minutes.

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DETERMINATION OF SOUNDNESS BY LE-CHATELIER METHOD

IS: 4031 - Part 3

1. Introduction

Cement should not exhibit large change in volume after setting. Soundness of cement is determined to ensure that the cement does not show any appreciable subsequent expansion after setting. This test method covers the determination of the soundness of hydraulic cement by Le-Chatelier method. The apparatus for conducting the Le-Chatelier test shall conform to IS: 5514-1969.

2. Apparatus

(i) Le-Chatelier apparatus with a pair of glass base plate and cover plates for each mould.
(ii) A balance or scale of capacity not less than 1000 gm, readable and accurate to 1 gm.
(iii) Standard weights with permissible variations in weight as stipulated in table 1 of IS: 4031 Part 3-1988.
(iv) A water bath capable of immersing the Le-Chatelier moulds with specimens and of raising their temperature from 27±2°C to boiling in 27±3 minutes.

3. Procedure

a) Samples of cement for testing shall be taken in accordance with the requirements of IS: 3535 and the relevant standard specification for the type of cement tested.
b) The temperature of the moulding room, dry materials and water shall be maintained at 27±2°C. The-relative humidity of the laboratory shall be 65±5%.
c) The moist closet or moist room shall be maintained at 27±2°C and at a relative humidity of not less than 90%.
d) Place the lightly oiled mould on a lightly oiled glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency [See IS: 4031 (Part 4) -1988].
e) The paste shall be gauged in the manner and under the conditions prescribed in IS: 4031 (Part 4) - 1988, taking care to keep the edges of the mould gently together while this operation is being performed.
f) Cover the mould with another piece of lightly oiled glass sheet and place a small weight on this covering glass sheet.
g) Immediately submerge the whole assembly in water maintained at a temperature of 27±2°C and keep there for 24 hours.
h) Measure the distance separating the indicator points to the nearest 0.5 mm.
i) Submerge the mould again in water at the temperature prescribed above. Bring the water to boiling, with the mould kept submerged in 25 to 30 minutes, and keep it boiling, for three hours.
j) Remove the mould from the water, allow it to cool and measure the distance between the indicator points.
k) The difference between the two measurements indicates the expansion of the cement.

4. Calculation

Calculate the mean of two values to the nearest 0.5 mm to represent the expansion of cement.

In the event of cement failing to meet the test for soundness, a retest may be made after aeration as given below:

a) Spread out the cement in a layer of 75 mm thickness.
b) Store it for 7 days in an atmosphere maintained at 27±2°C and relative humidity of 50 to 80 percent.
c) Retest this cement.

****

DETERMINATION OF COMPRESSIVE STRENGTH OF CEMENT

IS: 4031 - Part 6

1. Introduction

This part explains the procedure to find the strength of cement as represented by the compressive strength of standard cement mortar cubes compacted by standard vibration machine.

2. Apparatus

(i) Compression testing machine.
(ii) 7.06 cm cube moulds conforming to IS: 10080-1982.
(iii) Vibration machine conforming to IS: 10080-1982.
(iv) Poking rod conforming to IS: 10080-1982.
(v) Gauging trowel with steel blade with straight edges 100 to 150 mm long, weighing 210±10 gm.
(vi) Balance with a permissible variation of ±10 gm for 1000 gm.
(vii) Standard weights.
(viii) Graduated glass cylinders of 150 to 200 ml capacity.
(ix) Standard sand conforming to IS: 650-1991.

The standard sand shall be of quartz of light, gray or whitish variety and shall be free from silt. The sand grains shall be angular, the shape of grains approximating to the spherical form, elongated and flattened grains being present only in very small quantities. Standard sand shall pass through 2 mm IS sieve and shall be retained on 90 microns IS sieve with the following particle size distribution.

Particle size	*Requirement %*
Greater than 1 mm and less than 2 mm	33.33
Smaller than 1 mm and less than 500 micron	33.33
Less than 500 micron	33.33

3. Sample preparation

a) Maintain the temperature of room and water at 27±1°C throughout the test period.
b) Use only potable/distilled water for making test cubes.
c) Take 200 gm of cement and 600 gm of standard sand in a clean dry pan. Mix the cement and sand in dry condition with a trowel for 1 minutes and then select water to be added. The quantity of water shall be [(P/4) +3] % of combined weight of cement and sand where, P is the % of water required to produce a paste of standard consistency determined earlier as per IS: 4031 Part 4.
d) Add water and mix it until the mixture is of uniform colour. The time of mixing shall not be less than 3 minutes and not greater than 4 minutes.
e) Immediately after mixing the mortar, place the mortar in the cube mould and prod with the help of the rod.
f) The mortar shall be prodded 20 times in about 8 seconds to ensure elimination of entrained air and honey combing. If vibrator is used, the period of vibration shall be 2 minutes at the specified speed of 12000±400 vibrations /minute.
g) Keep the compacted cube mould at a temperature of 27±2°C and 90% relative humidity for 24 hours. After 24 hours, remove the cubes from the mould and immediately submerge in clean water till testing.

h) Take out the cubes from water just before testing. Testing should be done on their sides without any packing.

i) The rate of loading should be 350 kg/cm^2/minute and uniform. Test should be conducted for 3 cubes and report the average value as the test result for both 7day and 28 day compressive strength.

4. Calculation

Calculate the compressive strength of the cube tested by dividing the maximum test load by the cross sectional area.

$$\text{Compressive Strength} = \frac{\text{Maximum load applied}}{\text{Mean cross-sectional area of the specimen}} \ \text{kg/cm}^2$$

Defective specimens and strength values differing by more than 10% shall be discarded from the average value of compressive strength. After discarding specimens or test values a minimum of two values shall be available for calculating the average strength. If two values are not available for a particular age, the test shall be repeated.

5. Reporting of results

The compressive strength values are reported to the nearest kg/cm^2 or to the nearest 0.5 units of N/mm^2.

****

SLUMP TEST FOR DETERMINING WORKABILITY OF CONCRETE

IS: 1199

1. Introduction

This test method covers the determination of slump of concrete both in the laboratory and in the field. A sample of freshly mixed concrete is placed and compacted by rodding, in a mould having the shape of the frustum of a cone. The mould is then raised and the concrete is allowed to subside. The distance between the original position and the displaced center of the top surface of the concrete is measured and reported as slump of the concrete. This method is not applicable to aggregate sizes larger than 38 mm.

2. Apparatus

(i) Mould for placing concrete made of metal (brass or aluminium shall not be used) not attacked by cement paste. The mould shall be in the shape of the lateral surface of the frustum of a cone with base 200 mm diameter, top 100 mm diameter and height 300 mm. Interior of the mould shall be smooth and free from projections. It shall be provided with suitable foot pieces and also handles to facilitate lifting.

(ii) A round straight steel tamping rod of 16 mm diameter and about 600 mm long. The tip for tamping shall be rounded to hemispherical shape.

3. Sample size

a) The concrete sample selected for the test shall be representative of the entire batch of concrete and shall be not less than 0.02 m3 in volume.

b) It shall be composed of a mixture of portions taken from different points in the batch.

c) In case of concrete containing aggregate of maximum size more than 38 mm, the concrete shall be wet-sieved through 37.5 mm screen to exclude bigger aggregate particles.

4. Procedure

a) Clean the mould and place it on a flat, non-absorbent rigid surface.

b) It shall be held firmly in place by the operator standing on the two foot pieces during filling with concrete.

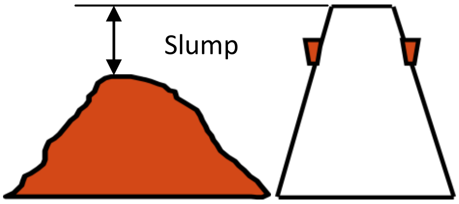
c) The mould shall be filled in four layers, each approximately one-quarter of the height of the mould.

d) Each layer shall be tamped with twenty-five strokes of the tamping rod.

e) After the top layer has been rodded, the concrete shall be struck off level with a trowel, so that the mould is exactly filled.

f) The mould shall be removed from the concrete immediately by raising it slowly and carefully in a vertical direction.

g) The slump shall be measured immediately by determining the difference between the height of the mould and that of the highest point of the specimen tested.

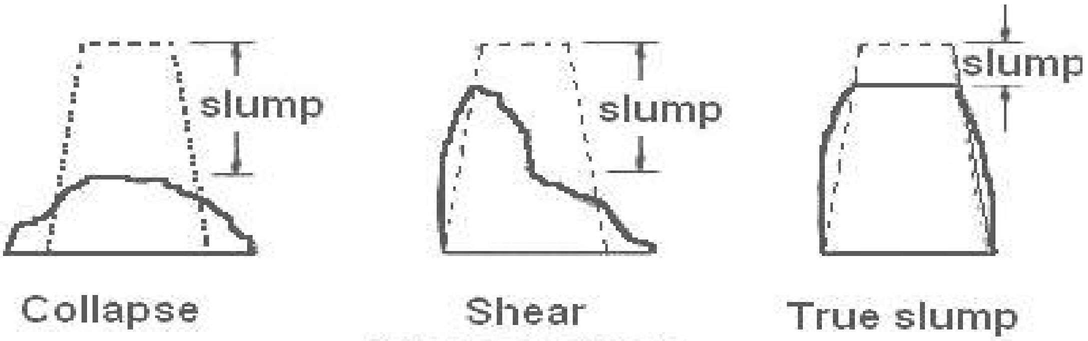


h) The above operations shall be carried out within a period of two minutes after sampling.

5. Calculations

a) The slump measured shall be recorded in terms of millimeters of subsidence of the specimen during the test.

b) Any slump specimen that collapses or shears off laterally gives incorrect result and if this occurs, the test shall be repeated with another sample.



Types of slump

c) If, in the repeat test also, the specimen shears, then the slump shall be measured and the observation that specimen sheared, shall be recorded.

d) After the slump measurement has been completed, the cohesiveness and workability of the mix can be verified gently tamping the side of the concrete with the tamping rod. A well-proportioned concrete will gradually slump further.

e) But if the mix has been badly proportioned, it is likely to fall apart.

f) The value of the slump obtained is compared with the recommended values of the slumps given in IS: 456.

Slump (mm)	*Workability*
Less than 25	Very low
25 - 75	Low
75 - 100	Medium
100- 150	High
More than 150	Very high

****

DETERMINATION OF COMPRESSIVE STRENGTH OF CONCRETE

IS: 516

1. Introduction

The ultimate compressive strength of a material is that value of uni-axial compressive stress reached when the material fails completely. This test method covers the procedure for determination of compressive strength of cement concrete. It is used to ensure the suitability of the available materials or to determine suitable mix proportions. The maximum nominal size of aggregate should not exceed 38 mm.

2. Apparatus

(i) Universal Testing Machine of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate of approximately 140 kg/cm^2 per minute. The permissible error shall be not be greater than ±2% of the maximum load.

(ii) Cube Moulds of 150 mm x 150 mm x 150 mm size preferably made of steel or cast iron, stout enough to prevent distortion.

(iii) Cylinders shall be of metal not less than 3 mm thick, capable of opening longitudinally. When assembled for use, the mean diameter shall be 150±2 mm and height 300±1 mm.

NOTE: *Some standards allow use of plastic moulds for casting specimens for compressive strength test. The shapes of plastic moulds are likely to change after use. In such cases, the dimensions shall be thoroughly checked before reusing the moulds.*

(iv) The base plate shall be of suitable dimension to support during filling without leakage, preferably attached to the mould by springs or screws.

(v) Tamping rod 16 mm diameter, 60 cm long with bullet pointed edge at the lower end.

3. Preparation of specimens

a) During assembling of the mould, the joints and inside of the mould and base plate are coated with a thin film of mould oil or light grease to prevent adhesion of the concrete.

b) The size of test specimens shall be 150 mm x 150 mm x 150 mm. If the maximum nominal size of aggregate in the concrete is not more than 2 mm, 100 mm size cubes may be prepared for testing.

c) Samples of concrete for testing shall be taken immediately after mixing.

d) Each batch of concrete shall be tested for consistency test as per IS: 1199-1959 immediately after mixing. The concrete used for consistency test shall be re-mixed with the concrete sampled before cubes are made.

e) Fill the concrete into the mould in layers of approximately 50 mm. Move the scoop around the top edge of the mould, to ensure symmetrical distribution of concrete in the mould.

f) Each layer of the concrete is given 35 strokes with the tamping rod. For 100 mm size cubes, 25 stokes are specified. For cylindrical specimens, 30 strokes are to be given. The strokes shall penetrate to the underlying and bottom layers.

g) Tap the sides of the mould to close any air voids resulting from tamping process.

h) The surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

i) When mechanical vibration is used for compaction of the concrete specimen, each layer shall be vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table.

j) Cylindrical specimens shall be capped using a thin layer of stiff, neat Portland cement paste or with a sulphur mixture consisting of 2 or 3 parts of sulphur to 1 part of inert filler such as fire-clay. Capping may also be done with hard plaster (Plaster of paris shall not be used) having a compressive strength not less than 140 kg/cm2 attained in one hour.

k) The cubes cast along with the mould and base plate is stored at site for 24±½ hours at a place free from vibration. The mould shall be kept under damp matting, sacks or similar materials. The temperature of storage shall be within 22°C to 32°C.

l) After 24 hours, the cubes are carefully removed from the mould and kept in clean water at 24°C till they are transported to the laboratory for testing.

m) The test cubes shall be transported to the laboratory, well packed in damp sand or sacks, to arrive there in damp condition not less than 24 hours before the time of test.

n) On arrival of the test cubes in the laboratory they are kept in water at 27±2°C till the time of test.

o) Records of daily maximum and minimum temperatures shall be kept during the period specimen remains and site and in the laboratory.

4. Procedure

a) The tests are normally carried out at 7 and 28 days. However during initial periods of the project, 1 day, 3 days and 14 days testing are also done to obtain the performance pattern of the mix.

b) At least three specimens, preferably from different batches, shall be made for testing at each selected age. The age is calculated from the time of adding water to the dry ingredient.

c) Specimen stored in the water is taken out and the surface water, girt and any projecting fins are removed. The bearing plate and the machine are also cleaned.

d) Measure the actual dimension of the specimen and record to the nearest 0.2 mm. Weigh the specimen and record.

e) Place the cube on the bottom plate in such a manner that the load shall be applied to opposite sides of the cubes in contact with the mould during casting. The position of the cube is carefully checked to be in the middle of the plate. No packing shall be used between the faces of the test cube and the plates.

f) The top plate is slowly brought down to touch the top of the cube specimen. A uniform seating shall be ensured by rotating the movable portion of the top plate with hand.

g) The instrument is then adjusted for any zero error. The loading is then started and continued gradually. The maximum load in kg applied on the specimen is noted.

h) The appearance of concrete and the failure pattern is also noted.

5. Calculation

Calculate the compressive strength of the cube tested by dividing the maximum test load by the cross sectional area.

$$\text{Compressive Strength} = \frac{\text{Maximum load applied}}{\text{Mean cross-sectional area of the specimen}} \quad \text{kg/cm}^2$$

The compressive strength values are reported to the nearest kg/cm^2 or to the nearest 10 units of N/mm2.

Average of three values shall be taken as the representative of the batch provided the individual variation is not more than ±15% of the average. Otherwise repeat tests shall be made.

6. Report

The following information shall be included in the report:

(i) Location of the sample.
(ii) Structure or pavement component.
(iii) Date of casting.
(iv) Identification mark of the specimen.
(v) Date of test.
(vi) Age of specimen at testing date.
(vii) Curing conditions.
(viii) Weight of specimen.
(ix) Dimensions of specimen.
(x) Cross sectional area.
(xi) Maximum load.
(xii) Compressive strength.
(xiii) Appearance of fractured faces of concrete and type of fracture.

A typical format for reporting compressive strength test report is attached for guidance.

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KERALA PUBLIC WORKS DEPARTMENT

Form No. QC-C1/2015

CONCRETE CUBE TEST DATA
IS: 516

Report No.

Date:

REGIONAL LABORATORY:

DISTRICT LABORATORY:

Name of work:

Division:

Sub Division:

Section:

TYPE OF STRUCTURE: Building / bridge / culvert / pavement/

COMPONENT | Column / beam | Foundation | Pier/abutment | Slab

Sl. No.	Date of test	Date cast	Age days	ID #	Mix type	Length mm	Breadth mm	Height mm	Weight gm	Density gm/cm^3	Max load kN	Comp strength kN/mm^2	Failure type	Remarks
1														
2														
3														
4														
5														
6														
7														
8														
9														

RESULT:

Compressive strength at ……………. days = kN/mm^2

Required value: kN/mm^2

Tested: Technician/Overseer (QC)	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF FLEXURAL STRENGTH OF CONCRETE

IS: 516

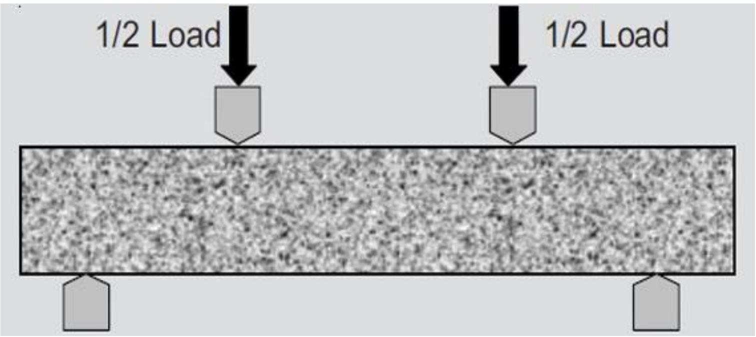
1. Introduction

Flexural strength is a parameter that indicates the capacity of concrete to withstand bending stress. The flexural strength is expressed as Modulus of Rupture (MR) in MPa or Kg/cm^2 and is determined by third-point loading or centre point loading method.

Flexural tests are extremely sensitive to specimen preparation, handling, and curing procedure. Beams are very heavy and can be damaged when handled and transported from the jobsite to the lab. Allowing a beam to dry will yield lower strengths. Beams must be cured in a standard manner, and tested while wet. Meeting all these requirements on a job site is extremely difficult, often resulting in unreliable and generally low values.

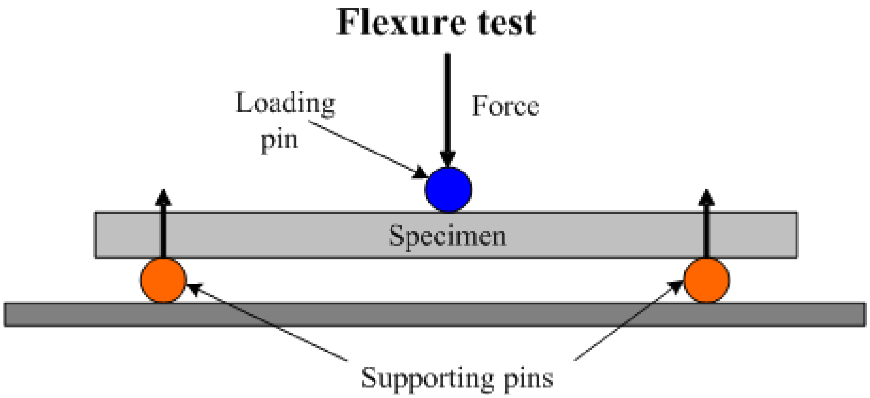
2. Apparatus

a) The mould for casting flexural strength test specimens shall made of metal, preferably steel or cast iron and of sufficient thickness to prevent spreading or warping.
b) The mould constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimens without damage.
c) Each mould provided with a metal base plate and two loose top plates of 4.0 x 0.6 cm cross-section and 5.0 cm longer than the width of the mould.
d) The height of the mould is 15.0±0.005 cm or 10.0±0.005 cm, and the corresponding internal width of the mould is 15.0±0·02 cm or 10.0±0.02 cm respectively.
e) A steel tamping bar 40 cm long, weighing 2 kg, with a ramming face 25 mm^2.
f) The base plate supports and rigidly attached to the mould, without leakage during the filling and subsequent handling of the filled mould.
g) The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the rate specified in procedure. The permissible errors shall be not greater than ± 0·5 percent of the applied load where a high degree of accuracy is required and not greater than ±1·5% of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15·0 cm specimens or 40 cm for 10·0 cm specimens.



h) In two-point loading system, the load shall be applied through two similar rollers mounted at the third points of the supporting span, that is, spaced at 20 or 13·3 cm centre to centre.

i) In centre point loading, the load is applied at the centre of the beam as shown below.



j) The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

3. Preparation of specimens

a) The standard size of specimens for flexural strength test shall be 15x15x70 cm. Alternatively, if the largest nominal size of the aggregate does not exceed 19 mm, 10x10x50 cm size specimens are used.

b) The proportions of the materials, including water in concrete mixes used for determining the suitability of the materials available, are similar in all respects to those to be employed in the work.

c) The preparation of concrete shall be done in the same way as in the case of making compression test specimens.

d) The quantities of cement, each size of aggregate and water for each batch shall be determined by weight, to an accuracy of 0.1% of the total weight of the batch.

e) Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test beams/cubes and the unit weights of the materials.

f) The concrete mixed by hand or preferably in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials.

g) Each batch of concrete shall be of such a size as to leave about 10 percent excess after moulding the desired number of test specimen.

h) Each batch of concrete tested for consistency immediately after mixing by one of the methods described in IS: 1199-1959.

i) Provided that care is taken to ensure that no water or other material is lost, the concrete used for the consistency tests may be remixed with the reminder of batch before making the test specimen. The period of remixing shall be as short as possible, yet sufficient to produce a homogeneous mass.

j) Apply the mould oil to the inner faces of the mould to ensure that no water escapes during the filling of the mould, and also ensure that to prevent the adhesion of concrete.

k) At least three specimens, preferably from different batches, shall, be made from testing at each selected age.

l) The test specimens are stored in a place, free from vibration, in moist air of at least 90% relative humidity and at a temperature of 27±2°C for 24±½ hours from the time of addition of water to the dry ingredients.

m) After this period the specimens marked and removed from the moulds and, unless required for test within 24 hours, immediately submerged in clean, fresh water or saturated lime solution and kept there until taken out just prior to test. The water or solution in which the specimens are submerged are renewed every seven days and shall be maintained at a temperature of 27±2°C. The specimens are not allowed to become dry at any time until they have been tested.

n) The tests are conducted at recognized ages of the test specimens, the most usual being 7 and 28 days.

o) Ages of 13 weeks and one year are recommended if tests at greater ages are required. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24±½ hours and 72±2 hours.

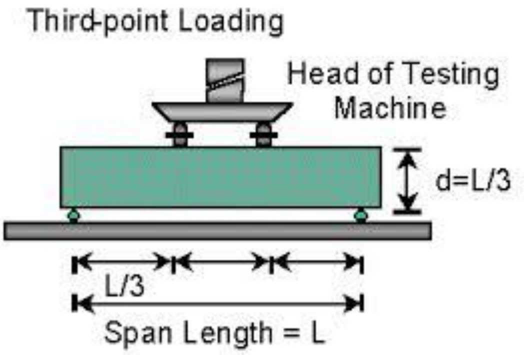
p) The age shall be calculated from the time of the addition of water to the dry ingredients.

4. Procedure

a) The dimensions of each specimen shall be noted before testing. No preparation of the surfaces is required.

b) The bearing surfaces of the supporting and loading rollers shall be wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers.

c) The specimen shall then be placed in the machine in such a manner that the load applied to the uppermost surface as cast in the mould, along two line spaced 20·0 or 13·3 cm apart.



d) The axis of the specimen is carefully aligned with the axis of the loading device.

e) No packing shall be used between the bearing surfaces of the specimen and the rollers.

f) The load is applied without shock and increasing continuously at a rate of loading of 400 kg/min for the 15·0 cm specimens and at a rate of 180 kg/min for the 10·0 cm specimens.

g) The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded.

h) The appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.

5. Calculation

The flexural strength of the specimen shall be expressed as the modulus of rupture f_b calculated to the nearest 0.5 kg/cm^2 depending on ‘a’, which is the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen in cm.

When ‘a’ is greater than 20 cm for a 15 cm specimen or greater than 13.3 cm for a 10 cm specimen, the modulus of rupture f_b shall be calculated to the nearest 0.5 kg/cm^2 as follows:

$f_b = (p \times l)/ bd^2$, where

b = measured width in cm of the specimen.

d = measured depth in cm \If the specimen at the point of failure.

l = length in cm of the span on which the specimen was supported.

p = maximum load in kg applied to the specimen.

If ‘a’ is less than 17 cm for a 15 cm specimen or less than 11 cm for a 10 cm specimen, the results of the test shall be discarded.

When 'a' is less than 20·0 cm but greater than 17 cm for 15 cm or less than 13·3 cm but greater than 11 cm for a 10 cm specimen, f_b shall be calculated as follows:

$$f_b = (3p \times a)/ bd^2$$

6. Test report

The test report shall include the following information on each specimen:

(i) Identification mark.
(ii) Date of sampling.
(iii) Date of test.
(iv) Age of specimen.
(v) Curing conditions.
(vi) Size of specimen.
(vii) Span length.
(viii) Maximum load.
(ix) Position of fracture (Value ‘a’).
(x) Modulus of rupture (kg/cm^2) and
(xi) Appearance of concrete and type of fracture, if these are unusual.

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NON-DESTRUCTIVE TESTING OF CONCRETE USING REBOUND HAMMER

IS: 13311 - Part 2

1. Introduction

The concrete test hammer invented by Ernst Schmidt and introduced by Proceq at the beginning of the 1950's remains to this day the most widely used non-destructive test instrument for a rapid assessment of the condition of a concrete structure.

When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound are related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

2. Apparatus

(i) Rebound Hammer consisting of a spring controlled mass that slides on a plunger within a tubular housing.

(ii) The impact energy required for rebound hammers for different applications are given in table 1.

Table 1: *Impact Energy for rebound hammers for different applications.*

Sl. No.	*Application*	*Approximate Impact Energy required for rebound hammers (Nm)*
i)	For testing normal weight concrete	2.25
ii)	For light weight or small and impact sensitive parts of concrete	0.75
iii)	For mass concrete in roads, airfield pavements and hydraulic structures	30.00

(iii) Testing anvil of steel having Brinell hardness of about 5000 N/mm^2. The readings on anvil for different types of rebound hammers should be indicated by the manufacturer.

3. Correlation between compressive strength and rebound number

The correlation between compressive strength and rebound number can be obtained by simultaneously testing concrete cubes in compression testing machine and using the rebound hammer.

a) The concrete cubes are held in the compressive testing machine and rebound number is determined first. The compressive strength is then determined as per IS: 516.

b) The seating load of 7 N/mm^2 is considered equal to 2.2 Nm of impact energy of the rebound hammer. This load is added to the test load of rebound hammer.

c) For calibrating rebound hammers of lower impact energy (2.2 Nm), 150 mm cubes are sufficient. However for testing large structures, rebound hammer shall be calibrated using at least 300 mm size cubes.
d) Cubes shall be tested only under dry condition.
e) If wet curing is adopted, the specimens are taken out from water and kept in the laboratory atmosphere for 24 hours before testing.
f) Rebound hammer test on wet cubes is not recommended.
g) If wet strength is to be evaluated, a correlation between compressive strengths of wet and dry cubes cast from the same mix is determined.
h) Only the vertical face of the cubes casted shall be used for testing.
i) The point of impact of the hammer needle shall be 20 mm away from the edges and the same point shall not be tested again.

4. Factors affecting rebound index

The rebound numbers are influenced by several factors mentioned below:

(i) *Type of cement* - Concrete made with high alumina cement gives 100% higher strength while concrete with supersulphated cement gives 50% strength than with ordinary Portland cement.

(ii) *Type of aggregate* - Concrete with normal aggregates such as gravel or crushed stones give similar correlations. But concrete with light weight aggregates needs special correlation.

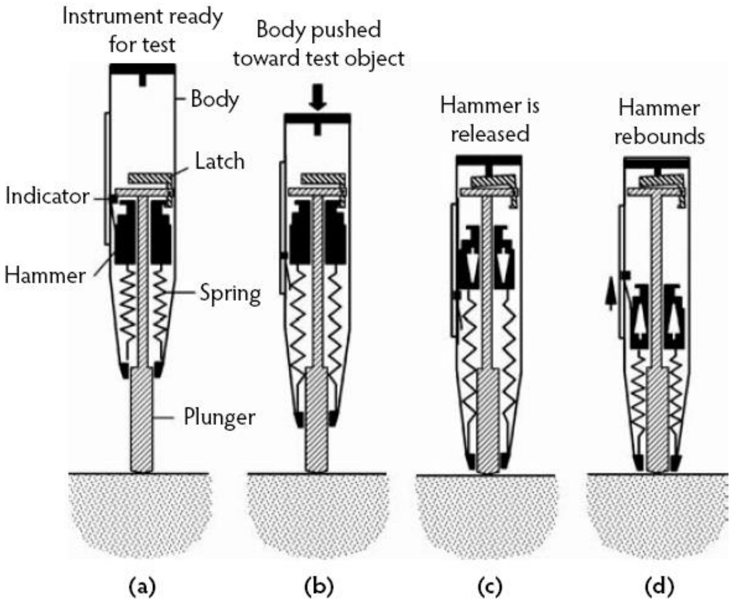
(iii) *Surface condition* - Rebound hammer test is suitable for concrete with smooth surface. Open textured surfaces of masonry blocks, honey-combed concrete or no-fines concrete is not suitable for this test. The correlation assumes full compaction of the concrete. Trowelled or floated surfaces give higher rebound index than moulded surfaces.

(iv) *Moisture content* - In structural concrete, a wet surface may give up to 20% lesser compressive strength than an equivalent concrete with dry surface.

(v) *Curing* - The relationship between hardness and strength of concrete varies as a function of time. The variations in the initial rate of hardening, subsequent curing, conditions of exposure etc also influence the relationship.

(vi) *Age of concrete* – The effect of age can be generally ignored for concrete between 3 days and 3 months old.

(vii) *Carbonation of concrete surface* – Influence of carbonation of concrete surface on the rebound number is very significant. In extreme cases, increased strength up to 50% is



indicated when tested on carbonated concrete surface. Satisfactory results can be obtained after removing the carbonated layer from the concrete and testing on the uncarbonated concrete.

5. Procedure

a) A smooth clean, dry surface is selected for testing. A grinding wheel or stone may be used to make the surface smooth.
b) Rough surfaces resulting from loss of grout, spalling, application of tools etc do not give reliable results and hence shall be avoided.
c) The rebound hammer is held at right angles to the surface.
d) At least six readings are taken around each observation point.
e) After deleting outliers as per IS: 8900-1978, the average value will give the rebound index of the point of observation.

6. Reporting of results

a) If suitable correlation curves are established, rebound hammer test gives a convenient and rapid indication of the compressive strength of concrete.
b) If the concrete is heterogeneous or having internal micro-cracks or flaws, the rebound hammer indices will not be the same.
c) The error in test results when tested on non-uniform concrete surface can be up to ±25%.
d) If the accuracy of the rebound index can be checked with compressive tests core samples or cubes made with the same mix, the results can be predicted with increased perfection.

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METHOD FOR TENSILE TEST OF STEEL

IS: 1608/ISO: 6892

1. Introduction

The tensile testing of metallic materials involves straining a test piece by tensile force, generally to fracture, for the purpose of determining one or more of the mechanical properties. The test is carried out at ambient temperature between 10°C and 35°C, unless otherwise specified. Tests carried out under controlled conditions shall be made at a temperature of 23°C.

2. Apparatus

a) Tensile testing machine of suitable capacity. Universal testing machine (UTM) of 1000 kN capacity, with loading accuracy of +1%, provided with attachments for tension testing of shouldered and threaded specimens is recommended.

b) Extensometer for UTM for measuring elongation of the specimen.

3. Test piece

3.1 *Shape and dimensions*

a) The shape and dimensions of the test pieces depend on the shape and dimensions of the metallic product from which the test pieces are taken. The test piece is usually obtained by machining a sample from the product or a pressed blank or casting.

b) The cross section of the test piece may be circular, square, rectangular, annular or even any other shape.

c) Machined test pieces shall incorporate a transition curve between the gripped ends and the parallel length, if these have different dimensions.

d) The dimensions of this transition radius are important and it is recommended that they may be defined in the material specification if they are not given in the appropriate annexure of IS: 1608.

e) The gripped ends may be of any shape to suit the grips of the testing machine. The axis of the test piece shall coincide with or parallel to the axis of the application of the forces.

f) The parallel length (L_c) or, in the case where the test pieces has no transition curve, the free length between the grips, shall always be greater than the original gauge length L_o.

g) If the test piece consists of an unmachined length of the product or of an unmachined test bar, the free length between the grips shall be sufficient for gauge marks to be at a reasonable distance from the grips.

h) As cast test pieces shall incorporate a transition radius between the gripped ends and the parallel length.

i) The gripped ends may be of any shape to suit the grips of the testing machine. The parallel length (L_c) shall always be greater than the original gauge length L_o.

3.2 *Types*

The main types of test pieces are defined in annexure A to D of IS: 1608 according to the shape and type of product as indicted in table1.

3.3 *Preparation of test pieces*

The test pieces shall be taken and prepared in accordance with the requirements of the relevant international standards (ISO: 377) for the different materials.

Table 1: Main types of test pieces

Type of product		*Reference to annexure of IS: 1608.*
Sheets & flats with thickness given below ▨	*Wires, bars and other sections with dia or side in mm* ◍ ▨ ⬣	
0.1 mm to less than 3 mm	-	A
-	Less than 4 mm	B
3 mm and more	4 mm and more	C
Tubes		D

3.4 *Determination of original cross-sectional area* (S_o)

The original cross sectional area shall be calculated from the measurements of the appropriate dimensions. The accuracy of this calculation depends on the nature and type of the test piece. It is indicated in annexes of A to D for the different types of test piece.

3.5 *Making the original gauge length* (L_o)

Each end of the original gauge length shall be marked by means of fine marks or scribed lines, but not by notches which could result in premature fracture. Annex F gives a nomogram for determining the original gauge length corresponding to the dimensions of the test pieces of rectangular cross sections. The original gauge length shall be marked to an accuracy of ±1%.

If the parallel length (L_c) is much greater than the original gauge length, as, for instance, with unmachined test pieces, a series of overlapping gauge length is drawn.

4. Conditions of testing

a) Unless otherwise specified in the product standard, the speed of testing within the elastic range and up to the upper yield strength (R_{eH}) shall correspond to the stressing rates given in table 2.

Table 2: Rate of stressing

Modulus of Elasticity of the material N/mm^2	*Rate of stressing N/mm^2 per second*	
	Minimum	*Maximum*
<150,000	2	20
≥150,000	6	60

b) If only the lower yield strength (R_{eL}) is to be determined, the rate of straining the parallel length of the test piece shall be between 0.00025/s to 0.0025/s. However the rate of stressing within the elastic range shall not exceed the values in table 2.

c) If both the upper yield strength (R_{eH}) and the lower yield strength (R_{eL}) are to be determined, the conditions for determining lower yield strength (R_{eL}) shall be followed.

d) For determining proof strengths, the rate of stressing shall be as given in table 2. Within the plastic range and up to proof strength, the straining rate shall not exceed 0.0025/s.

e) If the testing machine is not capable of measuring or controlling the strain rate, a cross head separation rate equivalent to the rate of stressing given in table 2 shall be used till the completion of the yield.

f) For determining tensile strength (R_m), the straining rate of the parallel length shall not exceed 0.008/s within the plastic range. If yield stress or proof stress is not required, the maximum rate of the machine permitted in the plastic range may be used.

g) The test pieces shall be held by suitable means such as wedges, screwed grips, shouldered holders etc.

h) Ensure that test pieces are held in such a way that the force is applied as axially as possible.

5. Calculations

5.1 *Determination of percentage elongation after fracture* (*A*)

a) Increase in length of the gauge after removal of the specified stress expressed as a percentage of the original length (L_o) is called percentage permanent elongation.

b) Permanent elongation of the gauge length after fracture (L_u-L_o) expressed as a percentage of the original length (L_o) is called percentage elongation after fracture.

c) Special precautions shall be taken to ensure proper contact between the broken parts of the test piece while measuring the final gauge length.

d) Elongation after fracture (L_u-L_o) is determined to the nearest 0.25 mm with a measuring device of 0.1 mm resolution.

e) The value of percentage elongation after fracture (*A*) is rounded off to the nearest 0.5%.

f) It is not necessary to mark gauge lengths if the machine is fitted with extensometer to measure the extension at fracture.

5.2 *Determination of percentage total elongation at maximum force (A_{gt})*

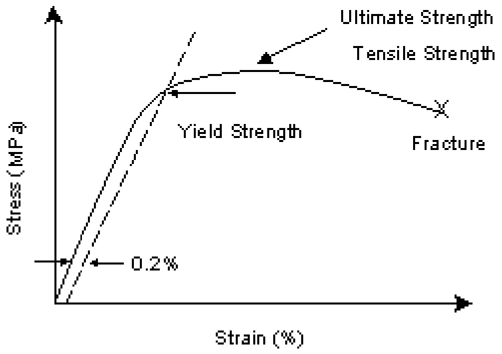
a) From the force-extension diagram obtained with an extensor meter, the extension at maximum force (ΔL_m) is determined.

b) The extensometer gauge length (L_e) shall be recorded on the test report.

c) The percentage total elongation at maximum force is calculated by the following formula:

$$A_{gt} = \Delta L_m / L_e \times 100$$

5.3 *Determination of proof strength, non-proportional extension (R_p)*



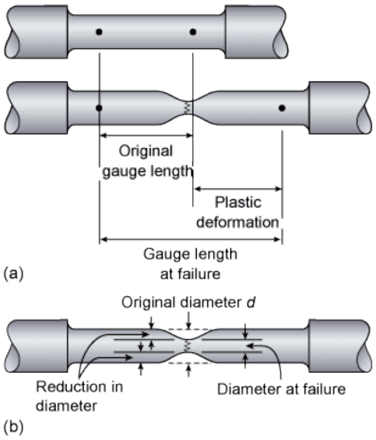
a) The proof strength (non-proportional extension) is determined from the force-extension diagram as explained below:

(i) Select a point on the X-axis at a distance equivalent to the specified non-proportional percentage (Say 0.2%).

(ii) Through this point, draw a line parallel to the straight portion of the curve.

(iii) The point at which the line intersects the curve gives the force corresponding to proof strength (non-proportional extension).

(iv) This force divided by the cross sectional area (S_o) of the test piece gives the desired proof strength.



5.4 *Determination of proof strength, total extension (R_t)*

a) The procedure is similar to 5.3 except that the line is drawn at the point of specified total extension.

b) If automatic devices are fitted with the testing machine, force-extension plot is directly obtained.

c) The test piece is subjected to a force corresponding to the specified stress for 10 to 12 seconds. After removing the force, the permanent set extension or elongation is checked and verified that it does not exceed the limit specified for the original gauge length.

5.5 *Determination of percentage reduction of area (Z)*

a) The maximum change in cross sectional area (S_o-S_u) occurred during the test is expressed as a percentage of the original area to determine the percentage reduction in area (Z).

$$Z = (S_o - S_u) / S_o \times 100$$

b) Two broken fractions of the tested piece is carefully fitted together and the minimum cross-sectional area after fracture is determined (S_u). Knowing the original area of cross section (S_o), Z can be calculated.

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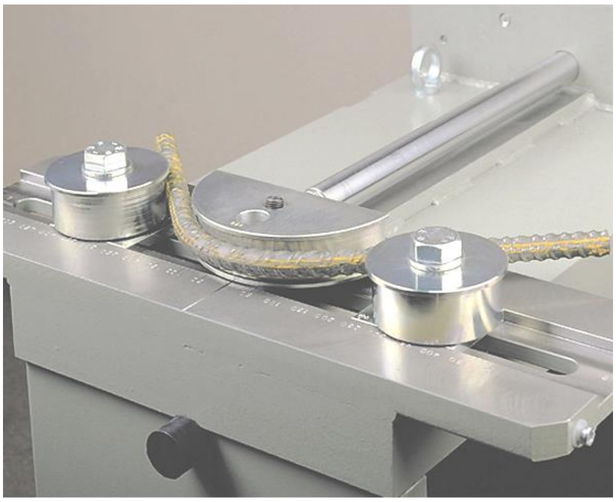
METHOD FOR BEND TEST OF STEEL

IS: 1599

1. Introduction

Bend test is conducted for determining the ability of metallic materials to undergo plastic deformation in bending. The above standard is not applicable to certain materials such as tubes in full section or welded joints, for which other standards exist. The bend test consists of subjecting a test piece of round, square, rectangular or polygonal cross section to plastic deformation by bending without changing the direction of loading until a specified angle of bend is reached.



2. Apparatus

The bend test shall be carried out in testing machines or presses equipped with the following devices:

a) *Bending device with two supports and a mandrel (Fig.1)*:

The length of the supports and the width of the mandrel shall be greater than the width or diameter (d) of the test piece. The diameter of the mandrel (D) is determined by the material standard. The test piece supports shall be rounded to a radius between 1 and 10 times the thickness of the test piece and shall be sufficiently hard. Unless or otherwise specified, the distance between the supports (l) shall be taken as approximately, $l = D + 3d$, and shall not change during the bend test.

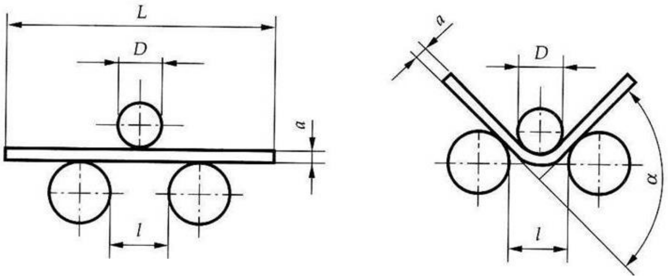


Figure 1 - *Simple bend test*.

b) *Bending device with a V-block and a mandrel (Fig.2):*

The tapered surface of the V-block shall form an angle of 180°- α, where α is the angle of the bend. The edges of the V-block shall be rounded to a radius between 1 and 10 times the thickness of the test piece (d) and shall be sufficiently hard.

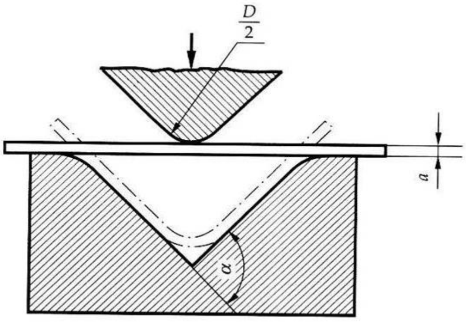


Figure 2 - *Bend test using a V-block*.

c) *Bending device with a clamp:*

The device consists of a clamp and a mandrel of sufficient hardness it may be equipped with a lever for applying force to the test piece.

3. Test piece

a) Round square, rectangular or polygonal cross section test pieces are used in the test. The edges of rectangular test pieces shall be rounded to a radius not exceeding 1/10th of the thickness of test pieces.

b) Any areas of the material affected by shearing or flame cutting and similar operation during cutting of test pieces shall be removed.

c) The rounding shall be made in such a way that no transverse burrs, scratches or marks are formed which might adversely affect the test result.

d) The width of the test piece should be same as its width, when the width of the product is equal to or less than 20 mm.

e) When the width of the product is more than 20 mm, the width of test piece shall be:

(i) 20±5 mm for products of thickness less than 3 mm.

(ii) Between 20 mm and 50 mm, for products of thickness equal to or greater than 3 mm.

f) The thickness of the test piece from sheets, strips and sections shall be equal to the thickness of the product to be tested.

g) If the thickness of the product is greater than 25 mm, it may be reduced by machining one surface to not less than 25 mm. During bending, the un-machined side shall be the tension-side surface of the test piece.

h) The round or polygonal cross section test piece is subjected to the bend test in the cross section equal to that of the product.

i) When the diameter or the inscribed circle diameter of the test piece exceed 30 mm up to and including 50 mm, it may be reduced to not less than 25 mm.

j) The length of a test piece depends on the thickness of the test piece and the test equipment used.

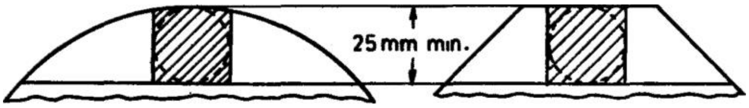


Figure 3 - *Position of test piece for round or polygonal section*.

k) The test is carried out at ambient temperature between 10 and 35°C.Tests carried out under controlled conditions shall be made at a temperature of 23±5°C.

4. Procedure

a) The bend test is carried out using one of the following methods specified in the relevant standard.

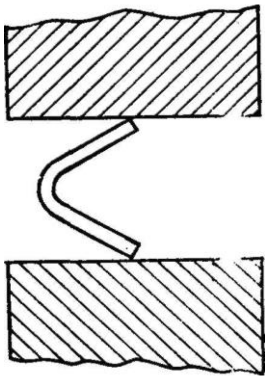
(i) That a specified angle of bend is achieved under the force and for the given conditions.

(ii) The legs of the test piece are parallel to each other at a specified distance apart while under force.

(iii) The legs of the test piece are in direct contact while under the force.

b) The test piece is placed over the supports (Fig.1) or V-block (Fig.2) and the bending force applied slowly to permit free plastic flow of the material.

c) If it is not possible to bend the test piece to the specified angle in the above manner, complete the bend by pressing directly on the ends of the legs of the test piece.



d) In the bend test to parallelism of the legs, the test piece may be sent first by pressing directly on the ends of the legs of the test piece and then placed between the parallel plates of the press where it is further formed by the application of a continuously increasing force to obtain parallelism of the legs. The test may be carried with or without the insert. The thickness of the insert shall be defined in the relevant standard or by agreement.

d) If specified, the test piece, after its preliminary bending, is further bent between the parallel plates of the press, by application of a continuously increasing force to obtain direct contact between the legs of the test piece.

5. Calculation

a) If the requirements of test materials are not specified, absence of cracks visible without the use of magnifying aids is considered as the evidence that the test piece has withstood the bend test.

b) The angle of bend, specified in material standards, is always considered as a minimum requirement.

c) If the internal radius of bend is specified, it is considered to be the maximum.

6. Test report

The test report shall include the following information:

(i) Reference to the relevant standard.
(ii) Identification of the test piece (i.e., type of material, cast number, direction of test piece axis relative to a product etc.).
(iii) Shape and dimension of the test piece.
(iv) Test method.
(v) Test result.

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Part - III

SOILS TESTING

DRY PREPARATION OF SOIL SAMPLE FOR TESTING

IS: 2720 - Part 1

1. Introduction

This method describes the preparation of soil samples received from the field for mechanical analysis, physical tests, compaction tests etc.

2. Apparatus

(i) Wooden Mallet-for breaking clods.
(ii) Pulverizing apparatus.
(iii) A suitable riffle sampler or sample splitter for quartering samples.
(iv) IS test sieves of sizes 75 mm, 63 mm, 37.5 mm, 19 mm, 13.2 mm, 9.5 mm, 6.7 mm, 4.75 mm, 2.00 mm and 425 micron.
(v) Trays for air drying soil with non-corroding metal.
(vi) Drying oven, thermostatically controlled, capable of maintaining temperatures of 110± 5°C for drying soil samples.
(vii) Balances of capacities 10 kg with sensitivity 100 gm, 1 kg with sensitivity of 1 gm and 250 gm with sensitivity 0.01 gm.

3. Preparation of the soil sample

(i) The sample received from the field is air dried or dried in the drying apparatus at temperature not exceeding 60°C.
(ii) The type, temperature and duration of drying are indicated in table 1 below.

Table 1: *Quantity of sample required for various tests.*

Sl. No.	*Test*	*Type, temperature and duration of drying*	*Amount of soil sample required for testing*	*Degree of pulverisation*
1	Water content	Oven, 24 h	As given in table 2	-
2	Specific gravity	Oven, 105-110°C, 24 h	50 gm for fine grained soils, 400 gm for fine medium and coarse grained soil	2 mm (for fine grained soil)
3	Grain size analysis	Air drying	As given in table 3	-
4	Liquid limit	Air drying	270 gm	425 micron
5	Plastic limit	Air drying	60 gm	425 micron
6	Shrinkage factors	Air drying	100 gm	425 micron
7	Light Compaction	Air drying	6 kg (15 kg if soil is susceptible to crushing)	19 mm
8	Heavy compaction	Air drying	do	19 mm
9	CBR	Air drying	6 kg	
10	Permeability	Oven, 105 - 110°C, 24 h	2.5kg (100 mm dia)/5kg (200 mm dia)	9.5 mm
11	Chemical test - Organic matter	Air drying	100 gm	2 mm
12	Sand Equivalent value	Oven, 105±5°C	1500 gm	4.75 mm
13	Free swell index	Oven dry	20 gm	425 micron

(iii) The material is separated into two parts using riffle sampler or by quartering.

(iv) Gravelly soils shall not be quartered by forming a cone. The entitrematerial shall be thoroughly mixed, spread flat, split into quadarnts and quartering done.

(v) Aggregations of soil particles are broken up using the pulverizing apparatus but without breaking their natural size.

(vi) Big clods shall be pulverised with wooden mallet. Further, pulvurising shall be carried out in pestle and mortar.

(vii) The pulverised soil is then passed through the specified sieve for testing. Any material retained is again subject to pulverisng with out breaking the particles.

(viii) The quantity of material required for water content determination shall be as given in table 2.

Table 2: *Quantity of sample required for moisture content determination.*

Size of particles more than 90% passing IS sieve	*Minimum quantity of soil to be taken for the test (in gm)*
425-micron	25
2-mm	50
4.75 mm	200
9.50 mm	300
19 mm	500
37.5 mm	1000

(ix) The quanity of soil required for grain size analysis shall be as given in table 3.

Table 3: *Quantity of soil required for grain size analysis*

Maximum size of material (in mm)	Mass to be taken for test (in kg)
75	60
37.5	25
19	6.5
13.2	3.5
9.5	1.5
6.7	0.75
4.75	0.40

4. Test sample for other tests

For the quantity of materials for other tests, refer to the specific test procedure.

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GRAIN SIZE ANALYSIS OF SOILS

IS: 2720 - Part 4

1. Introduction

This test covers the method for the quantitative determination of grain size distribution of soils. Two methods are given for finding the grain size distribution of soil particles larger than 75 micron:

a) In the wet analysis method, wet sieving of the soil is done.
b) The dry analysis is applicable to soils which do not have an appreciable amount of clay.
c) For finding the grain size analysis of soils smaller than 75 micron size, pipette method is considered as the standard method.
d) Hydrometer analysis also can be adopted as a subsidiary method. However, this method is not applicable if less than 10% of the material passes 75 micron sieve.
e) Soil fraction retained on 4.75 mm and passing 4.75 mm IS sieves shall be separately taken for analysis.

2. Apparatus

(i) Any suitable apparatus capable of drying samples at temperature not exceeding 60°C.
(ii) IS test sieves 100 mm, 75 mm, 19 mm, 4.75 mm, 2.00 mm, 425 micron, 75 micron and other sizes as required for the specified tests.
(iii) Rubber pestle and mortar.
(iv) Sieve brushes and a wire brush or similar stiff brush.
(v) Weighing balance sensitive to 0.1% of the weight of sample.
(vi) Drying oven thermostatically controlled with non-corroding material interior, capable of maintaining temperature between 105°C and 110°C for drying wet samples.

(vii) Pulverizing apparatus like rubber covered pestle and mortar or any mechanical device capable of breaking aggregations without reducing the size of the individual grains.
(viii) A suitable riffle sampler or sample splitter.
(ix) Chemical reagent sodium hexametaphosphate or any other suitable dispersing agent.
(x) Miscellaneous equipments like trays or pans 300 mm dia and 75 mm depth for collecting the wash water from sieve, metal or rigid plastic trays or basins 45 cm2 to 90 cm2 area and 100 to 150 mm deep for soaking soil samples, containers for storing samples without loss of moisture etc.

3. Procedure for the sieve analysis of soil fraction retained on 4.75 mm IS sieve (Dry method)

a) The sample from the field is air dried or oven dried at 60°C.
b) The aggregations shall be then thoroughly broken in a mortar with rubber covered pestle.
c) A representative sample is then selected by the method of quartering or by using sampler.
d) The portion of air dried sample selected for the purpose of mechanical analysis and physical tests shall be weighed.

e) The sample is then separated into two parts using 4.75 mm IS sieve.

f) The material retained on 4.75 mm IS sieve is weighed and mass recorded as uncorrected for hygroscopic moisture.

g) The material passing 4.75 mm sieve is carefully stored for analysis by method given under item 4.

h) The quantity of soil sample taken shall depend on the maximum particle size present in the soil in substantial quantities as given in table 1 below:

Table 1: *Quantity of soil samples for analysis*.

Max size of particle (mm) present in substantial quantities	*Mass of sample taken for test in kg*
75	60
40	25
25	13
19	6.5
12.5	3.5
10	1.5
6.5	0.75
4.75	0.4

i) The sample is separated into various fractions by sieving through the desired sieves.

j) While sieving through each sieve, the sieves shall be agitated such that the particles roll over the mesh of the sieve in an irregular motion.

k) Particles shall not be forced through the sieve openings. The materials in the sieve may be rubbed with rubber pestle taking care that individual particles are not broken.

l) The quantity taken in each sieve for sieving shall be such that the maximum weight retained in the sieve after sieving shall not exceed the values given in table 2.

Table 2: *Maximum weight of material allowed to be retained.*

IS sieve designation in mm	*450 mm dia sieves in kg*	*300 mm dia sieves in kg*
80	15	6
20	4.0	2
4.75	1.0	0.5

m) The mass of the material retained on each sieve is recorded. It the sample appears to contain more than 5% moisture, then amount of moisture shall be determined as per IS: 2720 (Part 2) and necessary corrections applied.

n) The percentage of soil retained on each sieve shall be calculated on the basis of the total mass of soil sample taken and from these results the percentage passing through each of the sieves shall be calculated.

4. Procedure for the sieve analysis of soil fraction passing 4.75 mm IS sieve and retained on 75 micron IS sieve

4.1 *Analysis by wet sieving*

a) The portion of the soil passing 4.75 mm IS sieve obtained as per item 3 above is oven dried at 105°C to110°C.

b) The oven dried material is riffled to get a convenient mass.

c) This quantity shall be 200 gm, if major portion is particles close to 4.75 mm. If particle sizes are smaller a lesser sample size is sufficient.
d) This shall be weighed to 0.1% of its total mass and the mass recorded.
e) The sample is then spread in a large tray or basin and covered with water.
f) Take one litre of water. Add two grams of sodium hexametaphosphate. Alternately, one gram of sodium carbonate and one gram of sodium hydroxide can be used.
g) Add this prepared solution of dispersing agent to the soaked soil sample.

NOTE: *The amount of dispersing agent may vary depending upon the type of soil. In some cases a dispersing agent may not be required.*

a) Thoroughly stir the mix and keep for soaking.
b) The soaked soil is washed thoroughly over the set of IS sieves 2.0 mm, 425 micron and 75 micron. Continue washing till water passing through each sieve is substantially clean.
c) The fraction retained in each sieve is emptied carefully and oven dried at 105°C to110°C. Fraction in each sieve is weighed separately.
d) Alternately the washing of the soil sample can be done using 75 micron sieve till the water passing is substantially clean. The fraction retained on 75 micron sieve is then dried in oven and sieved through various sieves to get the fraction retained on each sieve.
e) The permissible maximum mass of material to be retained on 200 mm diameter sieve is as given in table 3.

Table 3: *Maximum weight of material allowed to be retained.*

IS sieve designation	*Maximum mass of sample in gm*
2.0 mm	200
425 micron	50
75 micron	25

4.2 *Analysis by dry sieving*

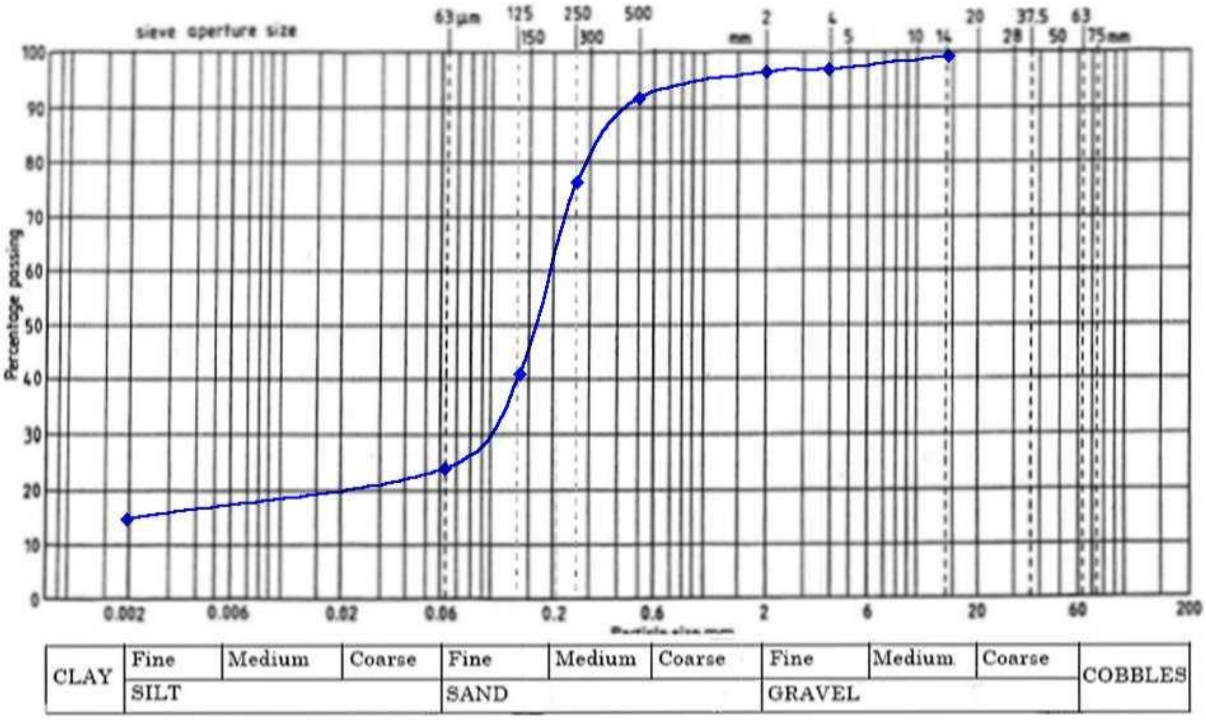
a) This method is not applicable to clayey soils.
b) The portion of the soil passing 4.75 mm IS sieve obtained as per item 3 above is oven dried at 105°C to110°C.
c) A representative portion of the soil shall be weighed to 0.1% of its total mass and the mass recorded.
d) The test sample is sieved through the required sieves.
e) Agitate the sieves while sieving so that sample rolls in an irregular motion over the sieves. No particles shall be pushed through the sieves.
f) Material remaining on the sieve shall be rubbed with a rubber pestle to ensure that only individual particles are retained on the sieve.
g) The material in the receiver is transferred to a steel tray.
h) The next sieve is fitted to the receiver. The material in the tray is again sieved.
i) Repeat the process till all the specified sieves are finished.
j) If mechanical shaker is used, the sieving is carried out in one operation.
k) Care shall be taken to ensure that sieving is complete.

l) A minimum of 10 minutes shaking shall be done.

m) The soil fraction retained on each sieve is carefully collected in containers and weight determined accurately.

5. Calculation

The cumulative mass of soil fraction retained on each sieve is calculated. The percentage retained on each sieve is then calculated from the weight of sample passing 4.75 mm sieve taken for sieving. The combined grading of the material is then worked out on the basis of the total sample tested and represented in a semi-log graph as shown below.



A typical format to report the result is attached.

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KERALA PUBLIC WORKS DEPARTMENT

QUALITY CONTROL WING

Form No.
QC-S1/2015

Grain size analysis of soil by wet sieving **IS: 2720 – Part 4**	Report No.	Date:

REGIONAL LABORATORY……………………………	**DISTRICT LABORATORY………………………………....**
Name of work:	

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

MATERIAL TYPE:					Date of testing:
LAYER:	Fill	Subgrade	Subbase		

Weight of sample for sieving	gm	Weight passing 425 mm sieve (After oven drying)	gm
Weight retained in 425 mic sieve	gm	Weight passing 425 mm sieve (From wash liquid)	gm
Weight passing 425 mic sieve	gm	*Total passing 425 mic*	gm

IS Sieve designation	Weight retained in gm	% weight retained	Cumulative % retained	Percentage finer	***Required value***
Pan					

Remarks:

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF WATER CONTENT OF SOILS

IS: 2386 - Part II

Method I: Oven drying method

1. Introduction

Water content or moisture content of a soil is the ratio of a given weight of water in a given soil sample to the weight of solid present in the soil sample. The given soil mass is dried in an oven at 105°C to110°C to constant weight to remove the water. The weight of soil remaining after oven drying is the solid particles in the soil sample.

Test samples shall be in accordance with the table 1, unless specified otherwise.

Table 1: *Recommended weight of sample for moisture content determination*

Max. particle size in the soil IS sieve designation	*Minimum sample weight in gm*
425 micron	25
2.0 mm	50
4.75 mm	200
9.5 mm	300
19.0 mm	500
37.5 mm	1000

2. Apparatus

(i) Any suitable non-corrodible air tight container.

(ii) Weighing balance of sufficient sensitivity to weigh the soil samples to an accuracy of 0.04 percent of weight of the soil taken for the test.

(iii) Thermostatically controlled oven capable of maintaining temperatures of 105°C to 110°C for drying wet samples.

3. Procedure

a) Weigh accurately a clean dry container with lid (W_1) and place the wet soil sample in it.

b) Replace the lid immediately and weigh the container and soil with the lid (W_2).

c) Now remove the lid and place the container in the oven maintained at 105°C to 110°C and dry to constant mass (W_3) .

NOTE: *It is not practical to check every soil sample to determine that it is dried to constant weight - normally 15 to 16 hrs. In case of doubt, drying should be continued till two successive readings are constant. New wet samples shall not be placed before removing dry samples from the oven.*

4. Calculation

The water content w of the soil is given by:

w = [(Wt of water/wt of soil)] x 100 % and is reported to the nearest 0.1 percent.

$= [(W_2 - W_3)/(W_3 - W_1)] \times 100$ percent.

Report the result in the format attached with 2 significant digits accuracy.

Method II: Sand-bath method

1. Introduction

This method is used for determination of the water content of a soil as a percentage of its dry mass. This test is less accurate and more suitable as a field test. The method shall not be used if it is suspected that the soil contains a large proportion of gypsum, calcareous matter or organic matter.

2. Apparatus

- (i) Any suitable non corrodible air tight container.
- (ii) Heat-resistant tray of suitable metal and about 5 to 7 cm deep.
- (iii) Weighing balance of sufficient sensitivity to weigh the soil samples to an accuracy of 0.04% of weight.
- (iv) Sand-bath containing clean sand to a depth of at least 3 cm.
- (v) Kerosene stove or spirit lamp for heating the sand-bath
- (vi) One palette knife or steel spatula about 20 cm long and 10 cm wide.

3. Procedure

- a) Clean the container, dry and weigh (W_1).
- b) Take the required quantity of the soil specimen in the container, crumbled and placed loosely and weigh (W_2).
- c) Add a few pieces of white paper so that overheating will be indicated if the paper turns brown.
- d) Place the container on the sand-bath and heat the sand-bath. Overheating should be strictly avoided.
- e) During heating, the specimen shall be turned frequently and thoroughly with the palette knife.
- f) When drying is complete, remove the container from the sand bath, cool and weigh with the lid (W_3).

4. Calculation

The percentage of water content w is calculated as follows:

$w = [(W_2-W_3)/ (W_3-W_1)] \times 100$ where

w = Water content percent.

W_2 = Mass of container with lid (or tray) with wet soil in gm.

W_3 = Mass of container with lid (or tray) with dry soil in gm.

W_1= Mass of container with lid (or tray) in gm.

Report the result in the format attached.

Method III: Alcohol method

1. Introduction

This method covers the determination of the water content of a soil as a percentage of its dry mass. This method is less accurate and is more suitable as a field test. Since methylated spirit is used, care shall be taken against risk of fire. The method shall not be used if the soil contains a large proportion of clay, gypsum, calcareous matter or organic matter.

Test samples shall be in accordance with the table 2, unless specified otherwise.

Table 1: *Recommended weight of sample for alcohol method.*

Size of particles more than 90% passing IS sieve designation	*Minimum quantity of soil specimen in gm to be taken for test*
2 mm	30
19 mm	300

2. Apparatus

- (i) Evaporating dish, 10 to 15 cm in diameter.
- (ii) Weighing balance of sufficient sensitivity to weigh the soil samples to an accuracy of 0.04% of weight.
- (iii) One palette knife or steel spatula having a blade 10 cm long and 2 cm wide.
- (iv) Methylated spirit.

3. Procedure

- a) Clean the evaporating dish, dry and weigh (W_1).
- b) Take the required quantity of the soil specimen in the evaporating dish and weigh (W_2).
- c) Pour methylated spirit over the soil so that the soil is well covered.
- d) Mix the methylated spirit well into the soil with the palette knife and break up any large lumps of soil.
- e) Place the evaporating dish on a surface which will not be affected by heat and ignite the methylated spirit.
- f) Stir the soil constantly with the spatula.
- g) After the methylated spirit has burnt away completely allow the dish to cool and weigh it with the contents (W_3).

4. Calculation

The percentage of water content *w,* is calculated as follows:

$w = [(W_2-W_3)/ (W_3-W_1)] \times 100$ where,

w = Water content percent.

W_2 = Mass of dish with wet soil in gm.

W_3 = Mass of dish with dry soil in gm.

W_1 = Mass of dish in gm.

Report the result in the format attached.

Method IV: Calcium Carbide method

1. Introduction

This is a method for rapid determination of water content from the gas pressure developed by the reaction of calcium carbide with the free water of the soil. This test requires about 6 gm of soil sample.

2. Apparatus

- (i) Metallic pressure vessel, with clamp for sealing cup, and a gauge calibrated in % water content.
- (ii) A counterpoised balance for weighing sample.
- (iii) A suitable scoop for measuring absorbent (Calcium Carbide).
- (iv) One bottle of the absorbent, Calcium Carbide.
- (v) One Cleaning brush.
- (vi) Three steel balls of about 12.5 mm diameter and one steel ball of 25 mm diameter.

3. Procedure

a) Set up the balance.
b) Place sample in pan till the mark on the balance arm mass lines with the index mark.
c) Unclamp the clamping screw of the instrument sufficiently to move the U-clamp off the cup. Lift off the cup.
d) Gently deposit the absorbent to fill half of the chamber. Then lay the chamber down without disturbing it.
e) Transfer the soil from the pan to the cup.
f) Holding approximately horizontal, bring the cup and chamber together without disturbing sample. Bring the U-clamp round and clamp the cup tightly into place.
g) With gauge downwards, shake the moisture meter up and down vigorously for 5 seconds. Then quickly turn it so that the gauge is upwards. Ensure that all the contents fall into the cup.
h) Hold the rapid moisture meter downwards. Again shake for 5 seconds, then turn it with the gauge upwards and tap. Hold for one minute. Repeat this for a third time.
i) Invert the rapid moisture meter one more time. Shake up and down to cool the gas.
j) Turn the rapid moisture meter with the gauge upwards and dial horizontal, held at chest height.
k) When the needle comes to rest take the reading. The readings on the meter (m) are the percentages of water on the wet mass basis.
l) Finally release the pressure slowly by opening the clamp screw and taking the cup out.
m) Empty the contents and clean the instrument with a brush.

4. Calculation

From the water content (m) obtained on the wet mass basis as the reading on the rapid moisture meter, the water content (w) on the dry mass basis is calculated as follows:

$$w = [m/ (100-m)] \times 100\%$$

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-S2/2015
	QUALITY CONTROL WING	

Moisture content determination **IS: 2720 - Part 2**	Report No.	Date:
REGIONAL LABORATORY………………………………..	**DISTRICT LABORATORY**……………………………......	

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

MATERIAL TYPE:				Date of testing	
LAYER:	Fill	Subgrade	Subbase	Test method	Oven dried at 110 ± 5 ºC

1. Determination No.	*1*	*2*	*3*
2. Container No.			
3. Wt of container = W_1 gm			
4. Wt. of container + wet soil = W_2 gm			
5. Wt of container + dry soil = W_3 gm			
6. Wt of water = W_2-W_3 gm			
7. Wt of soil = W_3-W_1 gm			
8. Moisture content $w = (W_2-W_3) / (W_3-W_1) \times 100$ %			
Average			

RESULT:	***Required value***
Moisture content = *%*	%

Remarks:

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved*: Asst. Exe. Engineer (QC)

DETERMINATION OF WATER CONTENT-DRY DENSITY RELATION OF SOILS USING LIGHT COMPACTION

IS: 2720 - Part 7

1. Introduction

These methods are intended to determine the maximum dry density (MDD) and optimum moisture content (OMC) of soil under light (Standard) compaction.

a) In this method, a 2.6 kg rammer falling through a height of 310 mm is used.
b) The test is carried out on soils passing 19.0 mm IS sieve.
c) The soils can be compacted either in 1000 ml or 2250 ml mould.
d) The fraction of soil retained on 19.0 mm sieve is discarded (up to 5%).
e) If the soil contains larger proportion of gravel retaining on 19.0 mm sieve, the use of bigger mould (2250 ml) is recommended.
f) For soils not susceptible to crushing during compaction, about 6 kg of air dried material is required.
g) However if the soil to be tested contains granular material of soft nature like soft limestone, sandstones etc the sample required is about 15 kg.

2. Apparatus

(i) Cylindrical mould of capacity 1000 ml (or 2250 ml) with detachable base plate and removable collar of 6 cm height.
(ii) Rammer 2.6 kg having a flat circular face equipped with suitable guide sleeve for a free fall of 310 mm conforming to IS: 9198-1979.

NOTE: *If mechanical rammer is used it shall be suitably calibrated*.

(iii) Sample extruder consisting of a jack, lever, frame etc.
(iv) Balances, one with approximate capacity 15 kg, when used with 2250 ml mould with sensitivity of 1 gm and one with capacity 200 gm with sensitivity of 0.01 gm.
(v) Drying oven, thermostatically controlled, capable of maintaining temperatures of 110 ± 5°C for drying wet samples.
(vi) Straight edge of hardened steel about 300 mm length.
(vii) IS Sieves 19 mm and 4.75 mm conforming to the requirement of IS 460: Part I – 1985-Specification for wire cloth test sieves.
(viii) Mixing tools such as tray or pan, spoon, trowel, spatula etc for thoroughly mixing soil with water.
(ix) Containers made of corrosion resistant material with close fitting lids, one container each for one moisture content determination.

3. Procedure for soil not susceptible to crushing during compaction

a) Mix thoroughly 5 kg of the dried soil sample passing 19 mm, with water to dampen it to approximately 4% below OMC.

NOTE: *For sandy and gravelly soils, 4% to 6% moisture will be sufficient. For cohesive soils 8% to 10% is required.*

b) Fill in the 1000 ml mould in three approximately equal layers. Compact each layer with 25 uniformly distributed blows with the free fall of 310 mm.

c) After compacting each of the first two layers, any loose soil adjacent to the mould walls shall be trimmed using a knife or spatula and evenly distributed on top of the compacted layer.

d) After filling each layer, give a slight tamp with the rammer, if the soil is loose or in a fluffy state.

e) After compaction, remove the extension collar, trim the compacted surface of the soil, even with the top of the mould, using the straight edge.

NOTE: *It is necessary to control the quantity of soil compacted in the mould. If the amount of soil struck after removal of the collar is too great, it is likely to affect the accuracy of the result*.

f) Weigh the compacted soil in the mould with the base plate to the nearest 1 gm.

g) Remove the soil from the mould, slice vertically through the centre, take a sample of about 50 gm in a container and proceed with moisture content determination as per IS 2720 (Part II Determination of water content).

h) Thoroughly break up the remaining portion of the soil from the mould, rub through 19.0 mm sieve and add to the sample in the mixing tray or pan.

i) Repeat the process with 1% to 2% increments of water.

NOTE: *Water increments shall be normally 1% to 2% of sample weight except in the case of cohesive soils where increments up to 4% are allowed*.

j) The mixing and compacting process is continued till a decrease in the weight of compacted soil is recorded.

NOTE: *For soils containing coarse material up to 40 mm size, 2250 ml mould shall be used for compaction. A sample weighing about 6 kg passing IS sieve 19.0 mm is used. Soil is compacted in approximately three equal layers but given 55 blows of the 2.6 kg rammer. The rest of the procedure is same as given under 3 above.*

4. Procedure for soil susceptible to crushing during compaction

a) The test procedure will be the same as given under 3 above, but the weight of total sample required will be 15 kg.

b) Five or six 2.5 kg air dried soil samples shall be taken and each mixed with different percentages of water.

c) After compaction of each sample, the remaining compacted material from the mould is discarded.

5. Calculations

Moisture content w of the compacted specimen is calculated using the equation:

$w = [(A - B)/B - C)] \times 100\ \%$ where

A = Weight of wet soil + container,

B = Weight of dry soil + container and

C = Weight of container.

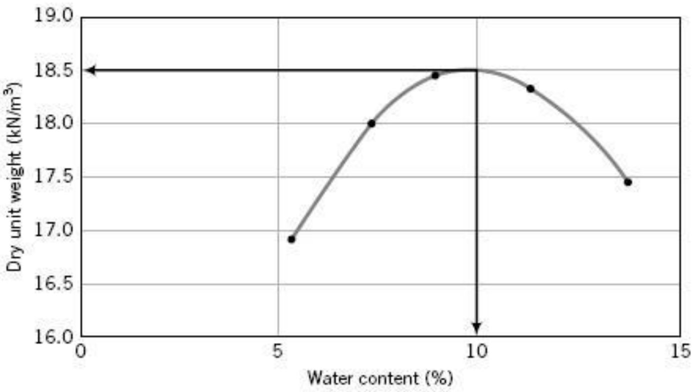
Dry density (Or unit weight), γ of the compacted soil is given by:

$$\gamma_{dry} = \gamma_{wet}/(1 + w)$$

6. Reporting of result

The test data may be tabulated in the format attached.

The oven dry density γ_{dry} (Y-axis) and corresponding moisture content percentage w (X-axis) are plotted in a graph.



The maximum density as read from the curve is reported as MDD and the corresponding moisture, as OMC.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-S3/2015
Compaction Test **IS: 2720 - Part 7/8**	Report No.	Date:

Volume of mould V = cm^3	*Rammer*	*2.5 Kg* (Part 7)	*4.5 Kg* (Part 8)

REGIONAL LABORATORY……………………………	**DISTRICT LABORATORY………………………………......**

Name of work:

Division:	Subdivision:	Section:
Location:	**Sample No.**	**Date:**

MATERIAL TYPE:		Date of testing:	

LAYER:	Fill	Subgrade	Subbase	

1. *Determination No.*	*1*	*2*	*3*	*4*	*5*
2. Weight of mould + base plate + soil = W_2 gm					
3. Weight of mould + base plate = W_1 gm					
4. Weight of compacted soil = (W_2-W_1) gm					
5a. Bulk density $\gamma = (W_2-W_1) / V$ gm/cm^3					
5b. Dry density = $\gamma_{dry} = \gamma /(1+w)$ gm/cm^3					
6. *Container No.*					
7. Weight of container = C gm					
8. Weight of container + wet soil = A gm					
9. Weight of container + dry soil = B gm					
10. Weight of water = A-B gm					
11. Weight of soil = B-C gm					
12. Moisture content w = (A-B) x 100/(B-C)					

RESULTS (From graph):

Maximum dry density (MDD) = gm/cm^3	**Required value for MDD (MoRTH table 300-1):**	Fill up to 3.0 m height = 1520 gm/cm3 Fill in flooding conditions = 1600 gm/cm3
Optimum moisture content (OMC) = %		Fill above 3.0 m height = 1600 gm/cm3 Subgrade/shoulder/backfill = 1750 kg/m^3

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF WATER CONTENT-DRY DENSITY RELATION OF SOILS USING HEAVY COMPACTION

IS: 2720 - Part 8

1. Introduction

These methods are intended to determine the maximum dry density (MDD) and optimum moisture content (OMC) of soil under heavy (Modified) compaction.

a) In this method, a 4.9 kg rammer falling through a height of 450 mm is used.
b) The test is carried out on soils passing 19.0 mm IS sieve.
c) The soils can be compacted either in 1000 cm^3 or 2250 cm^3 mould.
d) The fraction of soil retained on 19.0 mm sieve is discarded (up to 5%).
e) If the soil contains larger proportion of gravel retaining on 19.0 mm sieve, the use of bigger mould (2250 ml) is recommended.
f) For soils not susceptible to crushing during compaction, about 6 kg of air dried material is sufficient. However if the soil to be tested contains granular material of soft nature like soft limestone, sandstone etc the sample required is about 15 kg.

2. Apparatus

(i) Cylindrical mould of capacity 1000 cm^3 (or 2250 cm^3) provided with detachable base plate and removable collar of 6 cm height all conforming to IS: 10074-1982 – Specification for compaction mould assembly for light and heavy compaction of soils.
(ii) Rammer 4.9 kg having a flat circular face equipped with suitable guide sleeve for a free fall of 310 mm conforming to IS: 9198-1979 – Specification for compaction rammer for soil testing.

NOTE: *If mechanical rammer is used it shall be suitably calibrated*.

(iii) Sample extruder consisting of a jack, lever, frame etc.
(iv) Balances, one with approximate capacity 15 kg, when used with 2250 cm^3 mould with sensitivity of 1 gm and one with capacity 200 gm with sensitivity of 0.01 gm.
(v) Drying oven thermostatically controlled with non-corroding material interior, capable of maintaining temperature between 105 ^oC and 110^oC for drying wet samples.
(vi) Straight edge of hardened steel about 300 mm length and having one edge bevelled.
(vii) IS sieves 37.5 mm, 19 mm and 4.75 mm conforming to the requirement of IS 460: Part I – 1985- Specification for wire cloth test sieves.
(viii) Mixing tools such as tray or pan, spoon, trowel, spatula etc for thoroughly mixing soil with water.
(ix) Containers made of corrosion resistant material with close fitting lids, one container each for one moisture content determination.

3. Procedure for soil not susceptible to crushing during compaction

a) Mix about 5 kg of the air-dried soil sample with water approximately 4% below OMC to dampen it. It is important that soil is thoroughly mixed with the water added.
b) Fill in the 1000 cm^3 mould in 5 approximately equal layers.

c) Compact each layer with 25 uniformly distributed blows using 4.9 kg hammer with the free fall of 450 mm.

d) After compacting each of the first four layers, any loose soil adjacent to the mould walls shall be trimmed using a knife or spatula and evenly distributed on top of the compacted layer.

e) After filling each layer give a slight tamp with the rammer, if the soil is loose or in a fluffy state.

f) After compaction, remove the extension collar and trim the compacted surface of the soil, even with the top of the mould using the straight edge.

NOTE: *It is necessary to control the quantity of soil compacted in the mould. If the amount of soil struck after removal of the collar is too great, it is likely to affect the accuracy of the result*.

g) Weigh the compacted soil in the mould with the base plate to the nearest 1 gm.

h) Remove the soil from the mould, slice vertically through the centre, take a sample of about 50 gm in a container and proceed with moisture content determination as per IS: 2720 (Part II-Determination of water content).

i) Thoroughly break up the remaining portion of the soil from the mould, rub through 19.0 mm sieve and add to the sample in the mixing tray or pan.

j) Repeat the process with 1% to 2% increments of water.

NOTE: *Water increments shall be normally 1% to 2% of sample weight except in the case of cohesive soils where increments up to 4% are allowed*.

k) The mixing and compacting process is continued till a decrease in the weight of compacted soil is recorded.

NOTE: *For soils containing coarse material up to 37.5 mm size, 2250 ml mould shall be used for compaction. A sample weighing about 30 kg passing IS sieve 37.5 mm is used. Soil is compacted in approximately five equal layers but given 55 blows of the 4.9 kg rammer. The rest of the procedure is same as given under 3 above.*

4. Procedure for soil susceptible to crushing during compaction

a) The test procedure will be the same as given under 3 above, but the weight of total sample required will be 15 kg.

b) Five or more 2.5 kg of air dried soil samples shall be taken and each mixed thoroughly with different percentages of water.

c) After compaction of each sample, the remaining compacted material from the mould is discarded.

5. Calculations

Moisture content w of the compacted specimen is calculated using the equation:

$w = [(A - B)/B - C)] \times 100\ \%$ where

A = Weight of wet soil + container,

B = Weight of dry soil + container and

C = Weight of container.

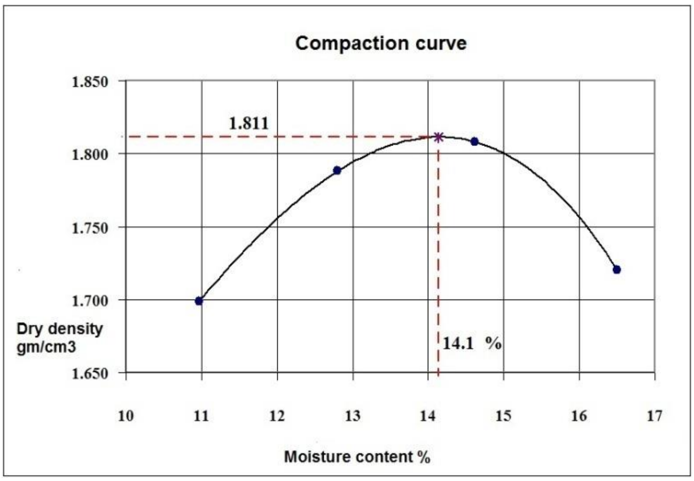
Dry density of compacted soil is given by:

$$\gamma_{dry} = \gamma_{wet}/(1 + w)$$

6. Reporting of results

The test data may be tabulated in the format attached with light compaction test.

The oven dry density γ_{dry} (Y-axis) and corresponding moisture content percentage w (X-axis) are plotted in a graph.



The maximum density as read from the curve is reported as MDD and the corresponding moisture as OMC.

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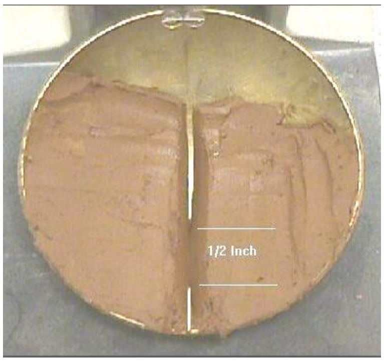
DETERMININATION OF LIQUID LIMIT OF SOILS

IS: 2720 - Part 5

1. Introduction



The physical properties of fine grained soils, especially clay, differ much with the percentage of water content in it. Clay may be almost in a liquid state, or it may show plastic behavior or may be very stiff depending on the amount of moisture in it. Plasticity is the most outstanding property of clayey soils which can be termed as the ability to undergo changes in shape without rupture.

Albert Mauritz Atterberg, a Swedish Chemist & Agriculturist in 1911, proposed a series of tests mostly empirical for the determination of the consistency and the plastic properties of fine grained soils. The limits he defined are Liquid Limit (LL), Plastic Limit (PL), Plasticity Index (PI) and Shrinkage Limit (SL). Atterberg suggested 2.0 micron as the limit for clay particles.

Liquid Limit is the minimum water content at which the soil will flow by the application of a small shearing force. Liquid limit of a soil is determined in the laboratory on samples passing 425 micron sieve. It is determined using Casagrande's Liquid Limit Device.

2. Apparatus

- (i) Liquid Limit Device with grooving tool and adjustment plate.
- (ii) Porcelain evaporating dish for mixing.
- (iii) Flat glass plate 10 mm thick, 45 cm square as an alternative to evaporating dish.
- (iv) Spatula with blade 2 cm wide and 8 cm long.
- (v) Palette knives two with blade about 20 cm long and 3 cm wide for mixing soil and water in the glass plate.
- (vi) Wash bottle or beaker containing distilled water.
- (vii) Height gauge.
- (viii) Containers for moisture content determination.
- (ix) Balance, sensitive to 0.01 gm.
- (x) Thermostatically controlled oven, capable of maintaining temperatures between 105°C and 110°C.

3. Adjustment of the liquid limit device

- a) Check whether the device is in good order.
- b) Side play will occur if the pin connecting the cup is worn. The screws connecting the hanger arm should be tight.
- c) The point of contact of the cup and the base shall not be excessively worn.
- d) The grooving tool shall be clean and dry.
- e) The height through which the cup is lifted and dropped with the base falls through exactly one centimetre for one revolution of the handle.

f) The adjustment plate is then secured by tightening the screw.

4. Procedure

a) About 120 gm of soil sample passing 425 micron sieve is thoroughly mixed with distilled water in the evaporating dish or glass plate to form a uniform paste.

b) The paste shall have a consistency that will require 30 to 35 drops of the cup to cause the required closure of the standard groove.

c) In the case of clayey soils, the soil paste shall be left to stand for a sufficient time (24 hours) so as to ensure uniform distribution of moisture throughout the soil mass. The paste should be remixed before the test.

d) A portion of the paste is placed in the cup above the spot where it touches the base. Squeeze and spread the soil paste in the cup with a spatula.

e) Trim off excess soil, if necessary, so that the maximum depth of soil in the cup is 10 mm.

f) Divide the soil paste through the middle by a firm stroke of the grooving tool so that a clean sharp groove is formed.

g) To avoid slipping of the soil cake, the grooving can be done in maximum six stages so that the last stroke touches the bottom of the cup.

h) The cup is lifted and dropped by turning the crank at the rate of 2 revolutions per second till the grove closes for a length of 12 mm.

NOTE: *If the soil slides on the surface of the cup instead of flowing, the result should be discarded and the test is to be repeated until flowing occurs. If sliding still occur, a note can be made that liquid limit cannot be determined*.

i) A slice of soil extending from edge to edge perpendicular to the grove is removed using the spatula and placed in the container for moisture content determination.

j) The soil remaining in the cup is transferred to the mixing dish and test continued for increased moisture content.

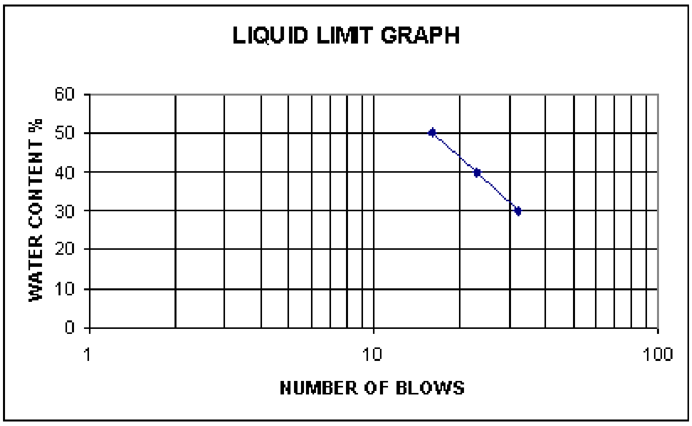
k) The cup and grooving tool is washed and dried for next trial.

NOTE: *The trial should be done at least four times. The specimens shall be of such consistency that the number of drops required to close the groove shall be not less than 15 or more than 35*.

5. Calculation

a) The water content of the soil is expressed as a percentage of the weight of the open dried soil. Calculate the moisture content to the nearest percentage.

b) A 'flow curve' showing the relationship between moisture content and number of shocks is plotted in a semi-logarithmic graph with moisture content in the arithmetic scale in the X-axis and number of drops as ordinates in the logarithmic scale.



c) The flow curve is a straight line drawn as nearly as possible through the four or more plotted points.

d) From the graph, the moisture content corresponding to 25 drops is reported as the Liquid Limit of the soil.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-S4/2015
Liquid Limit and Plasticity Index of soils **IS: 2720**	Report No.	Date:
REGIONAL LABORATORY…………………………….	**DISTRICT LABORATORY………………………………......**	
Name of work:		
Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

Determination number	*1*	*2*	*3*	*4*
LIQUID LIMIT DETERMINATION – IS: 2720 (Part V)				
No of blows				
Container No.				
Weight of container = W_1 gm				
Weight of wet soil + container = W_2 gm				
Weight of dry soil + container = W_3 gm				
Weight of water = $(W_2 – W_3)$ gm				
Weight of oven dry soil = $(W_3 – W_1)$ gm				
Moisture content = $w = (W_2 – W_3) /(W_3 – W_1) \times 100$ %				
PLASTIC LIMIT DETERMINATION – IS: 2720 (Part V)				
Container No.				
Weight of container = W_1 gm				
Weight of wet soil + container = W_2 gm				
Weight of dry soil + container = W_3 gm				
Weight of water = $(W_2 – W_3)$ gm				
Weight of oven dry soil = $(W_3 – W_1)$ gm				
Moisture content = $w = (W_2 – W_3) /(W_3 – W_1) \times 100$ %				

RESULTS:	***Required value***	
Liquid Limit (from flow curve) = **%** Plasticity Index = %	LL = %	PI = %

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved*: Asst. Exe. Engineer (QC)

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

IS: 2720 - Part 5

1. Introduction

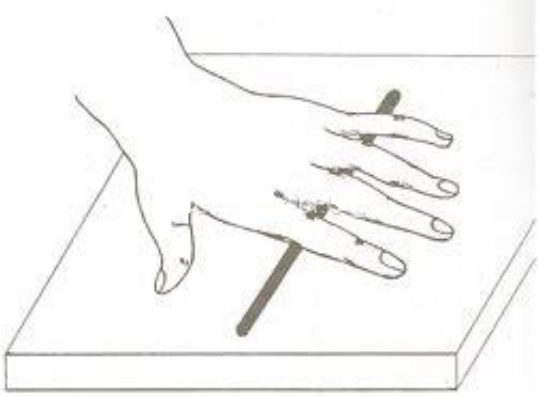
Plastic limit of a soil is the lowest water content at which the soil remains plastic. Plastic limit is the moisture content at which a soil when rolled into a thread of smaller diameter starts crumbling when the diameter reaches 3.0 mm.

2. Apparatus

(i) Plastic Limit rolling device (optional).
(ii) Paper for rolling device,
(iii) Ground-glass plate of about 20 cm x 15 cm size.
(iv) Porcelain dish for mixing.
(v) Spatula with blade 2 cm wide and 8 cm long.
(vi) Glass or metallic rod 10 cm long, 3 mm dia.
(vii) Air-tight containers for moisture content determination.
(viii) Balance, sensitive to 0.01 gm.
(ix) Thermostatically controlled oven capable of maintaining temperatures between 105°C and 110°C.

3. Procedure

a) Mix about 20 gm of over dry soil passing 425 micron sieve with distilled water in an evaporating dish until the soil mass becomes plastic enough to be easily shaped into a ball.
b) If soil is clayey, the plastic soil mass shall be left to stand for sufficient time (24 hours) to ensure uniform distribution of the moisture in the soil mass.
c) Take a ball of about 8 gm of this as test sample.
d) Roll this mass between the palm or fingers and the glass plate with just sufficient pressure to roll it into a thread of uniform diameter.
e) The rolling is continued till the diameter of the thread is 3.0 mm.



f) The soil thread is kneaded together into a ball and rolled again to form a thread of 3.0 mm.
g) The process of alternate rolling and kneading is repeated till the thread crumbles under pressure.
h) The thread of 3.0 mm dia which crumbles during rolling is transferred to a container for moisture determination.
i) The above process is continued till three consistent values of Plastic Limit are obtained.

4. Calculation

a) The Plastic Limit is the mean value of the moisture content determination rounded to the nearest whole number.

b) The Plasticity Index is calculated as the difference between the Liquid Limit and Plastic Limit.

$$\text{Plasticity Index } (I_p) = \text{Liquid limit } (w_L) - \text{Plastic limit } (w_p)$$

c) If liquid limit or plastic limit cannot be determined, it is reported as NP (non-plastic).

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DETERMINATION OF FREE SWELL INDEX OF SOILS

IS: 2720 - Part 40

1. Introduction

Free swell index is the increase in volume of the soil without any external constraints when subjected to submergence in water.

2. Apparatus

- (i) Two graduated cylinders, 100 ml capacity each.
- (ii) Balance with approximate capacity of 200 gm with sensitivity of 0.01 gm.
- (iii) Drying oven thermostatically controlled with non-corroding material interior, capable of maintaining temperature between 105°C and 110°C for drying wet samples.
- (iv) IS sieve 425 micron conforming to the requirement of IS 460: Part I–1985 Specification for wire cloth test sieves.

3. Procedure

- a) Take two specimens of 10 gm soil passing 425 micron IS sieve and oven dried.
- b) Pour each soil specimen into 100 ml capacity graduate glass cylinders.
- c) Pour distilled water in one and kerosene oil in other cylinder up to 100 ml mark.
- d) Remove entrapped air by gentle shaking or stirring with glass rod.
- e) Allow the sample in both cylinders to settle.
- f) Allow attainment of equilibrium state of volume of suspension (for not less than 24 hours).
- g) Final volume of soil in each of the cylinder shall be read out.

4. Calculations

The free swell index of the soil, in percentage, is calculated as follows:

Free swell index = $(V_d - V_k)/ V_k \times 100$ where

V_d = Volume of soil specimen read from the graduate cylinder containing distilled water.

V_k = Volume of soil specimen read from the graduate cylinder containing kerosene.

5. Reporting of result

The free swell index of the soil is reported in percentage.

A correlation of Free swell index, degree of expansiveness and Plastic Limit of soil is given in the table below:

Free swell index %	*Degree of expansiveness*	*Plasticity Index*
<20	Low	0 - 35
20-35	Moderate	25 - 50
30-50	High	35 - 65
>50	Very high	>45

****

DETERMINATION OF SAND EQUIVALENT VALUE OF SOILS

IS: 2720 - Part 37

1. Introduction

This method describes the procedure for determining the sand equivalent value of soils. The purpose of this test method is to indicate, under standard conditions, the relative proportions of clay-like or plastic fines and dusts in granular materials and fine aggregates, that pass the 4.75 mm IS sieve.

A minimum sand equivalent value may be specified to limit the permissible quantity of clay-like fines in an aggregate. The test may also be used for determining changes in the quality of aggregates during production or placement.

2. Apparatus

- (i) Graduated cylinder, of transparent acrylic plastic and a rubber stopper to fit the mouth of the cylinder.
- (ii) Irrigator tube made of stainless steel tubing 6.4 mm outside dia, with one end closed to form a wedge shaped point. Two holes of 1 mm dia are drilled laterally through the flat side of the wedge near the point.
- (iii) Siphon assembly including a 4 litre bottle, a 5 mm outside dia copper bent tube with a pinch clamp, a blow tube consisting of a 5 mm dia copper tube 50 mm long and a 50 mm blow hose, 3 mm dia and a rubber stopper to fit the graduated cylinder.
- (iv) Weighted Foot Assembly of mass 1000±5 gm.
- (v) Measuring cans of a capacity of 90±5 ml.
- (vi) IS sieve 4.75 mm.
- (vii) Miscellaneous supplies such as suitable pan for mixing, funnel, timing device and a sand equivalent shaker.

3. Materials

- (i) *Stock Calcium Chloride Solution*: Prepare the stock solution by dissolving 480.4 gm of anhydrous calcium chloride in 2 liters of distilled water. Cool, filter and add 2179 gm of glycerin. Add 49.7 gm of formaldehyde and mix thoroughly and dilute to 4 litres.
- (ii) *Working Calcium Chloride Solution*: Prepare working solution by diluting 90 ml of stock solution to 4 litres of distilled water.

NOTE: *Local tap water may be used if established by sand equivalent tests that the results are not affected*.

4. Sample Preparation

- a) Screen the sample on the 4.75 mm sieve.
- b) Materials retained on the sieve is rubbed between the hands and rescreened.
- c) Combine the rescreened material with the original material and mix thoroughly.
- d) Carefully obtain 1500 gm of test sample by quartering the combined material passing the 4.75 mm sieve.
- e) Fill 4 measuring cans with the material passing 4.75 mm sieve.

f) The test sample will consist of sufficient material to fill the measuring cans to a slightly rounded level above the brim after tapping.
g) Record the volume or mass of the material in each of the 4 measures.
h) Return the material, mix and prepare necessary sample for the test.
i) Dry each test specimen to constant mass at 105±5°C and cool to room temperature before testing.

5. Preparation of the apparatus

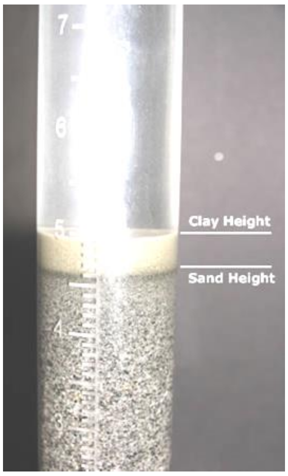
a) Fit the siphon assembly to a 4 litre bottle of working calcium chloride solution.
b) Place the bottle on a shelf, 915±25 mm above the working surface.
c) Start the siphon by blowing into the top of the solution bottle through a short piece of tubing while the pinch clamp is open.
d) When using either the mechanical or the manually operated sand equivalent shaker, fasten the apparatus to a firm and level mount.

6. Procedure

a) Start siphon and add working calcium chloride solution to a depth of 100±2 mm in the graduated cylinder.
b) Pour one of the samples into the cylinder using the funnel and tap firmly on the palm of hand to dislodge any air bubbles and aid in wetting the sample.
c) Leave the wetted sample undisturbed for 10±1 minutes.
d) At the end of the 10 minute soaking period, stopper the cylinder; then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.
e) Place the stoppered cylinder in the mechanical sand equivalent shaker, set the time, and allow the machine to shake the cylinder and the contents for 45±1 seconds.
f) Set the cylinder upright and remove the stopper.

7. Irrigation procedure

a) Keep the cylinder vertical with the base in contact with work place.
b) Insert the irrigator tube and start the flow, rinsing the material from the cylinder walls as the tube is lowered.
c) Force the irrigator through the material at the bottom of the cylinder.
d) Flush the fine material into suspension by gentle stabbing and twisting of the irrigation tube to the bottom of the cylinder. This flushes the fine material into suspension above the coarser sand particle.
e) The process should be continued until the cylinder is filled to the 380 mm graduation.
f) Raise the irrigator tube slowly and adjust the flow to the 380 mm level of the cylinder.
g) Allow the cylinder and contents to stand undisturbed for 20



minutes ±15 seconds for sedimentation. Start the timing immediately after withdrawing the irrigator tube.

h) Record the "clay reading" from the cylinder gradations and if the reading lies between gradations, record the higher gradation.

i) Lower the weighted foot in the cylinder until it comes to rest on the sand.

j) As the weighted foot comes to rest on the sand, tip the assembly towards the graduations on the cylinder until the indicator touches the inside of the cylinder.

k) Subtract 250 mm from the level indicated by the extreme top edge of the indicator and record this value as the ‘sand reading’.

l) If clay or sand readings fall between 2 mm graduations, record the level of the higher graduation as the reading.

8. Calculation

Calculate the sand equivalent using the following formula, record to the nearest whole number.

Sand Equivalent (SE) = (Sand Reading/Clay Reading) x 100

9. Reporting of results

When the result of this calculation is not a whole number, the sand equivalent (SE) shall be the next higher whole number.

Example:

SE = 84/204 x 100 = 41.2 = 42

If it is desired to average a series of sand equivalent values, average the whole number values determined as described above.

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DETERMINATION OF ORGANIC CONTENT OF SOILS

IS: 2720 - Part XXII

1. Introduction

Organic matter is an undesirable constituent of the soil from the engineering point of view since it causes swelling or shrinkage of the soil from when the moisture content or the applied load changes. The estimation of organic matter, therefore, forms an important part of soil examination. A wide variety of both dry and wet combustion methods are in use for the determination of the organic matter of soils. Two methods which are widely in use are given in this revision of the BIS. These methods give reproducible results and the results are sufficiently accurate for common engineering purposes. The first method is given as the standard method and the other as an alternative method.

Method I- Based on organic carbon content of soil

2. Apparatus

(i) A chemical balance, sensitive to 0.001 gm.
(ii) Two volumetric flasks with1 litre capacity.
(iii) Two burettes of 25 ml each, graduated in 0.1 ml.
(iv) A thermostatically controlled oven, capable to maintain a temperature of 105 to 110°C with interior of non-corroding material.
(v) Pipettes of 10 ml and 1 ml, fitted with a rubber teat.
(vi) Two conical flasks of 500 ml capacity.
(vii) Graduated measuring cylinders of 200 ml and 25 ml.
(viii) Desiccator with any desiccating agent other than sulphuric acid.
(ix) Glass weighing bottle approximately 25 mm in diameter and of 50 mm height fitted with a ground glass stopper.
(x) IS test sieves of 10 mm, 425 micron and receivers.
(xi) Wash bottle.

3. Reagents

(i) *Potassium Dichromate normal solution*: Dissolve 49.035 gm of Potassium Dichromate in distilled water to make 1 litre of the solution.
(ii) *Ferrous Sulphate solution (Approximately 0*.5 N): Dissolve about 140 gm of Ferrous Sulphate in 0.5 N Sulphuric acid to make 1 litre solution. Add 14 ml of concentrated Sulphuric acid to distilled water to make 1 litre of 0.5 N Sulphuric acid solution.

NOTE: *This solution is unstable in air. Hence should be kept tightly stoppered. It should be standardised against the potassium dichromate solution at least once in a week.*

(iii) *Sulphuric acid concentrated of specific gravity 1.836.*
(iv) *Orthophosphoric acid, 85% of specific gravity 1.70 to 1.75.*
(v) *Indicator solution:* Dissolve 0.25 gm of sodium diphenylamine-sulphonate in 100 ml of distilled water.

4. Standardization of Ferrous Sulphate solution

a) Run 10 ml of the normal potassium dichromate solution from a burette into a 500 ml conical flask.
b) Add 20 ml of concentrated sulphuric acid and the mixture is swirled carefully and allowed to cool for some minutes.

c) Add 200 ml of distilled water to the mixture followed by 10 ml of phosphoric acid and 1 ml of indicator, and the mixture shaken thoroughly.
d) Ferrous sulphate solution is added from the second burette in 0.5 ml increments, the contents of the flask being swirled, until the colour of the solution changes from blue to green.
e) A further of 0.5 ml of potassium dichromate is then be added changing the colour back to blue.
f) Ferrous sulphate solution is then added drop by drop with continued swirling until the colour of the solution changes from blue to green after the addition of single drop.
g) The total volume of ferrous sulphate solution used (X) shall be noted to the nearest 0.05 ml (1 ml ferrous sulphate solution is equivalent to 10.5/X ml potassium dichromate).

5. Soil sample preparation for test

a) The soil samples as received from the field is prepared in accordance with IS: 2720-Part 1.
b) The portion of the air dried sample selected for the purpose of this test is weighed, its moisture content determined using separate sample for the purpose and the equivalent oven-dried weight (W_1) is recorded.
c) It shall then be sieved on a 10 mm IS sieve and all particles other than stones crushed to pass through the sieve.
d) The equivalent weight on oven dry basis of the material passing 10 mm sieve (W_2) shall be calculated and recorded to the nearest 0.1% of its total weight.
e) A sample weighing approximately 100 gm shall be obtained from the material passing the 10 mm IS sieve by quartering. This sample shall then be pulverized so that it passes the 425 micron IS sieve.

NOTE: *This method gives high results of organic content in soils containing sulphides. The sulphides can be destroyed at this stage by the addition of dilute (2N) Sulphuric acid. Acid to be added until no further evolution of hydrogen sulphide occurs*.

NOTE: *This method gives high results of organic content in soils containing chlorides. The chlorides may be removed at this stage by washing the soil with distilled water until no turbidity is obtained when a drop of the washing water is tested with silver nitrate solution. Alternatively the effect of chlorides on the determination can be partly eliminated by using concentrated sulphuric acid in which silver sulphate has been dissolved in place of the concentrated sulphuric acid. If the ratio of carbon to chloride does not exceed unity, 25 gm silver sulphate per litre of sulphuric acid will be sufficient to precipitate the chloride.*

6. Procedure

a) The sample of soil is placed in a glass weighing bottle and weighed nearest to 0.001 gm.
a) A small quantity, from 5 gm to 0.2 gm, depending on the organic content is transferred to a dry 500 ml conical flask.
b) The weighing bottle is reweighed and the equivalent weight on oven dry basis of soil specimen removed (W_3) is calculated by difference, allowing for the moisture content of the soil.

NOTE: *The size of the specimen for chemical analysis will vary with the amount of the organic matter present in the soil. As much as 5 gm may be required for soil low in organic matter and as little as 0.2 gm with a very peaty soil. After a number of determinations have been made,* *experience will indicate the most suitable size of specimen to be taken. In unfamiliar types of soil, it is suggested that a series of specimens of varying sizes should be weighed out and tested. The determination giving a total of 5 to 8 ml dichromate solution reduced should be taken as the correct result.*

c) 10 ml of the normal potassium dichromate solution is run into conical flask from a burette and 200 ml of concentrated Sulphuric acid is added to it very carefully from a measuring cylinder.

d) The mixture is thoroughly swirled for about one minute and allowed to stand on a heat insulating surface, such as asbestos or wood for 30 minutes to allow oxidation of the organic matter to proceed. During this period the flask shall be protected from draughts.

e) 200 ml distilled water is added along with 10 ml of orthophosphoric acid and 1 ml of the indicator, and the mixture shaken vigorously. If the indicator is absorbed by the soil, a further 1 ml of the solution is added.

f) Ferrous sulphate solution is added from the second burette in 0.5 ml increments, the contents of the flask being swirled, until the colour of the solution changes from blue to green. A further of 0.5 ml of potassium dichromate is then be added changing the colour back to blue.

g) Ferrous sulphate solution is then be added drop by drop with continued swirling until the colour of the solution changes from blue to green after the addition of single drop. The total volume of ferrous sulphate solution used (Y) shall be noted to the nearest 0.05 ml.

7. Calculations

The total volume (V ml) of potassium dichromate used to oxidize the organic matter in the soil is given by the following formula:

$$V = 10.5\,[1- (Y/X)]$$ where

Y = Total volume of ferrous sulphate used in this test.

X= Total volume of ferrous sulphate used in the standardization test.

The percentage of organic -matter (OM) present in the oven-dried sample shall be calculated from the following formula:

$$\text{OM, percent by weight} = 0.67W_2\,V/\,W_1W_3$$ where

W_2 = Weight on oven-dry basis of the soil sample passing I0 mm IS sieve.

V = Total volume of potassium dichromate used to oxidize the organic matter.

W_1 = Weight on oven-dry basis of the total soil sample taken for the test before sieving.

W_3 = Weight on oven-dry basis of the soil specimen used in the test.

8. Reporting of results

The report shall include the following data:

(i) The test result should be recorded suitably. A recommended proforma for recording the results is given in Appendix A.

(ii) The organic matter content present shall be reported to the nearest 0.1 percent of the original oven dried soil.

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DETERMINATION OF SPECIFIC GRAVITY OF FINE MEDIUM AND COARSE GRAINED SOILS

IS: 2720 - Part 3: Section 2

1. Introduction

This test lays down the procedure for the determination of specific gravity of soil particle of fine, medium and coarse grained soils. Specific gravity is the ratio of the weight in air of a given volume of soil solids at a specified temperature to the weight in air of equal volume of distilled water at that temperature. Specific gravity is required to find out the degree of saturation and unit weight of moist soils. The unit weight is needed in pressure, settlement and stability related problems in soil engineering.

2. Apparatus

a) A glass jar of 1000 ml capacity fitted with rubber bung or stopper.
b) Ground glass plate or a plastic slip cover for closing the jar.
c) A mechanical shaking apparatus capable of rotating the glass jar at about 50 revolutions per minute.
d) Weighing balance readable to 0.2 gm sensitivity.
e) A glass thermometer of range 0 to 50°C, readable to 1°C accuracy.

3. Procedure

a) Dry the gas jar and ground plate/plastic slip cover and weigh to the nearest 0.2 gm.
b) Take about 200 gm of fine grained soil or 400 gm of medium or coarse grained soil and dry in oven at 105°C to 110°C. Cool this in a desiccator.

NOTE: *If there is a chance of loss of water of hydration, the soil should be dried at not more than 80°C.*

c) Transfer this sample from desiccator direct to the gas jar. Weigh the gas jar with ground glass plate/slip cover and the soil sample to the nearest 0.2 gm.
d) Add 500 ml of water within ±2°C of the average room temperature during the test into the jar. Insert the rubber stopper into the gas jar.
e) Keep aside the jar along with the contents for at least 4 hours if the soil is medium or coarse grained.
f) If the sample is fine grained, shake the jar with hand immediately after the addition of water until the particles are in suspension.
g) Then place the jar in the shaking apparatus and shake for 20 to 30 minutes.
h) Remove the rubber stopper and carefully wash any soil particles adhering to the stopper into the jar.
i) Add water to the jar within 2 mm of the top. Allow the soil to settle for few minutes. Fill the jar to the brim with more water.
j) Place the glass plate over the jar ensuring that no air is entrapped under the plate.
k) Wipe the outside of the gas jar dry and find the weight to the nearest 0.2 gm.
l) Empty the gas jar, wash thoroughly and fill with water up to the brim.
m) Place the glass plate over the jar with water, ensuring that no air is entrapped under the plate.
n) Wipe the outside of the gas jar and plate dry and find the weight to the nearest 0.2 gm.
o) Repeat the procedure with a second sample to obtain two values.

NOTE: *If there is a large difference in air temperature, sufficient water should be drawn for the required number of tests and allowed to stand in room temperature in which the tests are done until the temperature is within the given range.*

4. Calculation

The specific gravity of the soil at room temperature is given by:

$G = W_2 – W_1 / [(W_4 – W_1) – (W_3 – W_2)]$ where

W_1 = Weight of gas jar + glass plate in gm.

W_2 = Weight of gas jar + glass plate + soil in gm.

W_3 = Weight of gas jar + glass plate + soil + water in gm.

W_4 = Weight of gas jar filled with water + glass plate in gm.

Specific gravity is reported to the nearest 0.01. Specific gravity is calculated at 27°C. If the test is done at a different temperature, the corrected specific gravity is given by $G^1 = K G$, where

K = Relative density of water at room temperature/ Relative density of water at 27°C.

Report the result in the format attached.

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-S5/2015
	QUALITY CONTROL WING	

Specific gravity of soils **IS: 2720 – Part 3 Section 2**	Report No.	Date:

REGIONAL LABORATORY………………………………	**DISTRICT LABORATORY…………………………………**

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**

LAYER #		Original ground	Fill	Subgrade	Subbase	

INITIAL TEMPERATURE **=** T_i = ºC	FINAL TEMPERATURE **=** T_x = ºC
Relative density at T_i = *gm/cm3*	Relative density at T_x = *gm/cm3*

1. Pycnometer No.	*A*	*B*
2. Weight of empty pycnometer = W_f gm		
3. Weight of pycnometer + water = W_a gm (at temperature T_i)		
4. Weight of pycnometer + soil = W_s gm		
5. Weight of soil = $W_o = W_s – W_f$ gm		
6. Weight of pycnometer + water + soil = W_b gm (at temperature T_x)		
Calculations:		
7. Weight of water at $Ti = W_a - W_f$ gm		
8. Relative density at Tx/ Relative density at Ti = Rf		
9. Adjusted weight of water W_a at T_x = Rf ($W_a - W_f$) + Wf gm		
10. Weight of water equal to volume of soil = $W_o+(W_a-W_b)$ gm		
11. Specific gravity of soil at T_x = $W_o / [W_o+(W_a-W_b)]$		
12. Correction factor for Specific gravity at 20 ºC		
13. Corrected specific gravity at 20 ºC		

RESULTS:	***Required value:***
Specific gravity at 20 ºC =	

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DETERMINATION OF SPECIFIC GRAVITY OF FINE GRAINED SOILS

IS: 2720 - Part 3: Section I

1. Introduction

The methods of test for the determination of specific gravity of fine grained soil particles are given under this part. Specific gravity is required to find out the degree of saturation and unit weight of moist soils. The unit weight is needed in pressure, settlement and stability problems in soil engineering.

2. Apparatus

(i) Two density bottles (pycnometer) with stoppers 50 ml capacity.

(ii) Water bath maintained at constant temperature within ±0.2°C (If standard density bottles are used, the constant temperature is 27°C).

(iii) One Vacuum Desiccator, about 200 to 250 mm diameter size.

(iv) One Desiccator about 200 to 250 mm diameter size containing anhydrous silica gel.

(v) *A* thermostatically controlled drying oven, capable of maintaining temperatures of 105°C to 110°C for drying wet samples.

(vi) A weighing balance, readable to 0.001 gm sensitivity.

(vii) A vacuum pump as a source of vacuum.

(viii) One spatula, about 150 mm long and 3 mm wide or 3 mm dia glass rod to go through the neck of the pycnometer.

(ix) Wash bottle made of plastic, containing air free distilled water.

(x) Multiple slot type sample divider (riffle box) with 7 mm wide opening.

(xi) Rubber tube to fit the vacuum pump and desiccator.

3. Procedure

a) Dry the pycnometer with stopper in oven at 105°C to 110°C, cool it in a desiccator and weigh to the nearest 0.001 gm (W_1).

NOTE: *If a density bottle is used, it should not be dried in oven to avoid distortion. It may be dried by rinsing with acetone or an alcohol-ether mixture and then blowing with warm air.*

b) Take about 50 gm of sample and ground if necessary, to pass through a 2 mm IS test sieve.

c) Obtain 5 gm to 10 gm of sample by riffling and dry in oven at 105 ^{o}C to 110°C. Cool this in a desiccator.

NOTE: *If there is a chance of loss of water of hydration, the soil should not be dried at not more than 105°C.*

d) Transfer this sample from desiccator direct to the density bottle. Weigh the bottle and sample to the nearest 0.001 gm (W_2).

e) Add sufficient air-free distilled water into the bottle such that the soil sample is just covered.

f) Keep the bottle along with the contents but without stopper, in a vacuum desiccator and evacuate gradually at a pressure of 20 mmHg.

g) During this process ensure that the air trapped in the soil do not bubble violently to prevent drops of suspension escaping through the mouth of the bottle. Continue this for at least one hour or till no further loss of air is apparent.

h) The vacuum is released and lid of desiccator removed.

i) The soil in the bottle is carefully stirred with a spatula or vibrated. Before removing the spatula from the bottle, clean the particles of soil adhering to blade of the spatula using a few drops of air-free distilled water.

NOTE: *Alternately the entrapped air can be removed by heating the pycnometer placed on a water-bath or sand-bath.*

j) Remove the bottle and contents from the desiccator and fill with air-free distilled water till the bottle is full. Insert the stopper.

k) Then immerse the bottle up to the neck in the constant-temperature bath at least for 1 hour or till it has attained the constant temperature of the bath.

NOTE: *If a constant-temperature room or cabinet is available then keeping the bottle in constant-temperature bath is not necessary.*

l) If there is apparent deduction in the volume of liquid inside the bottle, remove the stopper, fill the bottle with air-free liquid and replace the stopper.

m) Return the bottle to the constant-temperature bath and keep till the required temperature is attained. If the bottle is still not completely full, repeat the process.

n) Take the stoppered bottle out, wipe it dry and find the weight to the nearest 0.001 gm (W_3).

NOTE: *With certain soils containing soluble salts, kerosene or white sprit is used as testing liquid. In such cases, the specific gravity of the liquid at room temperature is carried out separately.*

o) The volume of the density bottle has to be determined. For this, the bottle is then cleaned out and completely filled with air-free liquid. Insert the stopper.

p) Immerse the bottle with water in a constant temperature bath for minimum one hour or till it attains the constant temperature of the bath. It there is apparent deduction in the volume of liquid inside the bottle, remove the stopper, fill the bottle with air-free liquid and replace the stopper.

q) Return the bottle to the constant-temperature bath and keep till the required temperature is attained. If the bottle is still not completely full, repeat the process.

r) Take the stoppered bottle out, wipe it dry and find the weight to the nearest 0.001 gm (W_4).

Two determinations of the specific gravity of the same soil are normally carried out.

NOTE: *Many soils contain substantial amount of heavy or light particles. This may lead to erratic values of specific gravity. Hence it is recommended that a number of specific gravity determinations may be done to obtain a good average value.*

4. Calculation

When air-free water is used, the specific gravity of the soil at room temperature is given by:

$$G = W_2 - W_1 / [(W_4 - W_1) - (W_3 - W_2)]$$ where

W_1 = Weight of density bottle in gm.
W_2 = Weight of density bottle + soil in gm.
W_3 = Weight of density bottle + soil + water in gm.
W_4 = Weight of density bottle filled with water in gm.

The average of the two values obtained is taken as the specific gravity. If the two results differ by more than 0.03, the test is repeated. Specific gravity is reported to the nearest 0.01. Report the result in the format attached.

If kerosene is used, the specific gravity G obtained as above is multiplied by the specific gravity of kerosene determined separately at the constant temperature.

Specific gravity is calculated at 27°C. If the test is done at a different temperature, the corrected specific gravity is given by $G^1 = K\ G$, where

K = Relative density of water at room temperature/Relative density of water at 27°C.

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DENSITY OF SOIL IN-PLACE FOR FINE AND MEDIUM GRAINED SOILS BY SAND REPLACEMENT METHOD USING SMALL POURING CYLINDER

IS: 2720 - Part 28

1. Introduction

The dry density of the compacted soil or pavement material is a common measure of the amount of compaction achieved during the construction. Knowing the field density and field moisture content, the dry density is calculated. Therefore field density test is important as a field control test for the compaction of the soil or any other pavement layer.

a) The sand replacement method sometimes also termed as field density test is done for determining the in-place dry density of the compacted fine and medium grained soil.
b) This method covers the determination of in-place density of natural or compacted fine or medium grained soils for which a small sand pouring cylinder is used.
c) The method is not applicable for layers exceeding 150 mm thickness.

2. Apparatus

(i) Small sand pouring cylinder consisting of a metal cylinder of capacity 3 litres,115 mm in diameter and 380 mm length with an inverted funnel or cone at one end and a shutter to open and close the entry of sand and a cap on the other end.

(ii) Hand tools for excavating such as scraper with handle for leveling the surface, bent spoon, a dibber or an elongated trowel for digging and excavating the material.

(iii) Cylindrical calibrating container with an internal diameter of 100 mm and depth 150 mm. The volume of the container should be given to an accuracy of 0.25%.

(iv) Balance with approximate capacity 10 kg with the sensitivity of 1.0 gm,

(v) Glass or Perspex plate about 450 mm square and 9 mm thick or larger for calibration purpose.

(vi) Metal container of any convenient size about 150 mm diameter and 200 mm depth with a removable lid for collecting the excavated material.

(vii) Metal tray 300 mm square and 40 mm deep with a 100 mm dia hole in the centre.

(viii) Dry and clean test sand of uniform gradation passing 1.0 mm and retained on 600 micron IS sieve.

3. Calibration of the apparatus

a) Clean and oven dry the test sand, passing 1.0 mm IS sieve and retained on 600 micron IS sieve. Store for a period of one week for the water content in the sand to reach equilibrium with the atmospheric humidity.
b) Sand is collected in sufficient quantity required for at least three to four sets of test.
c) The top cap of the small sand pouring cylinder is removed and the shutter (above the cone) is closed.
d) The cylinder is filled with sand up to about 10 mm from the top and the cap is replaced.
e) The weight of the cylinder with the sand is determined accurate to 1 gram and is recorded (W_1). In all the subsequent tests for calibration as well as for the field density

tests, every time the sand is filled into the cylinder such that the initial weight of the cylinder with sand is exactly W_1.

f) The shutter is opened and sand equal to the volume of the calibration cylinder or the excavated test hole is allowed to flow out under gravity and the shutter is closed.

g) The sand pouring cylinder is now placed on a clean plane surface (glass or Perspex plate) the shutter is kept open till the sand fills up the cone fully and there is no visible movement of sand as seen from the top of the cylinder.

h) The shutter is closed, the cylinder is removed and the sand which occupied the cone is carefully collected from the plate and weighed (W_2).

i) The sand pouring cylinder is refilled with sand such that the total weight is again W_1.

j) Now the cylinder is placed centrally on the top of the calibration container and the shutter is opened.

k) When the sand fills up the calibration container and the cone completely and there is no movement of sand, the shutter is closed and the sand pouring cylinder and the remaining sand is weighed (W_3).

l) The above steps are repeated 3 times and the mean values of W_2 and W_3 are determined such that the mean value of the weight of sand required to fill the calibration container up of the level top can be determined.

m) The volume of the calibrating container V is determined either by measuring the internal dimensions or by filling with water and weighing.

n) From the weight of sand W_a and its volume V in the calibrating container, the density of sand is determined.

4. Measurement of field density

a) The point on the compacted layer where the field density test is to be conducted is cleaned and levelled using a scraper for an area of about 450 mm square.

b) The metal tray with central hole is placed on the prepared surface. Using this central hole as pattern, the soil /material is excavated using a dibber or a trowel up to a depth of 150 mm.

c) The loose material is removed and carefully collected in the metal container and is weighed (W_w).

d) The sand pouring cylinder is refilled with sand such that its weight is again W_1.

e) The metal tray with central hole is removed and the sand pouring cylinder is placed centrally over the excavated hole.

f) The shutter is opened till the sand fills the excavated hole and the cone completely and there is no further movement of sand in the cylinder.

g) The shutter is closed and the cylinder is weighed again (W_4) so that the weight of the sand filling the excavated hole alone W_b can be found.

h) The moisture content of the excavated soil w% is determined by taking a sample of soil from it in a moisture content dish, weighing, drying in oven at 110°C and reweighing (Method specified in IS:2720-Part 2).

i) Alternatively, the moisture content (*w*%) is determined by placing the entire excavated soil collected from the hole (of weight W_w) in the oven and finding its dry weight Wd.

j) The above steps for the determination of the weights of excavated soil , the weight of the sand filling the hole and the weights of samples for the moisture content determination are repeated at least three times and the average values taken for the determination of field density (wet and dry) values.

5. Calculations

(a) Bulk density determination of sand:

Weight of cylinder + sand filled up to 10 mm from top edge = W_1 gm.

Weight sand in the cone (mean value) = W_2 gm.

Weight of sand + cylinder after pouring into the calibration container and cone = W_3 gm.

Weight of sand + cylinder after pouring into the excavated hole and cone = W_4 gm.

Volume of calibrating container = V ml.

Weight soil from the excavated hole = W_w gm.

Weight of sand required to fill the hole = W_b gm.

Weight of dry soil from the hole = W_d gm.

Moisture content of the soil in % = w

The weight of sand filling the calibrating container only W_a = $(W_1-W_3-W_2)$ gm.

Bulk Density of sand, γ_s = (W_a/V) g/cm^3.

(b) Bulk density determination of soil:

Weight of sand filling the excavated hole alone, W_b = $(W_1-W_4-W_2)$ gm.

Weight of wet soil per cubic meter, γ_b = $(W_w/W_b) \times \gamma_s$ kg/m^3.

Dry density of soil, γ_d = $(W_d/W_b) \times \gamma_s$ kg/m^3.

6. Reporting of results

The following values shall be reported:

a) Dry density of soil in kg/m^3 to the nearest whole number or in g/cm^3 correct to the second place of decimal

b) Water content of the soil in percent reported to two significant figures.

c) Compaction achieved in the field as a percentage of the maximum laboratory dry density.

A typical format to record the results is attached.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-S6/2015
Density of soil in-place by Sand Replacement Method - IS: 2720 – Part 28	Report No.	Date:

REGIONAL LABORATORY…………………………	**DISTRICT LABORATORY………………………………**

Name of work:		
Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**
Type of material:		Date of testing:

LAYER NUMBER		Original ground	Fill	*Subgrade*	*Subbase*	

Determination of Bulk Density of sand	*Trial 1*	*Trial 2*	*Trial 3*	Average
1. Wt of sand + cylinder before pouring = W1 gm				
2. Mean wt of sand in the cone = W2 gm				:
3. Volume of calibrating jar in cm^3				
4. Wt of sand + cylinder after pouring = W3 gm				
5. Wt of sand filling calibrating can W_c= (W1-W3)-W2 gm				
6. Bulk density of sand γ_s = 5/3 gm/cm^3				
Determination of Bulk Density of soil				
7. Wt of wet soil in the hole = W gm				
8. Wt of sand + cylinder after pouring in hole = W4 gm				
9. Wt of sand in the hole = W_h =(W1-W4) - W2 gm				
10. Field Bulk density of soil $\gamma = W/W_h \times \gamma_s$ gm/cm^3				
Moisture content determination	*Trial 1*	*Trial 2*	*Trial 3*	Average
11. Container number				
12. Wt of container + lid = W1 gm				
13. Wt of container + lid + wet soil = W2 gm				
14. Wt of container + lid + dry soil = W3 gm				
15. Wt of water Ww = (W2 - W3) gm				
16. Wt of soil Ws = (W3 - W1) gm				
17. Moisture content *w %* = Ww/Ws*100				
18. Field Dry density $\gamma_d = \gamma/(1 + w)$ gm/cm^3				

RESULTS:		***Required value:***	
Field dry density =	g/cm^3		gm/cm^3
Percentage compaction =	%		%

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DENSITY OF SOIL IN-PLACE FOR, FINE, MEDIUM AND COARSE GRAINED SOILS BY SAND REPLACEMENT METHOD USING LARGE CYLINDER

IS: 2720 - Part 28

1. Introduction

The dry density of the compacted soil or pavement material is a common measure of the amount of compaction achieved during the construction. Knowing the field density and field moisture content, the dry density is calculated. Therefore field density test is important as a field control test for the compaction of the soil or any other pavement layer.

a) The sand replacement method sometimes also termed as field density test is done for determining the in-place dry density of the compacted fine, medium or coarse grained soils.
b) This method covers the determination of in-place density of natural or compacted soils containing stones which make the use of small sand pouring cylinder difficult.
c) The method is applicable for layers exceeding 150 mm thickness but not exceeding 250 mm thickness.

2. Apparatus

(i) Large sand pouring cylinder consisting of a metal cylinder of capacity 16.5 litres, 215 mm in diameter and 610 mm length with an inverted funnel or cone at one end and a shutter to open and close the entry of sand and a cap on the other end.

(ii) Hand tools for excavating such as scraper with handle for leveling the surface, bent spoon, a dibber or an elongated trowel for digging and excavating the material.

(iii) Cylindrical calibrating container with an internal diameter of 200 mm and depth 250 mm fitted with a flange 75 mm wide and 5 mm thick. The volume of the container should be found to an accuracy of 0.15%

(iv) Balance with approximate capacity 10 kg with the sensitivity of 1.0 gm,

(v) Glass or Perspex plate about 600 mm square and 10 mm thick or larger for calibration purpose.

(vi) Metal container of any convenient size about 150 mm diameter and 200 mm depth with a removable lid for collecting the excavated material.

(vii) Metal tray 450 mm square and 50 mm deep with a 200 mm dia hole in the centre.

(viii) Dry and clean test sand of uniform gradation passing 1.0 mm and retained on 600 micron IS sieve.

3. Calibration of the apparatus

a) Clean and oven dry the test sand passing 1.0 mm IS sieve and retained on 600 micron IS sieve and store for a period of one week for the water content in the sand to reach equilibrium with the atmospheric humidity.
b) Sand is collected in sufficient quantity required for at least three to four sets of test.
c) The top cap of the small sand pouring cylinder is removed and the shutter (above the cone) is closed.

d) The cylinder is filled with sand up to about 10 mm from the top and the cap is replaced.

e) The weight of the cylinder with the sand is determined accurate to 1 gram and is recorded (W_1). In all the subsequent tests for calibration as well as for the field density tests, every time the sand is filled into the cylinder such that the initial weight of the cylinder with sand is exactly W_1.

f) The shutter is opened and sand equal to the volume of the calibration cylinder or the excavated test hole is allowed to flow out under gravity and the shutter is closed.

g) The sand pouring cylinder is now placed on a clean plane surface (glass or Perspex plate) the shutter is kept open till the sand fills up the cone fully and there is no visible movement of sand as seen from the top of the cylinder.

h) The shutter is closed, the cylinder is removed and the sand which occupied the cone is carefully collected from the plate and weighed (W_2).

i) The sand pouring cylinder is refilled with sand such that the total weight is again W_1.

j) Now the cylinder is placed centrally on the top of the calibration container and the shutter is opened.

k) When the sand fills up the calibration container and the cone completely and there is no movement of sand, the shutter is closed and the sand pouring cylinder and the remaining sand is weighed (W_3).

l) The above steps are repeated 3 times and the mean values of W_2 and W_3 are determined such that the mean value of the weight of sand required to fill the calibration container up of the level top can be determined.

m) The volume of the calibrating container V is determined either by measuring the internal dimensions or by filling with water and weighing.

n) From the weight of sand W_a and its volume V in the calibrating container, the density of sand is determined.

4. Measurement of field density

a) The point on the compacted layer where the field density test is to be conducted is cleaned and levelled using a scraper for an area of about 60 cm^2.

b) The metal tray with central hole is placed on the prepared surface. Using this central hole as pattern, the soil /material is excavated using a dibber or a trowel up to a depth of 250 mm.

c) The loose material is removed and carefully collected in the metal container and is weighed (W_w).

d) The sand pouring cylinder is refilled with sand such that its weight is again W_1.

e) The metal tray with central hole is removed and the sand pouring cylinder is placed centrally over the excavated hole.

f) The shutter is opened till the sand fills the excavated hole and the cone completely and there is no further movement of sand in the cylinder.

g) The shutter is closed and the cylinder is weighed again (W_4) so that the weight of the sand filling the excavated hole alone W_b can be found.

h) The moisture content of the excavated soil w% is determined by taking a sample of soil from it in a moisture content dish, weighing, drying in oven at 110°C and reweighing (Method specified in IS:2720-Part II).

i) Alternatively, the moisture content (w%) is determined by placing the entire excavated soil collected from the hole (of weight W_w) in the oven and finding its dry weight Wd.

j) The above steps for the determination of the weights of excavated soil , the weight of the sand filling the hole and the weights of samples for the moisture content determination are repeated at least three times and the average values taken for the determination of field density (wet and dry) values.

5. Calculations

(a) Bulk density determination of sand:

Weight of cylinder + sand filled up to 10 mm from top edge = W_1 gm.

Weight of sand in the cone (mean value) = W_2 gm.

Weight of sand + cylinder after pouring into the calibration container and cone = W_3 gm.

Weight of sand + cylinder after pouring into the excavated hole and cone = W_4 gm.

Volume of calibrating container = V ml.

Weight wet soil from the excavated hole = W_w gm.

Weight of sand required to fill the hole = W_b gm.

Weight of dry soil from the hole = W_d gm.

Moisture content of the soil in % = w

The weight of sand filling the calibrating container only W_a = $(W_1\text{-}W_3\text{-}W_2)$ gm.

Bulk Density of sand, γ_s = (W_a/V) g/cm^3.

(b) Bulk density determination of soil:

Weight of sand filling the excavated hole alone, W_b = $(W_1\text{-}W_4\text{-}W_2)$ gm.

Weight of wet soil per cubic meter, γ_b = $(W_w/W_b) \times \gamma_s$ kg/m^3.

Dry density of soil, γ_d = $(W_d/W_b) \times \gamma_s$ kg/m^3.

6. Reporting of results

The following values shall be reported:

(i) Dry density of soil in kg/m^3 to the nearest whole number or in g/cm^3 correct to the second place of decimal

(ii) Water content of the soil in percent reported to two significant figures.

(iii) Compaction achieved in the field as a percentage of the maximum laboratory dry density.

The typical format included to record the results for small pouring cylinder may be used for this test also.

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DETERMINATION OF LABORATORY CALIFORNIA BEARING RATIO

IS: 2720 - Part 16

1. Introduction

This test covers the laboratory determination of California Bearing Ratio (CBR). The ratio expressed as a percentage of the force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm /min to that force required to penetrate a standard material is called CBR. The ratio is usually determined for 2.5 mm and 5.0 mm penetrations of the plunger. Where the ratio is consistently higher for 5.0 mm penetration than for 2.5 mm, the ratio for 5.0 mm is used. The Standard load is obtained from test on crushed stone sample and is defined as CBR 100%. The test may be performed on undisturbed or remolded specimens. The remoulded specimens may be subjected to either static or dynamic compaction.

2. Apparatus

(i) CBR moulds provided with detachable base plate, removable collar, stay rods and wing nuts, spacer discs, surcharge weights etc all conforming to IS: 9669-1980 – Specification for CBR moulds and accessories.

(ii) Metal rammer conforming to IS: 9198-1979 – Specification for compaction rammer for soil testing.

NOTE: *If mechanical rammer is used it shall be suitably calibrated*.

(iii) Sample extruder consisting of a jack, lever, frame etc.

(iv) Penetration plunger conforming to IS: 9669-1980.

(v) Loading machine with at least 5000 kg capacity with a movable head or base which will enable the plunger to penetrate into the specimen at the rate of 1.25 mm/min.

(vi) Expansion measuring apparatus having adjustable stem with perforated plates and tripod conforming to IS: 9669-1980.

(vii) Two dial gauges reading to 0.01 mm accuracy.

(viii) Balances, one with approximate capacity 15 kg, when used with 2250 cm^3 mould with sensitivity of 1 gm and one with capacity 200 gm with sensitivity of 0.01 gm.

(ix) Drying oven thermostatically controlled with non-corroding material interior, capable of maintaining temperature between 105°C and 110°C for drying wet samples.

(x) Straight edge of hardened steel about 300 mm length and having one edge bevelled.

(xi) IS sieves 37.5 mm, 19 mm and 4.75 mm conforming to the requirement of IS: 460 Part I – 1985 - Specification for wire cloth test sieves.

(xii) Mixing tools such as tray or pan, spoon, trowel, spatula, calibrated measuring jar, filter paper etc.

(xiii) Containers made of corrosion resistant material with close fitting lids, one container each for one moisture content determination.

3. Procedure for preparing undisturbed specimens

a) A steel cutting edge, 150 mm diameter, is attached to the mould and then pushed gently to the ground.
b) This process may be facilitated by digging away soil from outside as the mould is pushed down.
c) When the mould is full of soil, it shall be removed by under digging.
d) The top and bottom surfaces shall be trimmed flat so as to give the required length of specimen for testing.
e) The density of the soil shall be determined either by weighing the sample with the mould or by measuring the in-situ density by Sand Replacement method IS: 2720 (Part 28).

4. Procedure for preparing disturbed specimens

The material passing 19 mm IS sieve shall be used in the remoulded specimen. Allowance for fraction larger than 19 mm shall be made by replacing with equal amount of material passing 19.0 mm but retaining on 4.75 mm IS sieve.

4.1 *Procedure for static compaction*

A batch of soil shall be thoroughly mixed with water to give the required water content. The correct mass of the moist soils shall be placed in the mould and compaction obtained by pressing the displacer disc. A filter paper is placed between the disc and the soil.

4.2 *Procedure for dynamic compaction*

a) Mix about 4.5.kg of the air-dried fine grained soil or 5.5 kg of granular soil sample with the require amount of water to dampen it.
b) The soil is thoroughly mixed with the water added.
c) If the soil is to be compacted to the maximum dry density (MDD) at the optimum moisture content (OMC), the exact mass of soil required shall be taken and necessary water added so that the soil sample is at the optimum water content.
d) The mould with the extension collar attached is clamped to the base plate.
e) The spacer disc is then inserted over the base plate and a disc of coarse filter paper placed on the spacer disc.
f) Fill in the 2250 cm^3 mould in five approximately equal layers for heavy compaction (IS: 2720 Part 8) and compact each layer with 55 uniformly distributed blows.
g) For light compaction (IS: 2720 Part 7) fill the mould in five approximately equal layers and compact each layer with 25 uniformly distributed blows.

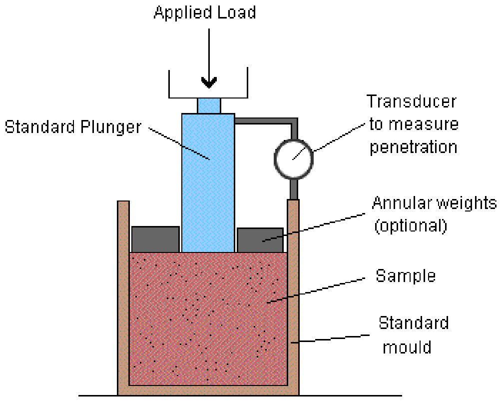
NOTE: *Some specifications may desire three specimens compacted with 10, 25 and 65 blows per layer.*

h) While compacting the intermediate layers, any loose soil adjacent to the mould walls shall be trimmed using a knife or spatula and evenly distributed on top of the compacted layer.
i) After filling each layer give a slight tamp with the rammer, if the soil is loose or in a fluffy state.
j) After compaction, remove the extension collar, trim the compacted soil surface of the soil even with the top of the mould using the straight edge. Any hole that may develop on the surface during trimming shall be patched with smaller size material.

NOTE: *It is necessary to control the quantity of soil compacted in the mould. If the amount of soil struck after removal of the collar is too great, it is likely to affect the accuracy of the result*.

k) Remove the perforated base plate and spacer disc and weigh the compacted soil in the mould to the nearest 1 gm.

l) A disc of coarse filter paper is then placed on the perforated base plate. The mould and the compacted soil is inverted and the perforated base plate is clamped to the mould with the filter paper below the compacted soil specimen.



NOTE: *In both cases of compaction, if the specimen is to be soaked, representative samples of the material at the beginning of compaction and another sample of the remaining material after compaction shall be taken for moisture content determination. If the specimen is not soaked one cut piece of the material after penetration test is taken to determine the water content. The water content shall be determined in accordance with IS: 2720 (Part 2) – Determination of water content.*

5. Procedure for measuring the swell

a) Place a filter paper over the compacted specimen. Place the adjustable stem and perforated plate over it.

b) Weights to produce a surcharge equal to the weight of the base material and pavement to the nearest 2.5 kg shall be placed on the compacted specimen.

c) The whole mould and weights is then immersed in a tank of water. Allow free access of water to the top and bottom of the specimen.

d) The tripod for the expansion measuring device is mounted on the edge of the mould. The initial dial gauge reading is recorded. This set up shall be kept undisturbed for 96 hours noting down the readings after every 24 hrs.

e) At the end of the soaking period, the final dial gauge reading is noted. The tripod is then removed and the mould is taken out of water.

f) The free water collected on the top of the mould is removed and the specimen allowed drain out for 15 minutes. The surface of the specimen shall not be disturbed while water is drained water.

g) The weights, perforated plate and the top filter plate are removed.

h) The soaked specimen with the mould is weighed and the mass recorded.

NOTE: *The swell test may be omitted if it is not required in the specification.*

6. Procedure for measuring the penetration

a) The mould containing the specimen with the base plate in position, but the top face exposed, is placed on the lower plate of the testing machine.

b) The required number of surcharge weights is placed on the specimen. Initially one 2.5 kg surcharge is placed before the seating of the penetration plunger is done. The seating is done with a load of 4 kg to establish full contact between the plunger and soil surface.

c) Now the load and deformations gauges are set to zero. The load shall be applied at the penetration rate of 1.25 mm/min.

d) Readings of the load gauge are taken at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10 and 12.5. Raise the plunger and detach the mould from the loading equipment.

e) About 50 gm of soil is collected from the top 30 mm portion and water content determined as per IS: 2720 (Part 2).

f) If the average water content is to be determined, sample shall be taken from the entire depth of the specimen.

g) If undisturbed specimen is to be used in the test, examine carefully for any oversized particle directly below the plunger which are likely to affect the results.

NOTE: *The penetration test may be repeated as a check test for the rear end of the sample.*

7. Calculations

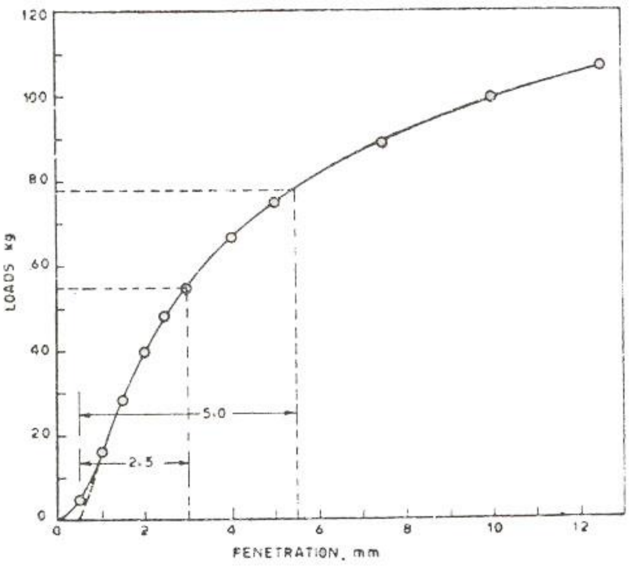
a) *Expansion ratio*: The expansion ratio of the soil tested is calculated as below from the swell measurements obtained as per item 5 above.

Expansion ratio = $[(d_f - d_s)/h)] \times 100$ % where

d_f = Final reading of the dial gauge in mm,
d_s = Initial reading of the dial gauge in mm and
h = Initial height of the specimen in mm.

The expansion ratio is used to evaluate the expansive nature of the soil.

b) *Load penetration curve*: The load obtained against each penetration reading is plotted with penetration in the X-axis. Normally the curve is convex upwards. But due to surface irregularities, the initial portion may convex downwards. A correction shall be then applied by drawing a tangent to the point of greatest slope. The point on the X-axis where the new tangent meets is considered as the origin of the load penetration curve. The points of 2.5 mm & 5 mm penetrations are shifted equal to the shift of the origin.



8. Reporting of results

The CBR values are normally calculated for 2.5 mm and 5 mm penetrations.

California Bearing Ratio (CBR) = $(P_T/P_S) \times 100$ where

P_T = Corrected load in kg for the selected penetration and
P_S = Standard in kg for the corresponding penetration.

The standard load for 2.5 mm depth penetration is taken as 1370 kg and for 5 mm depth penetration is 2055 kg. If the CBR for 5 mm penetration is higher than that for 2.5 mm penetration, the test is repeated. If the ratio is consistently higher for 5.0 mm penetration than for 2.5 mm, the ratio for 5.0 mm is reported as CBR of the material tested.

The test data may be tabulated in the attached formats. The results of the test are presented as CBR value and expansion ratio.

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KERALA PUBLIC WORKS DEPARTMENT

QUALITY CONTROL WING

Form No.
QC-S7(a)/2015

CBR Compaction data

IS: 2720 - Part 16

Volume of mould V = cm^3	*Rammer*	*….………. Kg*	
REGIONAL LABORATORY……………………………	**DISTRICT LABORATORY………………………………......**		
Report No.	Date:		

Name of work:

Division:	Subdivision:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TYPE:		Date of testing:

LAYER:	Fill	Subgrade	Subbase		

1. *Number of blows*	*56*	*25*	*10*
2. Weight of mould + base plate + soil = W_2 gm			
3. Weight of mould + base plate = W_1 gm			
4. Weight of compacted soil = $(W_2 - W_1)$ gm			
5a. Bulk density $\gamma = (W_2 - W_1) / V$ gm/cm^3			
5b. Dry density = $\gamma_{dry} = \gamma / (1 + w)$ gm/cm^3			
6. *Container No.*			
7. Weight of container + lid = W_1 gm			
8. Weight of container +lid + wet soil = W_2 gm			
9. Weight of container +lid + dry soil = W_3 gm			
10. Weight of water = W_2-W_3 gm			
11. Weight of soil = W_3-W_1 gm			
12. Moisture content $w = (W_2-W_3) / (W_3-W_1) \times 100\%$			
13. *Period of soaking*	4 days	4 days	4 days
14. Initial swell gauge reading			
15. Final swell gauge reading			
16. Swell or expansion mm			
17. Expansion ratio = Expansion/Ht of specimen %			

RESULTS (From graph): CBR at 95% compaction = %	*Required value*	%

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

KERALA PUBLIC WORKS DEPARTMENT

QUALITY CONTROL WING

Form No.
QC-S7(b)/2015

California Bearing Ratio (CBR) - IS: 2720 - Part 16

PENETRATION TEST DATA

Report No.

Date:

REGIONAL LABORATORY………………………………

DISTRICT LABORATORY……………………………….....

Name of work:

Division:	Sub Division:	Section:
Location:	**Sample No.**	**Date:**
MATERIAL TYPE:		Date of soaking:
MDD:	OMC: %	Date of testing:
Specimen No.	No of blows:	Condition: Soaked / unsoaked

Dial Reading	Penetration in mm	Load in kg	Dial Reading	Penetration in mm	Load In kg	Dial Reading	Penetration in mm	Load In kg
0	0	0	--	--	--	--	--	--
	0.25			3.00			5.75	
	0.50			3.25			6.00	
	0.75			3.50			6.25	
	1.00			3.75			6.50	
	1.25			4.00			6.75	
	1.50			4.25			7.00	
	1.75			4.50			7.25	
	2.00			4.75			7.50	
	2.25			5.00			8.00	
	2.50			5.25			10.00	
	2.75			5.50			12.50	

From graph:

CBR at 2.5 mm = / 1370 x 100 = %

CBR at 5.0 mm = / 2055 x 100 = %

RESULT:	**Required value:**
CBR = *%*	%

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

Part - IV

BITUMINOUS MATERIALS TESTING

DETERMINATION OF SOFTENING POINT OF BITUMEN

IS: 1205

1. Introduction

This method covers the determination of the softening point of bitumen in the range of 30 to 157°C using ring and ball apparatus immersed in distilled water (30 to 80°C). USP glycerin (above 80 to 157°C) or ethylene glycol (30 to 110°C). The softening point is the temperatures at which the substance attains a particular degree of softening under specified conditions of test. Softening point is useful in establishing the uniformity of the bitumen delivered at site and also indicates the level of tendency to flow at elevated temperatures.

2. Apparatus

(i) Two square shouldered brass rings conforming to the dimensions specified.

(ii) A flat, smooth brass plate approximately 50 by 75 mm size.

(iii) Two steel balls 9.5 mm dia having mass of 3.50 ± 0.05 gm.

(iv) Two brass guides for centering the steel balls, one for each ring.

(v) A brass holder having a bottom plate of 16 mm thickness with two vertical supports to hold the rings in a horizontal position. The bottom of the shouldered rings shall be 25 mm above the top surface of the bottom plate.

(vi) A thermometer capable of reading from 0°C to 250°C. The thermometer is suspended in the assembly such that the bottom of the bulb is in level with the bottom of the rings. Substitution of other thermometers is not permitted.

(vii) Heat resistant glass vessel not less than 85 mm in dia and 120 mm depth for the water bath.

(viii) A stirrer to ensure uniform heat distribution at all times during the test.

3. Reagents and materials

a) The use of freshly boiled distilled water is essential to avoid trapping of air bubbles on the surface of the specimen which may affect the result.

b) If USP glycerin is used it shall be kept in mind that its flash point is 160°C.

4. Sampling

a) Heat the bitumen preferably using an electric hot plate to a temperature 75 to 100°C above the expected softening point.

b) Bitumen shall not be heated more than 2 hours.

c) Take no more than 30 minutes to heat a coat-tar pitch sample to its pouring temperature and this shall be not more than 55°C above the expected softening point.

d) For repeating the test, start from fresh sample. Do not reheat the previous sample.

e) Stir until the sample is fluid and free from air bubbles and water.

- f) Heat the two brass rings close to the pouring temperature of the specimen and place over the plate coated with the releasing agent made of equal parts of glycerin and dextrin.
- g) Pour slightly excess heated bitumen into each ring and cool in ambient air for at least 30 minutes.
- h) After cooling, cut away the excess bitumen with a clean hot knife or spatula so that the top of specimen is in level with the top of its ring.
- i) Test should be completed within 240 minutes after the discs have been poured.

5. Procedure

- a) Carry out the test with the appropriate bath liquid and thermometer.
- b) Generally all softening points up to 80°C shall be determined in a water bath and all softening points above 80°C shall be determined in glycerin bath.
- c) Assemble the apparatus with the specimen rings, ball entering guides and the thermometer in position.
- d) Fill the bath liquid to a height of 50 mm above the upper surface of the rings.

- e) Place the two balls inside the bath so that they are also at the same starting temperature as with the rest of the apparatus.
- f) Cool the bath to reach the starting temperature for the test (5°C) and maintain it for 15 minutes.
- g) Now place the balls gently over the specimen in the rings.
- h) Gently heat the bath from below such that the rate of increase is uniformly at 5°C.
- i) At any one minute period, after the first three minutes, the rate of rise shall not vary by ± 0.5°C.
- j) Record the temperatures at which the bitumen surrounding the ball just touches the bottom plate as shown in the figure.

6. Report

The mean temperature from the two readings rounded to the nearest 0.5°C is reported as the softening point.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-B1/2015
Softening point of bitumen **IS: 1205**	Report No.	Date:
REGIONAL LABORATORY………………………………..	**DISTRICT LABORATORY…………………………………**	

Name of work:		
Division:	Subdivision:	Section:
Location:	**Sample No.**	**Date:**

Liquid used in the bath	Water/Glycerin	Date of testing:	
MIX TYPE:	Premix surfacing/Seal coat	Bituminous Macadam	Bituminous Concrete
Test data			
Time in minutes	Temperature °C	Time in minutes	Temperature °C
0		11	
1		12	
2		13	
3		14	
4		15	
5		16	
6		17	
7		18	
8		19	
9		20	
10			

Test property	*Ball No*		*Mean Value*
	(i)	(ii)	
Temperature (°C) at which sample touches the bottom plate			

RESULTS :

Bitumen grade =		***Required value***
Softening point =		

Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

PENETRATION TEST OF BITUMEN

IS: 1203

1. Introduction

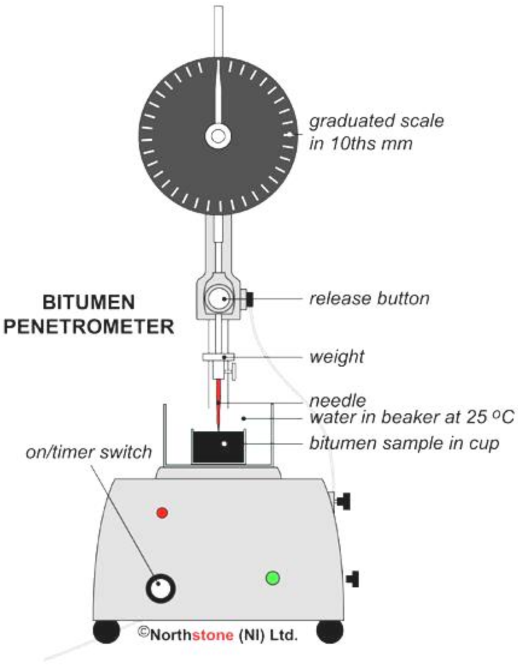
This method covers the determination of the penetration of bitumen, fluxed native asphalt and blown type bitumen. The penetration of a bituminous material is the distance in tenths of a millimetre that a standard needle will penetrate vertically into the sample of the material under specified conditions of test.

2. Apparatus

(i) A metal or glass cylindrical container conforming to the dimensions specified.

(ii) A straight highly polished cylindrical hard steel rod of specified dimensions with conical and parallel portions co-axial. The needle is provided with a shank to which it is fixed.

(iii) A water bath containing not less than 10 litres of water with thermostatic control to maintain the temperature at 25±0.1°C. The sample shall be immersed to a depth of not less than 100 mm from top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.



(iv) A transfer dish or tray with a firm base to prevent rocking of the test container and ensure full immersion of the test container during the test.

(v) Penetration apparatus to allow the vertical penetration of needle without any friction and calibrated to provided readings to tenths of a millimetre.

(vi) Thermometer capable of reading from 0°C to 44°C, length 340±10 mm with 0.2°C graduation. Substitution of other thermometers is not permitted.

(vii) A stop watch or electric timer for hand operated apparatus. If the apparatus is attached with automatic timer, it shall be properly calibrated.

3. Preparation of test sample

a) Heat the material preferably using an electric hot plate to a temperature not more than 90°C above the approximate softening point for bitumen and not more than 60°C for tars and pitches.

b) Stir it thoroughly to make it homogeneous and free from air bubbles and water.

c) Pour the hot material into the test cup to a depth at least 10 mm above the expected penetration.

d) Protect the sample from dust and allow it to cool for 90 to 120 minutes.

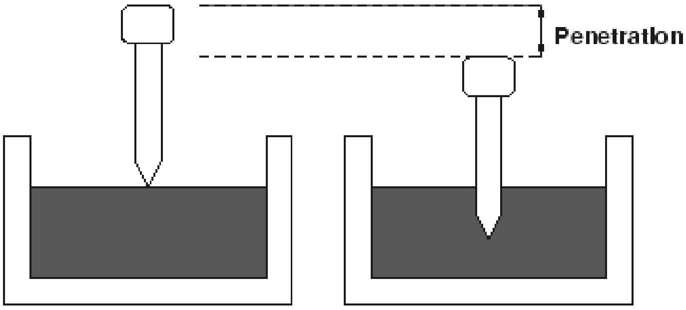
e) Place the cup in the transfer dish and keep both in a water bath maintained at 25±0.1°C.

4. Procedure

a) Unless otherwise specified the test shall be done at 25±0.1°C.

b) Fill the transfer dish with water from water bath to cover the container completely. Place the test cup under the penetrometer needle.

c) Ensure that the needle is properly cleaned with a suitable solvent, washed and dried properly.



d) The needle is adjusted to make contact with the surface of the specimen in the cup.

e) A source of light may be conveniently used to make the needle point just to touch its reflection.

f) Load the needle holder with the specified weight to make the total weight of 100±0.25 gm.

g) Note the reading of the dial or set the pointer to zero.

h) Make three penetrations by releasing the needle holder for 5 seconds.

i) Each test point shall be 10 mm apart and not less than 10 mm from the side of the test cup.

j) After the first reading, the test sample with transfer tray shall be returned to the water bath.

k) The needle shall be cleaned and dried before taking each of the succeeding reading.

5. Report

(i) The penetration of the needle expressed as tenths of a millimetre is noted.

(ii) The mean of three readings is taken as the penetration value.

(iii) The difference in readings shall not be more than 4, if the penetration is between 49 and 149.

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-B2/2015
	QUALITY CONTROL WING	

Penetration test of bitumen **IS: 1203**	Report No.	Date:

REGIONAL LABORATORY……………………………	**DISTRICT LABORATORY………………………………......**

Name of work:

Division:	Subdivision:	Section:

Location:		**Sample No.**	**Date:**
MIX TYPE:	Premix surfacing/ Seal coat	Bituminous Macadam	Bituminous Concrete
MATERIAL:	Bitumen VG………….	Date of testing:	

Test data

Pouring temperature °C		Test temperature °C	

Penetrometer dial readings	*Test 1*	*Test 2*	*Test 3*	*Mean value*
Initial				
Final				
Penetration value				

RESULTS :

Bitumen grade =		***Required value***
Penetration value =		
Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

DUCTILITY OF BITUMINOUS MATERIALS

IS: 1208

1. Introduction

The ductility of a bituminous material is measured by the distance to which it will elongate before breaking when two ends of a briquette specimen of the material are pulled apart at a specified speed of 5 cm/min and specified temperature of 25±0.5°C. This property indicates the tensile strength of the material and may be used for specification requirements.

2. Apparatus

(i) The mould for casting briquettes is made of brass with two end clips, two side plates of prescribed dimensions.

(ii) Constant temperature water bath specifically designed for the test and capable of maintaining the temperature within 0.1°C of the test temperature. The volume of the bath shall not be less than 10 lit. The specimen shall be supported on a perforated shelf not less than 5 cm from the bottom. The specimen shall be immersed to a depth not less than 10 cm.

(iii) The standard apparatus for ductility test shall pull the clips of the briquette mould at a uniform speed while the specimen is kept continuously immersed in water at the required temperature.

(iv) A thermometer having the range of 0°C to 44°C with graduations of 0.2°C.

3. Procedure

a) Assemble the mould on a brass plate. Thoroughly coat the surface of the plate and the interior surfaces of the mould with a thin layer of glycerin-dextrin mixture or talc or kaolin (China clay) to prevent the material from sticking to the plate and the mould.

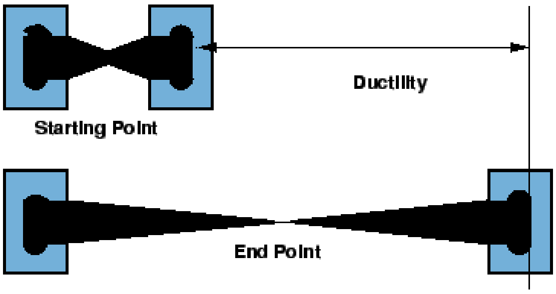
b) Bottom plate shall be level and the bottom of the mould shall be in full contact with the plate.

c) Carefully heat the bitumen in to a pouring consistency with out over heating, preferably using an electric hot plate. Strain the material through a 300 micron sieve if necessary.

d) Pour the material into the mould in a thin stream from end to end moving back and forth until the mould is slightly more than level.

e) Cool the sample in the mould for 30 to 40 minutes.

f) Transfer the plate and mould with specimen to the water bath maintained at the test temperature and keep for 30 minutes.



g) Then cut off the excess bitumen with a hot spatula or putty knife so that the mould is just filled level.

h) Keep the brass plate and mould with briquette specimen in water bath at test temperature for 90±5 minutes.

i) Now remove the briquette from the plate, detach the side plates and carry out the test immediately.

j) Attach the rings of the end clips to the pins or hooks in the testing machine.

k) Pull apart the clips at the specified uniform speed with the speed variation not exceeding ±5% till the briquette ruptures.

l) Maintain the temperature of the bath within 0.5°C of the test temperature during the entire test period.

m) The water level shall be minimum 2.5 cm above the specimen.

4. Report

(i) The average of three normal tests is reported as the ductility of the sample.

(ii) The test shall not be considered normal if the bituminous material comes in contact with the surface of water or the bottom of the bath. If this occurs, adjust the specific gravity of water by adding either methyl alcohol or sodium chloride and repeat the test.

(iii) If a normal test is not obtained after three trials, report the ductility of the material as not obtainable.

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	KERALA PUBLIC WORKS DEPARTMENT	Form No. QC-B3/2015
	QUALITY CONTROL WING	

Ductility of bituminous material **IS: 1208**	Report No.	Date:

REGIONAL LABORATORY……………………………	**DISTRICT LABORATORY………………………………......**

Name of work:		
Division:	Subdivision:	Section:

Location:		**Sample No.**	**Date:**
MIX TYPE:	Premix surfacing/ Seal coat	Bituminous Macadam	Bituminous Concrete
MATERIAL:	Bitumen VG…………	Date of testing:	

Test data

Test property	*Briquette number*			*Mean value*
	(i)	(ii)	(iii)	
Ductility value (cm)				

RESULTS :

Bitumen grade =		***Required value***
Ductility value of the sample =		
Tested: Technician/Overseer	*Verified*: Asst. Engineer (QC)	*Approved:* Asst. Exe. Engineer (QC)

FLOAT TEST FOR BITUMINOUS MATERIALS

IS: 1210

1. Introduction

This method covers the float test for bituminous materials. A plug of bitumen is cast in a tapered collar. The assembled float and collar is floated in a water bath of prescribed temperature. The time in seconds between placing the apparatus on the water and the water breaking through the material is taken as a measure of the consistency of the material.

2. Apparatus

(i) The float shall be of aluminum and aluminum alloy conforming to the figure shown above and the requirements given in table 1 below:

Table 1: *Requirements for float*

Item	*Minimum*	*Normal*	*Maximum*
Mass of float, gm	37.7	37.9	38.1
Total height of float, mm	34.0	35.0	36.0
Height of rim above lower side of the shoulder, mm	26.5	27.0	27.5
Thickness of shoulder, mm	1.3	1.4	1.5
Diameter of opening, mm	11.0	11.1	11.2

(ii) The collar shall be made of brass in accordance with the requirements given in table 2.

Table 2: *Requirements for collar*

Item	*Minimum*	*Normal*	*Maximum*
Mass of collar, gm	9.6	9.8	10.0
Overall height of collar, mm	22.3	22.5	22.7
Inside dia at bottom, mm	12.72	12.82	12.92
Inside dia at top, mm	9.65	9.70	9.75

(iii) The top of the collar shall screw up tightly against the lower side of the shoulder.

(vi) Low softening point thermometer having the range from -2 to +80 °C conforming to the requirements as specified in IS: 1210 clause 2.3.

(vii) A circular test water bath of at least 185 mm in internal diameter containing at least 185 mm depth of water or a rectangular bath with internal dimensions 150 mm x 300 mm size and 150 mm height containing at least 100 mm depth of water. The water bath shall be heated by suitable means like heater or gas stove.

(viii) A stand for holding the thermometer in position to check the bath temperature during heating.

(ix) A brass pouring plate 50 mm x 75 mm size treated to prevent sticking of material.

(x) A water bath of suitable dimensions maintained at a temperature of 5.0±1.0°C which may be accomplished by melting of ice.

3. Calibration of the assembly

a) The depth of immersion of the assembly in the bath shall be constant.
b) The assembled float and collar filled flush with bottom and weighed to a total mass of 53.2 gm shall float upon water with the rim 8.5±1.5 mm above the surface of water.
c) Fix the collar tightly to the bottom of the float and ensure that no water is trapped between the collar and float during the test.

4. Sample preparation

a) Place the brass collar with the smaller end on the coated brass pouring plate.
b) Melt the solid bitumen sample completely at the lowest possible temperature for pouring.
c) For cutbacks, heat the residue at the lowest possible temperature to bring it to a sufficiently fluid condition for pouring.
d) Stir thoroughly until it is homogeneous and free from air bubbles.
e) Fill the material into the collar slightly more than level with the top.

5. Procedure

a) For bitumen and bituminous products, cool the collar and plate to room temperature for 15 minutes and then place them for 5 minutes in the water bath at 5°C.
b) Trim the excess material with a hot knife or spatula to make it flush with the top of the collar. Again keep it in the water bath at 5°C for 15 to 30 minutes.
c) When tar products are tested, immediately after pouring, place the collar and plate for 5 minutes in the water bath at 5°C.
d) Trim the excess material with a slightly heated knife or spatula to make it flush with on the top of the collar.
e) Place them in the water bath at 5°C for 15 to 30 minutes.
f) Heat the water bath to the test temperature using any suitable means without stirring.
g) This temperature should not vary more than 0.5°C from the test temperature throughout the testing period.
h) Determine the temperature by immersing the bulb at a depth of 40±2 mm below the surface.
i) After the collar with the test specimen has been kept in the water bath at 5°C for 15 to 30 minutes, screw the collar to the bottom of the aluminum float.
j) Completely immerse the assembly for 1 minute in the water bath at 5°C. Transfer the float assembly to the water bath after removing the water inside the float.
k) Ensure that no spinning is imparted to the float assembly though lateral motion is permitted.
l) The temperature of the water bath will make the plug warm and fluid which will be forced upward by water from below causing the float to sink.
m) Using a stop watch, find of the time interval between, placing the float in the bath and the water forcing through the material.

6. Report

The time in seconds, between placing the float in the bath and the water forcing through the material, is considered as an indication of the consistency of the material.

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DETERMINATION OF ABSOLUTE VISCOSITY OF BITUMINOUS MATERIALS

IS: 1206 - Part II

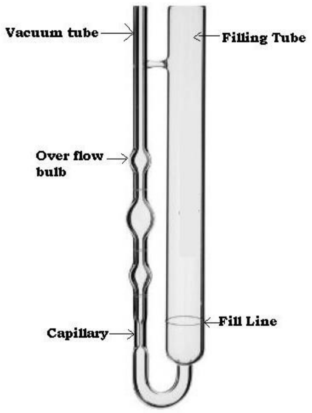
1. Introduction

Absolute or Dynamic Viscosity of a Newtonian Liquid is an internal friction, such that, if a tangential force of one dyne (0.00001 N) acting on planes of unit area separated by unit distance of the liquid produces unit tangential velocity.

A liquid in which the shear stress is directly proportional to the rate of shear strain is called a Newtonian liquid. The constant ratio of shear stress to the rate of shear strain is called the coefficient of viscosity of the liquid. If the ratio is not constant, it is called a non-Newtonian liquid.

This method is used for the determination of absolute viscosity of bitumen and cutbacks by vacuum capillary viscometers at any specified temperature. It is applicable to materials having a viscosity range of 42 to 200,000 Poises.

2. Apparatus



(i) A capillary type viscometer like Cannon-Manning Vacuum Capillary Viscometer as shown in figure.
(ii) Glass thermometer with cylindrical bulbs.
(iii) A suitable water bath with accuracy of ±1°C for immersion of viscometer.
(iv) Thermostatically controlled oven, with non-corroding material interior, capable of maintaining temperature of bituminous materials for testing.
(v) A suitable device for heating bitumen.
(vi) A Vacuum system capable of maintaining a vaccum to within ±0.05 cm of the desired level of mercury up to and including 30 cm.
(vii) A stop watch or stop clock capable of reading up to half a second.

3. Procedure

a) The bitumen sample is heated to pouring temperature not exceeding 90°C above the approximate softening point.
b) Transfer about 20 ml of the sample to a container and then place it in oven maintained at 135±5.5°C.
c) Stir the sample occasionally to prevent overheating and allow the entrapped air to escape.
d) Charge the viscometer by pouring the prepared sample into the filling tube of the viscometer until the level of the bitumen reaches with in 2 mm of the ‘fill line’ shown in figure.
e) The charged viscometer is placed in the oven or bath maintained at 135±5.5°C for 10±2 minutes to allow large air bubbles to escape.
f) The viscometer is now transferred vertically to the water bath maintained at test temperature of 60±0.1°C.

g) The viscometer is fixed in the bath in vertical position with the help of the holder such that the upper most timing mark is at least 20 mm below the surface of the bath liquid.
h) The vacuum unit with its suction pressure maintained at a vacuum pressure of 30± 0.05 cm of mercury is connected to the vacuum tube of the viscometer with the valve closed.
i) After being in the water bath for a period of 30±5 minutes, the valve is opened and the liquid bitumen is allowed to flow into the viscometer.
j) The time taken for leading edge of the meniscus to pass between successive pairs of timing marks is recorded within 0.5 seconds.
k) After completion of the test, remove the viscometer from the water bath and keep in the inverted position in the oven maintained at 135±5.5°C, till all the bitumen is drained off thoroughly.
l) Rinse the viscometer with appropriate solvent till it is clean.
m) Dry the tube by passing dry air through the capillary for 2 minutes.

4. Calculation

The absolute viscosity is calculated by the following equation:

Viscosity Poises = Kt where
K= Selected calibration factor, in poise per second and
t = Flow time, in seconds.

The calibration factor is selected that corresponding to the pair of timing marks used for the determination of viscosity. While reporting the viscosity, the test temperature and vacuum pressure should be mentioned and the value must be reported to three significant decimal places.

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DETERMINATION OF KINEMATIC VISCOSITY OF BITUMINOUS MATERIAL

IS: 1206 - Part III

1. Introduction

Kinematic Viscosity of a Newtonian Liquid is defined as the quotient of the absolute or dynamic viscosity divided by the density of the liquid under test; both at the same temperature.

A liquid in which the shear stress is directly proportional to the rate of shear strain is called a Newtonian liquid. The constant ratio of shear stress to the rate of shear strain is called the coefficient of viscosity of the liquid. If the ratio is not constant, it is called a non-Newtonian liquid.

The CGS unit of kinematic viscosity is stoke, which is cm^2 per second. For petroleum products, kinematic viscosity is usually expressed in centistokes (cSt) which is 1/100th of a stoke.

This method is used for the determination of kinematic viscosity of paving grade and cutback bitumen and distillation residues of cut-backs. It is applicable to the materials having viscosity range of 30-100,000 cSt.

2. Apparatus

(i) Cannon-Fenske Opaque Viscometer as shown in figure.

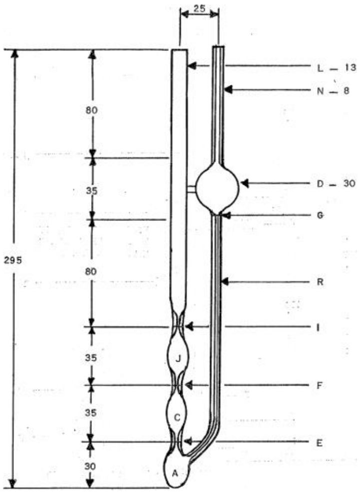
(ii) Thermometer.

(iii) A suitable water bath with accuracy of ±1°C for immersion of viscometer.

(iv) Thermostatically controlled oven, with non-corroding material interior, capable of maintaining temperature of bituminous materials for testing.

(v) A Vacuum system capable of maintaining a vaccum to within ±0.05 cm of the desired level of mercury up to and including 30 cm.

(vi) A stop watch or stop clock capable of reading up to half a second.



3. Calibration of Viscometer

a) Any liquid of known viscosity may be used for calibration purposes.

b) Charge the clean dry viscometer by pouring the reference material.

c) Transfer the charged viscometer to the water bath maintained within ±1°C of calibration temperature.

d) Keep the charged viscometer in the water bath long enough to reach the test temperature.

e) Measure the time within 0.1 seconds required for the leading edge of the meniscus to pass from the first timing mark to the second.

f) The calibration constant C is given by:

$C = V/t$ where

V = Viscosity in centistokes (cSt) for the standard liquid.

t = Efflux time in seconds.

g) If the viscometer is used in a location than the calibrating laboratory, the constant C should be corrected for the difference acceleration due to gravity as given below:

$C_2 = [g_2/g_1] \times C_1$ where

C_2 = Calibration constant for the testing laboratory.
C_1 = Calibration constant for the calibration laboratory.
g_2 = Acceleration due to gravity at the location of testing laboratory.
g_1 = Acceleration due to gravity for calibration laboratory.

4. Procedure

a) The bitumen sample is heated to pouring consistency and temperature not exceeding 90°C above the approximate softening point.
b) Stir the sample throughly and about 20 ml of the fluid binder is transferred in a 30 ml container ensuring that entrapped air is avoided. Seal the container immediately.
c) To charge the viscometer, it is inverted immersing tube N in the liquid bitumen sample to be tested.
d) Suction pressure is applied to the tube L of the viscometer.
e) The sample starts rising in the tube and when bulb is filled up and it reaches the mark 'G' the viscometer is taken out, inverted again so that it is in the normal position.
f) The excess bitumen at the end of the tube N is wiped clean. Stoppers are placed to close the ends of both the tubes.
g) The viscometer is then placed vertically in the bath for sufficient time to ensure that sample reaches equilibrium temperature. Normally it takes about 20 minutes for 38°C, about 25 minutes for 100°C and 30 minutes for 135°C.
h) When the test temperature is reached, the stoppers of the tubes are removed and the sample of bitumen binder is allowed to flow from bulb to the capillary tube under gravity.
i) The time required for the leading edge of the meniscus to pass from mark E to mark F is measured accurately with the timer unit.
j) If the time required is less than 60 seconds, another viscometer of smaller capillary diameter is selected and the experiment is repeated.
k) After completing the test the viscometer is immediately cleaned with suitable solvents.

5. Calculation

Calculate the kinematic viscosity up to three significant figures using the following equation:

Kinematic viscosity cSt = Ct
C = Calibration constant of the viscometer in centistokes per second.
t = Efflux time in seconds.

While reporting the viscosity, always indicate the test temperature and the value must be reported to three significant decimal places.

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SAYBOLT VISCOSITY OF PETROLEUM PRODUCTS

ASTM Designation: D 88-94 & AASHTO Designation: T 72-90

1. Introduction

This test covers the empirical procedures for the determination of Saybolt Universal or Saybolt Furol viscosities of petroleum products at specified temperatures between 21°C and 99°C.

Furol is the acronym for fuels and road oils. The Saybolt Furol viscosity is the corrected efflux time in seconds of 60 ml of sample flowing through a calibrated Furol orifice under specified conditions. The viscosity value is reported in Saybolt Furol seconds abbreviated as SFS at a specified temperature.

Saybolt Universal viscosity is the corrected efflux time in seconds of 60 ml of sample flowing through a calibrated Universal orifice under specified conditions. The viscosity value is reported in Saybolt Universal seconds abbreviated as SUS at a specified temperature.

The efflux time in seconds of 60 ml of sample flowing through a calibrated orifice is measured under specified conditions. This time is corrected by an orifice factor and reported as the viscosity of the sample at that temperature.

The Saybolt Furol viscosity is approximately one tenth of Saybolt Universal viscosity is recommended for characterization of petroleum products such as fuel oils and other residual materials having Saybolt Universal viscosities greater than 1000 seconds.

2. Apparatus

(i) Saybolt Viscometers with Universal or Furol orifices and bath with dimensions detailed in annexure A1 of ASTM D 88-94.

(ii) Withdrawal tube to use with Saybolt viscometer.

(iii) Thermometer support of suitable design.

(iv) Saybolt viscosity thermometers or any other temperature indicating means of equivalent accuracy as bath thermometers.

(v) Filter funnel equipped with interchangeable 150-µm (No. 100) and 75-µm (No. 200) wire-cloth inserts.

(vi) Receiving flask to use with Saybolt viscometer.

(vii) Timer graduated in tenths of a second and accurate within 0.1% over a 60 minute interval. Electric timers are acceptable if operated on a controlled frequency circuit.

(viii) ASTM Saybolt viscosity thermometers 17C/F to 22C/F to suite the material tested as listed in table 1.

Table 1: *ASTM Saybolt viscosity thermometers*

Standard test temperature °C	*ASTM thermometer number*	*Thermometer range °C*	*Sub divisions °C*
21.1	17C (17F)	19 to 27	0.1
25.0	17C (17F)	19 to 27	0.1
37.8	18C (18F)	34 to 42	0.1
50.0	19C (19F)	49 to 57	0.1
54.4	19C (19F)	49 to 57	0.1
60.0	20C (20F)	57 to 65	0.1
82.2	21C (21F)	79 to 87	0.1
98.9	22C (22F)	95 to 103	0.1

3. Preparation of the apparatus

(i) Use a Universal orifice or tip for lubricants and distillates with efflux time greater than 32 seconds. This orifice is not suitable for liquids with efflux time greater than 1000 seconds.

(ii) Use a Furol orifice or tip for residual materials with efflux time greater than 25 seconds to give the desired accuracy.

(iii) Clean the viscometer with a proper solvent of low toxicity. Remove all traces of the solvent from the viscometer and its gallery. Remove the receiving flask in the same manner. The plunger normally supplied with the viscometer should never be used for cleaning as it may damage the apparatus.

(iv) Set up the viscometer and bath in an area where they will not be exposed to drafts or rapid change in air temperature and dust or vapours that may contaminate the sample.

(v) Place the receiving flask below the viscometer such that the stream of oil will just strike the neck of the flask. The graduation mark of the flask shall be at 100 to 130 mm below the viscometer tube.

(vi) Fill the bath to at least 6 mm above the overflow rim of the viscometer. Select the appropriate bath medium from table 2.

Table 2: *Recommended bath media*

Standard test temperature ^oC	*Recommended bath medium*	*Max temp differential ^oC*	*Bath temperature control ^oC*
21.1	Water	± 0.05	± 0.05
25.0	Water	± 0.05	± 0.05
37.8	Water or oil of 120 to 150 SUS @ 37.8 ^oC	± 0.15	± 0.05
50.0	Water or oil of 50 to 70 SUS @ 37.8 ^oC	± 0.20	± 0.05
54.4	Water or oil of 50 to 70 SUS @ 37.8 ^oC	± 0.30	± 0.05
60.0	Water or oil of 50 to 70 SUS @ 37.8 ^oC	± 0.50	± 0.05
82.2	Water or oil of 300 to 370 SUS @ 37.8 ^oC	± 0.80	± 0.05
98.9	Water or oil of 300 to 370 SUS @ 37.8 ^oC	± 1.10	± 0.05

(vii) Provide adequate stirring and thermal control for the bath so that the temperature of the test sample will not vary more than 0.03 ^oC, after the test temperature is reached.

(viii) Do not make viscosity measurements at temperatures below the dew point of the room's atmosphere.

(ix) For calibration and referee tests, keep the room temperature between 20 and 30°C and record the temperature. Researches show that the error induced will be within 1% up to temperature of 38°C.

4. Calibration of equipment

a) Calibrate the Saybolt Universal viscometer at periodic intervals by measuring the efflux time at 37.8°C using standard viscosity oil. The efflux time of the standard viscosity oil shall be same as the certified Saybolt viscosity value.

b) If the efflux time differs by more than 0.2%, calculate the correction factor F for the viscometer as below:

F = V/t where
V = Certified Saybolt viscosity of the standard and
t = Measured efflux time at 37.8°C in seconds

c) Calibrate the Saybolt Furol viscometer at 50°C in the same manner as above, using a viscosity oil standard having a minimum efflux time of 90 seconds.

d) Viscometers or orifices requiring corrections greater than 1.0% shall not be used in referee testing.

5. Procedure

a) Establish and maintain the bath temperature at the selected test temperature. Standard test temperatures for measuring Saybolt Universal viscosities are 21.1, 37.8, 54.4 and 98.9°C. For Saybolt Furol viscosities the standard measurement temperatures are 25.0, 37.8, 50.0 and 98.9°C. Other standard measurement temperatures used include 60.0 and 82.2°C.

b) Insert a cock stopper, having a cord attached for its easy removal, into the air chamber at the bottom of the viscometer tube. The cork shall tightly fit to prevent the escape of air. This can be verified from the absence of oil when it is removed for the test.

c) If the selected temperature is above the room temperature, the test may be expedited by preheating the sample in its original container to not more than 1.7°C above the test temperature. Never preheat the sample within 28°C of its flash point to prevent loss of volatile matter.

d) Stir the sample well and strain through the 150-µm (No. 100) wire cloth in the filter funnel directly into the viscometer until the level is above the overflow rim.

e) The viscosities of steam-refined cylinder oils, black lubricating oils, residual fuel oils, and similar waxy products can be affected by their thermal histories. Use the following preheating procedures with such products to obtain uniform results below temperature 93°C.

(i) Heat the sample to 50°C in its original container. During heating stir and shake well to dissolve and blend waxy materials.

(ii) Pour about 100 ml into a 125 ml Erlenmeyer flask. Close loosely with a cork or rubber stopper.

(iii) Immerse the flask in a boiling water bath for 30 minutes.

(iv) Mix well, remove from the boiling water bath, wipe outside dry and strain the sample through the 75 micron wire cloth in the filter funnel directly into the viscometer until the level is above the overflow rim.

f) Stir the sample in the viscometer with the appropriate viscosity thermometer. Use a horizontal circular motion of 30 to 50 rpm.

g) When the sample temperature is steady within 0.03°C of the test temperature during 1 minute of continuous stirring, remove the thermometer. Never adjust the temperature by immersion hot or cold bodies into the sample.

h) Immediately place the tip of the withdrawal tube at one point in the gallery and apply suction to remove oil until the level is below the overflow rim. Do not touch the overflow rim with the withdrawal tube.
i) Check whether the receiving flask is in position.
j) Snap the cork attached to the viscometer tube by pulling the chord and start the timer at the same instant. Stop the timer at the instant the bottom meniscus of the oil reaches the graduation mark of the receiving flask.
k) The efflux time in seconds is recorded to the nearest 0.1 second.

6. Calculation and report

(i) Multiply the efflux time by the correction factor as determined during calibration.
(ii) Report the corrected efflux time as Saybolt Universal or Saybolt Furol viscosity at the test temperature.
(iii) The values below 200 SUS or SFS are reported to the nearest 0.1 seconds. Values above 200 are reported to the nearest whole second.

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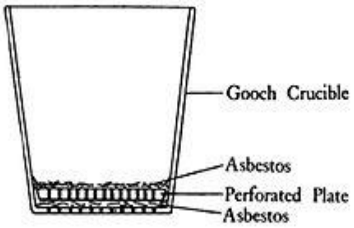
DETERMINATION OF SOLUBILITY OF BITUMINOUS MATERIALS

IS: 1216

1. Introduction

This method of test determines the degree of solubility of asphalt materials, having little or no mineral matters, in trichloroethylene or carbon disulphide. Pure bitumen is fully soluble in carbon disulphide and carbon tetrachloride. If some quantity remains un-dissolved, it exhibits the quantity of inert mineral present in the bitumen.

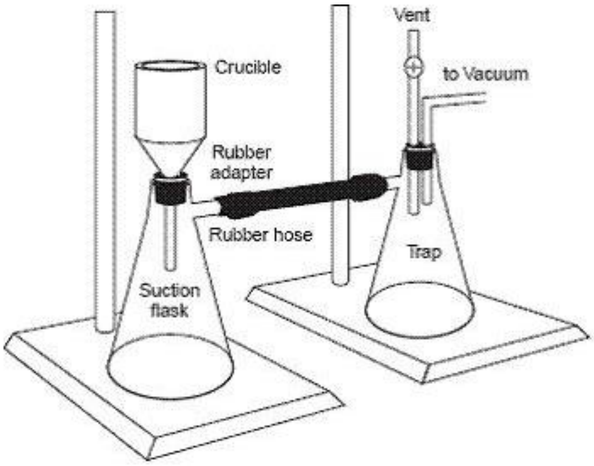
2. Apparatus



(i) Gooch crucible.
(ii) Conical glass flask of 200 ml capacity.
(iii) Filter flask.
(iv) Filter tube.
(v) Desiccator.
(vi) A thermostatically controlled oven.
(vii) Carbon Disulphide (Redistilled grade conforming to IS: 717-1969).
(viii) Trichloroethylene conforming to IS: 245-1970.

3. Preparation of Gooch crucible

a) Heat the sample by stirring quickly, to a temperature not exceeding 130°C until the water has been removed.
b) Insert the filter tube in the stopper of the filtering flask, set the Gooch crucible in the filter tube, and connect the flask to the suction pump using a rubber hose.
c) Fill the crucible with the suspension of asbestos in water and allow it to settle partly.
d) Apply a light suction to draw off the water, leaving a firm mat of asbestos in the crucible.
e) Add more suspended asbestos and repeat the process until a mat weighing 0.5±0.1 gm is built up after drying.
f) Wash the asbestos mat thoroughly with water and dry in the oven at a temperature of 150°C.



g) Cool the crucible in the desiccator and then weigh and replace it in the dry filter tube supported in the clean dry filtering flask.

4. Procedure

a) Take 2 g of the dry material in a 200 ml conical flask.
b) Add 100 ml of carbon disulphide or trichloroethylene.
c) Stir the contents of the flask, and then allow it to stand, loosely corked, for a period of one hour.
d) Filter the contents of the flask through the Gooch crucible prepared as described under item 3 above.
e) Moisten the asbestos pad with carbon disulphide before filtration, and filter at a rate of not more than two drops per second at first.
f) Transfer the insoluble matter remaining in the flask to the crucible by washing out the flask with a stream of carbon disulphide or trichloroethylene.

g) Wash the material retained in the crucible with successive small amounts of carbon disulphide or trichloroethylene until non-discolored filtrate is obtained.
h) Allow the crucible to dry in air for 30 minutes and after that place it in an oven at 100 to 110°C for one hour.
i) Allow the crucible to cool in a desiccator and then weigh.

5. Calculation and report

The total percentage matter soluble in carbon disulphide or trichloroethylene is calculated as below:

Matter soluble in carbon disulphide or trichloroethylene = [A-B/A] x 100 where,

A = weight of dry sample in gm and

B = weight of insoluble material retained in the Gooch crucible.

The result is reported to the nearest 0.05 percent.

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BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIX SPECIMENS

ASTM Designation: D 2726/AASHTO Designation: T 166-00

1. Introduction

This method test covers the determination of the bulk specific gravity of specimens of compacted bituminous mixes. This method is not applicable to mixes with open or interconnected voids and/or which absorbs 2.0% or more water. The bulk specific gravity is used for volumetric analysis in the Marshall method of mix designs and to compute the unit weight of the mixture.

2. Preparation of test sample

(i) The test specimens may be either from bituminous mixes moulded laboratory or cored from paved bituminous layer. The mix may be bituminous base, binder, wearing or leveling course.

(ii) It is recommend that the diameter of cored/moulded specimens or length of the sides of the sawed specimens shall be minimum four times the maximum size of the aggregate and the thickness of specimens shall be at least one and a half times the maximum size of the aggregates.

(iii) Specimens from pavement shall be taken with a core drill, diamond or carborundum saw or by other suitable means. Proper care shall be exercised to avoid damage to the specimens by distortion, bending or cracking during and after the extraction process.

(iv) The specimens shall be free from foreign materials such as tack coat, soil, paper, foil etc. If required, these shall be removed by sawing, without damaging the specimens.

3. Apparatus:

(i) A balance or scale, readable to 0.1 gm. The weighing device shall be provided with a suitable suspension device to allow weighing in water (Buoyancy balance as shown in figure).

(ii) The wire for suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. While weighing in water ensure that no trapped air bubbles exist under the specimen.

(iii) Water bath for immersing the specimen in water while suspended under the weighing device, equipped to allow overflow to maintain a constant water level.

(iv) Damp cloth towel to surface dry the specimens.

(v) Thermostatically controlled oven capable of maintaining a temperature of 110±5°C for drying the specimen to constant weight.

(vi) Pan large enough for holding the specimens while drying in the oven.

(vii) Thermometer having a range of 10 to 30°C with divisions of 0.2°C.

4. Procedure

a) Dry the specimen to a constant mass at 52±3°C till further drying will not change the mass of the specimen by more than 0.05% of its weight. The weighing is done at 2 hours interval.

b) Cool the specimen to 25±5°C before weighing and record this reading as A.

c) Immerse each specimen in water bath at 25±1°C for 4±1 minute suspended from the bottom of the buoyancy balance and record this submerged weight as C.

d) Remove the specimen from water. Dry the surface to dampness by carefully blotting with a damp towel as quickly as possible and find the weight in air to get the surface-dry weight B. Any water seeping out from the specimen is considered as part of the saturated specimen.

5. Calculation

a) Calculate the bulk specific gravity of the specimen to the nearest three decimal places as below:

Bulk specific gravity = A/(B-C), where
A = Mass of the specimen in air in gm.
B = Mass of the saturated surface dry specimen in air in gm.
C = Mass of the sample suspended in water in gm.

b) Calculate the percentage of water absorbed by the specimen (on a volume basis) as follows:

Percentage of water absorbed by volume = (B-A)/(B-C).

c) If the percentage of water absorbed by the specimen is more than 2.0%, then bulk specific gravity is determined as per ASTM D 1188–Bulk specific gravity of compacted bituminous mixtures using paraffin coated specimens.

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BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIX USING PARAFFIN WAX COATED SPECIMEN

ASTM Designation: D 1188/AASHTO Designation: T 175-00

1. Introduction

This method test covers the determination of the bulk specific gravity of specimens of compacted bituminous mix specimens coated with paraffin wax. This method applicable to mixes with open or interconnected voids and/or which absorbs 2.0% or more water. The bulk specific gravity is used for volumetric analysis in the Marshall method of mix designs and to compute the unit weight of the mixture.

2. Preparation of test sample

(i) The test specimens may be either from bituminous mixes moulded laboratory or cored from paved bituminous layer. The mix may be bituminous base, binder, wearing or leveling course.

(ii) It is recommend that the diameter of cored/moulded specimens or length of the sides of the sawed specimens shall be minimum four times the maximum size of the aggregate and the thickness of specimens shall be at least one and a half times the maximum size of the aggregates.

(iii) Specimens from pavement shall be taken with a core drill, diamond or carborundum saw or by other suitable means. Proper care shall be exercised to avoid damage to the specimens by distortion, bending or cracking during and after the extraction process.

(iv) The specimens shall be free from foreign materials such as tack coat, soil, paper, foil etc. If required, these shall be removed by sawing, without damaging the specimens.

3. Apparatus

(i) A balance or scale, readable to 0.1 gm. The weighing device shall be provided with a suitable suspension device to allow weighing in water.

(ii) The wire for suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. While weighing in water ensure that no trapped air bubbles exist under the specimen.

(iii) Water bath for immersing the specimen in water while suspended under the weighing device, equipped to allow overflow to maintain a constant water level.

(iv) Damp cloth towel to surface dry the specimens.

(v) Thermostatically controlled oven capable of maintaining a temperature of 110±5°C for drying the specimen to constant weight.

(vi) Pan, large enough for holding the specimens while drying in the oven.

(vii) Thermometer having a range of 10 to 30°C with divisions of 0.2°C.

(viii) Paraffin wax to coat the test specimens.

4. Procedure

a) Dry the specimen to a constant mass at 52±3°C till further drying will not change the mass of the specimen by more than 0.05% of its weight. The weighing is done at 2 hours interval.

b) Cool the specimen to 25±5°C before weighing and record this reading as A.

c) Coat the specimen completely using molten paraffin wax sufficiently thick to seal all voids.

d) Cool the specimen to 25±5°C and weigh again. Record the weight of paraffin coated specimen as D.
e) Immerse each specimen in water bath at 25±1°C for 4±1 minute suspended from the bottom of the buoyancy balance and record this submerged weight as E.
f) Remove the specimen from water. Determine the specific gravity F of paraffin wax at 25±1°C from manufacturer's literature or other sources.

5. Calculation

Calculate the bulk specific gravity of the paraffin coated specimen to the nearest three decimal places as below:

Bulk specific gravity = $A/D-E-[(D-A)/F]$, where
A = Weight of the uncoated specimen in air in gm.
D = Weight of the paraffin coated specimen in air in gm.
E = Submerged weight of the coated specimen suspended in water in gm.
F = Specific gravity of the paraffin wax used for coating.

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DETERMINING BITUMEN CONTENT BY EXTRACTION

ASTM Designation: D 2172 & AASHTO Designation: T 164

1. Introduction

This method covers the quantitative extraction of bitumen from hot-mixed paving mixes and pavement samples. Aggregate recovered from this test may be subjected to sieve analysis to check the grading. The result of the test is affected by the age of the material tested. Best quantitative results are obtained when the test is made on mixtures and pavements shortly after their preparation.

It may be noted that it is difficult to remove asphalt completely from certain aggregates and also some solvent may remain within the mineral matter which could affect the measured asphalt content.

The common solvents used for extraction are benzene, trichloroethylene and methyl chloride. The asphalt content is calculated by the differences from the mass of the aggregate extracted, moisture content and mineral matter in the extract. The asphalt content is expressed as a mass percent of moist-free mixture.

2. Apparatus

(i) A thermostatically controlled oven capable of maintaining temperatures at 110±5°C.

(ii) Extraction apparatus consisting of a bowl which can be rotated at variable speeds up to 3600 revolutions per minute. The apparatus is provided with a tight fitting lid which will prevent the solvent from throwing out. The solvent with dissolved binder is collected through a drain pipe fitted at the bottom of the bowl.

(iii) Paper filter rings to fit the rim of the bowl.

(iv) Flat pans of appropriate sizes to warm the test specimens.

(v) A balance of suitable capacity at least readable to 0.1 percent of the sample mass.

(vi) Electric hot plate with adjustable heating range.

(vii) Cylinders, graduated, 1000 ml or 2000 ml capacity and another one of 100 ml capacity as optional.

(viii) Ignition dish at least 125 ml minimum capacity.

(ix) Desiccators.

(x) Reagents such as Benzene or Trichloroethylene, Ammonium Carbonate.

3. Preparation of test specimens

a) If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan and warm at 110±5°C in an oven till it can be separated easily. Quarter the material till sufficient sample required for the test is obtained.

b) The size of the test sample is governed by the nominal maximum aggregate size of the mixture and conforming to the mass requirements specified below:

Nominal maximum aggregate size, mm	*Minimum mass of sample in kg*
4.75	0.5
9.5	1.0
12.5	1.5
19.0	2.0
25.0	3.0
37.5	4.0

Note: *When mass of the test specimen exceeds the capacity of the equipment used, the test specimen may be divided into appropriate fractions; the test carried out separately for each fraction and combined for arriving at the bitumen content*.

c) Unless the mixture is free from moisture, a test specimen is collected from the same sample selected for extraction test for moisture content determination.

d) The extraction test is intended to recover the binder only, then moisture content determination is not necessary. At the other hand, if recovery of bitumen from the extract is not required, the entire sample maybe dried in an oven at 149 to 163°C for 2 to 2.5 hours and proceeded with the extraction test.

4. Procedure

a) Place the test sample into the bowl. Cover the test portion with the approved solvent and allow sufficient time, not more than one hour, for disintegration of the mixture.

b) Place the bowl with the mixture and solvent in the extraction apparatus. Weigh the previously weighed filter ring dried in the oven at 110±5°C to a constant mass. Place the ring on the bowl mouth to fit around the edge of the bowl. Clamp the top lid over the bowl tightly. Place a container of suitable size below the drain pipe to collect the extract.

c) Start the centrifuge revolving slowly and gradually increase the speed to 3600 rpm until the solvent ceases to flow. Stop the machine, add 200 ml of the solvent and repeat the process.

d) Continue adding solvent and centrifuging till the extract is not darker than light straw color. Collect the extract and washings in an appropriate container for determination of the mineral matter.

e) Carefully transfer the filter ring and mineral aggregates in the bowl to a tared metal pan.

f) Dry in air under a hood until the fumes dissipate and then in an oven at 110±5°C to constant mass.

g) The mass of the extracted aggregate (W_3) will be equal to the mass of the contents in the pan minus the initial dry mass of the filter ring.

h) Brush the mineral particles sticking on the filter ring to the extracted mineral aggregate for further testing. Alternately the filter and aggregates may be dried in the oven along with the bowl. Sometimes the filter ring is dried separately in the oven at 110±5°C to constant mass. In such cases the aggregate may be transferred to a pan and dried in an oven or a hot plate. This will enable to continue the extraction test with another sample.

Note: *When low-ash paper filter rings are used, the filter paper is burned in the pan using a Bunsen burner or match after drying in the oven.*

i) The extracted aggregate is weighed and the mass of the aggregate is recorded as W_3.

Note: *The dry aggregate may absorb moisture from the atmosphere. Hence the mass of the aggregate shall be determined immediately after cooling to a suitable temperature*.

j) The amount of fines washed away by the solvent needs to be determined. To determine this amount of mineral matter W_4 present in the extract, measure the total mass or volume of the extracted liquid. Weigh a clean dry ignition dish. Pour 100 ml or 100 gm of the extract into it. Ensure that the extract is adequately stirred to get a uniform specimen.

k) Evaporate the liquid to dryness on a steam bath or hot plate. Burn the residue to ash at a dull red heat (500 to 600°C) and cool. Find the mass of the ash and add 5 ml of saturated ammonium carbonate per gram of ash. Keep at room temperature for one hour. Dry in an oven at 110±5°C to constant mass and cool. Determine the mass of ash Q, to the nearest 0.001 gm. The mass of total mineral matter in the extract W_4 is calculated as shown below:

$W_4 = Q \times [W_a / (W_a - W_q)]$ where
W_a = Total volume or weight of extract (ml or gm)
W_q = Volume or weight of aliquot (100 ml or 100 gm)
Q = Ash in aliquot in gm (nearest 0.001 gm)

5. Calculation

Calculate the percentage of bitumen (binder content) in the bituminous mix as below:

Bitumen content % = $100 \times [(W_1 - W_2) - (W_3 + W_4)] / (W_1 - W_2)$, where
W_1 = Mass of the test portion in gm.
W_2 = Mass of the water in the test portion in gm.
W_3 = Mass of the extracted mineral aggregate in gm.
W_4 = Mass of the mineral matter in the extract in gm.

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	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-B4/2015

Quantitative Extraction of Bitumen from Bituminous Paving Mixtures : ASTM D 2172

Report No.					Date:	
REGIONAL LABORATORY:			**DISTRICT LABORATORY:**			
Name of work:						
Division:		Sub Division:			Section:	
Sample location:	Km		**Sample No.**		**Date:**	
TYPE OF MIX	BM	BC	SMA	PMC	Test date:	
Area paved	Lane	L	R	Climbing	Shoulder	Bus bay
LAYER		Wearing/Surface course		Paving date		
		Base/binder course		Tested on		
Truck number/Test number						
Design binder content						
Weight of bituminous mix, gm						
Weight of filter before test, gm						
Amount of moisture in the mix						
Weight of mix before drying, gm						
Weight of mix after drying, gm						
Moisture content %						
Weight of water in the mix, gm						
Weight of sample after extraction						
Net weight of test sample						
Weight of dry aggregate & filter						
Weight of filter after test						
Weight of dry extracted aggregate						
Mineral matter in the extract						
Total volume of extracted liquid, gm						
Volume after removing aliquot, gm						
Ash in aliquot, gm						
Weight of mineral matter in the extracted liquid, gm						
Bitumen content %						
RESULTS:						
Average binder content % =			**Required value**			%
Tested: Technician/ Overseer		*Verified*: Assistant Engineer (QC)			*Approved*: Asst. Exe. Engineer (QC)	

STABILITY AND FLOW TEST ON BITUMINOUS MIXES USING MARSHALL APPARATUS

ASTM: D 1559/AASHTO Designation: T 245-97

1. Introduction

Marshall Stability and Flow test have been developed by Bruce Marshall as part of a procedure for Marshall method of mix design. The procedure described in the Asphalt Institute Manual MS-2, is followed generally in India for the design of bituminous mixes. This method of test covers the measurement of the resistance to plastic flow of cylindrical specimens of compacted bituminous mixtures by circumferential loading using Marshall Apparatus. This method is applicable to mixes containing bitumen, cut back or tar with the maximum size of the aggregate in the mix being 26.5 mm.

The bulk specific gravity of the specimen is also determined for volumetric analysis in the Marshall method of mix design and to compute the unit weight of the bituminous mix.

2. Apparatus

(i) The specimen mould assembly consist of mould cylinders 101.6 mm diameter and 76.2 height, base plate and extension collar. Normally three specimens are cast for the selected binder content.

(ii) The specimen extractor consists of a steel disc not less than 100 mm diameter and 12.7 mm thick. A hydraulic jack is used to apply the required pressure for extracting the compacted specimen from the mould with the use of collar.

(iii) The compaction hammer shall have a flat circular tamping face with a sliding weight 4536 ± 9 gm having a free fall of 457.2 ± 1.524 mm.

(iv) Instead of a hand operated compaction hammer, a properly calibrated mechanically operated hammer can be used.

(v) The compaction pedestal shall consist of a 203.2 mm x 203.2 mm x 457.2 mm wooden block capped with a steel plate 304.8 mm x 304.8 mm size and 25.4 mm thick to hold the mould assembly. The wooden block is secured to a solid concrete base by means of four angle brackets. The steel cap must be firmly fastened to the block. The pedestal assembly shall be installed so that the post is plumb and the steel cap is level.

(vi) The specimen mould holder is fitted centrally to the steel cap so as to hold the specimen mould, collar and the base plate securely in position during compaction of the mixture.

(vii) The Marshall testing head for applying circumferential load on the compacted specimen consists of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm. The lower head is mounted on a base having two perpendicular guide rods or posts extending upward.

(viii) The loading jack shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm per minute. An electric motor may be attached to the jacking mechanism. Instead of the loading jack, a mechanical or hydraulic loading system to produce the above uniform rate of movement can be used.

(ix) The load measuring device such as proving shall have a capacity of about 25 kN with sensitivity of 50 N and shall be equipped with a dial gauge graduated in 0.0025 mm divisions. Attachments are required at top and bottom of the proving ring for fixing to the load frame and testing head respectively.

(x) The flow meter consists of a guide sleeve and a gauge. The pointer of the gauge shall be placed freely over the guide rod of the breaking head and shall slide inside the sleeve with a slight amount of frictional resistance. The flow meter dial shall indicate divisions of 0.25 mm.

(xi) Ovens or hot plates thermostatically controlled are needed for heating aggregates, bituminous materials, moulds, base plate, compaction hammer etc. If a hot plate is used, a wire mesh or similar material shall be placed over the hot plate to prevent direct contact of the flame with the mixing bowl.

(xii) Mechanical mixing of the materials is recommended. A metal pan or bowl of sufficient capacity and hand mixing may also be used.

(xiii) The hot water bath shall be 152.4 mm deep, thermostatically controlled to maintain a temperature of 60±1°C. The tank shall have a perforated false bottom or a shelf for supporting the specimens fixed at 50.8 mm above the bottom of the bath.

(xiv) The air bath for bitumen cutback mixtures shall be thermostatically controlled to maintain the air temperature at 25 ±1°C.

(xv) Balance 2.0 kg capacity sensitive to 0.1 gm for weighing moulded specimens.

(xvi) Balance 5.0 kg capacity sensitive to 1.0 gm for weighing mix ingredients.

(xvii) Armored-glass, dial type or digital thermometers for determining the temperature of aggregate, bitumen and bitumen mixture with sensitivity 1.0°C with the range 0 to 200 ºC.

(xviii) Thermometers for water/air baths sensitive to 0.2°C with the required range.

(xix) Containers suitable for heating aggregates and bituminous material.

(xx) Mixing tools, either a steel trowel or spatula for spading and hand mixing.

(xxi) Miscellaneous tools like hot gloves for handling hot equipments, rubber gloves for removing specimens from water bath, marking crayons for identifying specimens, scoop for batching aggregates, spoon for placing mixture in the specimen moulds etc.

3. Mixing and compacting temperatures

The mixing temperature is determined from the viscosity of the binder. The temperature to produce a viscosity of 170±20 cSt shall be the mixing temperature. The temperature to produce a viscosity of 280±30 cSt shall be the compacting temperature for bitumen cement.

4. Procedure

a) Dry the aggregates to a constant mass at 105 to 110°C and carry out dry sieving. Find the proportion the aggregates to get the desired grading.

b) Mix the aggregates (about 1200 gm) required to produce a batch that will result in a compacted specimen of 63.5±1.27 mm in a pan.

c) Place the pan over a hot plate or in oven and heat to a temperature not exceeding the mixing temperature determined earlier by 28°C for bitumen and 14°C for cutback bitumen.

d) Heat the binder for one batch in a separate container. Transfer the heated aggregate mix to the mixing bowl.

e) Make a crater in the mixing bowl and pour the required amount of heated bitumen into it. Mix the aggregate and bitumen thoroughly till complete coating is achieved, ensuring no loss of material.

f) Clean the specimen mould assembly and face of the compaction hammer and heat them in boiling water, oven or hot plate to a temperature between 93.3°C and 148.9°C.

g) Fix the mould with base plate over the compaction pedestal. Place a filter paper at the bottom of the mould before the hot mixture is introduced. Place the entire batch in the mould and stir vigorously with a hot spatula or trowel 15 times around the perimeter and 10 times interior. Smooth the surface of the mixture to a slightly rounded shape. Temperature of the mixture immediately prior to compaction shall be the compaction temperature already established.

h) Replace the collar and place a filter paper or paper toweling cut to size, on the top of the mixture. Apply the specified number of blows with the hammer with a free fall of 457.2 mm. During compaction, hold the axis of the hammer perpendicular to the base of the mould assembly. Apply the same number of blows to the other side also after reversing the mould.

i) Allow the specimen to cool. Carefully remove the specimen from the mould using sample extruder.

j) Specimens prepared with bitumen are placed in a water bath for 30 to 40 minutes kept at 60±1ºC. For specimens with tar, the bath temperature is 37.8±1°C. The specimens prepared with cutback bitumen are kept in air bath at 25±1°C for 2 hours.

k) Clean the guide rods and inner face of the test head prior to making the test. Lubricate the guide rods so that the upper head slides freely. The testing head temperature shall be maintained between 21.1°C to 37.8°C using a water bath, if required.

l) Remove the specimen from bath and place centrally on the lower segment of the testing head. Place the upper segment over the specimen and place the assembly in position on the testing machine.

m) Place the flow meter over the testing head tightly clamped to one of the guide rod. Adjust the dial of the meter to zero before start of the test. Hold the flow meter in position at the time of loading.

n) Apply the load to the specimen at the constant rate of 50.8 mm per minute until the maximum load is reached. Calculate load from the dial reading of the micrometer.

o) Note the flow dial reading at the failure load when the load starts decreasing. The elapsed time from removal of the specimen from water bath to maximum load determination shall not exceed 30 seconds.

p) If the specimen thickness differs from 63.5 mm, apply correction to the load using the correction factors.

5. Report

The report shall include the following:

(i) Type of sample – laboratory or pavement core sample.
(ii) Average height of specimen for each sample.
(iii) Average maximum load of at least three specimens, corrected if required.
(iv) Average flow value of at least three specimens, in the required unit.
(v) Test temperature.

The format QC-B6/2014 included in Appendix A - Bituminous mix design may be used for recording the test data.

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Part - V

BUILDING MATERIALS TESTING

DETERMINATION OF COMPRESSIVE STRENGTH OF BRICKS

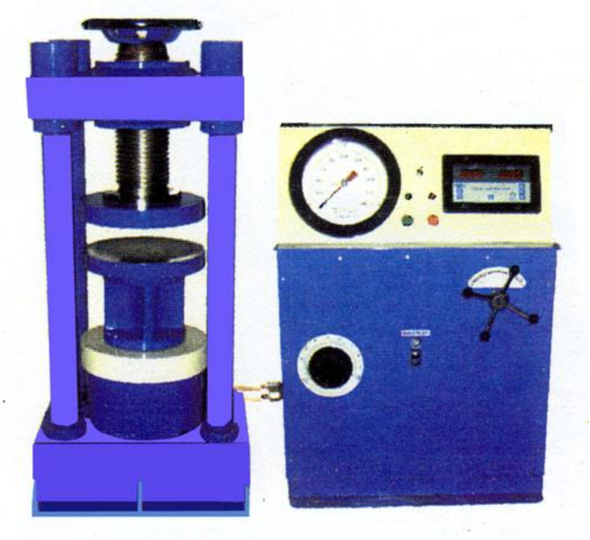
IS: 3495 - Part 1

1. Introduction

This test explains the procedure for the determination of compressive strength of burnt clay building bricks. The dimensions of the test specimens shall be measured to the nearest 1 mm. All apparatus and the testing equipment shall be calibrated at frequent intervals. The number of specimens for the test shall be selected according to IS: 5454-976.

2. Apparatus

A compressive testing machine, the compression plate of which shall have a ball seating in the form of portion of a sphere, the centre of which coincides with the centre of the plate, shall be used.



3. Method for solid bricks

a) Take a sample brick and measure its dimensions. From the dimensions calculate the cross sectional area of the specimens.
b) Remove unevenness observed in the bed faces by grinding, to provide two smooth and parallel faces.
c) Immerse the specimen in the water at room temperature for 24 hours.
d) Remove the specimen and drain out any surplus moisture at room temperature.
e) Fill the frog (where provided) and all voids in the bed face flush with cement mortar (1 cement, clean coarse sand of grade 3 mm and down).
f) Store the samples under the damp jute bags for 24 hours followed by immersion in clean water for 3 days.
g) Remove and wipe out any trace of moisture.

3.1 *Procedure*

a) Place the specimen with flat faces horizontal, and mortar filled face facing upwards between two plywood sheets, each of 3 mm thickness and carefully centred between plates of the testing machine.
b) Apply load axially at a uniform rate of 14 N/mm^2 per minute till failure occurs.
c) Note the maximum load at failure. The load at failure shall be maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

NOTE: *In place of plywood sheets plaster of paris may be used to ensure a uniform surface for application of load*.

3.2 *Calculation*

$$\text{Compressive strength in N/mm}^2 = \frac{\text{Maximum load at failure in N}}{\text{Average area of the bed faces in mm}^2}$$

Average of results shall be reported.

4. Method for perforated bricks

a) Immerse the specimen in the water at room temperature for 24 hours.
b) Remove the specimen from water and drain out any surplus water.

c) No mortar shall be filled in perforations and no mortar capping shall be provided.

4.1 *Procedure*

a) Place the perforated faces of the brick specimen between two plywood sheets each of 3 mm thickness and carefully centred between plates of the testing machine.

b) Apply load axially at a uniform rate of 14 N/mm^2 per minute till failure occurs. Measure the applied load and note down it.

c) The load at failure shall be maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

NOTE: *In place of plywood sheets plaster of paris may be used to ensure a uniform surface for application of load.*

4.2 *Calculation*

$$\text{Compressive strength in N/mm}^2 = \frac{\text{Maximum load at failure in N}}{\text{(Average net area of the two faces under compression in mm}^2\text{)}}$$

Average of results shall be reported.

****

DETERMINATION OF WATER ABSORPTION OF BUILDING BRICKS

IS: 3495 - Part 2

1. Introduction

This test explains the procedure for determination of water absorption of burnt clay building bricks. The dimensions of the specimen shall be measured to the nearest 1 mm. All apparatus and the testing equipment shall be calibrated at frequent intervals. The number of specimens for the test shall be selected according to IS: 5454-1976.

2. Apparatus

a) A sensitive balance capable of weighing within 0.1% of the mass of the specimen.
b) A properly ventilated oven capable of maintaining temperature 110±5°C.

3. Procedure

a) Remove any dirt adhering to the surface of the brick.
b) Dry the specimen in the oven at 105°C to 115°C till it attains a substantially constant mass.
c) Cool the specimen to room temperature and obtain its weight (M_1).
d) If specimen is warm, it shall not be weighed.
e) Immerse the dry specimen in clean water at 27±2°C for 24 hours.
f) Remove the specimen, wipe out any trace of water with a damp cloth and find the weight (M_2).
g) Complete the process of weighing within 3 minutes after removing from water.

4. Calculation

The water absorption after 24 hour immersion in cold water is calculated as below:

$$\text{Water absorption \%} = (M_2 - M_1)/M_1 \times 100.$$

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DETERMINATION OF EFFLORESCENCE OF BUILDING BRICKS

IS: 3495 - Part 3

1. Introduction

This test explains the procedure for the determination of efflorescence of burnt clay building bricks. The dimensions of the specimen shall be measured to the nearest 1 mm. All apparatus and the testing equipment shall be calibrated at frequent intervals. The number of specimens for the test shall be selected according to IS: 5454-1976.

2. Apparatus

a) A shallow flat bottom dish with sufficient distilled water to completely saturate the specimens.
b) The dish shall be made of glass, porcelain or glazed stoneware and of size 180 mm x 180 mm x 40 mm. Cylindrical shaped dish shall be 200 mm dia and 40 mm depth.

3. Procedure

a) Place the end of bricks in the dish. The depth of immersion shall be 25 mm.
b) Place the whole arrangement in a warm ventilated room (20°C to 30°C temperature) till all water is absorbed by the specimen and surplus water is evaporated.
c) Cover the dish containing the sample with a proper glass cylinder so that excess evaporation is prevented.
d) When water has been absorbed and bricks appear to be dry, add a similar quantity of water in the dish and allow it to evaporate as before.
e) Examine the bricks for efflorescence after the second evaporation and report the results.
f) Using a steel rule or wedge measure the greatest distance of the brick face from the flat surface.

4. Report

The liability to efflorescence shall be reported as 'nil', 'slight', 'moderate', 'heavy' or 'serious' in accordance with the following definitions:

a) *Nil* - When there is no perceptible deposit of efflorescence.
b) *Slight* - When not more than 10% of the exposed area of the brick is covered with a thin deposit of salts.
c) *Moderate* - When there is a heavier deposit than under 'slight' and covering up to 50% of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
d) *Heavy* - When there is a heavy deposit of salts covering 50% or more of the exposed area of the brick surface by unaccompanied by powdering or flaking of the surface.
e) *Serious* - When there is a heavy deposit of salts accompanied by powdering and/or flaking of the exposed surfaces.

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DETERMINATION OF WARPAGE OF BUILDING BRICKS

IS: 3495 - Part 4

1. Introduction

This test explains the procedure for determination of warpage of burnt clay building bricks. The dimensions of the specimen shall be measured to the nearest 1 mm. All apparatus and the testing equipment shall be calibrated at frequent intervals. The number of specimens for the test shall be selected according to IS: 5454-1976.

2. Apparatus

a) A steel rule graduated from one end in 0.5 mm divisions.
b) Alternatively, a steel measuring wedge 60 mm in length,15 mm in width and 15 mm in thickness at one end and tappered, starting at a line 15 mm from one end to zero thickness at other end. The wedge shall be graduated in 0.5 mm divisions and numbered to show the thickness of the wedge between the base and the slope.
c) A flat surface of steel or glass, not less than 300 mm x 300 mm in area and plane to 0.02 mm.

3. Procedure

3.1 *For measuring Concave warpage*

a) Remove any dirt adhering to the surface of the brick.
b) Place the flat surface of steel or glass on the surface to be checked.
c) Select the location that gives the greatest departure from straightness.
d) Using a steel rule or wedge measure the greatest distance of the brick face from the flat surface.

3.2 *For measuring Convex warpage*

a) Remove any dirt adhering to the surface of the brick.
b) Place the brick on the flat surface with the convex face in contact with the flat surface.
c) Measure the distance from flat surface to the four corners of the brick.
d) Take the maximum value of the four measurements.

4. Report

The highest of the distance obtained in 3.1 and 3.2 is reported as warpage.

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METHODS OF SAMPLING AND BASIS FOR ACCEPTANCE OF CERAMIC TILE

IS: 13630 - Part 15

1. Introduction

The method for batching, sampling and inspection of unfixed ceramic tiles are explained here. The terms associated with sampling of ceramic tiles are given below:

a) *Consignment:* A quantity of tiles delivered in two days time.
b) *Order:* A quantity of tiles ordered at a time. It may contain one or more consignments.
c) *Inspection lot*: A quantity of tiles submitted for inspection.
d) *Sample:* A specified number of tiles taken from an inspection lot.
e) *Sample size*: The number of tiles to be tested for each property.
f) *Requirement*: A characteristic of the tile specified in the product standard.
g) *Non-conforming units*: A tile that does not meet the requirement for the specified characteristics.

2. Sampling

a) A complete range of tests shall only be executed for inspection lots of more than 5000 m^2 of tiles.
b) Testing is not necessary for inspection lots of less than 1000 m^2 of tiles.
c) Two samples shall be taken at random from the inspection lot. It may not be necessary to test the second sample.
d) Each sample shall be packed separately and shall be sealed and marked.

Table 1: Sampling of ceramic tiles

Properties	*Sample size*		*Test method as per IS: 13630*
	Initial number	Second number	
Dimension (Only for tiles with individual area ≥4 cm^2)	10	10	Part 1
Surface quality (Minimum 30 tiles)	30 40 50 60 70 80 90 100 1 m^2	30 40 50 60 70 80 90 100 1m^2	Part 1
Water absorption (Sample size depend on size of tile)	5 10	5 10	Part 2
Modulus of rupture (Sample size depend on size of tile)	7 10	7 10	Part 6
Chemical Resistance – Glazed tile	5	5	Part 8
Resistance to Abrasion for glazed tiles (Only for tiles with individual area ±4 cm^2)	11	--	Part 11

NOTE: *Determination of Acceptability of Inspection lot and Inspection by average value can be found in IS: 13630 (Part 15) - 2006.*

e) A guideline to classify the relative importance of each property in relation to the application is explained in Table 2.

Table 2: *Properties recommended to be checked for tiles*.

Characteristics	*Floors*		*Walls*		*Reference to part of IS 13630*
	Interior	*Exterior*	*Interior*	*Exterior*	
Dimensions and surface quality					
Length and width	x	x	x	x	1
Thickness	x	x	x	x	1
Straightness of sides	x	x	x	x	1
Rectangularity	x	x	x	x	1
Surface flatness	x	x	x	x	1
Surface quality	x	x	x	x	1
Physical properties					
Water absorption	x	x	x	x	2
Modulus of rupture and breaking strength	x	x	x	x	6
Resistance to abrasion - glazed	x	x			11
Resistance to chemicals- glazed	x	x	x	x	7

NOTE: ‘x’ indicates test required.

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DETERMINATION OF WATER ABSORPTION AND BULK DENSITY

IS: 13630 - Part 2

1. Introduction

Water Absorption of tile can be defined as weight of water absorbed as the percentage of the weight of tile. Bulk density, B, in g/cm^3, of a tile is the quotient of its dry mass divided by the exterior volume, including pores.

2. Apparatus

(i) Drying oven capable of operation at about 110°C.
(ii) Heating apparatus made of suitable inert material, in which the boiling will take place.
(iii) Balance accurate to 0.01 percent of the mass of a test specimen.
(iv) Chamois Leather.
(v) Desiccator.
(vi) Wire Loop, Halter, basket capable of supporting specimens under water for making suspended mass measurements.
(vii) De-ionised or distilled water.

3. Test specimens

(i) A sample for each type of tile under test shall consist of 10 whole tiles.
(ii) If the proper surface area of each individual tile is greater than 0.04 m^2, then only 5 whole tiles shall be tested.
(iii) When the mass of each individual tile is below 50 gm, a sufficient number of tiles shall be taken so that each test specimen reaches a mass of 50 gm to 100 gm.
(iv) Tiles with sides larger than 200 mm may be cut up, but all pieces shall be included in the measurement.
(v) With polygonal or shaped tiles, the length and breadth shall be of the enclosing rectangles.

4. Procedure

a) Dry the tiles selected in an oven at a temperature of 110±5°C till they attain constant weight.
b) Cool the tiles in the desiccators over silica gel, until cooled to room temperature.
c) Weigh each tile and record the results (m_1) to the corresponding accuracy shown in table 1 below:

Table 1: *Tile mass accuracy measurement*

Sl. No.	*Mass of tile, gm*	*Accuracy of measurement, gm*
1	0 to 100	0.02
2	101 to 500	0.05
3	501 to 1000	0.25
4	1001 to 3000	0.50
5	Above 3000	1.00

d) Place the tiles vertically in the water bath so that there is a depth of 50 mm water above and below the tiles.
e) Heat the water until boiling and continue to boil for 2 hours.
f) Remove the source of heat and allow the tiles to cool overnight, still immersed in water.

g) Take out the specimens and remove the surface water from the tile pieces with chamois leather.

h) Weigh each tile (m_2) and to the same accuracy as for the dry state.

i) Determine to the nearest 0.01 gm, the mass m_3 of each specimen, while suspended in water.

NOTE: *For determination of bulk density by boiling water method, the size of tile shall not be 0.01 m2 (100 mm x 100 mm).*

5. Calculation

a) Calculate the water absorption to the first decimal place as percentage of the dry mass using the formula:

Water absorption = $[m_1 - m_2]/m_1 \times 100$ where
m_1 = Mass of the dry tile.
m_2 = Mass of the wet tile.

b) Calculate the bulk density as follows:

Bulk density B = (m_1/V)
Where m_1 = mass of the dry tile.
V = Volume of the tile in cm^3
V = $(m_2 - m_3)$ where
m_2 = Mass of the wet tile.
m_3 = Mass of the tile suspended in water after boiling and cooling.

6. Reporting results

a) The water absorption is reported to the first decimal place.

b) Calculate the average water absorption of the sample as the average of the individual results.

c) The test report shall include:
   (i) Description of the tiles.
   (ii) Water absorption and bulk density of each individual tile.
   (iii) Average water absorption and bulk density.

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DETERMINATION OF MODULUS OF RUPTURE AND BREAKING STRENGTH

IS: 13630 - Part 6

1. Introduction

This test is for determining the modulus of rupture and breaking strength of ceramic tiles by means of three-point loading.

2. Apparatus

(i) Drying oven, capable of operation at about 110±5°C.

(ii) Recording gauge accurate to 2%.

(iii) Modulus of Rupture machine as shown in the figure or any suitable loading machine with two cylindrical support rods and one central cylindrical rod.

(iv) Two cylindrical support rods made of metal and the parts in contact with the test specimen shall be covered with rubber of hardness 50±5 IHRD. One rod shall be slightly pivotable and the other one rotatable about its own axis. The dimensions of the rods shall be as given in table 1.

(v) Central cylindrical rod shall be of the same diameter and covered with the same rubber as support rods. This rod shall also be slightly pivotable. The dimensions of the rod shall be as given in table 1.

Table 1: *Diameter of the rods, thickness of rubber and length*

Sl. No.	*Dimension of the tile (mm)*	*Diameter of the rod 'd' (mm)*	*Thickness of rubber 't' (mm)*	*Over lap of tile beyond the edge supports 'l' (mm)*
1	95 and above	20	5	10
2	Above 48 up to 95	10	2.5	5
3	Above 18 up to 48	5	1	2

3. Specimens

a) As far as possible whole tiles, preferably rectangular test specimens shall be tested.

b) Tiles larger than 300 mm and non-rectangular tiles may be cut to fit in the testing apparatus. Tiles are to be cut such that its centre line coincides with the centre line of the specimen.

c) If the dimension of the test specimen is above 48 mm and up to 95 mm, a minimum of 7 specimens is be tested and if it is above 18 mm and up to 48 mm, a minimum of 10 specimens to be tested.

4. Procedure

a) Dry the tiles selected in an oven at a temperature of 110±5°C, till they attain constant weight.

b) Place the specimen on the two supporting rods, with the glazed surface upwards so that the test specimen project beyond each support rod as specified in table 1.

c) Position the central rod equidistant between the support rods and apply the load at a rate of I±0.2 N/mm^2/s and note the breaking load.

5. Calculation

The breaking strength (S), expressed in Newton, is calculated by the formula:

$S = FL/b$ where

F = Load required to break the tile, in N.

L = Span of the support rods, in mm.

b = Width of the tile, in mm.

The modulus of rupture expressed in Newton/ mm^2, is calculated by the formula:

$\partial = 3\,FL/2\,bh^2$ where

F = Load required to break the tile, in N.

L = Span of the support rods, in mm.

b = Width of the tile, in mm,

h = Minimum thickness of the test specimen measured after the test along the broken edge, in mm.

NOTE*: Only the results for test specimens that break within a central portion of length equivalent to the diameter of the central rod shall be used to calculate the average breaking strength and average modulus of rupture. A minimum of five acceptable results is necessary to calculate the average value.*

6. Report

The test report shall include:

(i) Description of the tiles.
(ii) Number of tiles tested.
(iii) Values of d, t l, and F.
(iv) Modulus of rupture and breaking strength of each specimen.
(v) Average modulus of rupture and breaking strength.

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DETERMINATION OF CHEMICAL RESISTANCE OF GLAZED TILES

IS: 13630 - Part 8

1. Introduction

The method of tests for determining the chemical resistance of the proper surface of glazed ceramic tiles at room temperature is given below. For testing the resistance to staining, the test solutions are allowed to drop on and dry and then the surfaces tested are inspected for visual changes. For testing the resistance to household chemicals, a part of the glazed surface is subjected to the action of the test solution for 6 hours and inspected for visual changes. For checking the resistance to hydrochloric acid and potassium hydroxide, the procedure is similar except that the period of test is 7 days.

2. Apparatus

A borosilicate glass cylinder of Type 1 grade according to IS: 2303 or of any suitable material with a lid or opening for filling. The bottom side of the cylinder shall be flat and perpendicular to the vertical axis.

3. Test specimen

Five undamaged test specimens, cleaned with a suitable solvent like Methanol, shall be used with each test solution.

4. Test solutions

4.1 *Stains*

(i) Methylene Blue, 10 gm/l.
(ii) Potassium Permanganate Solution, 10gm/l.

4.2 *Household chemicals*

(i) Ammonium Chloride Solution, 100g/l;
(ii) Standard cleaning agent solution, prepared from:
  1) Anhydrous sodium carbonate 33 percent (*m/m*).
  2) Sodium perborate 7 percent (*m/m*).
  3) Sodium silicate solution - of density 1.33 g/cm3 - 7 percent (*m/m*)
  4) Commercial sodium oleate soap flakes 30 percent (*m/m*)
  5) Distilled water or de-ionised water 23 percent (*m/m*)
(iii) 100 gm of this standard leaning agent contain 70 gm of dry substance. Use in a concentration of 10 gm dry substance per litre. The test solution shall be prepared immediately before use.

NOTE: *The soap can be prepared from concentrated sodium hydroxide solution and oleic acid in the proportion of 2.6 gm to 18.5 gm respectively*.

4.3 *Swimming pool salts*

(i) Sodium hypochlorite solution 20 mg/l, prepared from technical grade hypochlorite with about 13 percent active chlorine.
(ii) Copper sulphate solution, 20 mg/l.

4.4 *Acids*

(i) Hydrochloric acid solution, 3 percent.
(ii) Citric acid solution, 100 gm/l.

4.5 *Alkali*

Potassium hydroxide solution 200 gm/l.

5. Procedure for testing resistance to staining

a) Allow 3 or 4 drops of each of the test solutions specified in 4.1 to fall on a fresh part of the specimen.

b) Place a convex watch glass of approximately 30 mm dia on the applied drop in order to spread it to a circular area.

c) Keep it for 24 hours, then rinse the surface with running water and wipe with a damp cloth.

d) If a stain remains, thoroughly clean with a solution of the standard cleaning agent.

6. Procedure for testing resistance to household chemicals, swimming pool salts

a) Apply a uniform layer of the sealing material 3 mm thick, to the rim of the glass cylinder.

b) Turn the cylinder upside down on to a fresh part of the glazed surface and seal around the rim.

c) Pour the test solution through the inlet to a height of 20±1 mm.

d) Maintain the test assembly at a temperature of 27±2°C.

e) Maintain the test solution in contact with the test specimens for 6 hours.

f) Remove the cylinder and clean the glazed surface with a grease solvent.

NOTE: (i) *For testing resistance to hydrochloric acid and potassium hydroxide, maintain the test solution in contact with the test specimen for 7 days.*

(ii) *Shake the test assembly once in a day and ensure that the level of test solution does not change.*

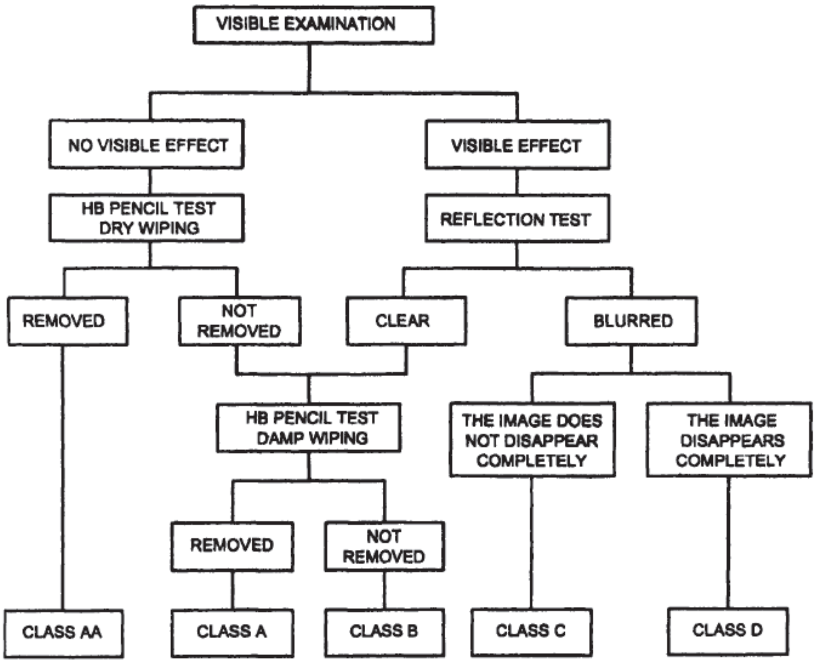
(iii) *Replace the test solution after 4 days. After 3 more days, remove the cylinder and clean the glazed surface with a grease solvent.*

7. Determination after procedure

a) Completely dry the surface to be tested before starting the assessment.

b) Draw several lines using a HB pencil on the untreated part of the glazed surface of the tiles. Try to remove the pencil marks with a soft dry cloth. If the marks cannot be removed, the pencil test is not applicable for the tile. Only visual assessment shall be carried out in such cases and the classification scheme given below is not applicable.

c) The classification scheme for tests with household chemicals, swimming pools salts, acids and alkalis are given in figure below.



7.1 *Initial visual examination*

a) Examine the surface tested from all angles from a standard distance of 250 mm with naked eye.
b) Any visible effect like change in reflection or development of brilliance is noted.
c) Artificial or day light illumination is allowed but avoid direct sunlight.
d) If no visible effect is observed, proceed with the pencil test. If there is a visible effect, carry out the reflection test.

7.2 *Pencil test*

a) Draw several lines with HB pencil both on the surface under test and the untreated surface.
b) Try to remove the lines using a soft dry cloth. If the lines disappear, the surface corresponds to class AA.
c) If not removed, try next, using a soft damp cloth, dampened by dipping in distilled or de-ionised water and then wringing out. If the lines are removed, the surface corresponds to class A. If not removed, it is class B.

7.3 *Reflection test*

a) Hold the tile such that the image of the lamp is reflected on the untreated surface.
b) The angle of incidence of the light upon the surface shall be approximately 45° and the distance between the surface and light source shall be 350±100 mm.
c) Position the tile so that the image fall simultaneously on both treated and untreated part and determine whether it is less clear in the treated part.
d) The criteria for judgment shall be the sharpness of the reflection and not the brightness of the surface.
e) If the reflection is clear, perform the pencil test with damp wiping. If the lines are removed, the surface corresponds to class A. If not removed, it is class B.
f) If the reflection is blurred, but does not disappear completely, the classification is C and if the image disappears completely, the classification is D.

NOTE: *The reflection test is not applicable to certain glazed tiles in particular which are dull.*

8. Classification by staining test

a) After the procedure with stain solution, glazes are divided into three classes as given in table 1.
b) Record the result for each test specimen with each stain solution.

Table 1 – *Classification by staining test*

Test solution	*Observation*	*Class*
Methylene blue or Potassium Permanganate	Stain removed by water	1
	Stain removed by cleaning agent	2
	Stain not removed	3

9. Classification by testing with household chemicals, swimming pool salts, acids, alkalis.

a) After the procedure with the prescribed test solution, the glazes are divided into several classes as given in the classification scheme.
b) Record the result for each test specimen with each test solution.
c) The classes of resistance are given below:

AA = Resistant.
A = Less resistant than AA but more resistant than B.

B = Less resistant than A, but more resistant than C.
C = Less resistant than B.
D = Not resistant.

d) The classes of resistance for which pencil test and/or reflection test are not applicable are given below:

AA = No visible effect.
A = Slight change in appearance.
B = Definite change in appearance.
C = Partial loss of the original surface.
D = Total loss of the original surface.

10. Test report

The test report shall contain the following:

(i) Description of the tile.
(ii) Test solution used.
(iii) Visual changes on the proper surface as a result of the test specified under para 7.
(iv) Classification for each test solution and for each test specimen as per para 8 and 9.

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DETERMINATION OF RESISTANCE OF SURFACE ABRASION OF GLAZED TILES

IS: 13630 - Part 11

1. Introduction

Abrasion resistance of the glaze of ceramic tiles is measured by rotation of an abrasive load on the surface and assessment of the wear by means of visual comparison of abraded test specimens and non-abraded tiles.

2. Apparatus

(i) Abrasion apparatus.
(ii) Apparatus for visual assessment.
(iii) Drying oven, capable of operation at 110± 5°C.
(iv) Balance, if loss in weight is to be determined.
(v) The total load on each test specimen consists of:
  - *a.* 70 gm of 5 mm diameter steel balls.
  - *b.* 52.5 gm of 3 mm diameter steel balls.
  - *c.* 43.75 gm of 2 mm diameter steel balls.
  - *d.* 8.75 gm of 1 mm diameter steel balls.
  - *e.* 3.0 gm of white fused aluminum oxide.
  - *f.* 20 ml of distilled or de-ionised water.

NOTE: *Calibration of the apparatus if necessary, shall be carried out as given in Annexure A of IS: 13630 (Part 11):2006.*

3. Test specimens

Test specimens shall be representative of the sample, usually with dimensions 100 mm x 100 mm. 11 test specimens are required for the test and an additional 8 test specimens are required for the visual assessment. Another 3 test specimens are also needed to check the result at the visual failure point.

4. Procedure

a) Clamp a metal holder on to the clean and dry glazed surface of each test specimen on the abrasion apparatus.
b) Introduce the abrasive load into the holder through a hole in its upper surface and seal it.
c) Preset the number of revolutions required for each abrasion stage of the test which is 100, 150, 600, 750, 1500, 2100, 6000 and 12000.
d) Remove one test specimen after each abrasion stage and continue the test until failure is observed.
e) After abrasion, rinse the test specimens under running water and dry in the oven at 110±5°C.
f) Surround an abraded test specimen by un-abraded tiles of the same type and view with naked eye through visual assessment apparatus, under an illumination of 300 lux, from a distance of 2 m and a height of 1.65 m.
g) Note the number of revolutions at which any change in the area that has been subjected to abrasion can be readily identified till the consensus of at least three observers is obtained.
h) The result is checked by retesting at the abrasion stage when failure is observed and at the next higher and lower abrasion stages.

i) If the result is not the same, the lower of the two abrasion stages shall be used to decide the classification.
j) Then test the abraded area of the tile which has passed 12000 revolutions stage for stain resistance.
k) Before each test, screen the steel balls in the abrasive load into specified categories and replace any mass in each size categories.
l) Clean the steel balls after test with water followed by Methylated sprit and dry thoroughly.
m) If the mass loss is to be determined, the dry mass of three test specimens before test and after 6000 revolutions is determined.

5. Results

The test specimens are classified according to table I.

Table 1 - *Classification of glazed ceramic tiles*

Sl. No.	*Abrasion stage: Failure visible at revolution*	*Class*
1	100	0
2	150	1
3	600	2
4	750,1500	3
5	2100, 6000, 12000	4
6	>12000*	5

*In order to be classified as Class 5, the tile must also pass the test specified in IS: 13630 (Part 8) - Test for resistance to stains on the abraded area. If there is no visual failure after 12 000 revolutions but if stains cannot be removed by any standard procedure the tile shall be of Class 4.

6. Test report

The test report shall contain the following:

(i) Description of tiles.
(ii) Preparation of test specimens.
(iii) Test method.
(iv) Classification according to table 1 above.
(v) Abrasion stage at which visual failure occurred.
(vi) Mass loss, colour change, gloss change of other properties if specified.

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DETERMINATION OF ACID RESISTANCE OF TILES

IS: 4457

1. Introduction

Acid resistant tiles are suitable for use as flooring and lining in all types of industries including pharmaceuticals, chemical plants, power houses, battery rooms, food processing units, paper mills, warehouses etc.

The procedure to determine the acid resistance of tiles is explained in this section. The details are given under annexure G of IS: 4457.

2. Apparatus

(i) Circular air oven having thermostatic control that will maintain a temperature of 110±5°C.
(ii) Balance of capacity 100 gm with a sensitivity of 0.1 gm.
(iii) Porcelain basin.
(iv) Concentrated nitric acid & sulphuric acid.

3. Preparation of test specimen

a) Crush the tiles to powder individually in a stoneware mortar.
b) Take 30 gm of powder of each tile which passes 850 micron IS Sieve and retained on 600 micron IS Sieve for testing.
c) Place the specimen in a porcelain basin and add about 150 ml of distilled water.
d) Keep the basin on a sand bath and heat the mixture for 1 hour in the basin to boiling.
e) Care shall be taken to avoid loss by spurting while boiling.
f) Drain the water and rinse the particles with cold distilled water.
g) Dry the material to constant mass keeping it in an oven maintained at a temperature of 110°C which will yield the specimen for testing.

4. Procedure

a) Place accurately weighed 25 gm of the prepared specimen in a porcelain basin.
b) Add a mixture of 7 ml nitric acid, 13 ml sulphuric acid and 65 ml distilled water to the specimen.
c) Place the basin and its contents on a sand bath and heat carefully, till all nitric acid has evaporated and sulphuric acid starts fuming profusely.
d) Cool the basin and its contents to 27±2°C.
e) Add 90 ml of distilled water and 10 ml of nitric acid.
f) Repeat the heating process, until the sulphuric acid again fumes strongly.
g) Cool the basin and contents. Gently and carefully pour out the acid without disturbing the sediments.
h) Add about 150 ml of cold distilled water and heat up to boiling and then again decant.
i) The cycle of addition of fresh water, boiling and decantation shall continue until drained liquid is found to be free from sulphuric acid when tested with barium chloride solution.
j) After final decantation, dry the sample in an oven maintained at 110°C to constant mass.

5. Calculation

Loss in mass, percent = $(M_1-M_2)/M_1 \times 100$ where
M_1 = Initial mass, in gm, and
M_2 = Final mass, in gm.

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TESTING OF PRECAST CONCRETE PAVER BLOCKS

IS: 15658 - 2006

1. Introduction

Concrete paver blocks were first introduced as replacement of paver bricks. These blocks were rectangular in shape and had more or less the same size as the bricks. Now, various paving blocks from non-interlocking to partially, fully or multiply interlocking types are used. The pavements in which non-interlocking blocks are used are designated as Concrete Block Pavement (CBP) or non-interlocking CBP, and those in which partially, fully or multiply interlocking blocks are used are designated as 'Interlocking Concrete Block Pavement (ICBP).

The specifications and tests for precast concrete blocks for pavement construction are laid out in IS: 15658-2006. The obligatory tests include determination of dimensions, aspect ratio, plan area, wearing face area, deviations from squareness, water absorption, compressive strength and abrasion resistance. Optional tests include determination of tensile splitting strength, flexural strength/breaking load and freeze-thaw durability.

2. Sampling procedure

The number of blocks to be sampled from each batch for each test shall be as given in table 1 (Refer IS: 15568-2006, table 4 – Sampling procedures).

Table 1: *Sampling requirements of paver blocks.*

Sl. No.	*Test*	*Reference to IS: 15568*	*For tests by supplier/contractor*	*For third party testing*
(i)	Visual inspection	Clause 7.1	4 (16)*	8
(ii)	Dimensions	Annexure B	4 (16)*	8
(iii)	Wearing layer thickness	Clause 6.2.3	4 (16)*	8
(iv)	Water absorption	Annexure C	3	3
(v)	Compressive strength	Annexure D	4 (16)	8
(vi)	Tensile splitting strength	Annexure E	4 (16)	8
(vii)	Flexural strength/ breaking load	Annexure F	4 (16)	8
(viii)	Abrasive resistance	Annexure G	4 (16)	8
(ix)	Freeze-thaw durability	Annexure H	3	3

**The number indicated in brackets is the total number to be sampled to avoid secondary sampling for confirmatory testing. The blocks remaining may be used for subsequent tests*.

TEST FOR LENGTH, WIDTH, THICKNESS AND ASPECT RATIO

1. Apparatus

(x) Steel calipers.

(xi) Steel rule 300 mm readable to an accuracy of 0.5 mm.

2. Procedure to determine length and width

h) The length and width of the specimens are measured across two opposite faces using steel caliper or rule.

i) Length is measured from two representative positions and width from three positions.

j) The mean value of length and width is noted to the nearest 1 mm.

3. Procedure to determine thickness

a) The thickness of the specimen is measured at four different positions.

b) The mean value of thickness is noted to the nearest 1 mm.

4. Procedure to determine aspect ratio

Aspect ratio is calculated by dividing the mean length by mean depth.

TEST FOR PLAN AREA AND WEARING FACE AREA

1. Apparatus

(i) Balance of capacity 200 gm readable to the accuracy of 0.001 gm.
(ii) Sheets of thin cardboard of uniform thickness.
(iii) Odd-leg marking gauge.
(iv) Steel rule 300 mm readable to an accuracy of 0.5 mm.
(v) Sharp pencil, scissors etc.

2. Procedure to determine plan area (*Method I*)

a) Suspend the specimens separately in water using a metal wire.
b) Record the weight W_a while completely submerged in water.
c) Remove specimen from water, place on a 10 mm mesh and allow the water to drain.
d) Absorb the visible water on the surface with a damp cloth.
e) Weigh the saturated specimens in air W_w immediately to 1 gm accuracy.
f) The volume of the specimen is given by ($W_w - W_a$) cm3.
g) If the thickness of specimen is available, volume divided by thickness will give the plan area.

3. Procedure to determine plan area (*Method II*)

a) The specimen is placed on a cardboard with wearing face upward and its perimeter is traced with a pencil.
b) The shape is cut with a sharp scissors and weight (m_{sp}) determined accurately to 0.01 gm.
c) A rectangular piece of size 200 mm x 100 mm is accurately cut from the same cardboard and weighed as (m_{std}).
d) The plan area A_{sp} is calculated as below:

$$A_{sp} = 20000 \times m_{sp} / m_{std}$$

4. Procedure to determine wearing face area

a) The width of the arris (Arris is the part of a block where two faces meet which can be beveled, rounded chamfered or splayed) of the block is determined at four locations and the average value is calculated.
b) A pen refill is attached to the one-leg marking gauge and the gauge is set to draw a line equal to the length of the arris.
c) Draw the length of arris along the periphery of the cardboard plan area, of weight m_{sp} of the block.
d) Cut out the marked arris portion from the cardboard and find the weight (m_{sw}) to 0.01 gm.
e) The wearing face area is calculated as below:

$$A_{sp} = 20000 \times m_{sw} / m_{std}$$

DETERMINATION OF WATER ABSORPTION

1. Apparatus

(i) A balance with sensitivity to within 0.5% of the mass of the smallest specimen tested.
(ii) Hot air oven, thermostatically controlled, capable of maintaining temperature at 110±5°C.
(iii) Container for soaking specimens.

2. Procedure

a) The selected specimens are soaked in water for 24±2 hours at room temperature.
b) Remove specimen from water, place on a 10 mm mesh and allow the water to drain.
c) Absorb the visible water from the surface with a damp cloth.
d) Immediately find the weigh the saturated specimens in air (W_w) to 1 gm accuracy.
e) The specimens are then dried in oven at 107±7°C for not less than 24 hours till two consecutive weights taken at 2 hours interval does not differ by more than 0.2% of the weight.
f) The dry weight of each specimen (W_d) is determined to the nearest 1 gm.

3. Calculation

The percentage water absorption is calculated as follows:

$$W \text{ percent} = [(W_w - W_d)/ W_d] \times 100$$

The individual and average water absorption of the specimens are reported.

DETERMINATION OF COMPRESSIVE STRENGTH

1. Apparatus

a) Compression testing machine equipped with two steel bearing blocks for holding the specimen.
b) Two steel bearing plates, not less than 12 mm thick, to place between the specimen and bearing blocks, if required.

2. Specimen preparation

a) The sampling of the specimens is done as required in table 1.
b) The upper face of the sample is capped as given in IS: 2185 (Part 1).
c) If specimens with surface projections are to be tested, its upper face is made plain by suitable capping using sulphur or gypsum.

3. Procedure

a) The dimensions and plan area of the specimens are determined first.
b) The blocks are then kept in water for 24±4 hours maintained at 20±5°C before testing.
c) The load is applied at a uniform rate of 1.5 tonnes per minute until no further load is sustained by the specimen or delamination occurs.
d) The maximum load applied is noted in kg.

4. Calculation

a) The apparent compressive strength of individual specimens is calculated by dividing the load by plan area of the specimen.
b) A correction factor is applied to the observed compressive strength to obtain the corrected compressive strength.
c) The correction factors are given in table 2.

Table 2: *Correction factors to observed compressive strength.*

Sl. No.	*Paver block thickness mm*	*Correction factor*	
		For plain block	*Arrised/chamfered block*
(i)	50	0.96	1.03
(ii)	60	1.00	1.06
(iii)	80	1.12	1.18
(iv)	100	1.18	1.24
(v)	120	1.28	1.34

e) The strength of the block is reported to the nearest 10 kg/cm^2.
f) For intermediate thickness of paver blocks, the correction factors shall be worked out by extrapolation.

DETERMINATION OF ABRASION RESISTANCE

1. Apparatus

(i) The abrasion testing machine as described in Annexure F of IS: 1237.

(ii) Hot air oven, thermostatically controlled, capable of maintaining temperature at 105±5°C.

(iii) Container for soaking specimens.

2. Specimen preparation

a) Square specimens of size 71±0.5 mm are cut from the paver block samples.

b) The contact face and the opposite face shall be made parallel by grinding if required.

c) The specimens are oven dried to a constant mass at 105±5°C for testing dry.

d) For testing wet/saturated specimens, the specimens are kept immersed in water for 7 days and wiped with a damp cloth after taking out from water before testing.

3. Procedure

a) The density of the specimen *PR* is determined to the nearest 0.1 gm.

b) The weight of the specimens is determined to the nearest 0.1 gm both prior to the abrasion test and after every four cycles.

c) In case of two layer specimens, the density taken separately of the wearing layer shall be determined.

d) The grinding path of the disc of the abrasion machine shall be strewn evenly with 20 gm of standard abrasive powder as per IS: 1237.

e) The specimens are fixed on the holding device such that the testing surface faces the grinding disc.

f) The specimen shall be centrally loaded with 294±3 N.

g) The grinding disc is run at a speed of 30 rpm and stopped after one cycle of 22 revolutions.

h) The disc and contact face of the specimens are cleaned of abrasive powder.

i) The specimen is rotated 90° clockwise and 20 gm of abrasive powder strewn on evenly on the testing track before starting next cycle.

j) While testing wet/saturated specimens, drip wetting shall be arranged on the central portion of the track. The water drops shall be supplied in the opposite direction of the motion of the disc at the rate of 200 drops (13 ml) per minute.

k) In case of wet testing, before each cycle is commenced, the track is to be cleaned using damp artificial sponge and moistened before strewn with abrasive powder.

l) The test is done for 16 cycles; the specimen turned 90° clockwise before starting of the succeeding cycle and 20 gm of abrasive powder strewn each time.

4. Calculation

The abrasive wear after 16 cycles is calculated as the mean of the loss in volume, ΔV of the specimen, from the equation:

$\Delta V = \Delta m / PR$ where

Δm = Loss in volume after 16 cycles in mm^3.

PR = density of the specimen in gm.

(In case of two layer specimens, the density of the wearing layer in gm/ mm^3 is considered).

5. Reporting of results

The abrasive wear shall be reported to the nearest whole number of 1000 mm^3 per 5000 mm^2.

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APPENDIX A

Bituminous mix design

MARSHALL METHOD OF BITUMINOUS MIX DESIGN

Asphalt Institute Manual Series No. 2 (MS-2)

1. Introduction

The objective of bituminous mix design is to determine the combination of bituminous binder and aggregates that will give durability to the pavement structure. Correct mix design involves adhering to certain laboratory test procedures and design criteria and hence these laboratory methods are to be followed exactly.

Any bituminous mix design procedure will have three basic components.

(a) Laboratory compaction of trial mixes.
(b) Stability and volumetric testing.
(c) Analysis of the test results.

The Marshall procedure of bituminous mix design explained here has been standardized by the American Society for Testing and Materials, given by ASTM Designation D 1559.

Several trial mixes have to be made before the mix required for the project can be finalized. To start with, a blended aggregate gradation close to the median of the specification limits is chosen for the initial trial mix. Before commencing preparation of trial mixes, it should be verified that all the mix constituents such as aggregate, filler, bitumen etc., comply to the required specifications. After carrying out the Marshall Stability and Flow tests and volumetric analysis of the trial mixes, necessary adjustments are made on the trial mix to finalise the job mix formula.

2. Aggregate sizes and proportioning

Aggregate fractions in the bituminous mix are generally designated as below.

Coarse aggregate	- Retaining on 2.36 mm sieve.
Fine aggregate	- Passing 2.36 sieve.
Mineral filler	- Passing 75 µm sieve.

After the aggregate properties are determined and compliance with the specifications is established, one or more trial blending is prepared. The aggregate percentages are normally specified excluding binder content ie., total aggregate equals 100%.

When aggregate and bitumen are mixed together, the bitumen content is expressed as a percentage of total mix. In some cases, it is also expressed as a percentage of dry aggregate.

3. Quality control testing system for bituminous mixes

Mix design is only the starting point in the process of producing a durable pavement. Field verification testing must be carried out continuously during construction, to ensure that the criteria established in the laboratory are achieved in the field also.

Normally, the project quality control system for bitumen mixes will have the following 4 phases.

(a) Pre-production sampling and testing: This ensures that the constituent materials of bituminous mix viz., aggregates, filler and bitumen satisfy the physical requirements set forth in project specifications.

(b) Job mix formula verification: Tests are done at the start of the plant production to compare the field mix with the approved job mix formula. Some slight adjustments may be required due to the variations in aggregate characteristics. This adjusted job mix formula may remain as the target for all subsequent quality control testing.

(c) Daily job control testing: Representative samples of hot mix are taken regularly and subjected to quality tests. The results are then compared with job mix specifications or requirements.

(d) In place acceptance testing: The sampling and testing of in-place bituminous layers are carried out in the last phase. The acceptance of paving work is based on the result of this.

4. Volumetric properties of compacted mix

In order to determine the volumetric properties of the bituminous mix, specific gravities of the constituent materials are to be found. The specific gravity of aggregates is computed in three ways:

(a) Bulk specific gravity.
(b) Apparent specific gravity.
(c) Effective specific gravity.

4.1 ***Bulk specific gravity of aggregate (G_{sb})***

Suppose P_1 and P_2 represent coarse and fine aggregate having bulk specific gravities G_1 and G_2 with 60 % and 40 % percentage compositions by weight in a mix. Then for 5% binder content by total weight of the mix, the total aggregates will be 95% in the mix. The percentage weight of aggregates will be 57 and 38 (0.95 times individual percentages) in the total mix. Now the bulk specific gravity of the aggregate mix is computed as

$G_{sb} = 95/[(57/G_1) + (38/G_2)]$

In determining the bulk specific gravities of aggregates, the weight of saturated surface dry (SSD) aggregate is used for computing the volume.

4.2 ***Apparent specific gravity of aggregate (Gsa)***

Apparent specific gravity (G_{sa}) of an aggregate mix is calculated in the same way as for effective specific gravity (G_{se}) except that apparent specific gravities of individual aggregates are substituted in the formula. In determining the apparent specific gravities of individual aggregates, oven dry weight of samples are taken to compute the volume - assuming that the material is impermeable.

4.3 ***Effective specific gravity of aggregate (Gse)***

This includes all voids except those that absorb bitumen. Effective specific gravity (G_{se}) is calculated as below.

$G_{se} = (P_m - P_b) /[(P_m/G_t) – (P_b/G_b)]$ where
P_m = Percentage weight of total mix = 100
P_b = Percentage of binder by total weight of mix.
G_t = Theoretical maximum specific gravity of mix (no voids).
G_b = Specific gravity of bitumen.

4.4 ***Maximum specific gravity of the compacted mix (Gt)***

The maximum specific gravity or the theoretical specific gravity (G_t) is determined by ASTM D 2041 or AASHTO T 129 method. G_t is the ratio of the weight of the bituminous mix in air without any voids to the weight of an equal volume of water. A vaccum procedure is used to remove the entrapped air in the mix and determine the volume in a void less state.

For each measured G_t, the G_{se} can be computed using the formula given in 4.3. Using the average of G_{se} values, the G_t for any binder content can be computed as below.

$G_t = P_m /[(P_s/G_{se}) + (P_b/G_b)]$ where
P_m = Percentage weight of total mix = 100.
P_s = Percentage of aggregate in the mix (100 minus % of binder by weight of total mix).

P_b = Percentage of binder by total weight of mix.

G_{se} = Average effective specific gravity of aggregate.

G_b = Specific gravity of bitumen.

Example:

If G_t of a bituminous mix is 2.535 as per ASTM D 2041 determination and G_b = 1.030 then G_{se} for 5.3 % binder content will be 2.761. With G_{se} = 2.761, G_t for 4 % binder can be computed as below.

G_t = 100 /[(96.0/2.761) + (4.0/1.030)] = 2.587.

4.5 *Bitumen absorption*

Mineral aggregate is porous and can absorb bitumen as well as water. The percentage of bitumen absorbed (P_{ba}) by the aggregates in the mix is expressed as a percentage by weight of aggregate (not as a percentage of total mix). P_{ba} is calculated as below.

P_{ba} = 100 x [(G_{se} – G_{sb})/(G_{sb} x G_{se})] x G_b where

G_{se} = Effective specific gravity of aggregate mix.

G_{sb} = Bulk specific gravity of aggregate mix.

G_b = Specific gravity of bitumen.

4.6 *Effective bitumen content for a bituminous mix (Pbe)*

P_{be} is the total bitumen content less quantity lost by absorption into aggregate. It is the bitumen content that remains outside the aggregate particles as a coating. It is P_{be} which governs the performance of a paving mix.

P_{be} = P_b – [(P_{ba}/100) x P_s] where

P_{be} = Effective bitumen t content, % by weight of total mix.

P_b = Percentage of binder by total weight of mix.

P_{ba} = Percentage of absorbed bitumen, % by weight of aggregate.

P_s = Percentage of aggregate in the mix (100 minus % of binder by weight of total mix).

Example:

If binder content is 5.3 % and assuming absorption of 0.8 %, then effective bitumen content is

P_{be} = 5.3 – (0.8/100) x 94.7 = 4.5 %.

4.7 *Voids in mineral aggregate for a compacted mix (VMA)*

VMA is expressed as a percentage of the bulk volume of the compacted mix

VMA = 100 – (G_m /G_{sb}) x P_s where

G_m = Bulk specific gravity of compacted mix (computed from saturated surface dry weight of compacted specimens).

G_{sb} = Bulk specific gravity of aggregate mix (Using formula in 4.1).

P_s = Percentage of aggregate in the mix (100 minus % of binder by weight of total mix).

4.8 *Percentage air voids in compacted (Va)*

V_a = 100 x (G_t – G_m)/G_t where

V_a = % air voids in the mix by percentage of total mix.

G_m = Bulk specific gravity of compacted mix.

G_t = Maximum specific gravity of mix (By direct measurement by ASTM D 2041 method or calculated using formula in 7.1.4).

4.9 *Percentage voids filled with bitumen in the compacted mix (VFB)*

VFB is the percentage of VMA filled with bitumen and is given by

VFB = 100 x (VMA - V_a)/VMA where

VMA = Percentage of air voids in aggregate of bulk volume.

V_a = % air voids in the mix by percentage of total mix by volume.

A typical work sheet for computing the density void analysis is given as form QC-B5/2014.

5. Preparing bitumen mix in Marshall Method of mix design

5.1 *General*

The original Marshall method is applicable only to hot bituminous paving mixes, with a maximum aggregate size of 25 mm. Subsequently modified Marshall Method has been developed for aggregates with maximum size up to 38 mm. The Marshall method uses standard test specimens of 64 mm height and 102 mm diameter. They are prepared using a specified procedure for proportioning materials, heating, mixing and compacting the aggregate-bitumen mixture. The two principal features of this method are a density void analysis and a stability flow test.

The stability is the maximum load taken by a specimen when tested after keeping in 60°C water bath for 30 to 40 minutes. The flow value is the deformation of the specimen in units of 0.25 mm or 1.0 mm at the maximum load condition.

Marshall Stability test is empirical in nature. Hence no modifications can be effected to the standard procedure, likely reheating of mix for preparing specimens.

5.2 *Initial binder content for test specimens*

To provide adequate data, at least three specimens are prepared for each bitumen content. The bitumen contents for trial mixes are selected in increments of 0.5%. At least two shall be below the expected design value or specified value and two above this. So, if six binder contents are tried, then 18 specimens will be required. Each specimen requires about 1200 gm of aggregate. The minimum aggregate requirement for 1 set of test will be 23 kg with 4 litres of bitumen.

If no binder content is specified, the expected design binder content can be arrived using the following formula.

$P = 0.035\,a + 0.045\,b + K\,c + F$ where

P = Approximate % binder content by weight of total mix

a = Percentage of aggregate retaining in 2.36 mm sieve

b = Percentage of aggregate passing 2.36 mm sieve and retaining in 75 µm sieve

c = Percentage of aggregate passing 75 µm sieve

K = A factor depending on percentage of aggregate passing 75 µm (No. 200) sieve

= 0.20 % for 5 % passing 75 µm sieve

= 0.18 % for 6 to 10 % passing 75 µm sieve

= 0.15 for 11 to 15 % passing 75 µm sieve

F = A factor based on absorption of aggregate, varying from 0 to 2.0. Normally it is taken as 0.70.

5.3 *Preparation of test specimens*

The following steps are recommended for preparing Marshall Test specimens:

At least three specimens are required for each aggregate grading and bitumen content.

Coarse and fine aggregates to be incorporated into the bitumen mix are initially subjected to various tests to ascertain its suitability. The following tests are generally essential.

(a) Specific gravity/water absorption.
(b) Los Angeles abrasion/Impact value.
(c) Sieve analysis.
(d) Sulphate soundness.

(e) Flakiness and Elongation.
(f) Stripping.

The selected aggregates are dried to constant weight at 105°C to 110°C. The aggregates are then dry sieved. The proportioning can be done by trial and error method. An initial gradation very close to the median of specification limits is selected for preparing specimens.

5.4 *Selection and testing of binder*

The selection of the bitumen grade for any paving mix is done based on the temperature, rainfall and traffic of the construction zone. The selected bitumen is subjected to the following tests.

(a) Penetration.
(b) Viscosity.
(c) Specific gravity.
(d) Ductility.
(e) Solubility.
(f) Softening point.

5.5 *Mixing and compaction temperatures*

The temperatures up to which the bitumen is to be heated to produce viscosities of 170±20 centistokes kinematic and 280±30 centistokes kinematic are denoted as mixing and compaction temperatures for the paving mix. By plotting viscosities against temperatures in a log scale, these values can be obtained.

5.6 *Preparation of mould and hammer*

The mould assembly is cleaned and heated to a temperature between 95°C and 150°C. A piece of filter paper, cut to size is placed at the bottom before the hot mix is poured.

5.7 *Preparing the bituminous mix*

Weigh into separate pans for each specimen, the required quantity of different aggregates. This will be about 1200 gm. It is desirable to prepare a trial specimen to work out the weight of material required to produce a specimen of height 63.5 mm. If the height of the trial specimen falls outside the limits, the quantity of aggregates has to be adjusted as below.

$$\text{Adjusted weight of aggregate} = 63.5\text{ mm} \times \frac{\text{Weight of aggregate used}}{\text{Height of trial specimen in mm}}$$

Heat the pans containing the aggregate mix in the oven to a temperature not exceeding 28°C above the mixing temperature determined as per 5.5. Transfer the aggregate mix to the mixing bowl and agitate thoroughly. Add the required weight of heated bitumen to the aggregate mix. Preferably with a mechanical mixer or by hand with a trowel, mix the aggregate and bitumen together till a uniform and well coated mix is obtained.

Place the mould assembly in the compaction pedestal. Place a paper disc at the bottom of the mould. Transfer the mix into it. Spade the mix with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. See that the temperature of the mix is not below the compaction temperature as per 5.5.

5.8 *Compaction of specimens*

Place a paper disk on top of mix. Apply the number of blows depending on the design traffic category, using the compaction hammer with free fall of 857 mm. Apply the same number of blows after reversing the specimen. Keep the mould with specimens to cool, normally for overnight. Remove the specimens using extrusion jack and keep on a smooth level surface ready to test.

6. Test procedure for Marshall Method of mix design

6.1 *General*

In the Marshall method of mix design, each compacted test specimen is subjected to the following tests and analysis.

- (a) Bulk specific gravity (G_m) determination.
- (b) Stability and Flow test.
- (c) Density and void analysis.

6.2 *Bulk specific gravity (Gm) determination*

Bulk specific gravities of saturated surface dry specimens are determined as per ASTM D 2726. This test is performed according to ASTM D 1188 for paraffin-coated specimens.

6.3 *Stability and flow tests*

After determining the bulk specific gravity of the test specimens, the stability and flow tests are performed. Immerse specimen in water bath kept at $60^oC\pm1^oC$ for 30 to 40 minutes before testing. When the testing apparatus is ready, remove the specimen from water bath and carefully dry the surface. Place the specimen centrally on the lower testing head and fit the upper head carefully. Fix the flow meter with zero as initial reading. The load is applied at a constant rate of deformation of 51 mm per minute. The total load at failure is recorded as its Marshall Stability value. The reading of flow meter in units of 0.25 mm gives the Marshall Flow value of the specimen. Flow value is reported in mm also.

The entire testing process, starting with the removal of specimen from bath up to measurement of flow and stability, shall not take more than 30 seconds. While the stability test is in progress, hold the flow meter firmly over the guide rod, remove when load begins to decrease and take the reading and record.

6.4 *Density and voids analysis*

After completion of the stability and flow test, a density and voids analysis is done for each set of specimens. The method of calculations is given in article 4 above – volumetric properties of compacted paving mix.

- (a) Average the bulk density determinations, for each bitumen content. Values obviously in error need not be considered. This average value of G_m is used for further computations in void analysis.
- (b) Determine the theoretical or maximum specific gravity (G_t) by ASTM D 2041 method for at least 2 bitumen contents nearer to the optimum binder content. An average value of effective specific gravity (G_{se}) of aggregate mix is found using these values. This average G_{se} can be used for calculating G_t for different bitumen contents.
- (c) VMA, V_a, and VFB are then computed using the equations given under articles 4.7 to 4.9 above.

7. Analysis of Marshall Mix design data

7.1 *Preparation of test data*

The stability/flow values and the void data are prepared as below.

- (a) The observed stability values are corrected multiplying by a factor, if the thickness of specimens is not 63.5 mm. Table 1 gives the correction factors.
- (b) Average the flow and the corrected stability values. The values obviously in error can be discarded.
- (c) Prepare the following graphs with bitumen content in X-axis:
  - (i) Stability Vs bitumen content.

(ii) Flow Vs bitumen content.
(iii) Unit weight of total mix (G_m x 1000) Vs bitumen content.
(iv) Percentage air voids (V_a) Vs bitumen content.
(v) Percentage voids filled with bitumen (VFB) Vs bitumen content.
(vi) Percentage voids in mineral aggregate (VMA) Vs bitumen content.

These graphs are used to get the design bitumen content of the mix.

Table 1: *Correlation values for correcting observed Marshall Stability values*

Approximate thickness in mm	Correlation ratio
50.8	1.47
52.4	1.39
54.0	1.32
55.6	1.25
57.2	1.19
58.7	1.14
60.3	1.09
61.9	1.04
63.5	1.00
65.1	0.96
66.7	0.93
68.3	0.89
69.8	0.86
71.4	0.83
73.0	0.81
74.6	0.78
76.2	0.76

7.2 *Determination of preliminary bitumen content of the mix*

The preliminary design bitumen content will be the one at 4 % air voids (mean value) in the total mix. For this bitumen content, the mix properties are obtained from other graphs, and evaluated against Marshall Mix design criteria. Table 2 and table 3 gives the design criteria prescribed in MS-2, to be followed in Marshall Method of mix design. If all the criteria are not met, the mix is revised or re-designed.

Table 2: *Marshall Mix design criteria*

Design mix criteria*	Light traffic		Medium traffic		Heavy traffic	
	Min	Max	Min	Max	Min	Max
No of blows on each end	35		50		75	
Stability	3336 N 750 lb		5338 N 1200 lb		8006 N 1800 lb	
Flow, 0.25 mm	8	18	8	16	8	14
Percentage air voids (V_a)	3	5	3	5	3	5
Percentage voids in mineral aggregate (VMA)	See table 3					
Percentage voids filled with bitumen (VFB)	70	80	65	78	65	75

NOTES:

- (i) *All criteria, not stability alone must be considered in designing bituminous paving mix.
- (ii) Traffic classifications

  Light traffic – Design EAL is $<10^4$
  Medium traffic – Design EAL is between 10^4 and 10^6
  Heavy traffic - Design EAL is $>10^6$
- (iii) The laboratory compaction should closely match the max density at the field after several years of traffic.
- (iv) The flow value refers to the point where the load begins to decrease.
- (v) The portion of the bitumen cement lost by absorption in to the aggregate particles must be allowed for when calculating percent air voids.
- (vi) Percentage voids in mineral aggregate are to be calculated on the basis of bulk specific gravity for the aggregate.

Table 3: *Minimum percentage voids in mineral aggregate (VMA)*

Nominal maximum particle size	Minimum VMA %		
	Design air voids %		
mm	3.0	4.0	5.0
1.18	21.5	22.5	23.5
2.36	19.0	20.0	21.0
4.75	16.0	17.0	18.0
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
50	9.5	10.5	11.5
63	9.5	10.0	11.0

NOTES:

- (i) As per MS-2, the nominal max particle size is one size larger than the first sieve to retain more than 10 percent.
- (ii) Interpolate for VMA for air voids between the given values.

7.3 *Trends in mix design data*

The curves plotted with test data prepared as mentioned in 7.1 (c) are attached for guidance. Normally the curves follow a general pattern even though variations can occur. The trends generally noted are:

- (a) The stability value increases with increase in bitumen content up to a maximum point and thereafter it decreases.
- (b) The flow value consistently increases with increase in bitumen content.
- (c) The unit weight (G_m x 1000) of the mix increases with increase in bitumen content up to certain limit and then it decreases.
- (d) The percentage air voids (V_a) steadily decreases with increase in bitumen content.
- (e) The percentage voids in mineral aggregate (VMA) decreases initially and then it rises.
- (f) The percentage voids filled with bitumen (VFA) steadily increases with increase in bitumen content. This is because the VMA is being filled with bitumen.

8. Selection of final mix design

8.1 *General*

Mix should not be designed to optimize one criteria. Mixes with abnormally high values of stability are found to be less durable and such mixes tend to crack prematurely. Normally the range of bitumen content, which passes all the criteria, is very narrow. Bitumen content within this range has to be chosen by the designer for the specific project. Some of the considerations for selecting the final bitumen content are discussed below.

8.2 *Voids in mineral aggregate (VMA)*

The VMA in the aggregate mix is not constant. With the addition of bitumen, the mix becomes more workable and compacts easily, which shows an increase in bulk density and decrease in VMA in the initial stage. The VMA curve has got a flattened U-shape as seen from the data curves. At some point when bitumen content increases, the VMA increases. Any binder content beyond the minimum point must be avoided. A mix with bitumen content on the “wet” side or right hand side of this curve has a tendency to bleed when placed in the field.

When the bottom of the U-shaped curve falls below the minimum VMA criteria, for the maximum size of aggregate used in the mix (Table 3), it indicates that a change in job mix formula is essential. The aggregate grading is to be changed to provide additional VMA.

If the entire curve falls below the minimum line, a significant revision of the mix including changing the source of materials will be required.

8.3 *Effect of air voids (Va)*

The design air voids (V_a) of 3% to 5%, is the level desired after several years of traffic. This does not vary with the traffic volume in these years. The compactive effort has to be selected according to the volume of traffic expected.

A pavement mix that ultimately consolidates to less than 3% air voids is expected to rut and shove. In the other way, if the pavement is constructed initially with more voids, brittleness, premature cracking, raveling, and stripping can happen. If the right compactive effort is chosen and if the percentage air voids after construction is about 8%, the design air voids range will normally be achieved.

8.4 *Effect of voids filled with bitumen (VFB)*

The criteria, V_a, VMA and VFB are interrelated. If any one of the two values is within the limits, normally the third will be also in order. The VFB criteria help to limit the maximum bitumen content, so that a minimum air voids is included in the mix composition.

8.5 *Effect of compaction level*

For the same bitumen content, both air voids (V_a) and voids in mineral aggregate (VMA) decrease with higher compactive effort. The bitumen content value for minimum VMA decreases with increase in compactive effort. So if a mix is designed with 50 blows (medium traffic) and if the pavement has to bear heavy traffic, the selected bitumen content will be on the higher (wet) side of VMA curve for 75 blows compaction. Ultimately a mix susceptible to rutting will be the result.

This can happen in the other way also. A mix designed for heavy traffic used on a pavement to carry out light traffic will end up with a high percentage of air voids (V_a). Such a pavement will crack prematurely or even the aggregate will ravels out due to loss of bitumen adhesion. So it is important to note that the compactive effort selected in the laboratory should simulate the expected design traffic.

8.6 *Influence of structure and climate*

Mix design is a compromise of several factors. A mix that provides best overall performance when used in the pavement should be the one with the design bitumen content.

For a bituminous concrete overlay over a cement concrete pavement, the main consideration will be to limit the rutting and minimize the reflective cracking. Mixes with bitumen content on the higher side of acceptable range are avoided in such situations. However, if the sub grade is not adequate the pavement performance has little to do with the mix design.

With all other factors being equal, mixes with bitumen content on the higher side of the range are less prone to cracking. Similarly, mixes on the low range of bitumen content are less susceptible to rutting. In some cases, the bitumen content may be selected depending on the future maintenance concern.

Finally, climate can also have an impact on the performance of the mix or the pavement. Mix design does not consider this factor except in selecting the grade of the bitumen.

In hot climates, harder, more viscous binders are normally used to obtain more stability. Bitumen content on the lower side of acceptable range is recommended in these areas.

In colder climates, softer, less viscous binders are recommended to produce a mix, which is less susceptible to low temperature shrinkage cracking. Rutting is less of a concern and so bitumen contents on the higher side of acceptable range are recommended to furnish a mix, which is more elastic and resilient.

However, it shall be kept in mind that the shift in bitumen content is only a minor amount within the narrow range that passes all the mix design criteria.

Traffic should be held off the pavement as long as possible while the mix is cooling to normal temperatures. This will help to impart more stability to the mix laid.

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KERALA PUBLIC WORKS DEPARTMENT
QUALITY CONTROL WING

Form No.
QC-B5/2015

Name of work:

Division: Sub Division: Section:

Test report on bituminous Mix Design/ Field mix samples (Marshall Method - ASTM D 1559)

REGIONAL LABORATORY **DISTRICT LABORATORY**

Type of Mix	BM	DBM	BC	SMA		Date of sampling:			2015	Date of test:		
Proportion	**P1 - %**	18	**P2 - %**	17	**P3 - %**	60	**P4 - %**	5	**P5 - %**	0	Total - %	**100**

	COMPOSITION OF PAVING MIXTURE							Total number of blows on each face				**75**
	Bitumen grade	VG20	VG30	Specific Gravity			Mix composition, % by weight of total mix					
				Apparent	Bulk		*1*	*2*	*3*	*4*	*5*	
1	Coarse Aggregate 1		G1		2.613	P1	17.01	16.92	16.83	16.74		
2	Coarse Aggregate 2		G2		2.615	P2	16.07	15.98	15.90	15.81		
3	Fine Aggregate		G3		2.627	P3	56.70	56.40	56.10	55.80		
4	Cement Filler		G4		2.612	P4	4.73	4.70	4.68	4.65		
5	Total aggregate		Gs			Ps	94.50	94.00	93.50	93.00		
6	Asphalt Content by total wt of mix		Gb	1.02		Pb	5.50	6.00	6.50	7.00		
7	Bulk Sp. Gr. of total aggregate		Gsb				2.622	2.622	2.622	2.622		
8	Max Sp. Gr. of total mix		Gmm				2.433	2.408	2.398	2.370		
9	Bulk Sp. Gr. Compacted mix		Gmb				2.291	2.319	2.326	2.321		
10	Eff. Sp. Gr. Total aggregate		Gse				2.644	2.635	2.644	2.630		
11	Absorbed asphalt - % of aggregate		Pba				0.34	0.20	0.33	0.12		
12	Eff. Asphalt content		Pbe				5.2	5.8	6.2	6.9		
13	Voids in mineral aggregate		VMA				17.42	16.85	17.04	17.67		
14	Air voids in total mix %		Va				5.8	3.7	3.0	2.1		
15	Voids filled with asphalt		VFA				66.5	78.1	82.4	88.3		

Materials used in the mix design						
Coarse aggregate 1 -	mm (P1)	Fine aggregate:	Crusher sand (P3)			
Coarse aggregate 2 -	mm (P2)	Filler:	Cement (P4)	Technician/ Overseer	Assistant Engineer (QC)	Asst. Exe. Engineer (QC)

	KERALA PUBLIC WORKS DEPARTMENT **QUALITY CONTROL WING**	Form No. QC-B6/2015

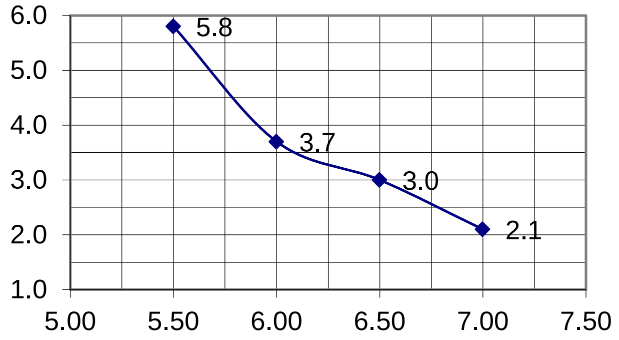
Name of work:

Division:	Sub Division:	Section:

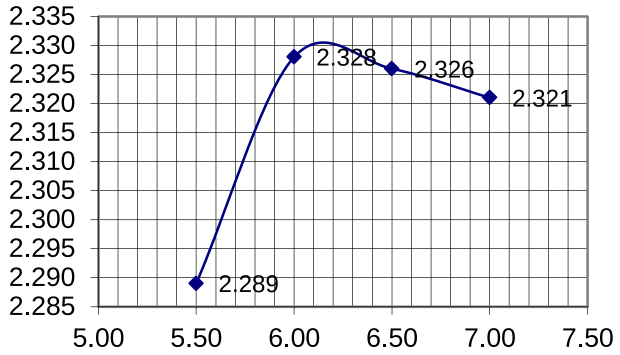
Test report on BC Mix Design/ Field mix samples (Marshall Method - ASTM D 1559)										Report No.				Date:	
REGIONAL LABORATORY								**DISTRICT LABORATORY**							
Type of Mix		BM	DBM	BC	SMA	Date of sampling				2014	2015	Date of test:			
Proportion		P1 - %	18	P2 - %	17	P3 - %	60	P4 - %	5	P5 - %		Total - %	**100**	Blows	**75**
Bulk Sp. Gr. of aggr.		Gsb		*Eff. Sp. Gr. of aggregate (Av)*			Gse	*Asphalt grade*		VG20	VG30		*Specific gravity*		
Bitumen %	Specimen height, mm	Weight in air gms	Wt in water gms	Wt in air, SSD, gms	Bulk volume in cm3	Bulk Sp. Gravity of specimen	Max Sp. Gravity of loose mix	Unit weight, pcf	% Va	% VMA	% VFA	Stability measured in N	Correction factor for height	Stability corrected in N	Flow value in mm
5.5	63.8	1171.5	664.0	1173.4	509.4	2.300						10167	0.99	10065	2.0
5.5	64.5	1173.0	662.7	1174.6	511.9	2.291						9405	0.98	9217	1.8
5.5	64.4	1169.1	658.8	1171.5	512.7	2.280						9152	0.98	8968	1.8
		Average				**2.291**	2.433	142.98	5.8	17.42	66.5			**9417**	**1.9**
6.00	63.6	1172.8	667.2	1173.6	506.4	2.316						9329	1.00	9329	2.3
6.00	63.1	1174.9	667.8	1175.1	507.3	2.316						9609	1.01	9705	2.5
6.00	63.2	1171.9	668.3	1172.6	504.3	2.324						9456	1.01	9551	2.5
		Average				**2.319**	2.408	144.73	3.7	16.85	78.1			**9528**	**2.5**
6.5	63.6	1170.8	667.4	1171.6	504.2	2.322						9355	1.00	9355	2.5
6.5	63.4	1171.2	668.3	1171.4	503.1	2.328						9202	1.00	9202	2.8
6.5	63.3	1172.1	669.4	1172.6	503.2	2.329						9202	1.01	9294	2.8
		Average				**2.326**	2.398	145.22	3.0	17.04	82.4			**9284**	**2.7**
7.0	63.4	1168.6	665.7	1168.9	503.2	2.322						9075	1.00	9075	3.6
7.0	63.2	1166.8	671.8	1172.2	500.4	2.332						9278	1.01	9371	3.0
7.0	63.3	1164.4	672.8	1176.8	504.0	2.310						9025	1.01	9115	3.6
		Average				**2.321**	2.370	144.91	2.1	17.67	88.3			**9187**	**3.4**

RESULTS: (*From graph*)				*Remarks:*		
Design air voids	4.0%	Marshall Stability in kN				
Air voids in the job mix formula Va		Marshall Flow in mm				
% binder recommended in the job mix formula		Voids in mineral aggregate (VMA)		Technician/ Overseer	Assistant Engineer (QC)	Asst. Exe. Engineer (QC)
Bulk sp. gravity of the compacted mix gm/cm3		Voids filled with asphalt (VFA)				

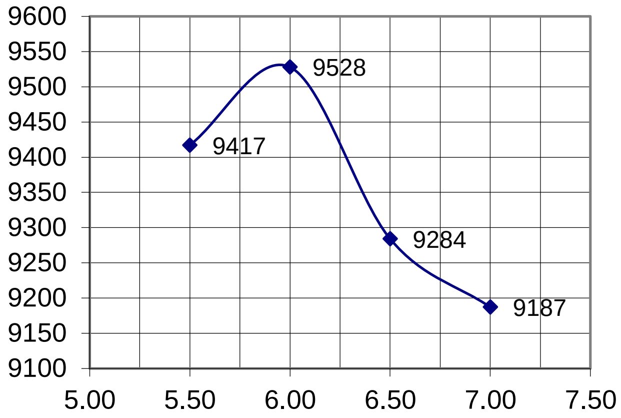
TYPICAL MARSHALL TEST CURVES



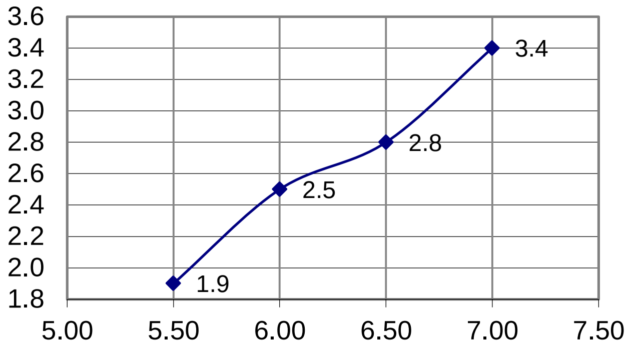
Binder content Vs Air voids in the mix (V_a) %



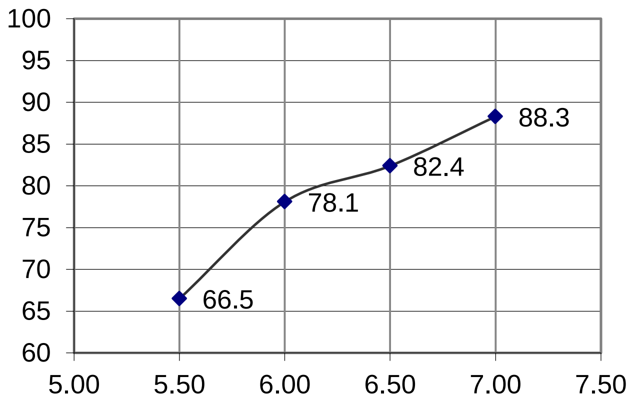
Binder content Vs Mix density gm/cm^3



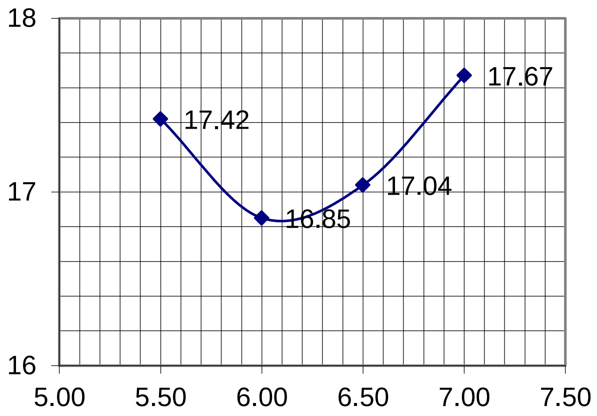
Binder content Vs Marshall stability in Kg



Binder content Vs Marshall Flow in mm



Binder content Vs Voids filled with bitumen (VFB)



Binder content Vs Voids in mineral aggregate (VMA)

APPENDIX B

Concrete mix design

CONCRETE MIX DESIGN

IS: 10262

1. Introduction

The ingredients of a concrete mix are expressed in terms of parts or ratios of cement, fine and coarse aggregates. For example, a 1:2:4 concrete means that it contains 1 part cement, 2 parts fine aggregates and 4 parts coarse aggregates by volume or mass.

The water cement ratio of the mix is usually expressed in mass.

Concrete mix design involves determination of the ingredients of the mix to obtain a concrete of the required strength, durability, workability and to the possible extent, economy. The proportioning is governed by two factors viz., workability and strength. If the concrete in the plastic state is not workable it cannot be properly placed and compacted. The compressive strength of concrete in the hardened state is considered to be its most important property and also as an index of other properties.

The selection and proportioning of the mix ingredients are governed by the following:

(i) The minimum compressive strength required from structural considerations as per specification.
(ii) Sufficient workability to fully compact the concrete with the available equipment.
(iii) Maximum water-cement ratio under the prevailing site conditions.
(iv) Minimum cement content to ensure durability of the structure.
(v) Maximum cement content to avoid shrinkage cracking due to evolution of high heat of hydration especially in mass concrete.

2. Types of mixes

The concrete mixes are generally classified as nominal mixes and design mixes. As per IS: 456-2000, the concrete mixes are designated into a number of grades viz., M10, M15, M20, M25, M30, M35 and M40. The letter 'M' stands for mix and the number to the 28 days compressive strength in N/mm^2.

a) *Nominal mixes*: In nominal mixes, the specifications of concrete prescribe the proportion of cement, fine aggregates and coarse aggregates by volume. The minimum compressive strength required is also included in many specifications to nominal mixes. The proportions of materials for nominal mix concrete shall be in accordance with table 1 (Ref: Table 9 of IS: 456).

Table 1: *Ingredients for nominal mix per 50 kg of cement*

Grade of concrete	*Total quantity of dry aggregates (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

b) *Designed mixes*: In these mixes, certain performance requirement of concrete is specified by the structural engineer. The concrete mix is then designed in the laboratory, after checking the properties of al the ingredients, site exposure conditions and level of supervision available at site to achieve the minimum prescribed strength and durability. The designed mix is then put into site trials and sometimes slight adjustments may be required to the laboratory proportions to achieve a workable mix. Design mix is preferred to nominal mixes. In any case design mix is mandatory for concrete grade M25 and above.

3. Factors affecting the selection of mix ingredients

The various factors affecting the mix design are:

a) *Compressive strength*: It is the most important property of concrete and influences many other properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix. The other factor affecting the strength of concrete at a given age and cured at a prescribed temperature is the degree of compaction. According to Abraham's law, the strength of fully compacted concrete is inversely proportional to the water-cement ratio.

(b) *Workability:* The degree of workability required for the mix depends on three factors viz., the size of the section concreted, the amount of reinforcement, and the method of compaction used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

(c) *Durability:* The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

(d) *Maximum nominal size of aggregate:* In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio. The workability of concrete increases with increase in maximum size of the aggregate. However, the compressive strength tends to increase with the decrease in size of aggregate. IS 456:2000, IRC: 112-2011 and IS 1343:1980 recommend that the nominal size of the aggregate should be as large as possible.

(e) *Grading and type of aggregate:* The grading of aggregate influences the mix proportions for a specified workability and water-cement ratio. Coarser the grading leaner will be mix. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive.

The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio. Uniformity in aggregate grading can be achieved by mixing different size fractions.

(f) *Quality Control:* The degree of control can be estimated statistically by the variations in test results. The variation in strength results from the variations in the properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. By exercising proper Quality Control, the difference between the mean and minimum strengths of the mix is maintained low. This will also help to keep the cement-content to the design minimum.

4. Procedure for mix design

a) Determine the mean target strength (f_t) from the specified characteristic compressive strength at 28-days (f_{ck}) and the level of quality control.

$f_t = f_{ck} + kS$, where S is the standard deviation based on the grade of the concrete obtained from table 2 below (Ref: Table 8 of IS: 456-2000).

Table 2: *Assumed standard deviation*

Grade of concrete	*Assumed standard deviation (MPa)*
M10 & M15	3.5
M20 & M25	4.0
M30, M35, M40, M45 & M50	5.0
NOTE: The above values correspond to the site condition having proper storage of cement, weigh batching of all materials, controlled addition of water, regular checking of all materials, aggregate grading and moisture content, and periodical checking of workability and strength. Where there is deviation from the above, the values given in the above table shall be increased by 1.0 MPa.	

The value of k depends on the probability of results falling below the specified characteristic strength. Table 3 gives the value of k for different probabilities. k = 1.65 (As per IS: 456-2000/IRC112-2011).

Table 3 – *Value of k for different probabilities.*

Sl. No.	*Probability of value falling below f_{ck}*	*k*
1	1 in 5	0.84
2	1 in 10	1.28
3	1 in 15	1.5
4	1 in 20	1.65
5	1 in 40	1.86
6	1 in 100	2.33

b) For initial design, free water-cement ratio corresponding to the 28 day target mean strength for the requirement of durability as per table 3 below (Ref: table 5 of IS: 456-2000) may be used for building works and table 4 (Ref: table 14.2 of IRC 112:2011) for bridge works.

c) The grades of concrete and minimum cement content are also selected from the tables 4 and 5.

Table 4 – *Minimum cement content, maximum water-cement ratio and minimum concrete grade for different exposure conditions for building works.*

Exposure	*PCC*			*RCC*		
	Min. cement content kg/m^3	*Max water-cement ratio*	*Grade of concrete*	*Min. cement content kg/m^3*	*Max water-cement ratio*	*Grade of concrete*
Mild	220	0.60	-	300	0.55	M20
Moderate	240	0.60	M15	300	0.50	M25
Severe	250	0.50	M20	320	0.45	M30
Very severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.40	M25	360	0.40	M40

Table 5 – *Minimum cement content, maximum water-cement ratio and minimum concrete grade for different exposure conditions for bridge works.*

Exposure	*PCC*			*RCC*		
	Min. cement content Kg/m^3	*Max water-cement ratio*	*Grade of concrete*	*Min. cement content Kg/m^3*	*Max water-cement ratio*	*Grade of concrete*
Moderate	340	0.50	M20	340	0.45	M25
Severe	360	0.50	M25	360	0.45	M30
Very severe	380	0.45	M35	380	0.40	M40
Extreme	400	0.40	M40	400	0.35	M45
The above values are for normal weight aggregates of 20 mm nominal maximum size.						

d) The minimum cement content indicated in tables 4 and 5 shall be adjusted for 10 mm and 40 mm aggregates as given in table 6 (Ref: table 6 of IS: 456-2000 & Table 14.3 of IRC 112:2011).

Table 6 - *Adjustments to minimum Cement content for nominal MSA*

Nominal maximum aggregate size (mm)	Adjustment to minimum cement content in tables 4 & 5 (kg)
10	+40
20	0
40	-30

(e) The quantity of maximum water per cubic metre of concrete may be determined from table 7 (Ref: table 6 of IS: 10262-2009).

Table 7 - *Maximum water content and percentage of sand for nominal MSA*

Nominal maximum aggregate size (mm)	*Maximum Water Content kg*	*% of sand of total aggregate by volume*
For grades up to M35		
10	208	40
20	186	35
40	165	30
For grades above M35		
10	200	28
20	180	25

(f) For changes in conditions mentioned in table 7 above and based on the grading zone of fine aggregate. Hence the sieve analysis of the fine aggregate is carried as per IS: 2386 and the grading zone is determined. Necessary adjustments in water content and percentage of sand the grading falls under zone I, III or IV shall be made as given in table 8 (Ref: IS: 10262).

(g) The water content in table 7 is for angular coarse aggregates and for 25 mm to 50 mm slump range. According to clause 4.2 of IS: 10262-2009, suitable corrections shall be made to maximum water content for other conditions as given in table 9.

Table 8 – *Adjustments for water content and percentage of sand*

Change in condition	*Correction to water content*	*Correction to % of sand*
Sand in grading zone I	0	+1.5%
Sand in grading zone III	0	-1.5%
Sand in grading zone IV	0	-3.0%
Increase/decrease of CF by 0.1	±3.0%	0
For each 0.05 increase or decrease in free-water cement ratio	0	±1.0%
For rounded aggregate	-15 kg/m^3	-7%

Table 9 - *Correction for maximum water content*

Condition	*Correction*
Sub-angular aggregates	10 Kg
Gravel + crushed particles	20 kg
Rounded gravel	25 kg
For every slump increase of 25 mm	+3%
Water Reducing admixture	-5% to +10%
Super-plasticizing admixtures	-20%

(h) The cement content per m3 of concrete is calculated from the free water-cement ratio and the corrected quantity of water per m3 of concrete. The cement content thus arrived is checked against the minimum value prescribed in table 4 or 5 and greater of the two values is selected for the design. The maximum cement content excluding fly ash and ground granulated blast furnace slag shall not be in excess of 450 kg/m^3 as per IS:456-2000 and IRC:112-2011.

(i) The amount of entrapped air in the concrete, based on nominal maximum aggregate size, is estimated from table 10.

Table 10 - *Approximate amount of entrapped air.*

Nominal maximum size of aggregate mm	*Entrapped air by % of volume of concrete*
10	3.0
20	2.0
40	1.0

i) The percentage volume of fine aggregate to total aggregate for different nominal maximum aggregate size is obtained from table 6. The quantities of fine and coarse aggregates are computed from the equation below.

$$V = [W + C/S_c + 1/p \times f_a/S_{fa}] \times 1/1000$$ for fine aggregate and

$$V = [W + C/S_c + 1/(1-p) \times c_a/S_{ca}] \times 1/1000$$ for coarse aggregate where,

V = Absolute volume of fresh concrete = gross volume – volume of entrapped air.

W = Mass of water per m3 of concrete kg or litre.

C = Mass of cement per m3 of concrete kg.

S_c = Specific gravity of cement normally assumed as 3.15.

p = Ratio of fine aggregate to total aggregate by absolute volume.

f_a, c_a = Total quantity of fine and coarse aggregates in kg per m3 of concrete.

S_{fa}, S_{ca} = Saturated surface dry specific gravities of fine and coarse aggregates.

For example, if the design cement content is 378 kg, water content 170 kg and sand content is 30% of the absolute volume, for 1% entrapped air absolute volume of concrete, V is given by

$1-0.1= [170 + 378/3.15 + 1/0.3 \times f_a/2.6] \times 1/1000$ (Assuming $f_a = 2.6$)

Simplifying, $f_a = 546$ kg/m^3.

Similarly, $0.99 = [170 + 378/3.15 + 1/0.7 \times c_a/2.7] \times 1/1000$ (Assuming $c_a = 2.7$)

Simplifying, $c_a = 1323$ kg/ m^3.

Thus mass of the ingredients of 1 m3 concrete will be cement = 378 kg, water = 170 kg, fine aggregate (SSD) = 546 kg and coarse aggregate (SSD) = 1323 kg. Water cement ratio is 0.45 and the proportion of cement: fine aggregate: coarse aggregate will be 1:1.44:3.5.

5. Report

The mix design report shall include the following details:

i) The name of project, type of structure and/or component.
ii) Grade of concrete and slump requirement.
iii) Type of cement, grade and specific gravity.
iv) Maximum size of aggregate.
v) Source of aggregates and its physical properties such as specific gravity, strength, grading etc.
vi) Fineness Modulus, silt content, grading zone etc of fine aggregates.
vii) Source of water and test reports to confirm its suitability for using in the concrete.
viii) Design water cement ratio and cement content per m3 of concrete.
ix) Proportioning of fine and coarse aggregate.
x) Details of admixture if recommended and its dosage.
xi) Test reports of compressive strength of 150 mm test cubes after 3-days, 7-days and 28-days curing.
xii) Quantities of ingredients for 1 m3 of concrete by weight as well as volume.
xiii) Any specific recommendations on the mix to be selected.

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APPENDIX C

Load test on piles

LOAD TEST ON PILES

IS: 2911 - Part 4

1. Introduction

Pile load test is the most direct method for determining the safe loads on piles including its structural capacity with respect to soil in which it is installed. It is considered more reliable on account of its being *in-situ* test than the capacities computed by other methods, such as static formula, dynamic formulae and penetration test data.

a) *Pile load capacity by high strain load test*: In this procedure, the force and velocity response of the pile to an impact force applied axially by drop of hammer causing large strain at the top of the pile are measured to arrive at the ultimate capacity of the pile. The two pairs of strain transducers and accelerometers are fixed at diagonally opposite sides of the pile, built up to 1.5 times the pile diameter. The strain induced under the impact of a heavy falling hammer at a pre-determined height is measured by the strain transducers. The accelerometers record the acceleration in the pile. The pile driving analyser converts the strain into force and acceleration into velocity. It is necessary to calibrate the results of the dynamic analyser with those of a static pile load test carried out according to IS: 2911. The details of the dynamic test are available in IRC: 78-20144, Appendix 7- Part 1.

b) *Pile integrity test (PIT)*: It is a non-destructive integrity test method for foundation piles. It is also known as “Low Strain” method, standardised by ASTM D 5882. Various methods are adopted to evaluate the integrity of piles:

    (i) Pile-Echo method.
    (ii) Force-Velocity method.
    (iii) Transient Response procedure
    (iv) Cross hole sonic logging.

Pulse-Echo method is most commonly used. In this method, the impact on the pile with a small hand held hammer and the resultant strain of extremely low magnitude are measured using an accelerometer attached to the top of the pile. The low strain test method is an indication of the quality of work and the pile capacity cannot be derived by this method.

The various aspects of load test on piles as given in IS: 2911 are included in this section.

There are two types of tests for each type of loading viz., initial and routine. Initial test may be one or more depending on the number of piles. It is carried out at 2 to 2.5 times the estimated safe load and up to the pile destruction. Routine test is carried out on about 1.5% to 2% of the total number of piles. It is carried out to 1.5 times the estimated safe load.

Pile load testing is performed when the concrete has reached 28 days strength. Mainly three types of loading tests are carried out on piles.

(i) Vertical or axial load test.
(ii) Lateral load test.
(iii) Pull out test.

2. General requirements for pile load testing

(i) Pile test may be carried out on a single pile or on a group of piles. In group testing, caps will be provided such that the required conditions of actual use are achieved.
(ii) Load application and measurement of deflection are generally made at the top.
(iii) In cases where top portion of piles are likely to be exposed due to scour or dredging, necessary allowance for the length of pile exposed shall be included. In such cases, the test shall be done on the pile cap without resting on the ground.

(iv) The tests shall be carried out at cut-off level as far as possible. Otherwise suitable allowance shall be made in the interpretation of the test results.

3. Vertical load test (Compression)

a) In this method, compressive load is applied to the pile top by means of a hydraulic jack against rolled steel joist or suitable frame capable of providing reaction and the settlement is recorded by suitably positioned dial gauges.

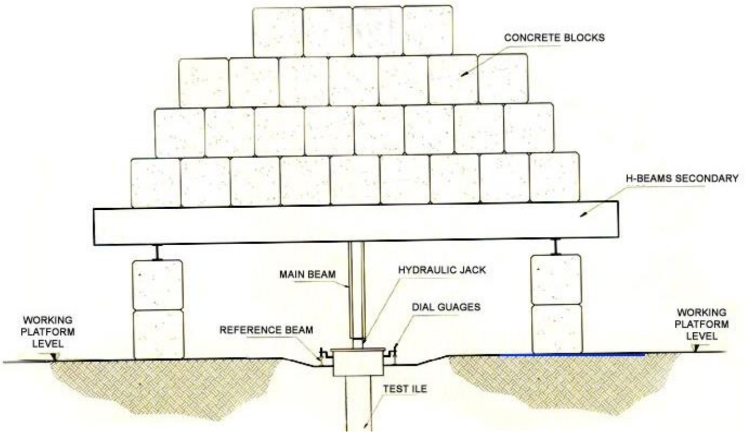
b) The pile top shall be chipped to get a hard, natural plane. The projecting reinforcement shall be cut off or bend. The surface of concrete shall be finished smooth and level with plaster of paris of similar synthetic material. A bearing plate with hole at the centre should be placed on the head of the pile for the jacks to rest.

c) The test is carried out by applying a series of vertical downward load increments of about 20% of the safe load on the pile.

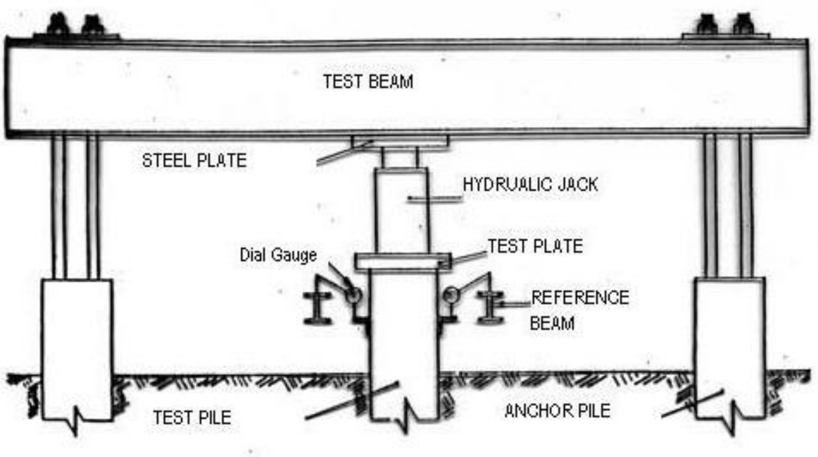
d) The reaction to be made available for the test should be at least 25% more than the final test load proposed to be applied.

e) The reaction may be obtained from the following:

   (i) Kentledge supported on a platform supported clear of the test pile. The centre of gravity of the kentledge should be on the axis of the pile and the load applied by the jack should be co-axial with the pile.



   (ii) Anchor piles located at 3 times the diameter of the test pile or at 2.0 metres minimum centre-to-centre. If the anchor piles are permanent working piles, it shall be ensured that their residual uplift is within the limits. The datum bar supports should not be affected by the heaving of the surrounding soil.



   (iii) Rock anchors at a distance of 1.5 m or twice diameter of test pile, whichever is greater.

f) Settlement shall be recorded with minimum 2 dial gauges for single pile and 4 gauges of 0.01 mm sensitivity for groups. Each shall be installed at equal distance around the piles, held by datum bars resting on immovable supports.

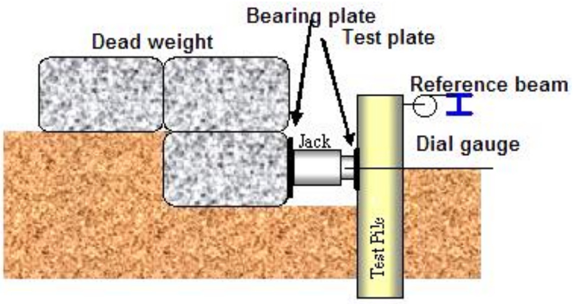
g) The safe load on single pile should be least of the following:

  - (i) Two-third of the final load at which the total displacement attains a value of 12 mm or to the stated total displacement.
  - (ii) 50% of the final load at which the total displacement is equal to 0% of the pile diameter in case of uniform diameter piles and 7.5% in the case of under-reamed piles.

NOTE: Routine test shall be carried out for a test load of 1.5 times the working load, the maximum settlement under the test loading not exceeding 12 mm.

4. Lateral load testing

a) This test is carried out by introducing a hydraulic jack of adequate capacity with pressure gauge abutting the pile horizontally and reaching against a suitable system. If it is conducted by jack located between two piles or groups, the full load imposed by the jack shall be taken as the lateral resistance of each pile or group.



b) The lateral load applied on the pile shall be measured by a calibrated pressure gauge mounted on the jack and supported by the datum bar arrangement.

c) The loading shall be applied in increments of about 20% of the estimated safe load. The next increment shall be applied after the rate of displacement is nearer to 0.1 mm per 30 minutes.

d) The next increment should be applied after the rate of displacement is nearer to 0.1 mm per 30 minutes or 0.1 mm per hour or 2 hours whichever is later.

e) Unless failure occurs first, test pile shall be loaded up to 2 times the design load (Initial test) and 1.5 times the design load (Routine test).

f) The maximum test load corresponds to the total displacement increased to 12 mm.

g) The displacement shall be read by at least two dial gauges of 0.01 mm sensitivity spaced at 30 cm and kept horizontally one above the on the test pile and displacement interpolated at cut-off level of the pile. However, one dial gauge placed diametrically opposite to the jack shall directly measure the displacement.

h) The datum bars shall be provided with rigid supports of steel sections, embedded well into the ground. The supports shall be located more than 3 times the diameter of pile.

i) The safe lateral load on the pile shall be taken least of the following:
  - (i) 50% of the final load at which the total displacement increases to 12 mm.
  - (ii) Final load at which the total displacement correspond to 5 mm and
  - (iii) Load corresponding to any displacement at cut-off level, as specified in the design.

j) Pile groups shall be tested under conditions as per actual use in the structure as far as possible.

5. Pull out test

a) The test shall be conducted on a separate pile installed specifically for this purpose.

b) The test pile shall be built up to the proper length and the head provided with suitable arrangements for anchoring the load applying system.

c) Uplift force may be applied by means of a hydraulic jack system resting on rolled steel joists supported on the ground. The supports shall be located at least 2.5 times diameter of the test pile.

d) The jack reacts against a frame attached to the top of the test pile such that when the jack is operated, the pile gets pulled up and the reaction is transferred to the ground. The frame work is normally attached to the reinforcing bars. A central rod designed to take the pile load and embedded into the concrete with sufficient bond length is sometimes preferred.

e) The test pile shall have adequate steel to withstand pulling.

f) The pull out load increments and consequent displacement readings shall be read as in the case of vertical load test.

g) The pull out load increments and consequent displacement readings shall be as in the case of vertical load test.

h) The safe load shall be taken least of the following:

   (i) Two-third of the final load at which the total displacement is 12 mm or the load corresponding to the specified permissible uplift.

   (ii) Half of the load at which the load-displacement curve shows a clear break (downward trend).

i) The initial test shall be carried out to 2.0 times the estimated safe load or till the load-displacement curve shows a clear break (downward trend).

j) Routine test shall be carried out to 1.5 times the estimated safe load or 12 mm total displacement whichever is earlier.

6. Report

The test report shall include the following:

(i) Tabulation of test data - Load and movement of test pile head, reference beam and reaction piles.

(ii) Load - settlement curve.

(iii) Time load curve.

(iv) Limit load analysis if the pile has failed within the maximum test load.

(v) Conclusion.

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