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Manual
of
Standard Tests

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PART - I
TEST ON SOIL

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1 Moisture Content of Soil

Reference IS: 2720 (Part 2)

1.1 Purpose

This method describes the procedure for determination of moisture content of soil. The properties of the soil like shear strength and compaction characteristics are greatly influenced by its water content and the changes therein. Water content thus indicates the likely behavior of soil.

1.2 Oven – Drying Method (Standard Method)

1.2.1 Apparatus

1. Containers/Moisture Cans/Tins with lid
2. Balance having capacity 300 g with accuracy of 0.01g
3. Thermostatically controlled electric Oven for temperature 110^0C ± 5^0C (sensitivity 10 C).
4. Desiccators

1.2.2 Procedure

1. Take any suitable non – corrodible air tight container. Clean the container with lid, dry and weigh (W1).
2. Take the required quantity of soil specimen in the container, crumbled and placed loosely and weigh with lid (W2).
3. Keep it in the oven with the lid removed and maintain the temperature of the oven at 110^0C ± 5^0 C.
4. If the soil contains gypsum or other minerals having loosely bound water of hydration or with significant amount of organic materials, the drying may be carried out at 60-80^0C.
5. Dry the specimen in the oven for 24 hrs.
6. Take out container from oven, place the lid back on the container and cool the container in desiccators.
7. Record the final weight (W3) of the container with lid and dried sample.

1.2.3 Calculation

Calculate the percentage of moisture content using the formula:

Moisture Content = [(W2-W3)/ (W3-W1)]

1.2.4 Reporting

Report the results in the percentage of moisture content nearest to 0.1, as given in the form 1 given below:

Form 1: Moisture Content Test of Soil by Oven Drying Method

Sample No.	Can/Tin No.	Wt. of Can/ Tin, (g) (W1)	Wt. of Can/Tin + wet soil, (g) (W2)	Wt. of Can/Tin + dry soil,(g) (W3)	Loss of Water, (g) (W2-W3)	Wt. of Dry Soil (g) (W3-W1)	Moisture Content (%) [(W2-W3)/(W3-W1)]*100

1.3 Determination of Moisture Content by Speedy Moisture Meter

Speedy moisture Meter is based on the principle that water will react with calcium carbide to form acetylene gas. Quantity of gas formed is directly proportional to the water present. The quantity of gas formed can be read from a pressure gauge which is calibrated in percentage of moisture on wet weight basis. This can then be converted to moisture content based on dry weight.

This test determines the moisture content of soil quickly, without having to wait for the evaporation of moisture. This is rapid method of determination of moisture content.

1.3.1 Apparatus

1. Speedy Moisture Meter consisting of one metallic pressure vessel with clamp for sealing cup and a gauge calibrated in percentage water.
2. One counterpoint balance, a scoop for measuring calcium carbide
3. Steel balls: 12.5mm diameter- 3 numbers and 25mm diameter – one number
4. Calcium carbide

1.3.2 Procedure

1. Set the balance and place the sample in the pan till the mark on the balance arm mass lines up with the index mark.
2. Unclamp the clamping screw to remove the U – clamp off the cup. Lift off the cup. Clean the cup and the body of moisture meter.
3. Hold the body horizontally. Gently deposit one level scoopful of calcium carbide halfway inside the chamber. Then lay the chamber down without disturbing the absorbent charge and transfer the soil weighed out as above from the pan to the cup.
4. Holding cup and chamber approximately horizontal bring them together, without disturbing sample or absorbent, bring the U clamp round and clamp the cup tightly into place.
5. With the gauge downwards, shake the moisture meter up and down vigorously for 5 seconds, then quickly turn it so that the gauge is upwards, give a tap to the body of the moisture meter to ensure that all the contents fall into the cup.
6. Hold the rapid moisture meter downwards, again shake for 5 seconds, then turn it with gauge upwards and tap. Hold for 1 minute. Repeat this for a third time. Once more invert the rapid moisture meter and shake up and down to cool the gas. Turn the rapid moisture meter with the gauge upwards, and dial horizontal held at chest height when the needle comes to rest, take the

reading. The readings on the meter are the percentage of water on the wet mass basis.

7. Alternatively, the three smaller steel balls can be placed in the cup along with the soil and the larger one in the body along with the absorbent and seal up the unit as usual. Hold the rapid moisture meter vertical so that the material in the cup falls into the body. Now holding the unit horizontally, rotate it for 10 seconds so that the balls are rolled round the inside circumference of the body. Rest for 20 seconds. Repeat the rotation – rest cycle until the gauge reading is constant (usually this takes 4 to 8 minutes). Note the reading as usual.
8. Finally release the pressure slowly (away from the operator) by opening the clamp screw and taking the cup out, empty the contents and clean the instrument with a brush.

1.3.3 Calculation

Calculate the water content (W) on the dry mass from the water content (M) obtained on the wet mass as the reading on the rapid moisture meter, as follows

W = {(M)/ (100 – M)}*100 percent

Where,

W = percent water content of the dry mass

M = percent water content of the wet mass

1.3.4 Reporting

Report the result in percentage nearest to a whole number.

2. Liquid Limit, Plastic Limit and Plasticity Index

Reference IS: 2720 (Part V)

2.1 Purpose

This method describes the procedure for determination of liquid limit, plastic limit and plasticity index of soil. The liquid and plastic limits (Atterberg Limits) of a soil indicate the water contents at which certain changes in the physical behavior of soil can be observed. From Atterberg Limits, it is possible to estimate the engineering properties of fine- grained soils. Plasticity is the property that enables a material to undergo deformation without noticeable elastic recovery and without cracking or crumbling. Plasticity is a major characteristic of soils containing an appreciable proportion of clay particles.

2.2 Definitions

The liquid limit of a soil is that water content, as determined in accordance with following procedure, at which the soil passes from a plastic to a liquid state.

Plastic limit of a soil is the lowest water content determined in accordance with the following procedure at which the soil remains plastic.

Plasticity Index of a soil is the range in water content, expressed as a percentage of the mass of the oven-dried soil, within which the material is in a plastic state. it is the numerical difference between the liquid limit and plastic limit of the soil.

2.3 Liquid Limit

2.3.1 Apparatus

1. Dish - Porcelain Dish, preferably unglazed, or similar mixing dish, about 115mm in diameter
2. Spatula – A Spatula or pill knife having a blade about 75mm in length and about 20 mm in width.
3. Liquid Limit Device – A device consisting of a brass dish and carriage
4. Grooving Tool – A grooving tool
5. Containers – Suitable containers, such as metal cans with lids which will prevent loss of moisture prior to and during weighing.
6. Balance – 300 g capacity with 0.01g accuracy
7. Oven – A thermostatically controlled drying oven capable of maintaining temperatures of 1100 ± 50 C for drying samples.

2.3.2 Procedure

1. Take 120 g of soil passing IS: 425 micron sieve.
2. Mix it with distilled water to form a uniform paste. The paste shall have a Consistency that will require 30 to 35 drops of the cup to cause required closure of the standard groove. In case of clayey soil, paste may be left standing for 24 h to ensure uniform distribution of moisture throughout the soil mass.

3. Remix the soil thoroughly and place a portion of the paste in the cup of the apparatus.
4. Squeeze down and spread the sample with as few strokes of spatula as possible, at the same time trim it down to a depth of 1 cm at the point of maximum thickness. Level the specimen to half the cup.
5. Cut the paste with the standard grooving tool along the centre line. In case, where grooving tool type A does not give a clear groove as in sandy soil, use grooving tool type B or C.
6. Start rotating the handle at 2 revolutions per second.
7. Count the number of blows till two parts of the sample come into contact at the bottom of the groove along a distance of 12 mm. This length shall be measured with the end of the grooving tool or a ruler.
8. Record the number of blows and determine moisture content of the sample taken near the closed groove.
9. Repeat the test by changing the moisture content so that the number of blows to close the groove is not less than 15 or more than 35, such that the points on the flow curve are evenly distributed. (Recommended ranges of blows for three determinations: 25 – 35; 20 – 30; 15 – 25)
10. Plot the graph between log of number of blows and moisture content, and draw / fit a straight line. (plot the graph on semi-log graph paper putting number of blows on X- axis, logarithmic scale and moisture content as percentage on Y – axis, arithmetical scale)
11. Read the moisture content corresponding to 25 blows from the graph. This gives the Liquid Limit of the soil.

2.3.3 Reporting

1. Complete the form 2 given below.
2. Report the Liquid Limit to the nearest whole number.

Form 2: Determination of Liquid Limit (LL) (Atterberg Limits Test)

Container Number	**1**	**2**	**3**	**4**	**5**	**Remarks**
Wt. of container + Wet soil						
Wt. of container + dry soil						
Loss of moisture						
Wt. of container						
Wt. of dry soil						
Moisture content %						
Number of blows						
Liquid Limit (LL) =	………………… percent					

2.4 Plastic Limit (PL)

2.4.1 Apparatus

1. Dish - Porcelain Dish, preferably unglazed, or similar mixing dish, about 115mm in diameter

2. Spatula – A Spatula or pill knife having a blade about 75mm in length and about 20 mm in width.
3. Surface for rolling – A ground glass plate or piece of smooth, unglazed paper on which to roll the sample
4. Glass rod – 3 mm diameter glass rod for reference
5. Containers – Suitable containers, such as metal cans with lids which will prevent loss of moisture prior to and during weighing.
6. Balance – 300 g capacity with 0.01g accuracy
7. Oven – A thermostatically controlled drying oven capable of maintaining temperatures of $110^0 \pm 5^0$ C for drying samples.

2.4.2 Procedure

1. Take about 20 g of soil passing IS: 425 micron sieve.
2. Mix it with distilled water to form a uniform paste which is plastic enough to be easily molded with fingers. In the case of clayey soils, leave the soil mass / paste standing for 24 h to ensure uniform distribution of moisture throughout the soil mass.
3. Take about 8 g of soil from the paste and make a ball.
4. Roll the ball on a glass plate with hand to make a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute counting a stroke as one complete motion of the hand forward and back to the starting position again.
5. When the diameter of the thread reaches 3 mm remold the soil again to a ball.
6. Repeat the process of rolling and remolding until the thread of soil just starts crumbling at a diameter greater than 3 mm. This shall be considered a satisfactory end point, provided the soil has been rolled into a thread of 3 mm diameter immediately before. At no point, shall an attempt be made to provide failure at exactly 3 mm diameter by allowing the thread to reach 3 mm, then reducing the rate of rolling or pressure or both and continuing the rolling without further deformation until the threads fall apart.
7. Determine the moisture content of the crumbled threads.
8. Repeat the test two more times with fresh portion of the soil mass.
9. The average of the moisture content of the soil in the three trials gives the Plastic Limit of the soil.

2.4.3 Reporting

1. Complete the form 3 given below.
2. Report the Plastic Limit to the nearest whole number.

Form 3: Determination of Plastic Limit (PL) (Atterberg Limits Test)

Container Number	**1**	**2**	**3**	**Remarks**
Wt. of container + Wet soil				
Wt. of container + dry soil				
Loss of moisture				
Wt. of container				
Wt. of dry soil				
Moisture content %	MC1	MC 2	MC 3	
Plastic Limit (PL) = (MC 1+MC 2+ MC 3)/3 = …… Percent				

2.5 Plasticity Index (PI)

1. Plasticity Index is determined by subtracting the value of Plastic Limit from the value of Liquid Limit.
   Plasticity Index (PI) = Liquid Limit (LL) – Plastic Limit (PL)
2. Report the difference calculated as above as the Plasticity Index, except under the following condition:
3. When the Liquid Limit or Plastic Limit cannot be determined, report the Plasticity Index as Non – Plastic (NP).
4. When the Plastic limit is equal to, or greater than the Liquid limit, report the Plasticity Index as Non – Plastic (NP).

3. Specific Gravity of Soil

Reference - IS: 2720 (Part III/Section 2) – 1980

3.1 Purpose

This standard provides the method of test for the determination of the specific gravity of soil particle of fine, medium and coarse-grained soils (Passing 4.75 mm sieve). It is not suitable for soils containing more than 10 percent of stones retained on a 40-mm IS sieve and such stones should be broken down to less than this size.

Specific Gravity (G) - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at that temperature.

3.2 Apparatus

1. A gas jar of 1 litre capacity, fitted with a rubber bung (see Note 1),
2. A ground-glass plate or a plastic slip cover for closing the gas jar,
3. A mechanical apparatus capable of rotating the gas jar, end-over-end, at about 50 rev/min (see Note 2),
4. A balance readable and accurate to 0.2 g, and
5. A thermometer to cover the temperature range 0°C to 50°C, readable and accuracy to 1°C.

3.3 Procedure

1. A sample weighing 200 g in the case of fine-grained soil and 400' g in the case of medium and coarse-grained soils, shall be obtained in accordance with the procedure for the preparation of disturbed soil samples for testing.
2. This sample shall have been oven dried (see Note 3) and then stored in an airtight container until required.
3. The gas jar and ground glass plate/plastic slip cover shall be dried and weighed to the nearest 0.2 g (m1).
4. Approximately 200 g of fine-grained soil or 400 g of medium or coarse-grained soil shall be introduced into the gas jar directly from the container in which it has been cooled.
5. The gas jar, ground-glass plate/plastic slip cover and contents shall be weighed to the nearest 0.2 g (m2).
6. Approximately 500 ml of water at a temperature within ± 2% of the average room temperature during the test (see Note 4) shall be added to the soil. The rubber stopper shall then be inserted into the gas jar and in the case of medium and coarse-gained soils the gas jar and contents shall be set aside for at least 4 hours.
7. At the end of this period, or immediately after the addition of water in the case of fine grained soils, the gas jar shall be shaken by hand until the particles are in suspension and then placed in the shaking apparatus and shaken for a period of 20 to 30 minutes.
8. The stopper shall then be removed carefully and any soil adhering to the stopper or the top of the gas jar shall be washed carefully into the jar; any froth that has formed shall be dispersed with a fine spray of water.

9. Water shall then be added to the gas jar to within 2 mm of the top.
10. The soil shall be allowed to settle for a few minutes and the gas jar then filled to the top with more water. The ground-glass plate /plastic slip cover shall then be placed on the top of the jar taking care not to trap any air under the plate.
11. The gas jar and plate shall then be carefully dried on the outside and the whole weighed to the nearest 0.2 g (m3).
12. The gas jar shall be emptied, washed out thoroughly, and filled completely to the brim with water. The glass plate shall be placed in position taking care not to trap any air under the plate. The gas jar and plate shall then be dried carefully on the outside and the whole weighed to the nearest 0.2 g (m4).
13. The procedure outlined in 3 to 12 above shall be repeated on a second sample of the same soil so that two values for specific gravity are obtained.

3.4 Calculations

1. The specific gravity, G, of the soil particles shall be calculated from the equation:

$$G = (m2 - m1) / [(m4 - m1)-(m3-m2)]$$

Where:

m1 = the mass of gas jar and ground glass plate;
m2 = the mass of gas jar, plate and soil;
m3 = the mass of gas jar, plate, soil and water;
m4 = the mass of gas jar, plate and water.

2. The specific gravity shall be calculated at 27°C. If the room temperature is different than 27°C, the following corrections shall be applied:

$$G' = KG$$

Where:

G' = corrected specific gravity at 27°C, and
K = Relative density of water at room temperature/ Relative density of water at 27°C

3.5 Reporting of Results

1. The specific gravity of the soil particles shall be reported to the nearest 0.0 1.
2. Three determinations of the specific gravity of the same soil sample shall be made. The average of the values obtained shall be taken as the specific gravity of the soil particles and shall be reported to the nearest 0.01. If the results differ by more than 0.03 from the average value, the tests shall be repeated.

Note:

i. A gas jar has been found to make a very effective pycnometer but any container of similar capacity can be used provided that it can be shaken in a mechanical shaking apparatus, and provided that the mouth can be sealed in such away that its volume is constant.

ii. An end-over-end shaker has been specified but shaking machines giving a vibrating motion would also be suitable. The choice of shaking machine depends on the type of pycnometer used.

iii. Oven drying of the soil has been specified for convenience. If there is any reason to believe that this will change the specific gravity due to loss of water of hydration, the soil should be dried at not more than 80%. This fact should be reported.

iv. If there is a large difference the air temperature sufficient water should be drawn for the required number of tests and allowed to stand in the room in which the tests are being done until the temperature is within the given range.

4. Grain Size Analysis

Reference IS: 2720 (Part 4) - 1985 (Second Revision)

4.1 Purpose

This method describes the procedure for determination of the distribution of the grain size of soil. Grain size analysis is carried out to determine the relative percentages of different sizes of particles in the sample. These sizes control the mechanical behavior of coarse grained soil. Dry method of sieving is used for coarser fractions (retained on 4.75 mm sieve) and wet method is used for finer fractions (retained on 75micron sieve) and pipette method is used for fractions passing 75 micron sieve.

4.2 Apparatus

1. Balance- sensitive to 0.1 percent of the weight of sample to be tested.
2. IS Sieves - 100-mm, 75-mm, 19-mm and 0-75-mm. Other sieves as per the requirement of the Specification shall be used.
3. Rubber Pestle and Mortar

4.3 Preparation of Sample for Tests

4.3.1 General

Soil sample as received from the field shall be dried in the air or in sun. In wet weather a drying apparatus may be used in which case the temperature of the sample should not exceed 60°C. The clods may be broken with a wooden-mallet to hasten drying. The organic matter, like tree roots and pieces of bark should be removed from the sample. Similarly, matter other than soil, like shells should also be separated from the main soil mass. A noting shall be made of such removals and their percentage of the total soil sample noted. When samples are to be taken for estimation of organic content, lime content, etc, total sample should be taken for estimation without removing shells, roots, etc.

4.3.2 Drying of the Sample

The amount of drying depends upon the proposed test to be conducted on the particular sample. When oven is used for drying, the temperature in the oven shall not exceed 110°C. Soils containing organic or calcareous matter should not be dried at temperature above 60°C.Chemical drying of samples should not be adopted for any tests.

4.4 Procedure

4.4.1 Dry Sieve Analysis

For soil fraction retained on 4.75 mm sieve

1. Prepare the sample by drying it in air or oven and bring it to room temperature.
2. Clean all the sieves to be used (100 mm, 75 mm, 19 mm, and 4.75 mm). The sieves should conform to the requirements of IS 460 (Part I) - 1985.

3. Weigh the required quantity of material from the prepared sample in accordance with Note 1 given below:

Note:

i. Depending on the maximum size of material present in substantial quantities in the soil, the mass of soil sample taken for analyses may be as follows:

Table 1: Mass of various sized Materials to be taken for Sieve Analysis

Maximum size of material present in sustainable quantities (mm)	**Mass to be taken for test (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

ii. Place the sieves over a clean tray one over the other in the ascending order of size.

iii. Shake the sieve with a varied motion, backwards and forwards, left to right, circular clockwise and anti-clockwise, and with frequent jerking, so that the material is kept moving over the sieve Surfaces.

iv. Do not force the material through the sieve by hand, except for sizes coarser than 19 mm.

v. Break the lumps of fine particles, if any, with fingers against the side of the sieve.

vi. Light brushing with a soft brush on the underside of sieves may be done to clear surface.

vii. Find the individual weight of material retained on each sieve and record.

viii. The quantity taken for sieving shall be such that the wt. of material retained on each sieve does not exceed the values given in Note 2.

4.4.1.1. *Calculation and reporting*

1. Calculate the percentage by weight of the total sample passing each sieve and report the results in the Form 4 given below.
2. Draw a graph on semi log graph paper; opening of sieve i. e. size of soil grain in mm in X - axis in logarithm scale and percentage of passing in Y axis in normal scale.

Note

ii. Maximum weight of material to be retained on each sieve at the completion of sieving shall be as follows:

Table 2: Maximum Weight of Material to be Retained on Each Sieve

IS Sieve Designation	450mm (Dia.)	300mm (Dia.)
75mm	15 kg	6 kg
20 mm	4 kg	2 kg
75mm	1 kg	0.5 kg

4.4.2 Wet Sieve Analysis

For soil fraction passing 4.75 mm sieve and retained on 75 micron sieve

1. Take a portion of the sample prepared by drying in oven at 105°C to 110°C and brought to room temperature.
2. Soak the sample in water containing two grams of sodium hexametaphosphate or one gram of sodium hydroxide and one gram of sodium carbonate per litre of water and leave it for soaking overnight.
3. Wash out the finer fraction passing through 75 micron sieve. Washing should be continued until the water pressure through 75 micron sieve is substantially clean.
4. Then dry it in oven for 24 h and sieve the dry particles on 2 mm and 425 micron sized sieves and find the percentage of soil passing through each sieve and report the results in form as given below.
5. Care shall be taken to see that the sieves are not overloaded. See Note 3.

Note:

iii. The permissible maximum mass of sample on the 200 mm diameter sieves shall be as follows:

Table 3: Maximum Weight of Mass to be Retained on Each Sieve

I.S Sieve Designation	Maximum Mass of Sample (g)
2 mm	200
425 micron	50
75 micron	25

6. Calculate the percentage by weight of the total sample passing each sieve and report the results in the Form 5 given given below.

Form 4: Forms for Sieve Analysis of Soil -Dry sieving

Wt. of Sample taken (g):

I.S. Sieve Designation (mm)	Wt. of Sample retained (g)	Percentage of Wt. retained (%)	Cumulative Percentage of wt. retained (%)	Percentage of Wt. Passing (%)
100				
75				
19				
4.75				

Form 5: Forms for Sieve Analysis of Soil -Wet sieving

Wt. of Sample taken (g):

I.S. Sieve Designation (mm)	Wt. of Sample retained (g)	Percentage of Wt. retained (%)	Cumulative Percentage of wt. retained (%)	Percentage of Wt. Passing (%)
2 mm				
425 micron				
75 micron				

Sieves of intermediate sizes shall be used as per the requirement of the Specifications. Wet

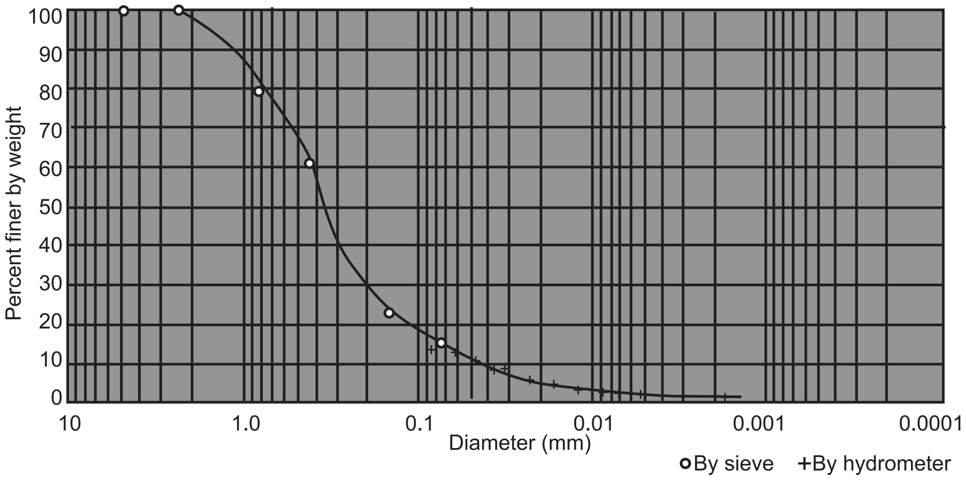
4.5 Summary of Results:

Clay / silt (-75 micron) percent:

Sand (-4.75 mm + 75 micron) percent:

Gravel (-100 mm + 4.75 mm) percent:

Figure 1: Typical Graph of Sieve Analysis/Grain Size Analysis



5. Deleterious Materials (Organic Matter)

Reference: IS: 2720 (Part 22)

5.1 Purpose

This method describes the procedures for determining the organic matter present in the soil. Deleterious materials containing in the soil such as organic matter affects its characteristics and behavior adversely and must therefore be controlled to be within 2%.

5.2 Apparatus

1. Sieves
2. Balance
3. Glass ware: conical flask, burettes
4. Chemicals: dilute sulphuric acid, potassium dichromate, concentrated sulphuric acid, distilled water, orthophosphoric acid, sodium fluoride, ferrous sulphate solution,

5.3 Procedure

1. Take an air dried sample of soil and determine its moisture content. Using another sample, prepare about 100 g of soil passing the 10 mm I.S. sieve. Pulverize this sample to pass through 4.25 micron I.S. sieve.
2. In case the soil contains a high percentage of sulphides or chlorides, it may be neutralized with dilute sulphuric acid or washed with distilled water to remove the salts.
3. Take 5 g of soil from thoroughly mixed soil passing 425 micron sieve and place it in a glass weighing bottle. The Wt. of sample should be less (up to 0.2g) for soil with higher content of organic matter.
4. Add 10 milliliters (ml) of potassium dichromate solution into the conical flask with a burette and add 20 ml of concentrated sulphuric acid. Whirl the mixture for about one minute and keep it on a heat insulated surface for 30 minutes to allow oxidation.
5. Add 200 ml of distilled water along with 10 ml of orthophosphoric acid and 1 ml of sodium fluoride as the indicator. Shake the mixture vigorously. If the indicator gets absorbed, add another 1 ml of the indicator (sodium fluoride).
6. Add ferrous sulphate solution from a second burette until the color of the solution changes from blue to green. Add a further 0.5 ml of potassium dichromate to change the color from green to blue.
7. Add ferrous sulphate solution drop by drop with continuous swirling until the color of the solution changes with a single drop. Note the total volume of ferrous sulphate used in the experiment (test).

5.4 Calculation

The total volume of potassium dichromate used to oxidize the organic matter in the soil is given by the following formula:

V = 10.5 (1.0 –Y/X)

Where,

Y = total volume of ferrous sulphate used in the test

X = total volume of ferrous sulphate used in the standardization test

The percentage of organic matter present in the oven dried sample may be calculated from the following formula:

The organic matter, percent by weight = (0.67*W2*V)/W1*W3

Where,

W1 = weight of oven dry total soil sample before sieving

W2 = weight of oven dry soil sample passing 10 mm IS sieve

W3 = weight of oven dry soil specimen used in the test

V = total volume of potassium dichromate used to oxidize the organic matter

5.5 Reporting

1. Complete the form 6 given below.
2. Report the organic matter content as percentage of soil sample by weight.

Form 6: Determination of Organic Matter Content

S. N.	Total volume of potassium dichromate used to oxidize the Organic Matter (V)(ml)	Wt. of soil sample (Oven dried) before sieving (W1) (g)	Wt. of soil sample (Oven dried) passing 10 mm sieve (W2) (g)	Wt. of soil sample (Oven dried) used in the test (W3) (g)	Organic matter percent by Wt. =(0.67*W2*V)/ (W1*W3)

6. Determination of Soluble Sulphate Content in the Soil

Precipitation Method (Standard Method)

Reference: IS: 2720 (Part 27)

6.1 Purpose

This describes the procedure for determination of total soluble Sulphate content in the soil by precipitation method. Sodium sulphate (salt) is easily hydrated and dehydrated under the influence of climatic changes. There are enormous volume changes during this process of hydration and dehydration, which influence the engineering properties of the soils.

6.2 Apparatus

1. Mortar and pestle
2. Glass bottle/funnel
3. Beakers
4. Mechanical shaker
5. Appparatus for steam bath
6. Burner / Muffle furnace
7. Dessicator
8. Balance
9. Filter paper

6.3 Chemicals

1. Distilled water
2. Pure potassium nitrate
3. Phenolphthalein indicator
4. Concentrated hydrochloric acid
5. Barium chloride

6.4 Procedure

1. Take the soil sample in a state in which it can be crumbled. If necessary, dry it in oven at 105°C to 110°C. Break the lumps in a mortar with a rubber covered pebble. Mix the sample thoroughly and sub- divide it by quartering.
2. Take 10 g of soil (W1) from the sample in a 250 ml bottle with 100 ml of distilled water. Shake it occasionally for about 2 hrs with a mechanical shaker. Allow the soil to stand overnight. In case the soil is dispersive, add 0.5 to 1.0 g of pure potassium nitrate to flocculate the particles.
3. Filter and take 25 ml of filtrate in a beaker. See if the solution is alkaline from phenolphthalein indicator. If so, add concentrated hydrochloric acid to just neutralize the solution. Add further 4 ml of hydrochloric acid to make the solution acidic.
4. Boil the solution. Remove the solution from the heat and add barium chloride solution in a fine stream with constant stirring, till there is no precipitation with further addition.

5. Place the beaker on a steam bath for a minimum period of 4 hrs and allow precipitate to settle. Further the precipitate through ash less filter paper wash free from chloride irons, dry and ignite filtration can be done through a pre- weighed sintered glass crucible or a Gooch crucible. In case of filter paper after drying, ashing shall be done. On a low flame and the precipitate then ignited over a burner or in muffle furnace at 600°C to 700°C for half an hour.
6. Cool in desiccators, take weight of the residue. This is the Wt. of the barium sulphate (W2).

6.5 Calculation

Calculate the corresponding weight of sodium sulphate and determine its percentage as follows:

a) Sulphate (SO_4) percent by mass = 41.15 W2/W1

b) Sodium Sulphate ($Na_2 SO_4$) percent by mass = 60.85W2/W1

Where,

W1 = Wt. of the soil contained in the solution taken for precipitation.

W2 = Wt. of the precipitate in g

6.6 Reporting

1. Complete the form 7 given given below.
2. Report the soluble sulphate content in the soil in percentage of soil sample by weight.

Form 7: Determination of Soluble Sulphate Content in the Soil

S. N.	Wt. of the Precipitate (W2) (g)	Wt. of the soil contained in the solution (W1) (g)	Sulphate as SO_4 = 41.15 W2/W1	Sulphate as Na_2So_4 = 60.85W2/W1

7. Proctor Density Test (Heavy Compaction)

Reference: IS 2720 (Part 8)

7.1 Purpose

This method describes the procedure for the determination of the relation between water content and the dry density of soils using heavy compaction. Compaction is a function of the water content, the compactive effort and the nature of soil. Compaction is measured in terms of dry density achieved. For the same compactive effort, this test determines the maximum dry density and the optimum moisture content of a given soil.

7.2 Apparatus

1. IS sieves: 37.5 mm, 19 mm, 4.75 mm
2. Rammer having wt of 4.9 Kg ± 50 gm and dropping height 450 ±0. 5 mm
3. Mould having diameter 152.4 mm along with base plate and collar/extension
4. Mixing Tray (metallic)
5. Sample Extruder
6. Scoop, trowel, straight edge
7. Balance capacity 15 Kg with accuracy of 1 g
8. Balance capacity 500 g with accuracy of 0.01 g
9. Moisture cans with lid
10. Oven thermostatically controlled for temperature of 110 ±5° C

7.3 Procedure

1. Weigh the mould (W1) to the nearest 1 g with the base plate attached.
2. Take about 6 Kg of air dried soil sample passing 19/20 mm IS sieve for soils not susceptible to crushing during compaction, or about 15 Kg of materials passing 19/20 mm IS sieve for soils susceptible for crushing during compaction (see Note 1). The Wt. of the particles retained on the 19/20 mm IS sieve should be recorded and discarded.

Note:

i. The soil should be considered susceptible to crushing during compaction if the sample contains granular materials of a soft nature, such as soft lime stone, sandstone, etc. which is reduced in size by the action of the 4.9 Kg rammer. The procedure given for soils susceptible to crushing during compaction can be applied to all soils, if it is convenient to do so. Aggregations of particles shall be broken down so that, if the sample is sieved on a 4.75 mm IS sieve, only separated individual particles would be retained.

Note:

ii. The removal of small amount of stones (up to 5 %) retained on 19mm IS sieve will affect the density obtainable only by amounts comparable with the experimental error involved in measuring the maximum dry density. The exclusion of large proportion of stone coarser than 19 mm may have a major effect on the density obtained compared with that obtainable *with the soil as a whole and the optimum moisture content. There is at present no generally accepted method of test or of calculation for dealing with this difficulty in comparing laboratory compaction test results with densities obtained in the field. For soils containing larger proportions of gravel, the use of a bigger mould (2250 ml) will avoid major errors. If proportion of gravel is more than 10%, modified MDD should be invariably found out or calculated so that Field dry density is correctly compared.*

iii. *The amount of water to be mixed with air dried soil at the starting of the test will vary with type of soil under test. In general, with sandy and gravelly soil, a moisture content of 4 to 6% would be suitable, whereas with cohesive soils moisture content about 8 to 10% below the plastic limit of the soil (plastic limit minus 10 to plastic limit minus 8) would usually be suitable.*

iv. *It is important that the water is mixed thoroughly and adequately with the soil, since in- adequate mixing gives rise to variable test results. This is particularly important with cohesive soils when adding a substantial quantity of water to the air dried soil. With clays of high plasticity or where hand mixing is employed, it may be difficult to distribute the water uniformly through the air dried soil by mixing alone. And it may be necessary to store the mixed sample in a sealed container for a minimum period of about 16 hrs continuing with the test.*

v. *It is necessary to control the total volume of soil compacted; since it has been found if the amount of the soil struck off after removing the extension from the mould is too great, the results will be inaccurate.*

vi. *The water added for each stage of the test should be such that a range of the moisture contents is obtained which include the optimum moisture. In general, increments of 1 to 2 % are suitable for sandy and gravelly soils and of 2 to 4 % for cohesive soils. To increase the accuracy of the test, it is often advisable to reduce the increments of water in the region of the optimum moisture content.*

7.3.1 Procedure for Soil not Susceptible to crushing during compaction:

1. Take a 6 Kg sample of air dried soil passing the 19mm IS sieve.
2. Mix thoroughly with a suitable amount of water depending on the type of soil (see Note ii, iii and iv)
3. Take Wt. of mould attached with the base plate to the nearest 1 g (W1).
4. Place the mould on a solid base, such as a concrete floor of plinth.
5. Compact the soil (already mixed with water) into the mould attached with extension in five layers of approximately equal mass, each layer being given 25 blows from the 4.9 Kg rammer dropped from a height of 450 mm above the soil.
6. The blows shall be distributed uniformly over the surface of each layer.
7. The operator shall ensure that the tube of the rammer is kept clear of soil so that the rammer always falls freely.
8. The amount of soil used shall be sufficient to fill the mould, leaving not more than about 6 mm to be struck off when the extension is removed (see Note v).

9. Remove the extension and level off the compacted soil carefully to the top of the mould with the help of straight edge.
10. Take Wt. of Mould with soil to the nearest 1 g (W2)
11. Remove the compacted soil specimen from the mould and place it on a mixing tray.
12. Take sample and determine the water content in the soil.
13. Break up the remaining soil sample by rubbing through the 19 mm IS sieve and mix it with the remainder of the original sample.
14. Add suitable increment s of water (see Note vi) successively and mix it into the soil sample.
15. Repeat the operations from III to XIV as mentioned above for each increment of water added.
16. The total number of determinations made shall be at least five and the range of moisture content, at which the maximum dry density occurs, is within that range.

7.3.2 Procedure for Soil Susceptible to crushing during compaction (See Note i):

1. Take five or more samples of air dried soil passing the 19 mm IS sieve having Wt. of 2.5 Kg each.
2. Mix thoroughly the samples with different amounts of water to give a suitable range of moisture contents (see Note iii and iv).
3. The range of the moisture contents, at which the maximum dry density occurs, should be within that range (see Note vi).
4. The operations from III to XII as mentioned above shall be used for each sample.
5. The remainder of each soil specimen shall be discarded.

7.3.3 Compaction in Large Size Mould

1. For compacting soil containing coarse materials up to 37.5 mm size, the 2250 ml mould should be used.
2. A sample weighing about 6 Kg and passing the 40 mm IS sieve is used for the test.
3. Soil is compacted in five layers being given 55 blows of the 4.9 Kg rammer.
4. The rest of the procedure is same as stated above.

7.4 Calculation

7.4.1 Bulk density

Calculate the Bulk Density γm , in gm/cm3 of each compacted specimen from the formula:

$\gamma m = (w2-w1)/ Vm$

Where,

Vm= volume of mould

7.4.2 Dry density

Calculate the Dry Density of, γd in gm/cm3 of each compaction specimen from the formula:

$\gamma d = 100\ \gamma m / (100+w)$

7.4.3 Maximum Dry Density and Optimum Moisture Content

Plot a graph of moisture content (w) as x-axis and dry density (γd) as y-axis, from the results obtained. Draw a smooth curve through the resulting points and find out the position of maximum dry density and corresponding moisture content as optimum moisture content.

7.5 Reporting

1. The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve shall be reported as the optimum moisture content.

Report

- to the nearest 0.2 for values below 5 percent,
- to the nearest 0.5 for values from 5 to 10 percent, and
- to the nearest whole number for values exceeding 10 percent.

2. The dry density in g/cm3 corresponding to the maximum point on the moisture content/dry density curve shall be reported as the maximum dry density to the nearest 0.01.
3. Complete the Form 8 given below.

Form 8: Proctor Density

Description of sample:	
Type of Test	**Modified Proctor/ Heavy Compaction**
Wt. of Mould (g), W1	
Volume of Mould (cc) Vm	
Percent Retained on 20 mm IS Sieve	

S. N.	Wt. of Mould + Compacted Soil (g) W2	Wt. of wet soil (g) (W2 – W1)	Bulk density, g/cc γm = (w2-w1)/ vm	Cont. No.	Wt. of Cont. (g)	Wt. of Cont. + wet soil (g)	Wt. of Cont. + dry soil (g)	Wt. of water Ww (g)	Wt. of dry soil (g)	M.C. %, m	Dry Density (g/cc) γd= (100γm)/ (100+w)

7.6 Factors affecting Compaction

Compaction is measured in terms of the dry density achieved. This is found to be a function of:

1. The water content
2. The compactive effort applied to the soil, and
3. The nature of the soil.

These effects are briefly discussed below.

The effect of water content on compaction:

The shearing resistance to relative movement of the soil particles is large at low water contents. As the water content increases, it becomes relatively easier to disturb the soil structure, and the dry density achieved with a given compactive effort increases. However if the dry density is plotted against the water content for a given compactive effort, it will be seen that the dry density reaches a peak, after which any further increase in water content results in a lower dry density.

From the dry density / water content curve, we can determine two quantities;

a. the maximum dry density, and
b. the optimum water content at which this maximum dry density is achieved

The effect of variations in compactive effort:

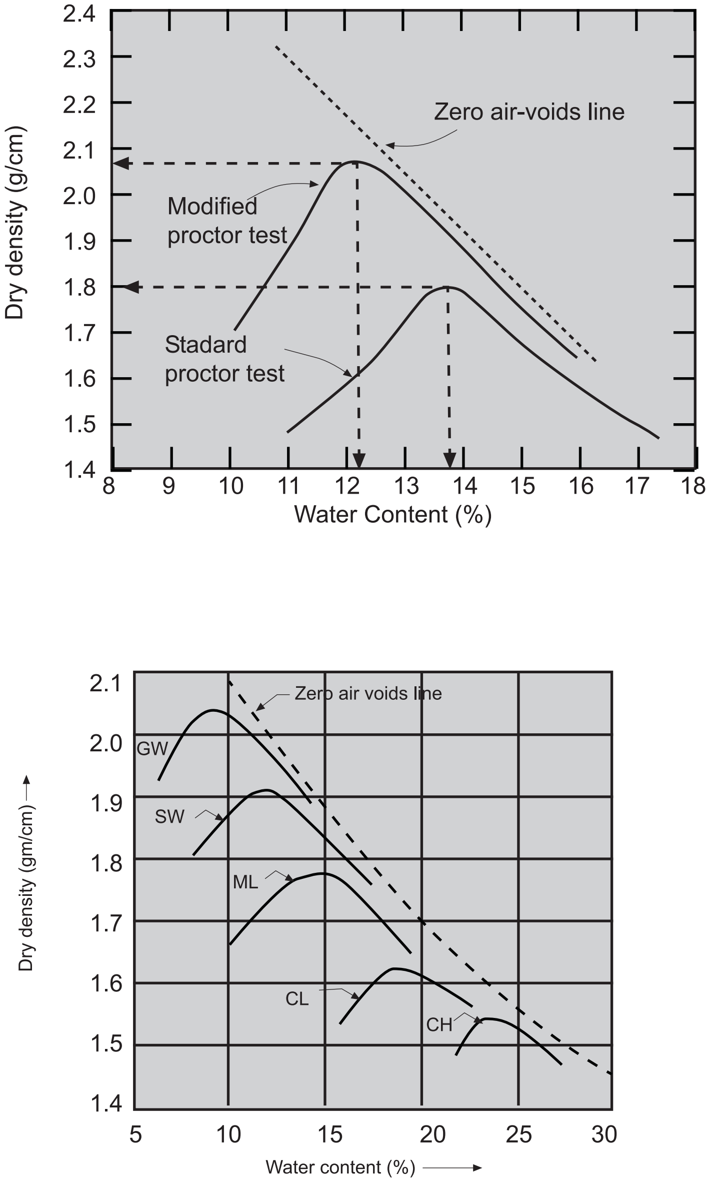
Both the maximum dry density and the optimum water content are found to depend on the compactive effort used. Increasing the compactive effort increases the maximum dry density, but reduces the optimum water content. The air void ratio at the peak density remains very much the same.

It may be seen that, at high water contents, there is little to be gained by increasing the compactive effort beyond a certain point.

The effect of soil type on compaction:

The highest dry densities are produced in well-graded coarse-grained soils, with smooth rounded particles. Uniform sands give a much flatter curve, and a lower maximum dry density. Clayey soils have much higher optimum water contents, and consequently lower maximum dry densities. The effect of increasing the compactive effort is also much greater in the case of clayey soils.

Figure 2: Typical Results of Compaction Tests for Different Soils and Different Moisture Content



8. CBR of Remoulded and Soaked Soil Samples

(Static Method and Dynamic Method)

8.1 Purpose

CBR value of a soil is an index which is related to its strength, modulus of sub grade reaction, modulus of resilience and plasticity index. The index is highly dependent on the condition of material at the time f testing.

The test will be performed on remolded specimens which may be compacted either statically or dynamically.

8.2 Preparation of Specimens

8.2.1 Remoulded Specimens:

The dry density for remoulding should be either the field density or if the sub grade is to be compacted, at the maximum dry density value obtained from the Proctor Compaction test. If it is proposed to carry out the CBR test on an un soaked specimen, the moisture content for remolding should be the same as the equilibrium moisture content which the soil is likely to reach subsequent to the construction of the road. If it is proposed to carry out the CBR test on a soaked specimen, the moisture content for remolding should be at the optimum and soaked under water for 96 hours.

8.2.2 Soil Sample:

The material used in the remoulded specimen should all pass through a 19 mm IS sieve. Allowance for larger material may be made by replacing it by an equal amount of material which passes a 19 mm sieve but is retained on a 4.75 mm IS sieve. This procedure is not satisfactory if the size of the soil particles is predominantly greater than 19 mm. The specimen may be compacted statically or dynamically.

8.3 Procedure

8.3.1 Compaction by Static Method

1. Find the weight of oiled empty CBR mould with base plate and filter paper placed in.
2. Calculate the weight of soil required at OMC by using the formula:

$$\textbf{Percentage Compaction required x MDD (g/cc) x } \left(1 + \frac{\textbf{OMC}}{\textbf{100}}\right) \textbf{ x volume of mould}$$

3. Take about 6 kg of dry soil and mix it thoroughly after adding the quantity of water required to bring it to OMC at which it can be compacted to attain its maximum dry density.
4. Take the required quantity of this soil as calculated in step 2.
5. Place this soil in the mould and obtain compaction by pressing in the displacer disc, placing a filter paper between the disc and the soil.

8.3.2 Compaction by Dynamic Method

1. Take 6 kg of oven dried soil.
2. Add water (optimum water content required to attain max. dry density) to it and mix it thoroughly.
3. Take the empty weight of oiled CBR mould.
4. Fit the extension collar to the mould.
5. Place a spacer disc in it and then place one filter paper over it.
6. Fill the soil mixture in the mould in 3 layers by giving 55 blows of 2.6 kg rammer with a drop of 310 mm to each layer.
7. Remove the collar and trim off by a straight edge.
8. Then remove the mould from base plate, take the spacer disc out.
9. Invert the mould and fix it in position on the base plate after placing a filter paper. The dynamically compacted specimen is now ready for testing.

8.4 Finding degree of compaction

1. After compaction, weigh the mould with specimen.
2. Find the weight of the specimen.
3. Take a portion of the remaining sample left in the tray and find the moisture content.
4. Find the dry density and compare it with the maximum dry density and find the degree of compaction (%) by comparing this with the maximum dry density.

8.5 Determining Swelling Index

1. After weighing the moulds, place 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 soil specimen. Place this assembly in the mould.
2. Place the tripod having the micrometer in place and adjust the stem to touch the micrometer indicator and find the initial reading on the micrometer.
3. Then place the mould in water tank and soak it for 96 h.
4. After 96 h, find the micrometer reading.
5. Find the difference in readings.
6. Find the swelling index by dividing the swelling by the height of the specimen before soaking. Express this in percentage as per the Form 9 given given below.

Form 9: Determining Swelling Index

Mould No.	**Height of Specimen**	**Dial Gauge Reading**		**Least Count of Dial Gauge**	**Total Swelling;** **(C -B)xD**	**Swelling Index:** **E/AX100**
	mm	**Initial**	**Final**	**mm**	**mm**	**%**
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**

8.6 Determining CBR

8.6.1 CBR in Dry Condition:

The material used for conducting the test will be in a dry condition. The mould containing the specimen with the base plate in position but the top face exposed shall be placed on the lower platen of the testing machine. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and the pavement shall be placed on the testing machine. Rest of the procedure will be same as described below for the test in soaked condition

8.6.2 CBR in Soaked Condition:

1. After 96 h of soaking and after measuring the swelling, find the weight of the mould with soaked specimen (to be used for finding degree of compaction after soaking).
2. Drain the excess water by keeping the specimen vertically or by tilting for 10- 15 min (for sandy specimen no tilting is to be done).
3. Remove the filter paper on the specimen and keep it in the CBR testing machine to show penetration when the specimen is loaded.
4. Place the same surcharge weight as used while soaking.
5. Adjust the penetration measuring micrometer and the platform on which the CBR mould containing the specimen rests, to show penetration when the specimen is loaded.
6. Start loading the specimen, after adjusting the penetration dial and proving ring to zero mark.
7. 5.7 Note the deflections in the dial gauge of the proving ring for corresponding penetrations as per the requirement. (deflections are noted for penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5,10.0 and 12.5 mm of the plunger).
8. Plot the deflections against the penetration (in mm) in a semi-log graph. (Alternatively, deflections can be converted into loads and plot penetration versus load).
9. Find the correction required to be applied for the deflections (when an S-type curve is formed, the lower bend can be avoided by drawing a straight line), see Figure 1.
10. Correct the deflection by shifting the points actually plotted, (if a correction of 0.5 mm is observed, instead of taking deflection for penetration of 2.5 mm, deflection for 3 mm shall be taken).
11. Take the deflection for 2.5 mm and, 5 mm (for corrected curves, corrected deflection shall be taken).
12. Convert these deflections into loads by applying the calibration factors.

8.7 Calculation

Find the CBR values for these penetrations by using the formula.

$$\mathbf{CBR} = \frac{P_T \times 100}{P_s}$$

Where,

P_T = Load corresponding to the chosen penetration.

P_s = Standard load for the penetration from the table given at end of this part.

Table 4: Standard Loads for the CBR Test

Penetration Depth	Unit Standard Load	Total Standard Load
2.5 mm	70 Kg /sq. cm.	1370 Kg
5.0 mm	105 Kg / sq. cm.	2055 Kg

8.8 Reporting

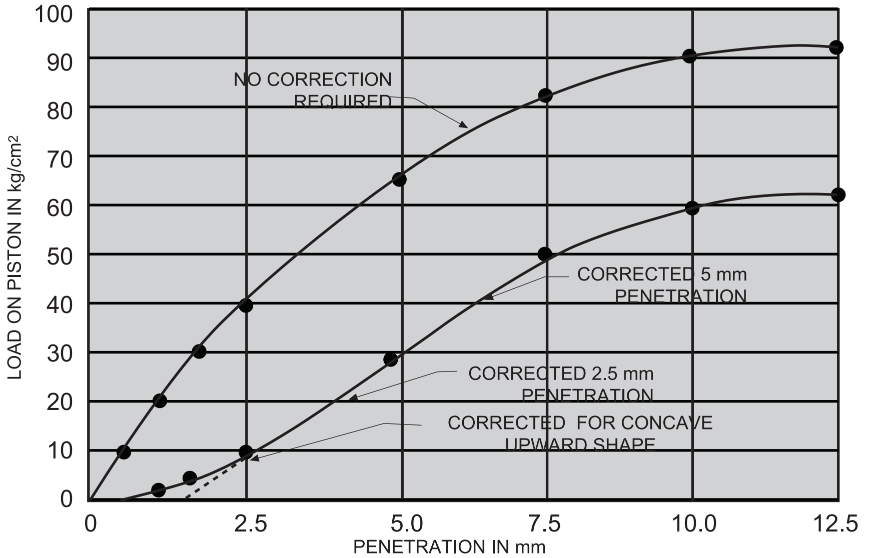
The higher of the two values is reported as CBR (as per Form 10 given below).

Generally the CBR value at 2.5 mm penetration will be higher than that at 5 mm penetration and in such case, the former shall be taken as the CBR value for design purpose. If the CBR value corresponding to a penetration of 5 mm exceeds that for 2.5 mm, the test shall be repeated. If identical results follow, the CBR corresponding to 5 mm penetration shall be taken for design.

8.9 Determining degree of compaction after soaking

1. Before testing itself, the weight of the specimen is noted as explained earlier.
2. After testing, take a portion of soil from the specimen (top portion where penetration tested) and find the moisture content.
3. Find the dry density and compare it with the maximum dry density and find the degree of compaction (%) by comparing this with the maximum dry.

Figure 3: Penetration-Load Curve



Penetration Depth (I) m.m	Unit Standard Load (2) kg/cm²	Total Standard Load (3) kgf
2.5	70	1 370
5.0	105	2 055

Form 10: CBR Test for Soil

Time of penetration Min-Sec	Penetration in mm	Proving Ring Reading; No. of Divisions			Corrected Load; (3) x Value of one Division in KN			Standard Load on Plunger Area, 19.64 cm^2 in KN	Un soaked/ Soaked CBR %: (4)/(5)x100			Average CBR %
(1)	(2)	(3)			(4)			(5)	(6)			(7)
		I	II	III	I	II	III		I	II	III	
0- 0	0.0											
0- 24	0.5											
0- 48	1.0											
1- 12	1.5											
1- 36	2.0											
2- 0	2.5							13.43 KN				
2- 24	3.0											
3- 12	4.0											
4- 0	5.0							20.14 KN				
6- 0	7.5							25.78 KN				
6- 0	7.5							31.17 KN				
10- 0	12.5							35.28 KN				

Average CBR at 2.5 mm penetration (%)

Average CBR at 5.0 mm penetration (%)

Average Saturation Moisture Content (%)

Average Swelling (%)

9. Determination of Sand Equivalent Value of Soils and Fine Aggregates

IS: 2720 (Part XXXVII) - 1976

9.1 Purpose

This standard covers the method for the determination of sand equivalent value of soils. This indicates, under standard conditions, the relative proportion of claylike or plastic fines and dusts in granular soils and fine aggregates that pass 4.75mm IS Sieve. This method is intended to serve as a rapid field-correlation test.

9.2 General Precautions

1. Maintain the temperature of the working solution at 27 ± 3^{o}C during the performance of this test.
    - 1.1. If field conditions preclude the maintenance of the temperature range, frequent referee samples should be submitted to a laboratory where proper temperature control is possible. It is also possible to establish temperature correction curves for each material being tested where proper temperature control is not possible. However, no general correction curve should be utilized for several materials even within a narrow range of sand equivalent values. Samples that meet the minimum sand equivalent requirement at a working solution temperature below the recommended range need not be subjected to referee testing.
2. Perform the test at a location free from vibration. Excessive vibration may cause the suspended material to settle at a greater rate than normal.
3. Do not expose the plastic cylinders to direct sunlight any more than is necessary.
4. Occasionally, it may be necessary to remove a fungus growth from the working calcium chloride solution container and from the inside of the flexible tubing and irrigator tube. This fungus can easily be seen as a slimy substance in the solution.
    - 4.1. To remove this growth, prepare a cleaning solvent by diluting sodium hypochlorite solution (household chlorine bleach) with an equal quantity of water.
    - 4.2. Fill the solution container with the prepared cleaning solvent, allow about 1 litre of the cleaning solvent to flow through the siphon assembly and irrigator tube, then place the pinch clamp on the end of the tubing to cut off the flow of solvent and to hold the solvent in the tube. Refill the container and allow standing overnight.
    - 4.3. After soaking, allow the cleaning solvent to flow out through the siphon assembly and irrigator tube.
    - 4.4. Remove the siphon assembly from the solution container and rinse both with clear water. The irrigator tube and siphon assembly can be rinsed easily by attaching a hose between the tip of the irrigator tube and water faucet and backwashing fresh water through the tube.
5. Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out using extreme care not to enlarge the size of the opening.

9.3 Apparatus

1. Graduated Cylinder- of transparent acrylic plastic having an inside diameter of 32 mm, a height of 430 mm, graduations up to 380 mm at 2 mm intervals, beginning at the bottom, and a rubber stopper to fit in mouth of the cylinder.
2. Irrigator Tube - made of 6.4 mm outside diameter stainless steel tubing with one end closed to form a wedge-shaped point. Two holes of 1 mm diameter are drilled laterally through the flat side of the wedge near the point.
3. Siphon Assembly- consisting of a 4-litre bottle, a 5-mm outside diameter copper bent tube 410 mm long, 1220 mm of 3-mm inside diameter rubber tubing (pure gum or equal) with pinch clamp, a blow tube consisting of 50 mm of 5-mm diameter copper tube and 50 mm of 3-mm inside diameter rubber tube (blow hose), and a 2-hole rubber stopper to fit the graduated cylinder specified in 1 above.
4. Weighted Foot Assembly- consisting of a 6-mm diameter brass rod 445 mm long, threaded on both ends, a brass hexagonal foot of 17.5 mm side by 14 mm diameter, a cylindrical weight of 50 mm diameter and 53 mm height of cold-rolled steel and a nylon, Sand reading indicator of 28 mm diameter and 15 mm height. The weight is attached to the top end of the rod to give the assembly of the weight, rod and foot a total mass of 1000 ± 5 g. The foot is attached to the lower end of the rod.
5. Measuring Can- 90 ± 5 ml capacity.
6. Sieve- 4.75-mm IS Sieve, conforming to IS: 460 - 1962*.
7. Funnel- wide mouth, for transferring soil into the cylinder.
8. Litre Bottles- two, to store stock solution and working solution.
9. Flat Pan-for mixing.
10. Timing Device- reading in minutes and seconds.
11. Sand Equivalent Shaker - mechanical or manually operated.
    - 11.1. Mechanical-having a throw of 200 ± 1 mm and operating at 175 ± 2 cycles per minute.
    - 11.2. Manually operated - capable of producing an oscillating motion at a rate of 100 complete cycles in 45 ± 5 seconds, with a hand-assisted half stroke length of 125 ± 5 mm.

9.4 Materials

1. **Stock Calcium Chloride Solution: The materials listed below will be required:**
    - a. 480.4 g of technical grade anhydrous calcium chloride conforming to IS: 1314- 1967*.
    - b. 2179 g of glycerin (technical grade) conforming to IS: 1796 -1961.
    - c. 49.7 g of formaldehyde (40 percent by volume solution) conforming to IS : 3321-1973.

   Dissolve the 480.4 g of calcium chloride in 2 litres of distilled water; Cool and filter through ready pleated rapid filtering filter paper. Add 2179 g of glycerin and the 49.7 g of formaldehyde to the filtered solution, mix well and dilate to 4 litres.
2. **Working Calcium Chloride Solution:** Prepare the working calcium chloride solution by diluting 90 ml of the stock calcium chloride solution to 4 litres with water. Use distilled or demineralized water for the normal preparation of the working solution. However, if it is determined that the

local tap water is of such purity that it does not affect the test results, it is Permissible to use it instead of distilled or demineralized water.

Note:

i. The effect of local tap water on sand equivalent test results may be determined by comparing the results of three sand equivalent tests using distilled water with the results of three sand equivalent tests using the local tap water. The six test specimens required for this comparison shall be prepared from the same sample of material and oven-dried as prescribed in this method.

9.5 Sample Preparation

1. Obtain at least 1 500 g of material passing 4.75-mm IS Sieve in the following manner.
    1.1. Separate the sample on the 4.75-mm IS Sieve by means of a lateral and vertical motion of the sieve, accompanied by a jarring action so as to keep the sample moving continuously over the surface of the sieve. Continue the sieving until not more than one percent by mass of the residue passes the sieve during one minute. The sieving operation may be performed either by hand or by a mechanical apparatus. When thoroughness of mechanical sieving is being determined, test by the hand method described above using a single layer of material on the sieve.
    1.2. Breakdown any lumps of material in the coarse fraction to pass the 4.75-mm IS Sieve. A mortar and rubber-covered pestle or any other means that will not cause appreciable degradation of the aggregate may be used.
    1.3. Remove any coatings of fines adhering to the coarse aggregate. These fines may be removed by surface-drying the coarse aggregate, then rubbing between the hands over a flat pan.
    1.4. Add the material passing the sieve as obtained in 1.2 and 1.3 to the separated fine portion of the sample.
2. Prepare test specimens from the material passing 4.75-mm IS Sieve portion of the sample by the procedure described in either 2.1 or 2.2.

Note:

ii. Experiments show that as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is decreased. For this reason, it is imperative that extreme care be exercised when preparing the test specimens.

2.1. Split or quarter enough material to fill four can measures to the brim or slightly rounded above the brim in the following manner.
    2.1.1. If it appears necessary, dampen the material to avoid segregation or loss of fines during the splitting or quartering operations. Use care in adding water to the sample to retain a free-flowing condition of the material.
    2.1.2. Using the measuring can, dip out four of these measures from the sample. Each time a measure full of the material is dipped from the sample, tap the bottom edge of the measure on a work table or other hard surface at least four times and jog it slightly to produce a measure of consolidated material level-full or slightly rounded above the brim.

2.1.3. Determine and record the amount of material contained in these four measures either by mass or by volume in a dry plastic cylinder.

2.1.4. Return this material back to the sample and proceed to split or quarter the material making the necessary adjustments to obtain this predetermined mass or volume. When this mass or volume is obtained, two successive splitting or quartering operations without adjustment should provide the proper amount of material to fill the measure.

2.1.5. Dry each test specimen to constant mass at 105 ± 5^0C and cool to room temperature before testing.

Note:

iii. Sand equivalent results on test specimens that have not been dried will generally be lower than the results obtained on identical test specimens that have been dried. As a time-saving expedient, it is permissible to test most materials without drying when the sand equivalent value is used to determine compliance with a specification giving a minimum acceptable test value. If the resulting test value is lower than that specified, however, it will be necessary to rerun the test on a dried test specimen. If the sand equivalent, determined from a test on one dried test specimen, is below the minimum specification limit, it will be necessary to perform two additional tests on dried test specimens from the same sample.

2.2. Prepare the desired number of test specimens from the sample as follows.

2.2.1. Maintaining a free-flowing condition, dampen the material sufficiently to prevent segregation or loss of fines.

2.2.2. Split or quarter out 1000 to 1500 g of the material. Mix thoroughly with a hand trowel in a circular pan by stopping toward the middle of the pan while rotating it horizontally. Mixing or remixing should be continued for at least 1 minute to achieve uniformity. Check the material for the necessary moisture condition by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If a cast is formed that permits careful handling without breaking, the correct moisture range has been obtained. If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. If the material shows any free water it is too wet to test and should be drained and air-dried, mixing it frequently to ensure uniformity. This overly wet material will form a good cast when checked initially, so the drying process should continue until a squeeze check on the drying material gives a cast which is more fragile and delicate to handle than the original. If the ‘as received’ water content is within the limits described above, the sample may be run immediately. If the water content is altered to meet these limits, the sample should be put in a pan, covered with a lid or with a damp trowel that does not touch the material, and allowed to stand for a minimum of 15 minutes.

2.2.3. After the minimum curing time, remix for 1 minute without water. When thoroughly mixed, form the material into a cone with a trowel.

2.2.4. Take the can measure in one hand and push it directly through the base of the pile while holding the free hand firmly against the pile opposite the measure.
2.2.5. As the can travels through the pile and emerges, apply enough hand pressure to cause the material to fill the can to overflowing. Press firmly with the palm of the hand, compacting the material until it consolidates in the can. The excess material should be struck off level with the top of the can, moving the edge of the trowel in a sawing motion across the brim.
2.2.6. To obtain additional test specimens, repeat the procedures in 2.2.3 to 2.2.5.

9.6 Preparation of Apparatus

1. Fit the siphon assembly to a 4-litre bottle of working calcium chloride solution. Place the bottle on a shelf 915±25 mm above the work surface.

Note:

iv. Instead of the 4-litre bottle, a glass or plastic vat having a larger capacity may be used provided the liquid level of the working solution is maintained between 915 and 115 mm above the work surface.

2. Start the siphon by blowing into the top of the solution bottle through a short piece of tubing while the pinch clamp is open.
3. When using either the mechanical or the manually operated sand equivalent shaker, fasten the apparatus to a firm and level mount.

Note:

v. If only a few sand equivalent tests are to be performed at one location, it is possible to hold the manually operated shaker by hand on a firm mount.

9.7 Procedure

1. Siphon 100 ±2 mm (indicated on the graduated cylinder) of working calcium chloride solution into the graduated cylinder.
2. Pour one of the test specimens into the graduated cylinder using the funnel to avoid spillage.
3. Tap the bottom of the cylinder sharply on the palm of the hand several times to release air bubbles and to promote thorough wetting of the specimen.
4. Allow the wetted specimen and cylinder to stand undisturbed for 10 ± 1 minute.
5. At the end of the I0-minute soaking period, stopper the cylinder; then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.
6. After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following three methods.
    6.1. Mechanical Shaker Method - 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 second.
    6.2. Manual Shaker Method - Secure the stoppered cylinder to the shaker and shake for 100 strokes, with half stroke length of 125 ± 5 mm.

6.3. Hand Method

6.3.1. Hold the cylinder in a horizontal position and shake it vigorously in a horizontal linear motion from end to end.

6.3.2. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of 230 ± 25 mm. A cycle is defined as a complete back and forth motion. To shake the cylinder at this speed properly, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

7. Following the shaking operation, set the cylinder upright on the work table and remove the stopper.

8. Irrigation Procedure

8.1. Curing the irrigation procedure, keep the cylinder vertical and the base in contact with the work surface. Insert the irrigator tube in the top of the cylinder, remove the spring clamp from the hose, and rinse the material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles.

8.2. Continue to apply a stabbing and twisting action while flushing the fumes upward until the cylinder is filled to the 380 mm graduation. Then raise the irrigator tube slowly without shutting off the flow so that the liquid level is maintained at about the 380 mm graduation while the irrigator tube is being withdrawn. Regulate the flow just before the irrigator tube is entirely withdrawn and adjust the final level to the 380 mm graduation.

9. Allow the cylinder and contents to stand undisturbed for 20 minutes ±15 seconds. Start the timing immediately after withdrawing the irrigator tube.

10. At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension as prescribed in 9.8.4. This is referred to as the ‘clay reading’. If no clear line of demarcation has formed at the end of the specified 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained; then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual specimens of the same material. Record the clay column height for the sample requiring the shortest sedimentation period as the clay reading.

9.8 Sand Reading Determination

1. After the clay reading has been taken, place the weighted foot assembly over the cylinder and gently lower the assembly until it comes to rest on the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered.

2. 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. Subtract 250 mm from the level indicated by the extreme top edge of the indicator and record this value as the ‘sand reading’.

3. When taking the sand reading, take care not to press down on the weighted foot assembly since this could give an erroneous reading.
4. If clay or sand readings fall between 2-mm graduations, record the level of the higher graduation as the reading.

9.9 Calculations

1. Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

   SE = (Sr / Cr) x 100

Where,

Sr = sand reading (see 9.8.1, 9.8.2), and
Cr = clay reading (see 9.7.10).

2. When the result of this calculation is not a whole number, the sand equivalent (SE) shall be the next higher whole number.
3. If it is desired to average a series of sand equivalent values, average the whole number values determined as described in 9.9.2.

9.10 Precision

Before an operator is allowed to perform the sand equivalent test, s/he should be capable of obtaining consistent test results on representative samples of any given material when the test is performed in accordance with the prescribed procedure for the particular method used. An operator’s test results are considered to be consistent if the individual results of three tests performed by him on representative samples of the same material do not vary by more than ± 4 points from the average of these test.

10. Measurement of Field Density/In-Situ Density/Degree of Compaction

(Sand Replacement Method)

Reference: IS 2720 (Part 28)

10.1 Purpose

Field density of soil affects its permeability and compressibility. It is a measurement of compaction in terms of dry density achieved and can be compared with the maximum dry density achieved in the laboratory test for the same material.

10.2 Apparatus

1. Density Apparatus consisting of density bottle/Jar along with calibration container and base plate/metal tray having 10 cm dia. Hole.
2. Oven
3. Balance 1 g accuracy having capacity 15 Kg and 0.01 g accuracy having capacity of 500 g
4. Miscellaneous equipment - Small pick, chisels, spoons for digging hole and taking soil out of hole: moisture cans with lid, bucket with lid, plastic sacks, small brush etc.
5. Sand passing through 1mm IS sieve and retained on 600 micron IS sieve

10.3 Procedure

1. Fill the pouring cylinder with sand up to (about) 10 mm of the top and take Wt. of it (W1). This Wt. should be maintained constant throughout the tests for which the calibration is used. Volume of the sand equivalent to that of the excavated hole in the soil (or equal to that of the calibration container) shall be allowed to run out of the cylinder. The shutter on the pouring cylinder shall then be closed and the cylinder placed on a plane surface such as the glass plate.
2. The shutter on the pouring cylinder shall be opened and sand allowed to run down. When no further movement of sand takes place in the cylinder, the shutter then closed and the cylinder moved carefully.
3. The sand that has filled the cone of the pouring cylinder (that is the sand that is left on the plane surface) shall be collected and weighed to the nearest 1 g. Repeat this operation at least three times and note the mean Wt of the sand in the cone (W2).
4. Calculate the internal volume of the calibrating container in cc by measuring internal dimensions or by filling it with water.
5. Place the pouring cylinder with the shutter in closed position concentrically on the top of the calibrating container after being filled it with the sand to the constant Wt. (W1).
6. Open the shutter of the pouring cylinder allowing the sand to flow down to fill the calibrating container and cone. When no further movement of sand takes place, close the shutter.
7. Remove the pouring cylinder and take Wt. of it.
8. Repeat the operations from 5 to 7 as mentioned above at least three times and take the mean of three Wt. (W3).

9. A flat area, approximately 45 cm2, of the soil to be tested shall be exposed and trimmed down to level surface, perfectly with the aid of scrapper tool.
10. A round hole approximately 10 cm dia and depth of the layer to be tested up to maximum of 10 cm shall be excavated in the soil. For this purpose the metal tray with a central hole shall be laid on the prepared surface of the soil having the hole over the portion of the soil to be tested.
11. Dig the hole using the hole on the metal tray as a guide to dig about 10cm dia and 10 cm deep hole. No loose materials shall be left in the hole.
12. Collect the excavated soil carefully and weigh it to the nearest g.
13. Take representative sample for the determination of moisture content.
14. Remove the metal tray from the hole of the soil and place the pouring cylinder having filled with the sand to the constant Wt. (W1) in such a way that the base of the cylinder covers the hole concentrically and the shutter is in closed position.
15. Open the shutter and allow the sand to flow down into the hole on the soil. In this operation there should not be any vibration of the pouring cylinder as well as surrounding area.
16. When no further movement of the sand takes place, close the shutter. Remove the pouring cylinder and weigh it to the nearest g (W4).

10.4 Calculations:

1. The weight of sand (Wa) required to fill the calibrating container, in g shall be determined as follows:

   Wa = W1 – W2 – W3

Where,

W1 = Weight of pouring cylinder and sand before pouring into calibrating container in g
W2 = mean weight of sand in cone in g
W3 = Mean weight of cylinder with residual sand after pouring into calibrating container

2. The bulk density of the sand YS in g/cc shall be calculated as follows:

   γS = Wa /V g/cc

Where,

V = volume of calibrating container in cc.

3. The weight of sand (Wb) in g required to fill the excavated hole shall be calculated as follows:

   Wb = W1 – W4 – W2

Where,

W1 = Weight of cylinder and sand before pouring into hole in g
W2 = Mean Wt. of sand in cone in g
W4 = Wt. of cylinder and remaining sand after pouring into hole and cone in g

4. The bulk density of soil γb shall be calculated as follows:

   γb = (WW/ Wb)* γS g/cc

Where,

WW = Weight of natural soil excavated in g

Wb = Wt of the sand required to fill the hole

γS = Bulk density of sand

5. The density of dry soil γd shall be calculated as follows:

γd = [100 /(100 + W)]* γb g/cc

Where,

W = moisture content of the soil in percent

γb = bulk density of soil

10.5 Reporting

a. Dry density of soil in g/cc

b. Moisture content of soil in percent

c. Complete the form 11 given below.

Form 11: Field Density of Soil (Sand replacement method)

Road/Section Details: Date of Testing:

Location of test point: Thickness of layer: mm

Observation Tables

a) Calibration

(i)	Mean weight of sand in cone (of pouring cylinder) (W2) in g.
(ii)	Volume of calibrating cylinder (V) in cm3, -
(iii)	Weight of sand (+ cylinder) before pouring into calibrating container (W1) in g. -
(iv)	Mean weight of sand (+cylinder) after pouring into calibrating container (W3) in g. -
(v)	Weight of sand to fill calibrating cylinder. (Wa = W1- W2- W3) in g. -
(vi)	Bulk density of sand γs= (Wa/V) g/cm3 -

b) **Determination of soil density**

(i)	Determination number =
(ii)	Weight of wet soil from hole (Ww) in g, =
(iii)	Weight of sand (+ cylinder) before pouring into hole (W1) in g. =
(iv)	Weight of sand (+ cylinder) after pouring into hole and cone (W4) in g. =
(v)	Mean weight of sand in cone (W2) in g. =
(vi)	Weight of sand in hole, in g. Wb= (W1- W4- W2) =
(vii)	Bulk density γb= (Ww/Wb)x γsg/cm^3 =
(viii)	Moisture content container number =
(ix)	Moisture content (W) percent =
(x)	Weight of dry soil from the hole in g. (Wd) =
(xi)	Dry density γd= (Wd / Wb)x γs gm/cm^3 = [(100 x γb/(100 + w)] =

11. Field Density

(Core Cutter Method)

Reference: IS: 2720 (Part 29) – 1975

11.1 Purpose

Field density can be determined by core cutter also. The method can be used successfully whenever soil conditions permit pushing of cutter for sampling and taking it out in the laboratory without much disturbance.

11.2 Apparatus

1. Core cutter with dolly and rammer
2. Balance

11.3 Procedure

1. Measure the inside dimensions of the cutter and calculate its volume.
2. Weigh the cutter without dolly.
3. Remove loose soil from the site.
4. 4. Place the dolly over the cutter and ram it gently into the soil till about one cm of the dolly protrudes above the surface.
5. Dig out the cutter containing the soil extruding from the ground.
6. Remove the dolly and trim off any soil extruding from the ends.
7. Weigh the cutter full of soil and keep a representative sample for water content determination.

11.4 Calculation

1. Calculate the dry density of the soil by knowing its weight, volume and water content.
2. Complete the form 12 given below.

Form 12 : Determination of Field Density of Soil (Core Cutter Method)

S.N.	**Observation**	**1**	**2**	**3**
1	Volume of Core Cutter = V cm^3			
2	Weight of empty Core Cutter = W g			
3	Weight of Core Cutter + Wet Soil = W1 g			
4	Weight of Wet Soil = W1-W g			
5	Bulk Density $\gamma b = (W1 - W)/V$ g/cm^3			
6	Container No.			
7	Weight of Container + Soil Sample = W2 g			
8	Weight of Container+ Soil Sample after oven drying = W3 g			
9	Moisture Content = W2 – W3 g			
10	Weight of empty Container = W4 g			
11	Weight of Dry Soil = W3 – W4 g			
12	Percentage of Moisture Content, m ={(W2 – W3)/ (W3 – W4)} x 100 %			
13	Dry Density $\gamma d = \{100/(100+m)\} x\, \gamma b$ g/cm^3			

PART - II
TEST ON AGGREGATES

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List of Forms and Figures

1. Gradation Analysis of Aggregates

Reference: IS: 2386 Part 1

1.1 Purpose

This method covers the procedure for the determination of particle size distribution of fine, coarse and all-in-aggregates by sieving or screening. A combination of well graded coarse and fine aggregates is essential for producing a durable granular mix for pavement courses.

1.2 Apparatus

1. IS Sieves: 80mm, 63mm, 50mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron, 150 micron, 75 micron (Different sizes of sieves should comply with the requirement of Specifications)
2. Balance: Minimum 20 Kg capacity having accuracy of 1 gm
3. Sieve shaker (Optional)
4. Metal trays, scoop, brush

1.3 Procedure

1. A minimum quantity of sample (obtained from larger sample either by quartering or by means of a sample divider) as given in table below.
2. Bring the sample to an air dry condition either by drying at room temperature or in oven at a temperature of 100^{o}C to 110^{o}C and then cooled. Take the weight of the sample.
3. Clean all the Sieves.
4. Pass the sample successively through the sieves starting with the largest. Care should be taken that the sieves are clean before use.
5. If sieving is carried out by hand each sieve should he shaken separately over a clean tray for a period of not less than two minutes. The shaking should be done with a varied motion backwards and forwards left to right circular clockwise and anticlockwise and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions. Material smaller than 20 mm should not he helped through the sieve by hand or by brushing. Lumps of fine materials, if present, may be broken by gentle pressure with fingers against the side of the sieve.
6. If sieving is carried out the nest of sieves on a machine not less than 10 minutes sieving will be required for each test.
7. On completion of sieving the material retained on each sieve, together with any material cleaned from the mesh shall be weighed on a balance.
8. The percentage by weight retained on each sieve shall be calculated and the results shall be given to the nearest 0.1 percent. From these results the cumulative percentage by weight of the total sample passing each of the sieves will be calculated and recorded to the nearest whole number, the results of sieving tests shall he recorded graphically on the chart for recording sieve analysis.

Note:

i. *The coarse aggregates used for granular construction are normally of the sizes 80 mm, 40 mm, 20 mm, 10 mm and 4.75 mm. The fractions from 4.75 mm to 150 micron are termed as fine aggregates. The size 4.75 mm is a common size appearing in both the fractions.*

ii. *Grading pattern of aggregates - coarse, fine or combined - is determined by sieving a sample successively through all the sieves mounted one over the other in order of size, with the larger sieve on the top. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.*

iii. *Sieve analysis gives the gradation and the fineness modulus. Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregates retained on each of the dividing standard sieves and dividing by 100. The larger figure shows that the material is coarser.*

iv. *Minimum weight of laboratory samples required for sieve analysis is given in the table below:*

Table 1: Minimum Weight of Laboratory Samples Required for Sieve Analysis

Maximum Size of Aggregates (mm)	Minimum Wt. of Sample to be taken(Kg)
63	50
50	35
40	15
20	02
12.5	01
10	0.5
4.75	0.2
2.36	0.1

1.4 Calculation

Complete the calculation on form 1 given below.

Form 1: Gradation Analysis of Aggregates

Road / Section Details: Weight of Sample Taken (g):

Sample No. : Material for: (Sub base, Base, Concrete) ________ Date of Testing:

IS Sieve Designation (mm)	Wt. of sample retained (g)	Percentage of Wt. retained (%)	Cumulative Percentage of Wt. retained (%)	Percentage of Wt. Passing (%)	Remarks

2. Flakiness Index

Reference: IS : 2386 (Part 1) - 1963

2.1 Purpose

This method of test lays down the procedure for determining the flakiness index of coarse aggregate. This weighted percentage, the amount of flat or non cubical particles in a given aggregate sample.

Note :

i. *The flakiness index of an aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.*

ii. *Use of flaky aggregate results in loss of strength of granular base and surface course.*

2.2 Apparatus

The apparatus shall consist of the following

a. Balance:

The balance shall be of sufficient capacity and sensitivity and shall have an accuracy of 0.1 per cent of the weight of the test sample.

b. Metal Gauge:

The metal gauge shall be of the pattern shown in the figure 1 Below with elongated slots. The tolerance on dimension shall he ± 0.20 mm for dimensions equal to or more than 50 mm and ± 0.10 mm for dimensions less than 50 mm. Opening Sizes of Metal Gauge are given below in Table 2

Table 2: Opening Sizes of Metal Gauge

Size of Aggregates		Thickness Gauge Opening, Width (0.6 times mean sieve) (mm)	Thickness Gauge Opening, Length (mm)
Passing through IS Sieve(mm)	Retained on IS Sieve (mm)		
63	50	33.90	100
50	40	27.00	90
40	31.5	21.50	80
31.5	25	16.25	70
25	20	13.50	65
20	16	10.80	50
16	12.5	8.55	40
12.5	10	6.75	35
10	6.3	4.89	25
Total			

c. **Sieves:**

IS Sieves of size 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm.

2.3 Procedure

1. The sample is sieved through IS sieve 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm
2. Minimum 200 pieces of each fraction to be tested are taken and weighed (W g).
3. Separate the flaky material by using the standard flakiness gauge.
4. Take the weight of flaky material which passes through standard gauge (M g)

2.4 Calculation

Calculate the Flakiness Index of Aggregate as follows:

$$\text{Flakiness Index (FI)} = \frac{\text{Weight of material passing the gauge (M)}}{\text{Total weight of sample (W)}} \times 100$$

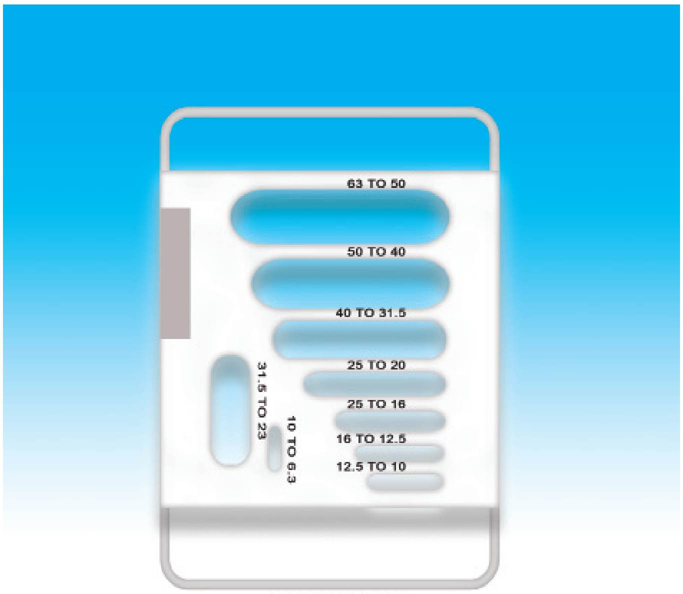
2.5 Reporting

Report the observations in the Form 2 given below.

Form 2: Flakiness Index of Aggregate

Size of Aggregates		Wt. of the Fraction consisting at least 200 pieces of Aggregates (g)	Wt. of Aggregate in each fraction passing Thickness Gauge (g)
Passing through IS Sieve(mm)	Retained on IS Sieve (mm)		
63	50	W1 =	M1 =
50	40	W2 =	M2 =
40	31.5	W3 =	M3 =
31.5	25	W4 =	M4 =
25	20	W5 =	M5 =
20	16	W6 =	M6 =
16	12.5	W7 =	M7 =
12.5	10	W8 =	M8 =
10	6.3	W9 =	M9 =
Total		**∑W =**	**∑M =**

$$\textbf{Flakiness Index (F.I.)} = \frac{\sum M}{\sum W} \times 100 \ (\%)$$



THICKNESS GAUGE

3. Determination of Elongation Index

Reference: IS : 2386 (Part I)

3.1 Purpose

This method of test lays down the procedure for determining the elongation index of coarse aggregate.

Note:

i. The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four-fifths times their mean dimension. Normally, the properties of interest to the engineer are sufficiently covered by the flakiness or angularity tests. The elongation test is not applicable to sizes smaller than 6.3 mm.

3.2 Apparatus

1. Balance – The balance shall be of sufficient capacity and shall have an accuracy of 0.1 percent of the weight of the test sample.
2. Length Gauge - The length gauge shall be of the pattern shown in Figure 2 below.
3. Sieves - IS Sieves of the sizes 63-mm, 50-mm, 40-mm, 31.5-mm, 25-mm, 20-mm, 16-mm, 12.5-mm, 10-mm & 6.3-mm
4. Sample -A quantity of aggregate shall be taken, sufficient to provide a minimum number of 200 pieces of any fraction to be tested.

3.3 Procedure

1. The sample is sieved in accordance with the method described in Gradation of aggregate through IS sieve 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm
2. Minimum 200 pieces of each fraction to be tested are taken and weighed (W g).
3. The aggregate pieces shall be gauged individually for length on a standard length gauge of the pattern shown in Fig. 2 below. The gauge length used shall be that specified in col 4 of Table give below for the appropriate size of material.
4. Separate the elongated material retained on the standard length gauge.
5. Take the weight of elongated material which retained on the standard length gauge (M g)

3.4 Calculation

Calculate the Elongation Index of Aggregate as follows:

$$\text{Elongation Index (EI)} = \frac{\text{Total Weight of material retained on the gauge (M)}}{\text{Total weight of sample (W)}} \times 100$$

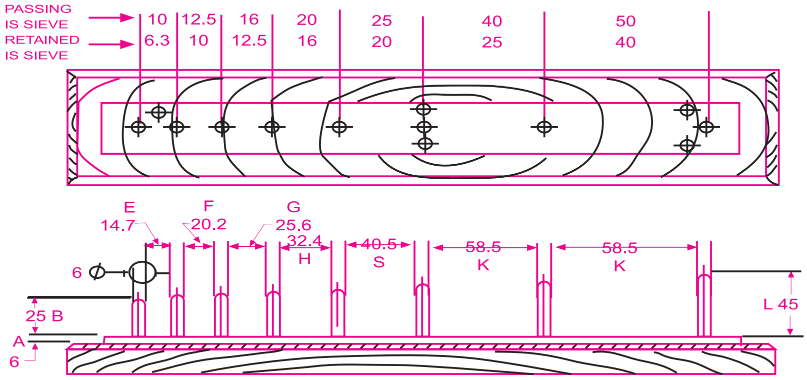
3.5 Reporting

Report the observations in the Form 3 given below.

Form 3: Elongation Index of Aggregate

Size of Aggregates		Wt. of the Fraction consisting at least 200 pieces of Aggregates (g) (3)	Length Gauge Size (1.8 times mean sieve) (mm) (4)	Wt. of Aggregate in each fraction retained on Length Gauge (g) (5)
Passing through IS Sieve(mm) (1)	Retained on IS Sieve (mm) (2)			
50	40	W1 =	81.0	M1 =
40	25	W2 =	58.5	M2 =
25	20	W3 =	40.5	M3 =
20	16	W4 =	32.4	M4 =
16	12.5	W5 =	25.6	M5 =
12.5	10	W6 =	20.2	M6 =
10	6.3	W7 =	14.7	M7 =
Total		∑W =		∑M =

$$\textbf{Elongation Index (EI)} = \frac{\sum M}{\sum W} \times 100$$



4. Determination of Specific Gravity and Water Absorption Of Aggregates

Reference: is: 2386 part 3

4.1 Purpose

Water absorption shows the porosity of aggregates in one way. The more, it absorbs, the less it is durable. This method provides the procedure for the determination of Specific Gravity and water absorption of aggregates.

4.2 Apparatus

a. Balance: The balance or scale of capacity not less than 3 Kg. readable and accurate to 0.5 Kg and of such a type and shape as to permit the basket containing the sample to be suspended from the beam and weighed in water.

b. Oven: A well ventilated oven, thermostatically to maintain a temperature of 100^0 to 110^0C

c. A wire basket of not more than 6.3 mm mesh or perforated container of convenient size preferably chromium plated and polished, with wire hangers not thicker than one millimeter for suspending it from the balance.

d. A stout water tight container in which the basket may be freely suspended.

e. Two dry soft absorbent clothes each not less than 75x45 cm.

f. A shallow tray of area not less than 650 cm^2.

g. An air tight container of capacity similar to that of the basket.

4.3 Sample

A sample of not less than 2000 gm of the aggregate shall be tested. Aggregate which have been artificially heated shall not normally be used, if such material is used the fact shall be stated in the report. Two tests shall be made, and it is recommended that the two samples should not be tested concurrently.

4.4 Procedure

1. The sample shall be thoroughly washed to remove finer particles and dust, drained and then placed n the wire basket immersed in distilled water at a temperature between 22^0 and 32^0C with a cover of at least 5 cm of water above the top of the basket.
2. Immediately after immersion the entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and aggregate shall remain completely immersed during the operation for a period of 24±1/2 hours.
3. The basket and the sample shall then be jolted and weighed in water at a temperature of 22^0 to 32^0C. If necessary for them to be transferred to a different tank for weighing, they shall be jolted 25 times as described above in the new tank before weighing (Weight A1)
4. The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the aggregate shall be gently emptied from the basket on to one of the dry

cloths and the empty basket shall be returned to the water, jolted 25 times and weighed in water (Weight A2).

5. The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. It shall be spread out not more than one stone deep on the second cloth, and left exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes or until it appears to be completely surface dry (which with some aggregate may take an hour or more) the aggregate shall be turned over at least once during this period and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregate. The aggregate shall then be weighed (Weight B).
6. The aggregate shall than be placed in the oven in the shallow tray, at a temperature of 100^0 to 110^0C and maintained at this temperature for 24±1/2 hours. It shall then be removed from the oven, cooled in the air-tight container and weighed (weighed C).

4.5 Calculations

Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:-

1. **Specific gravity = C / (B – A)**
2. **Apparent specific gravity = C / (C – A)**
3. **Water absorption = [(B – C)/ C] x 100**
   (Percent of dry weight)

Where

A = Weight of the saturated aggregate in water (A1 - A2) (g)
A1 = Weight of sample + basket in water (g)
A2 = Weight of basket in water (g)
B = Weight in gm of the saturated surface dry aggregate in air and
C = Weight in gm of oven-dried aggregate in air.

4.6 Reporting of Results

1. The individual and mean results shall be reported in the form 4 given below.
2. The size of the aggregate tested shall be stated and whether it has been artificially heated before testing should also be reported.

Form 4: Water Absorption of Aggregate

S. N.	Specimen No.	Wt. of basket in water (g) A2	Wt. of sample + basket in water (g) A1	Wt. of saturated surface dry sample in water (g) A=A2-A1(g)	Wt. of saturated surface dry sample in air (g) B	Wt. of oven dry sample (g) C	Water absorption [(B-C)/C*100 (%)]

5. Determination of Bulking of Sand

5.1 Purpose

This method provides the procedure for the determination of the bulking of sand. The standard test for bulking is based on the fact that while damp sand bulks the volume of saturated sand completely soaked with water which is the same as if the sand were dry.

5.2 Apparatus

1. a measuring jar or in its absence any straight sided container and
2. a ruler,
3. a steel rod to rod sand with and
4. a second container to tip it into.

5.3 Procedure

1. Fill the container about two third full with the sand to be tested. Drop it loosely, do not pack it down. Level off the top and pushing a steel rule down through it to the bottom, measure the height of the sand. Suppose it is 15 Cm.
2. Empty the sand into another container (taking care that none of it is lost in the process) and half fill the first container with water, put back the sand into the water bit by bit and keep rodding to remove the air when the entire sand is fully saturated push the rule through the sand as before and measure the height. Say it measure 12.5 Cm.

5.4 Calculation

The bulking is calculated from the volume of dry sand or saturated sand and hence in this case bulking is 2.5 Cm. i.e.

$$\text{Bulking} = \frac{2.5}{12.5} \times 100 = 20\%$$

The volume used should therefore be 20% more than quoted in the specification.

6. Determination of Los Angeles Abrasion Value

Reference: IS: 2386 Part 4

6.1 Purpose

The test covers the method of determining the abrasion value of coarse aggregate by the use of Los Angeles machine. This test gives a measure of the aggregate's resistance to abrasion and impact. It can be used to indicate the quality of similar aggregates from different sources.

6.2 Apparatus

a. Los Angeles Machine
b. Steel balls
c. IS Sieves as required depending upon the size of aggregates to be tested and 1.70 mm Sieve
d. Balance accurate to 1 g

6.3 Abrasive Charge

1. The abrasive charge shall consist of cast iron spheres or steel spheres approximately 48 mm diameter and each weighting between 390 and 445 grams.
2. The abrasive charge depending upon the grading of the test sample shall be as follows:

Grading	**Number of spheres**	**Weight of charge (g)**
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

6.4 Test Sample:

1. The field sample shall be reduced to give test sample approximately 20 Kg for aggregates larger than 20 mm and 10 Kg for aggregates smaller than 20 mm.
2. The test sample shall then be washed and dried in an oven at 105° to 110°C to substantially constant weight and
3. The test sample shall confirm to one of the grading shown in Table 3 as given below. The grading used shall be those most nearly representing the aggregate furnished for the work.

Table 3: Gradings of Test Samples

Sieve size (mm)		Weight of test sample for grade (g)							Remarks
Passing	**Retained on**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	
80	63	-	-	-	-	2500*	-	-	
63	50	-	-	-	-	2500*			
50	40	-	-	-	-	5000*	5000*		
40	25	1250					5000*	5000*	
25	20	1250						5000*	
20	12.5	1250	2500						
12.5	10	1250	2500						
10	6.3			2500					
6.3	4.75			2500					
4.75	2.36				5000				

* Tolerance of ±2 per cent permitted.

6.5 Procedure

1. Clean the inside of the L.A machine of all dust.
2. Place the test sample and the abrasive charge in the Los Angeles abrasion testing machine
3. Set the counter to zero and switch on the machine.
4. The machine should rotate at a speed of 20 to 33 rev/min. For grading A, B, C and D the machine shall be rotated for 500 revolutions. For grading E, F & G it shall be rotated for 1000 revolutions.
5. After the completion of the required revolutions, switch off the machine.
6. Discharge the material and all dust from the machine onto a tray.
7. Preliminary separation of the sample made on a sieve coarser than the 1.70mm Sieve. The finer portion shall then be sieved on a 1.70 mm sieve.
8. The material coarser then the 1.70 mm Sieve shall be washed, dried in an oven at 100°to 110° C to a substantially constant weight, and accurately weighed the nearest gram.

6.6 Calculation

1. The difference between the original weight of sample taken and the final weight of the test sample retained on 1.70mm sieve shall be expressed as a percentage of the original weight of the test sample.
2. This value shall be calculated as the percentage of wear which is the Abrasion Value of the sample.

$$\text{Abrasion Value} = \frac{W1 - W2}{W1} \text{ X } 100$$

Where

W1 = Weight of Initial dry sample taken.
W2 = Weight of material retained by 1.70 mm Sieve

W1-W2 = Weight of material passing 1.70 mm Sieve.

6.7 Reporting of results

Report the Los Angeles Abrasion (LAA) Value in Form 5 given at the end of this part.

Form 5: Los Angeles Abrasion (LAA) Test

S. N.	Wt. of Sample taken (g) W1	Wt. of material retained on 1.70 mm sieve (g) W2	Wt. of material passing 1.70mm sieve (g) W1 –W2	% passing (Abrasion Value) = [(W1 –W2)/W1]x100	Average LAA Value
1					
2					
3					

7. Aggregate Impact Value

Reference: IS: 2386 Part 4

7.1 Aggregate Impact Value (Dry)

7.1.1 Purpose

This method covers the procedures for determination of the impact value of the aggregates in dry condition. The purpose of determining the Aggregate Impact Value is to assess its resistance to disintegration against impact loading.

7.1.2 Apparatus

1. Aggregate Impact Test Apparatus including measuring cylinder and temping rod
2. IS Sieves 12.5 mm, 10 mm and 2.36 mm
3. Trays
4. Weighing balance
5. Oven

7.1.3 Procedure

1. Take the test sample consisting of aggregates the whole of which passes 12.5 mm IS sieve and is retained on 10 mm IS sieve. Dry the aggregate comprising the test sample in an oven for a period of four hours or till such time that its weight becomes constant at a temperature of 105^0 C to 110^0 C. Cool the aggregates.
2. Use the aggregates as obtained above for conducting the test in a dry condition, following the procedure described below.
3. 3. Aggregate shall be filled in the cylindrical measure in 3 layers by tamping each layer by 25 blows. Determine the net weight of aggregate in the measure (W1). Transfer the sample from the measure to the cup of the aggregate impact testing machine and compact it by tamping 25 times.
4. The hammer is raised to height of 38 cm above the upper surface of the aggregate in the cup and is allowed to fall freely on the specimen.
5. After subjecting the test specimen to 15 blows, the crushed aggregate is sieved on IS 2.36 mm sieve.

7.1.4 Calculation

Weigh the fraction passing through IS 2.36 mm sieve (W2).

$$\text{Aggregate Impact Value (AIV)} = \frac{W2}{WI} \times 100$$

7.1.5 Reporting

Report the Aggregated Impact value in form 6 given below.

Form 6: Aggregate Impact Value Test (Dry)

Observation	Test No.			Average
	1	2	3	
Wt. of aggregate sample filling in the cylinder = W1 (g)				
Wt. of aggregate passing IS sieve 2.36 mm after the test = W2 (g)				
AIV = (W2/W1)* 100				

7.2 Aggregate Impact Value (Wet)

7.2.1 Procedure

1. Determine the net weight of aggregate sample in the measure (W1) in dry condition as mentioned above test procedure for dry condition.
2. Submerge the sample in water for three days. Make it surface dry, and put the sample in the cup of Testing Machine. Fix the cup firmly on position on the base of the machine.
3. Raise the hammer until its full face is 380 mm above the upper surface of aggregate in the cup and allow it to fall freely.
4. Subject the test sample to 15 such blows.
5. Remove the crushed aggregate from the cup and sieve it on 2.36 mm IS sieve. Wash it wit water till no further significant amount passes in one minute.
6. Dry the fraction retained on the sieve at 105^0C to 110^0C and weigh to an accuracy of 0.1 gm. Subtract the weight of the portion retained on the sieve (weight B) from the weight of the oven dried sample to get the weight of the portion passing the sieve.

7.2.2 Calculation

Express this weight as the percentage of original weight to get the Aggregate Impact Value as shown at the end:

$$\text{Aggregate Impact Value} = \frac{A - B}{A} \times 100$$

Where

A = weight of oven dried sample

B = weight of fraction retained on 2.36 mm IS sieve

7.2.3 Reporting

Complete the calculation on the form 7 given below

Form 7: Aggregate Impact Value Test (Wet)

Observation	Test No.			Average
	1	2	3	
Wt. of the oven dry sample (A) g				
Wt. of weight of fraction retained on 2.36 mm IS sieve (B)g				
AIV ={ (A-B)/A} X 100				

8. Crushing Strength of Coarse Aggregates

Reference IS: 2386 (Part IV)

8.1 Purpose

This method provides the procedure to determine the Crushing Strength of Coarse Aggregates.

8.2 Apparatus

1. Apparatus for the standard test shall consist of the following:
2. A 15 cm diameter open ended steel cylinder, with plunger and base plate. The surfaces in contact with the aggregate shall be machined and case-hardened.
3. For measuring the sample, cylindrical metal measure of sufficient rigidity to retain its form under rough usage and of the following internal dimensions:
   i. Diameter 11.5 cm
   ii. Height 18-0 cm
4. A compression testing machine capable of applying a load of 40 tonnes and which can be operated to give a uniform rate of loading so that the maximum load is reached in 10 min. The machine may be used with or without a spherical seating.
5. A straight metal tamping rod of circular cross sectional 16mm diameter and 45 to 60 cm long rounded to one end.
6. A balance having capacity of 3 Kg, readable and accurate to 1 gm.
7. Sieves of sizes 12.5 mm, 10 mm and 2.36mm

8.3 Preparation of Test Sample

1. The material for the standard test shall consist of aggregate passing a 12.5 mm IS Sieve and retained on a 10 mm IS Sieve, and shall be thoroughly separated on these sieves before testing.
2. Test the aggregate in a surface-dry condition.
3. If dried by heating, the period of drying shall not exceed four hrs, the temperature shall be 100°C to 110°C and the aggregate shall be cooled to room temperature before testing.
4. The quantity of aggregate shall be such that the depth of material in the cylinder, after tamping shall be 10 cm.
5. The appropriate quantity may be found conveniently by filling the cylindrical measure in three layers of approximately equal depth, each layer being tamped 25 times with the rounded end of the tamping rod and determine the weight of material comprising the test sample (weight A).
6. Take the same weight of sample for the repeat test.

8.4 Procedure

1. Apply load at uniform rate as far as possible so that the total load is reached in 10 min (about 67Kg/Sec). The total load shall be 40 tonnes.
2. At least two tests shall be performed.
3. In all of these operations, care shall be taken to avoid loss of the fines.

4. Place the apparatus with the test sample and plunger in position, between the platens of the testing machine and
5. Put the cylinder of the test apparatus in position on the base-plate and
6. Put the test sample in thirds, each third being subjected to 25 strokes from the tamping rod.
7. Release the load.
8. Remove whole of the material from the cylinder.
9. Sieve the material on a 2.36 mm IS Sieve for the standard test. The fraction passing the sieve shall be weighed (Weight B)
10. The surface of the aggregate shall be carefully leveled and the plunger inserted so that it rests horizontally on this surface, care being taken to ensure that the plunger does not jam in the cylinder.

8.5 Calculation

1. Express the ratio of the weight of fines formed to the total sample weight in each test as a percentage, the result being recorded to the first decimal place:

$$\textbf{Aggregate crushing value} = \frac{B}{A} \times 100\ (\%)$$

Where

B = weight of fraction passing the appropriate sieve, and
A = weight of surface-dry sample.

2. Report the results in Form 8 given at the end of this part.

Form 8: Crushing Strength of Coarse Aggregates

S.N.	Wt. of container(g) C	Wt. of surface dry specimen + container (g) A	Wt. of fines passing 2.36mm IS sieve + container (g) B	Crushing Strength =[(B-C)/(A-C)]x100 (%)	Average Crushing strength (%)

9. Soundness of Aggregates with Sodium Sulphate

Reference: IS 2386 (Part 5)

9.1 Purpose

This method covers the procedure for the determination of the soundness of aggregates with sodium sulphate. The test determines the resistance to disintegration of aggregate by saturated solution of Sodium Sulphate. It indicates soundness against weathering action.

9.2 Apparatus

a. Sieves
b. Oven
c. Balance

9.3 Preparation of Saturated Solution

Prepare saturated solutions of Sodium Sulphate by adding sufficient quantities of salt into water at a temperature of 25 to 30°C. The solution may be cooled to 27±1°C. and kept at that temperature at least for 48 h before use.

9.4 Prepare the samples as given below

9.4.1 Fine Aggregate

Fine aggregates for the test shall pass through 10 mm IS Sieve. The sample shall be of such a size that it will yield not less than 100g of each of the following sizes, which shall be available in amount of 5% or more expressed in terms of the following sieves:

Passing IS Sieve	Retained on IS Sieve
600 micron	300 micron
1.18 mm	600 micron
2.36 mm	1.18 mm
4.75 mm	2.36 mm
10 mm	4.75 mm

9.4.2 Coarse Aggregate

Coarse Aggregates for the test shall consist of materials from which sizes finer than 4.75 mm have been removed. The sample shall be of such a size that it will yield not less than the following amounts of the different sizes which shall be available in amounts of 5% or more.

S.No.	Size of sieve	Yield	Consisting of:	
1	10 mm to 4.75 mm	300 g		
2	20 mm to 10 mm	1000 g	12.5 mm to 10 mm	330 g (33 percent)
			20 mm to 12.5 mm	670 g (67 percent)

3	40 mm to 20 mm	1500 g	25 mm to 20 mm	500 g (33 percent)
			40 mm to 25 mm	1000 g (67 percent)
4	63 mm to 40 mm	3000 g	50 mm to 40 mm	1500 g (50 percent)
			63 mm to 50 mm	1500 g (50 percent)
5	80 mm and larger size by 20 mm. Spread in sieve size, each fraction 3000 g.	3000 g		

9.5 Procedure

1. Wash the sample and dry to the constant weight at 105°C to 110°C. Separate into different sizes as shown above by sieving to refusal. Weigh out the samples and keep them in separate containers.
2. Immerse the samples in prepared solutions of sodium sulphate for not less than 16 h and not more than 18 h in such a manner that the solution covers them to a depth of at least 15 mm.
3. Cover the container to reduce evaporation and maintain the solution at a temperature of 27±1°C.
4. Remove the sample after the immersion period and allow it to drain for 15±5 min. Place it in the drying oven at a temperature of 105° to 110°C; and dry it to a constant weight.
5. During the drying period, the sample shall be removed from the oven, cooled to room temperature and weighed at intervals of neither less than 4 hours nor more than 18 hours. Constant wt. may be considered to have been achieved when two successive weights for any sample differ by less than 0.1 gm in the case of coarse aggregate samples.
6. Repeat a number of cycles and determine the loss of weight of specimen after each cycle in accordance with the procedure given below.
7. After the completion of the final cycle and after the sample has been cooled, the sample shall be washed free from the sodium sulphate as determined by the reaction of the wash-water with barium chloride ($BaCl_2$).
8. After the sodium sulphate solution has been removed, each fraction of the sample shall be dried to constant weight at 105°C to 110°C and weighed. Fine aggregates shall be sieved over the same sieve on which it was retained before the test and coarse aggregate over the sieve shown below for the appropriate size of particle.

Size of Aggregate	**Sieve used to Determine Loss**
63 mm to 40 mm	31.5 mm
40 mm to 20 mm	16 mm
20 mm to 10 mm	8 mm
10 mm to 4.75 mm	4 mm

9.6 Qualitative Examination

Fractions of sample coarser than 20 mm shall be examined qualitatively after each immersion and quantitatively at the completion of the test.

The qualitative examination and record shall consist of two parts (a) observing the effect of the action (see note) by the sodium sulphate and the nature of the action, and (b) counting the number of particles affected.

Note:

i. *Different type of results may be expected. In general, results may be classified as disintegration, splitting, crumbling, cracking flaking etc.*

ii. *While only particles larger than 20 mm in size are required to be examined qualitatively it is recommended that examination of the small sizes be also made in order to determine whether there is any evidence of excessive splitting.*

9.7 Report

1. Complete the form 9 given at the end of this part.
2. The Soundness of the sample shall be reported as percentage of loss of weight of the sample.

Form 9: Soundness with Sodium Sulphate

Sample No.: Date of Sampling:

Name of Quarry / Location: Date of Testing:

Type of Reagent Used: No. of Cycles:

Sieve Size (mm)		Grading of original sample (%)	Wt. of each fraction before test (g)	Wt. of materials passing finer sieve(designated sieve) g	Percentage passing finer sieve after test (actual percent loss)	Weighted average (corrected percentage loss)
Passing	Retained					
60	40					
40	20					
20	10					
10	4.75					
Number of particles coarser than 20mm before test				Number of particles affected, classified as to the number disintegrating, splitting, crumbing, cracking or flaking		
Passing	Retained	Number before test	Splitting	Crumbling	Cracking	Flaking
40 mm	20 mm					
60 mm	40 mm					

10. Determining of Deleterious Material and Organic Impurities

Reference: IS: 2386 Part 2

10.1 Determination of Clay Lumps

10.1.1 Purpose

This method of test covers the procedure for the approximate determination of clay lumps in the routine examination of aggregates.

10.1.2 Apparatus

The apparatus shall consist of the following

a. Balance: having accuracy within 0.1 percent of the weight of the sample to be weighed

b. Containers: Containers of a size and shape that will permit the spreading of the sample on the bottom in a thin layer.

c. Sieves: Sieves conforming specification of Test Sieves.

10.1.3 Sampling

Samples shall be obtained by quartering or by the use of a sampler, from a representative sample selected from the material to be tested. They shall he handled in such a manner as to avoid breaking up clay lumps which may be present.

Samples of shall he died to constant weight at a temperature not exceeding 110^0C.

Samples of fine aggregates shall consist of particles coarser than 1.18 mm Sieve and shall weight not less than 100 gm.

Samples of coarse aggregate shall be separated into different sizes using 4.75 mm, 10 mm, 20 mm and 40 mm Sieves. The weight of the sample for different sizes shall be not less than those indicated in the table below:

Table 4: Minimum Weight of Different Sample Sizes

Size of particles making up the sample (mm)	Weight of Sample min.(gm)
Over 4.75 to 10	1,000
Over 10 to 20	2,000
Over 20 to 40	3,000
Over 40	5,000

10.1.4 Procedures

The sample shall be spread in a thin layer on the bottom of the container and examined for clay pumps. Any particles which can be broken into finely divided particles with the fingers, shall be classified as clay pumps. After all discernible clay lumps have been broken, the residues from the clay lumps shall be removed by the use of sieves indicated below:

Size of particles making up the samples	Sieve for sieving Residue of clay lumps
Fine aggregate (retained on 1.18 mm Sieve)	850 micron
Over 4.75 mm to 10 mm	2.36 mm
Over 10 mm to 20 mm	4.75 mm
Over 20 mm to 40 mm	4.75 mm
Over 40 mm to	4.75 mm

10.1.5 Calculations

The percentage of clay lumps shall be calculated to the nearest 0.1 percent in accordance with the following formula:

$$\mathbf{L = \frac{W - R}{W} \times 100}$$

Where

L= Percentage of clay
W= Weight of sample, and
R=Weight of sample after removal of clay lumps

10.1.6 Reporting of Results

The percentage of clay lumps in the aggregate shall be reported to the nearest 0.1 per cent.

10.2 Determination of Light-Weight Pieces

(Coal and Lignite)

10.2.1 Purpose

This method of test covers the procedure for determination of approximate percentage of light-weight pieces in aggregate by means of sink-float separation In a heavy liquid of suitable specific gravity.

10.2.2 Apparatus

a) Balances — For weighing fine aggregates, a balance having a capacity of not less than 500 g, sensitive to at least 0. I g; for weighing coarse aggregates, a balance having a capacity of not Iess than 5000 g, sensitive to at least 1 g.

b) Containers — Containers suitable for drying the aggregate sample, and containers suitable for holding the heavy liquid during the sink-float separation.

c) Skimmer — A piece of 300-micron sieve cloth of suitable size and shape for separating the floating pieces from the heavy liquid.

d) Hot-Plate or Oven.

10.2.3 Heavy Liquid

The heavy liquid shall consist of a mixture of carbon tetrachloride, and 1, 1, 2, 2 tetrabromoethane, bromoform, and monobrome benzene, or bromoforn and benzene (see Note 1), in such proportions that the desired specific gravity will be obtained (see Note 2). Bromotrichloromethane may be used as a heavy liquid having a specific gravity of 2.00. The specific gravity shall be maintained within ± 0.01 of the specified value at all times during the test.

Note:

i. Recovery of the bromoform in the bromoform benezene mixture can he effected by running a stream of water through mixture until all benezene has been dissolved and removed.

ii. Caution -The Chemicals listed above are highly toxic, both by absorption through the skin and by inhalation. They shall he used only in a hood, and are shall be taken to avoid contact with the skin or inhalation of the fumes.

The approximate volumes of materials to be combined to produce a mixture of the desired specific gravity may be computed from the following specific gravity of the different liquids:

Liquid	Specific Gravity
1,1,2,2 Tetrabromoethane	2.97
Benezene	0.88
Bromoform	2.88
Carbon tetrachloride	1.58
Monobromobenzene	1.49

For determining coal and lignite, the heavy liquid used shall have a specific gravity of 2.00 ± 0.01.

10.2.4 Sample

The minimum size of test sample shall he as follows:

Maximum size of Aggregate mm	Minimum weight of sample gm
6.3 (fine aggregate)	200
20	3,000
40	5,000
80	10,000

10.2.5 Procedure

10.2.5.1 Fine Aggregate

Allow the dried sample of fine aggregate to cool to room temperature and then sieve over a 300-micron Sieve until less than one percent of the retained material passes the sieve in one minute of continuous sieving. Weigh the material coarser than the 300 micron Sieve to the nearest 0.1 gm then introduce it into the heavy liquid in a suitable container, the volume of liquid being at least three times the absolute volume of the aggregate. Pour the liquid off into a second container, passing it through the skimmer and taking care that only the floating pieces are poured off with the liquid and that none of the sand is decanted onto the skimmer. Return to the first container the liquid that has been collected in the second container and, after further agitation of the sample by stirring, repeat the decanting process just described until the sample is free of floating pieces. Wash the decanted pieces contained on the skimmer in carbontetrachloride, until the heavy liquid is removed, and then dry. The pieces will dry very quickly, but may be placed in an oven at 105°C for a few minutes if desired. Brush the dry decanted pieces from the skimmer onto the balance pan and determine the weight to the nearest 0.1 gm.

10.2.5.2 Coarse Aggregate

Allow the dried sample of coarse aggregate to cool to room temperature and sieve over a 4.75 mm Sieve. Weigh the material coarser than the 4.75 in Sieve to the nearest I gm, then introduce it into the heavy liquid in a suitable container, the volume of liquid being at least three times the absolute volume of the aggregate. Using the skimmer, remove the pieces that rise to the surface, and save them. Repeatedly agitate the remaining pieces and remove the floating pieces until no additional pieces rise to the surface. Wash the decanted pieces in carbon tetrachloride until all of the heavy liquid is removed, and allow to dry.

Determine the weight of the decanted pieces to the nearest one gram.

Note:

iii. Materials, brownish black or black shall he considered as coal and lignite and shall he collected and weighed.

10.2.6 Calculations

Calculate the percentage of light weight pieces (pieces floating on the heavy liquid) as follows:-

For fine aggregate:

$$L = \frac{W1}{W2} \times 100$$

For Coarse aggregates:

$$L = \frac{W1}{W3} \times 100$$

Where

L = percentage of light-weight pieces,
W1 = dry weight in gm, of decanted pieces.
W2 = dry weight in gm., of portion of sample coarser than 300 micron Sieve, and
W3 = dry weight in gm., of portion of sample coarser than 4.75 mm Sieve

10.2.7 Reporting of Results

The percentage of light-weight pieces (coal and lignite) in the aggregate shall be reported to the nearest 0.1 percent.

10.3 Determination of Soft Particles

10.3.1 Purpose

This method of test deals with the procedure of determining the quantity of soft particles in coarse aggregates on the basis of scratch -hardness.

Note:

i. *This method is intended to be used to identify materials that are soft, including those which are so poorly bonded that the separate particles in the piece are easily detached from the mass.*
ii. *The test is not intended to identify other types of deleterious materials in aggregates.*

10.3.2 Apparatus

The apparatus shall consist of a brass rod, having a Rockwell hardness of 65 RBH to 75 RHB. A brass rod of about 1.6 mm diameter and of proper hardness inserted into the wood shaft of an ordinary lead pencil is a convenient tool for field of laboratory use.

10.3.3 Sample

Aggregates for the test shall consist of material from which the sizes finer than the 10 mm Sieve have been removed. The sample tested shall be of such size that it will yield not less than the following amounts of the different sizes, which shall be available in amounts of 10 percent or more:

Sieve. Size (Square opening sieves) mm	**Sample weight gm**
Over 10 to 12.5	200
Over 12.5 to 20	600
Over 20 to 25	1,500
Over 25 to 40	4,500
Over 40 t0 50	12,000

If the sample contains Iess than 10 percent of any of the sizes specified under Chapter 12 the size shall not he tested but, for the purpose of calculating the test results, it shall he considered to contain the same percentage of the soft particles as the average of the next smaller and the next large size or if one of these sizes is absent, it shall he considered to have the same percentage of soft particles as the next larger or next smaller size whichever is present.

10.3.4 Procedure

Each particle of aggregate under test shall be scratched with the brass rod described in para given above using only a small amount (about 1 Kg.) of pressure. Particles are considered to be soft if during the scratching process, a groove is made in them without deposition of metal from the brass rod or if separate particles are detached from the rock mass.

Note:

iii. In the case of some sandstones, brass fragments may be deposited on hard individual grains while at the same time separate particle are detached from the mass due to a week binding medium. Such particles are to be considered as soft.

10.3.5 Calculation and Report

The report shall include the following information:-

a. Weight and number of particles of each size of each sample tested with the brass rod.
b. Weight and number of particles of each sample classified as soft in the test.
c. Percentage of test sample classified as soft by weight and by number of particles, and
d. Weighed average percentage of soft particles calculated from percentage in item (c) and based on the grading of sample of aggregate received for examination or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative.

Note:

iv. In these calculations, sizes finer than the 10 mm Sieve shall not be included.

10.4 Estimation of Organic Impurities

10.4.1 Purpose

This method of test covers an approximate method of estimating whether organic compounds are present in natural sand in sufficient quantities to be harmful, and hence intended to show whether further tests are necessary or desirable.

Note:

v. Harmless organic materials may cause coloration and certain naturally occurring organic compounds do not cause coloration.

10.4.2 Apparatus

350-ml graduated clear glass medicine bottle

10.4.3 Chemicals

1. sodium hydroxide
2. tannic acid
1. The sand shall be tested as delivered and without drying.
2. A 350-ml graduated clear glass medicine bottle shall be filled to the 75-ml mark with 3 percent solution of sodium hydroxide in water.

3. The sand shall be added gradually until the volume measured by the sand layer is 125 ml.
4. The volume shall then be made up to 200 ml by adding more solution.
5. The bottle shall be stoppered and shaken vigorously and then allowed to stand for 24 hours.
6. Other tests shall be made if the color of the liquid above the sand is darker than a standard solution freshly prepared as follows:-
    a. Add 2.5 ml of 2 percent solution of tannic acid in 10 percent alcohol, to 97.5 ml of a 3 percent sodium hydroxide solution.
    b. Place in a 350 ml bottle, stopper, shake vigorously and allow to stand for 24 hours before comparison with the solution above the sand.
    c. Alternatively, an instrument or colored acetate sheets for making the comparison can be obtained, but it is desirable that these should be verified on receipt by comparison with the standard solution.

10.4.5 Report

If the color of the liquid above the sand is darker than a standard solution freshly prepared as mentioned in the procedure above, report that ‘organic compounds are present in natural sand in sufficient quantities to be harmful and further tests are necessary or desirable’.

11 Crushing Ratio

11.1 Purpose

This test method describes the procedure for determining the percentage of the crushed aggregates. Crushed aggregate means at least two faces of the aggregate should be fractured.

Crushing ratio furnishes the information which is helpful in judging the interlocking / bonding characteristics of the aggregates.

11.2 Apparatus

a. Balance
b. Sieve 4.75mm

11.3 Sample

About 2 kg of the aggregates with proper gradation as required for the work should be used.

11.4 Procedure

1. The sample should be sieved through 4.75mm sieve.
2. Take the weight of the aggregates retained on 4.75mm sieve (A).
3. Separate the crushed aggregates and uncrushed aggregates manually
4. Take the weight of the crushed aggregates (B).

11.5 Calculation

Crushing ratio = (Weight of the crushed aggregates / total weight of the aggregates) x 100

11.6 Report

Report the test result in the percentage as calculated above to the nearest whole number.

12. Degradability Test

Reference: NFP 94-067

12.1 Purpose

This test method describes the procedure for determining the resistance of the aggregates to disintegration by soaking and drying. It furnishes the information which is helpful in judging the soundness of aggregates subjected to weathering.

12.2 Apparatus

1. Oven capable to maintain the temperature of 110 ± 5^{o}C.
2. Soaking Tank
3. Sample container
4. Sieves: 20, 19, 16, 12.5, 11.2, 10, 6.3, 4.75, 2.36, 2, 1.17, 1.18, 0.6, 0.3, 0.18, 0.09, 0.075 mm
5. Balance

12.3 Sample

2 Kg of aggregates passing through 20mm sieve and retained on 10mm sieve should be thoroughly washed and dried to 110 ± 5^0 C.

12.4 Procedure

1. The prepared sample should be sieved and sieve analysis curve should be drawn.
2. Find out the diameter of the aggregates corresponding to 10 % passing [D10 (i)] from the graph.
3. Place the whole sample aggregates in the sample container and let it soak in the soaking tank for 8 hrs at room temperature.
4. After 8 hrs of soaking, take out the sample from the soaking tank and dry it in the oven at 110 ± 5^{o}C for 16 hrs.
5. After 16 hrs of drying, take out the sample from the oven. This completes one cycle of soaking and drying.
6. Repeat steps 3 to 5 as mentioned above for 3 more cycles of soaking and drying.
7. After completing 4 cycles of soaking and drying, perform the sieve analysis again and draw the sieve analysis curve.
8. Find out the diameter of the aggregates corresponding to 10% passing [D10 (f)] from the graph.

12.5 Calculation

Degradability (DG) = D10 (i) / D10 (f)

12.6 Report

Report the sample as highly degradable, moderately degradable or poorly degradable, with reference to the data given below

- **DG>20** – highly degradable
- **5<DG<20** – Moderately degradable
- **DG < 5** – poorly degradable

13. Bulk Density and voids

Reference- IS 2386 Part 3

13.1 Purpose

This method of test describes the procedures to determine the unit weight or bulk density and voids of aggregates.

13.2 Apparatus

1. Balance: A balance having sensitivity 0.5% of the weight of the sample to be taken.
2. Cylindrical Measure measures: 3.15 & 30 litres capacity, water tight with sufficiently rigidity to retain its form under rough use, as given in table 5 below.
3. Tamping Rod: A straight metal rod cylindrical cross section 16mm dia. and 60cm long rounded at one end.

Table 5: Size of Measure for Bulk Density Test

Size of largest particles	Nominal size (Litre)	Inside Diameter (cm)	Inside height (cm)	Thickness of Metal (Minimum) (mm)
4.75mm and under	3	15	17	3.15
Over 4.75mm to 40mm	15	25	30	4.00
Over 40mm	30	35	31	5.00

13.3 Calibration

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 measure. The capacity in litre shall be obtained by dividing the weight of water in kg required to fill the container at 27°C, which may be taken as 1 kg.

13.4 Procedure

13.4.1 Condition of Sample

The test shall normally be carried out on dry materials when determining the voids, but when bulking ests are required, materials with a given percentage of moisture may be used.

13.4.2 Rodded or Compacted Weight

1. Fill the measure about one third with thoroughly mixed sample aggregates and temped 25 strokes by the rounded end of the tamping rod.

2. Fill the next one third with the sample aggregates and temped 25 strokes by the rounded end of the tamping rod.
3. Fill the measure with the sample aggregates overflowing and temped 25 strokes by the rounded end of the tamping rod.
4. Struck off the surplus aggregates with the help of the tamping rod as straight edge.
5. Determine the net weight of the aggregates in the measure.
6. Calculate the bulk density in Kg per cu. m.

13.4.3 Loose Weight

1. Fill the cylindrical measure (measure) with the sample aggregates by a shovel or scoop until it is overflowing, the aggregate should not be poured into the measure from a height of more than 5 cm(from the top of the measure).
2. Sample should not be segregated
3. Level the surface of aggregate with straight edge or tamping rod
4. Determine the net weight of the aggregate in the measure
5. Calculate the bulk density in kg per cu.m.

13.5 Calculation of Voids

The percentage of voids shall be calculated as follows:

Percentage of Voids = $[(Gs - \gamma) / Gs] \times 100$

Where

Gs = Sp. Gr. of the aggregates, and

γ = Bulk density of aggregates Kg/cum

13.6 Reporting

1. The Bulk density shall be reported to the nearest 0.01 Kg/cum.
2. The percentage of voids shall be reported to the nearest to whole number.
3. The condition of aggregates should be stated like oven dry, saturated, surface dry or with a given percentage of moisture.

PART - III
TEST ON CEMENT

Table of Contents

List of Forms and Tables

1. Normal Consistency

Reference IS-4031 (Part 4)

1.1 Purpose

This method covers the test procedures to find out the consistency of standard cement paste.

1.2 Apparatus

1. Standard vicat.s apparatus.
2. Balance accuracy of 1 g

1.3 Procedure

1. Weigh accurately about 300 gms. of cement to be tested and place in a crucible.
2. Mix water, starting with 25%, with the help of a spatula for about 30 seconds. Then mix with hand for about a minute. Prepare a ball of the paste & toss it from one hand to another at least six times and then fill in the split mould of the apparatus.
3. Care should be taken to see that it is filled from large end towards shorter end and no pressure is used in filling.
4. When mould is completely filled, strike off the excess with the palm and place the larger end of the mould on the glass plate and whole assembly below the needle of 1cm dia.
5. Adjust the movable rod so that the end of the needle just touches the surface of the cement paste.
6. Take the initial reading and then immediately release the rod without jerk and allow the needle to penetrate.
7. The whole process of adding water to penetration should finish within 3 to 5 minutes.
8. The temperature of water and room should be 27°C±2° C and there should be no vibration of any type on the table.
9. The final reading is noted and the whole test is repeated with increased quantity of water till a penetration of 33 to 35 mm is obtained, which is the paste of standard consistency.

1.4 Result

The quantity of water expressed as percentage by weight of cement at which the penetration of 1 cm dia pin is 33 to 35 mm is reported as Normal Consistency of that cement.

Complete the calculation on the worksheet provided in the annex (***refer format 1: Normal Consistency of Cement***).

2. Fineness of Cement

Reference I.S. 4031 (Part 2) – 1999

2.1 Purpose

This method covers the procedures for the determination of fineness of cement. The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer the cement, faster will be the gain in strength.

2.2 Apparatus

1. Variable flow type air permeability apparatus (Blaine type) and accessories
2. Timer readable to 0.2 s
3. Balance readable to 1mg
4. Pycnometer
5. Manometer liquid
6. Mercury
7. Filter paper
8. Reference cement with known specific surface.
9. Sieve 90 micron

2.3 Methods

Two methods are used for the determination of fineness of cement.

- Sieve Test Method
- Air Permeability Method

2.3.1 Sieve Test Method

2.3.1.1 Procedure

1. Weigh correctly 100g of cement and take it on a standard IS Sieve No.9 (90 micron)
2. Break down the air-set lumps in the sample with fingers.
3. Continuously sieve the sample by giving circular and vertical motions for a period of 15 min. A sieve shaker may also be used.
4. Weigh the residue left on the sieve.
5. This residue should not be more than 10 percent, for ordinary cement.

2.3.1.2 Calculation

Complete the worksheet provided in the annex (***refer format 2: Residue Test on IS 90 Micron Sieve***).

2.3.2 Air Permeability Method

This method covers the procedures for the determination of fineness of cement as represented by specific surface expressed in total surface area in cm^2/g.

Note:

i. The values obtained are relative rather than absolute.

2.3.2.1 Test Condition

The laboratory where the air permeability test is carried out shall be maintained at a temperature of 27±2^{0}C and the relative humidity not more than 65 %.

2.3.2.2 Compacted Cement Bed

The compacted cement bed comprises a reproducible arrangement of cement particles with a specified volume of air included between the particles. This air volume is defined as a fraction of total volume of bed and is termed as porosity, e.

2.3.2.3 Preparation of Sample

Agitate the sample of cement to be tested shaking for 2 min in a stoppered jar to disperse the agglomerates, wait for 2 min and stir the resulting powder using a clean dry glass rod in order to distribute the fines throughout the cement.

2.3.2.4 Determination of Density

Determine the density of cement using the pycnometer or Le –chatelier flask and non reactive liquid to a accuracy of 0.01 g/cm3.

2.3.2.5 Formation of Bed

a. Weigh quantity of cement calculated as below to give a cement bed having porosity, e = 0.500:

$M1 = 0.500 \times \rho \times V$ (g)

Where

ρ = -density of cement (g/ cm^3) ,

V= volume of cement (cm^3)

This mass correctly compacted will produce a bed of porosity 0.500.

b. Place the perforated disc on the ledge at the bottom of the cell and place on it a new filter paper disc.

c. Ensure that the filter paper disc fully covers the perforated disc and press the filter paper with a clean dry rod to make it flat.

d. Place the weighed quantity of cement, M1 in the cell taking care to avoid loss of cement.

e. Tap the cell to level the cement.

f. Place a second new filter paper disc on the leveled surface of cement.

g. Insert the plunger to make contact with the filter paper disc.

h. Press the plunger gently but firmly so that the lower face of the cap is in contact with the cell.

i. Slowly withdraw the plunger about 5mm, rotate it through 900 and gently but firmly press the plunger once again until the plunger cap is in contact with the cell.

j. The bed is now compacted and ready for permeability test.

k. Slowly withdraw the plunger.

Note:

ii. Too rapid and vigorous pressing may change the particle size distribution and therefore change the specific surface of the bed. The maximum pressure should be that comfortably exerted by a thumb on the plunger.

2.3.2.6 Basis:

Specific surface Sw is calculated as

$$Sw = \frac{K}{\rho} \times \frac{\sqrt{e3}}{(1-e)} \times \frac{\sqrt{t}}{\sqrt{0.1\eta}} \ cm^2/g$$

Where

K is the apparatus constant
e is the porosity of the bed
t is the measured time (S)
ρ is the density of cement (g/cm^3), and
η is the viscosity of air at the test temperature with the specified porosity of e = 0.500, and temperature 27°C ± 2°C,

$$\mathbf{S = \frac{521.08 \ k \sqrt{t}}{\rho} \ (cm^2/g)}$$

The Apparatus constant can be determined from the use of Standard Cement as follows:

$$\mathbf{K = \frac{So \ \rho o \ (1 - e) \ \sqrt{0.1 \eta o}}{\sqrt{e3} \quad \sqrt{to}}}$$

Where

So = Specific surface of Standard Cement
ρo = Density of Reference Cement
to = Mean of three measured time
ηo = Air viscosity at mean of the three temperatures with e = 0.500, the equation reduces to

$$\mathbf{K = 1.414 \ So \ \rho o \ x \ \frac{\sqrt{0.1} \ \ \eta o}{\sqrt{to}}}$$

2.3.2.7 Procedure

a. Insert conical surface of the cell into the socket at the top of the manometer ensuring airtight joint but without disturbing the cement bed.
b. Close the top of the cylinder with a suitable plug.
c. Open the stopcock and with gentle aspiration raise the level of the level of the manometer liquid to that of the highest etched line.
d. Close the stopcock and observe that the level of manometer remains constant.

e. If it falls, remake the cell manometer joint and check the stopcock, repeat the leakage test until the improved sealing produces steady level of liquid.

f. Open the stopcock and with gentle aspiration adjust the level of liquid to that of highest etched line.

g. Close the stopcock and remove the plug from the top of the cylinder.

h. The manometer liquid level will start to flow.

i. Start the timer when the liquid reaches the second etched line.

j. Stop the timer when the liquid reaches the third etched line.

k. Record the time t, nearest 0.2 s and the temperature nearest to 1°C.

l. Repeat the procedure a to k on the same bed and record the additional values of time and temperature.

m. Prepare a fresh bed of same cement with a second sample following the procedure as stated above in Formation of Bed. In case, there is no second sample available, break the used sample bed and prepare a new bed as stated above in Formation of Bed.

n. Carry out the permeability test twice on the second bed and record the time and temperature as before.

2.3.2.8 Calculation

Calculate the Specific Surface of the cement using the above equations mentioned above in Basis.

2.3.2.9 Report

Where the porosity of cement e = 0.500, the four times and temperatures resulting from the procedures as mentioned above shall be checked for the temperature fall within the range of 27°C ± 2°C. The resulting value of S shall be reported nearest to the 10 cm^2/g as the Specific Surface of the cement.

3. Soundness of Cement

Reference I.S. 4031 (Part3) - 1988

3.1 Purpose

The testing of soundness of cement is done to ensure that the cement does not show any appreciable subsequent expansion. The non soundness of cement is due to the presence of excess of lime, excess of magnesia or excessive proportion of sulphates.

3.2 Requirements

Soundness of cement can be determined by two methods, namely Le-Chatelier method and Autoclave method. The unaerated cement should not have an expansion of more than 10 mm and 0.8 percent respectively when tested by the two methods. In the event of cements failing to comply with any or both the requirements mentioned above, further tests would be undertaken on another portion of the same sample after aeration. Aeration shall be done by spreading out the sample to a depth of 75 mm at a relative humidity of 50 to 80% for a total of 7 days. The expansion of cements 80% aerated shall be not more than 5 mm and 0.6% when tested by Le-Chatelier and Autoclave method respectively.

3.3 Method 1: Le-Chatelier Method

3.3.1 Procedure

1. Prepare a cement paste by gauging cement with 0.78 times the water required to give a paste of standard consistency.
2. Oil the mould lightly. Keep it on a lightly oiled glass plate and fill up the mould with cement paste.
3. Cover the mould with another piece of lightly oiled glass sheet and immediately submerge the whole assembly in water at 27+ 2^{o}C and keep it there for 24 h.
4. Measure the distance separating the indicator points. Submerge the mould again in water and bring it to boil in 25-30 minutes. Keep it boiling for 3 hours. Remove the mould from water and allow it to cool.
5. Measure the distance between the indicator points. Difference between two measurements gives the expansion of cement.
6. Repeat the procedures 2 to 5 above to test for another sample.

Calculate the mean of the two values obtained as above and report to nearest of 0.5mm as the soundness of the cement (Refer Form1: Soundness of Cement by Le- Chatelier's Method, given below).

Form 1: Soundness of Cement by Le- Chatelier's Method

Specimen No.	**Wt. of cement (g)**	**Distance separating the indicator point (mm)**		**Soundness of cement =(B) – (A) (mm)**	**Mean value**
		Before submergence (A)	After submergence (B)		
1					
2					

4. Initial and Final Setting Time of Cement

Reference : I.S. 4032 (Part 5) – 1988

4.1 Purpose

Cement, when used in construction, should set in a reasonable time. It should not set too early, so that it can be transported to the place where it is to be placed. Also it should not take too long for setting, so that the formworks can be removed and further work started.

4.2 Apparatus

Standard Vicat apparatus with a needle of 1 mm2 (diameter 1.13 ± 0.05 mm), a plunger of 10 ± 0.05 mm in diameter and the Vicat mould of truncated conical form with an internal diameter of 70 ±5 mm at the top, 80 ± 5 mm at the bottom and a height 40 ± 0.2 mm.

4.3 Procedure

1. Prepare a neat cement paste by mixing the cement with 0.85 times the water required to give a paste of standard consistency, using potable or distilled water.
2. Start a stop watch at the instant when water is added to the cement.
3. Fill the Vicat mould with the cement paste, the mould resting on a non-porous plate.
4. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould.
5. 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.
6. In the beginning, the needle will completely pierce the 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.
7. The period elapsing between the 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 measured from the bottom, is called the initial setting time.

4.4 Final Setting time

1. Replace the needle by the annular attachment.
2. The cement shall be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression, thereon, while the annular attachment fails to do so.
3. The period elapsing between the time when water is added to the cement and the time when cement is finally set as indicated above, shall be the final setting time.
4. In the event of a scum forming on the surface of the test block, use the underside of the block for the determination.

4.5 Report

The Initial and Final setting times shall be reported to the nearest 5 minutes.

Complete the worksheet provided in the annex (*refer form 2 below, or refer in Annex format 3: Time of Setting of Cement by Vicat Needle*).

Form 2: Setting Time of Cement

S. N.	Starting time (Stop watch) (S) T0	Time when Initial setting time taken place (S) T1	Time when Final setting time taken place (S) T2

Initial Setting Time = T1 - T0
Final Setting Time = T2 - T0

5. Compressive Strength of Cement

Reference : I.S. 4031 (Part 6) - 1988

5.1 Purpose

This method of test provides the procedures for determining the strength of cement represented by the Compressive strength test on mortar cubes compacted by means of standard vibration machine.

The compressive strength of hardened cement is the most important property as it controls the mix design. Strength tests are not conducted on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking. Strength of cement is therefore found indirectly, by testing cement mortar in a specific proportion.

5.2 Apparatus

1. Vibration machine
2. Poking rod
3. Cube Mould 70.6 mm size
4. Gauging Trowel
5. Balance
6. Graduated Glass cylinders

5.3 Standard Sand

The standard sand shall be of quartz, light grey or whitish variety free from silt, shall pass 100 percent through 2mm sieve and retain 100 percent on 90 micron sieve, as given in table below:

Table 1: Sieve Analysis of Standard Sand

Passing on Sieve	Retain on sieve	Percentage
2 mm	1mm	33.33
1mm	500 Micron	33.33
500 Micron	90 Micron	33.33

5.4 Procedure

1. Take 200 g of Cement and 600 g of Standard Sand (conforming IS 650) in a non-porous enamel tray and mix them with a trowel for one minute, then add water equal to (P/4 + 3.5) percent of combined weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour. The time of mixing should not be less than 3 min.
2. Immediately after mixing, the mixture is filled into 9 cube moulds of 7.06cm; the area of each face being 50 sq.cm.
3. Compact the mortar either by placing it on the vibrating table for two minutes at the specified speed of 12000± 400 vibrations per min.

4. Keep the compacted cubes in the mould at a temperature of 27^{0}C ± 2^{0}C and at least 90 percent humidity for 24 h.
5. At the end of 24 h, remove the moulds and immediately submerge them in clean fresh water and keep them there until taken out just before conducting the test.
6. Test three cubes each for compressive strength after 3 days, 7 days and 28 days. The cubes shall be tested on their sides without any packing. The rate of loading shall be 35 N/mm^2 per min.
7. The compressive strength is calculated by dividing the maximum load applied to the cubes during the test divided by the cross sectional area and reported to nearest 0.5 N/mm^2.
8. In determining compressive strength, do not consider specimens that are manifestly faulty, or that give strengths differing by more than 10 % from the average value of all the test specimens.
9. After discarding specimens or strength values, if less than two strength values are left for determining the compressive strength at any given period, a re-test shall be made.

Form 3: Compressive Strength of Cement

S.N.	**Compressive strength after 3 days/7 days**				**Compressive strength after 28 days**			
	Observation			**Average Strength**	**Observation**			**Average Strength**
	Plan Area (A) mm^2	**Load at failure (W) N**	**Compressive strength (N/ mm^2)**		**Plan Area (A) mm^2**	**Load at failure (W) N**	**Compress ive strength (N/ mm^2)**	

5.5 Calculation

Complete the worksheet provided in the annex (refer Format 4: Cube Test for Cement Mortar) or Form 3 provided above.

6. Annexes

6.1 Test format for Cement

Format 1: Normal Consistency of Cement

Nepal Government
Ministry of Physical Infrastructure and Transport
Department of Roads
Central Road Laboratory
Normal Consistency of Cement

IS 4031

Office/Project ______________

Operator ________________

Date __________________

Sample No ________________________________

Cement Brand:-

	Determination Number	1	2	3	4	
	Temp. of Laboratory (27±2^{o}C)					
	Temp. of Mixing Water (27±2^{o}C)					
A	Wt. of Cement (650g)					
B	Wt. of Water Added					
C	Penetration of Plunger from bottom of mould					

Water/Cement Ratio = $\frac{D}{A}$ x 100% ___________ x 100%

Reported Water/Cement Ratio = % ___________ 100%

Tested By: Approved By:

Format 2: Residue test on IS 90 Micron Sieve

Ministry of Physical Infrastructure and Transport
Department of Roads
Central Road Laboratory
Chakupat, Lalitpur

RESIDUE TEST ON IS 90 MICRON SIEVE

Project
Sample Type
Cement
Grade

Operator
Date
Sample No.

SN	Description	Result Obtained				Remarks
	Sample no.					
1	Original wt. of Cement (gm)					
2	wt. retained on IS 90 micron Sieve (gm)					
3	wt. passing IS 90 micron Sieve (gm)					
4	% retained on IS 90 micron Sieve					
5	Reported Residue test on IS 90 micron Sieve %					

Tested by

Checked by

Approved by

Format 3: Time of Setting of Cement by Vicat Needle

Nepal Government
Ministry of Physical Infrastructure and Transport
Department of Roads
Central Road Laboratory
Time of Setting of Cement bby Vicat Needle

Office/Project

Operator

Date

Cement Brand:- Sample No:-

	Wt. Cement		Gms
	Water/Cement ratio		%
	Wt. of Mixing Water		M
	Temp. of Mixing Water (27±2°C)		°C

	Determination Number	1	2	3	4	5	6	
T.	Time After Moulding							MN
	Temp of Lab (27±2°C)							°C
D.	Penetration of Needle from bottom of mould							mm

	Determination Number	7	8	9	10	11	12	
T.	Time After Moulding							MN
	Temp of Lab (27±2°C)							°C
D.	Penetration of Needle from bottom of mould							mm

Plot Graph of D Agniest T (on Cantinussion Chest)

Extra determinations may be recorded on Continuation Sheets.

Tested by Checked by

Format 4: Cube Test for Cement Mortar

Nepal Government
Ministry of Physical Infrastructure and Transport
Department of Roads

Central Road Laboratory

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CUBE TEST FOR CEMENT MORTAR

Operator : ______________________ Project: ______________________
Date : ______________________ Sample No: ______________________

Preparation

Wt. of Cement used		gm
Wt. of Dry Sand used		gm
Vol. of Water used		ml
Compaction Tamping or Vibration		

Test

	Cube Number	1	2	3	
L	Length of Cube				mm
B	Breadth of Cube				mm
H	Height of Cube				mm
V	Volume of Cubes = (LxBxH0 + 10^2				M^3
A	Weight of Cube				kg
D	Density of Mortar = A ÷ V				kg/m^3
	Age of Cube at Test				DAYS
M	Maximum Load				KN
	Cube Strength = (M÷ [LxB]) x 1000	C1=	C2=	C3=	N/mm^2
	Average Cube Strength				N/mm^2

PART - IV
TEST ON CONCRETE

Table of Contents

1. Slump of Concrete

BS 1881 Part 102.

1.1 Purpose

This method gives the procedure for determining the slump of concrete.

Notes:

i. This gives an indication of WORKABILITY i.e. how easy the concrete will compact around reinforcement etc.

ii. If the slump varies a lot from that expected from the mix design, then a redesign of the amounts of aggregate, cement and water may be necessary.

1.2 Apparatus

1. Mould, Scoop, 16 mm diameter tamping rod, metal tray and metal ruler

1.3 Sample Preparation

1. A representative sample shall be obtained and mixed thoroughly.
2. Care shall be taken to prevent loss of moisture from the concrete and not to expose the concrete to high temperatures.

1.4 Test Procedure

1. Place the metal tray on a flat solid surface so that no movement
2. Ensure the inside of the mould is clean and dampen it lightly with a wet cloth.
3. Place the mould on the base plate, hold it firmly in place by standing on foot pieces and fill it in 3 equal layers, each layer being tamped 25 times.

Notes:

iii. Expect for the bottoms layer, the tamping rod shall be plunged through each layer and just penetrate the lower layer.

iv. On the top layer, heap the concrete above the mould before tamping and, if necessary, add further concrete to keep the concrete above the mould as tamping is carried out.

4. After tamping, Strike off excess concrete with the tamping rod and clean away concrete from the base of the mould.
5. Push down with hands on handles and remove the feet from the foot pieces.
6. With a slow and steady vertical motion remove the mould taking between 5 and 10 seconds.

Notes:

v. The entire test from start of filling to removal of mould should be completed within 2 ½ minutes

7. Set the mould beside the sample and lay the tamping rod across the top of the mould so that it extends over the slumped concrete.
8. Measure from the bottom edge of the rod to the highest point of the slumped concrete to the nearest 5 mm.

Note:

vi. The test is only valid if it yields a true slump. If the sample shears or collapses take another sample and repeat the test. If this sample does not give a true slump, then report that slump is not obtainable.

1.5 Calculation

The true slump is that recorded in step 8 above to the nearest 5 mm.

2. Density, Yield and Cement Content of Concrete

BS -1881 Part 107

2.1 Purpose

This method gives the procedure for determining

a) Density of freshly mixed concrete
b) The yield- volume of concrete/ unit wt of cement
c) Cement content- wt cement/unit vol of concrete.
d) Volume of concrete/batch

2.2 Apparatus

1. Balance - capacity 50 kg, accuracy 10g or better.
2. Watertight rigid cylindrical metal measure of normal volume 0.0Im3 (1/3 ft3)
3. Concrete poker vibrator
4. Straight edge
5. Steel float
6. Steel sample tray

2.3 Calibration of Measure

1. Weigh the empty measure in kg (W1)
2. Place in on the horizontal scale pan and fill with water so that no meniscus is above the rim.
3. Record the weight of measure full of water in Kg(W2)
4. Calculate the volume of the measure by dividing, the weight of water by 1000 kg/m^3. Record the volume to the nearest 0.00001 m^3.
   $V = (W2 – W1)/1000$ m^3

2.4 Sample Preparation

1. Empty the sample onto the sample tray and mix thoroughly.
2. Fill the measure in 6 equal layers and compact each laver carefully with the poker vibrator.

Notes:

i. Vibration should stop when the surface of each layer becomes smooth and has a glazed look.

ii. Remove the poker slowly from the concrete to avoid getting "hole".

3. After the top layer has been compacted, smooth and level with the top of measure, using the steel float and straight edge.
4. Wipe clean the outside of the container. Weigh and record the weight in kg (W3).

2.5 Calculations

Density of Concrete = W3 /V kg/ m^3

3. Mixing of Concrete Using a Drum Mixer

BS -1881 Part 125

3.1 Purpose

This method provides the procedure for mixing of concrete using a drum mixer.

3.2 Apparatus

1. Drum Mixer
2. Sample Tray

3.3 Materials

1. Cement
    a. Should be stored in a dry place.
    b. If the cement is “old” there is a danger that it may have no strength
2. Aggregates shall be either
    a. Oven dry
    b. Air dry
    c. Saturated surface dry, or
    d. Saturated by soaking in water for 24 hrs.
3. All materials should be between 15^0C and 25^0C before mixing in concrete.
4. The quantity of concrete in each batch shall be at least 10% more than required for the tests. (see step I below)

3.4 Mixing

1. The quantity of concrete in the batch shall be between 50 % and 90 % of the rated capacity of mixer.
2. Before using the mixer, clean out any fresh concrete remaining from an earlier batch and remove free water with a damp cloth.
3. Using dry aggregates
    a. Add1/2 the coarse aggregate to the drum
    b. Add all the fine aggregate.
    c. Add the rest of the coarse aggregate
    d. Run mixer for between l5 and 30 seconds
    e. Continue mixing and add about 1/2 the water
    f. After 3 minutes mixing, stop the mixer and leave concrete for 15 minutes.
    g. Add all the cement and mix for 30 second then add the remaining water.
    h. Continue mixing for between 2 and 3 minutes.
    i. Discharge the concrete on to a sample tray.
4. Using saturated aggregates
    a. Add 1/2 the coarse aggregate to the drum
    b. Add all the fine aggregate
    c. Add all the cement.
    d. Add the rest of the coarse aggregates
    e. Start the mixer and add all the water during the first 30 second of mixing.
    f. Continue mixing for between 2 and 3 minutes.
    g. Discharge the concrete on to a sample tray

4. Making Test Cubes from Fresh Concrete

BS-1881 part 108

4.1 Purpose

This method gives the procedure for making test cubes from fresh concrete.

Notes:

Test cubes should be either

i. 100 mm for maximum aggregate size of 20 mm

Or

ii. 150 mm for maximum aggregate size of 40mm

4.2 Apparatus

1. MOULD - Usually 6 No. are required for each sample tested i.e. 3 No to be tested at 7 days and 3 No at 28 days.
2. Tamping bar (25mm sq.) or vibrating hammer.
3. Steel float
4. Sample tray
5. Curing tank

4.3 Sample Preparation

1. Obtain a fresh sample of concrete and empty into the sample tray.
2. Thoroughly mix the sample.

4.4 Procedure

1. Make sure each mould is clean, tightly bolted together and all internal faces thinly coated with oil.
2. Fill the mould in 3 layers and compact each layer by either.

a. Tamping 35 strokes/layer for 150mm cubes

b. Tamping 25 strokes/layer for 100mm cubes

3. Vibrating each layer until the surface of the concrete becomes smooth and glassy.
4. After the top layer has been compacted smooth its level with the top of the mould and wipe clean the outside of the mould.
5. Store the cubes in their moulds on the floor, cover them with damp sacks and cover them all with polythene.
6. After 24 hours remove the cubes from the moulds and mark each cube (PERMANENT INK) with sample No/code No.
7. Submerge each cube in the curing tank until just before testing.

Notes:

iii. The tank should contain clean water, which is chanced once a month.

iv. The temperature should be kept between 18^{0}C and 22^{0}C.

5. Cube Test for Hardened Concrete

BS-1881 Part 116

5.1 Purpose

This method gives the procedure for testing hardened concrete cubes.

5.2 Apparatus

Compression testing machine

5.3 Test Procedure

1. Do not test cubes which have been made in badly assembled moulds or which are clearly misshaped.
2. Remove any projecting fins from each cube
3. Weigh each cube
4. Measure the dimensions of each cube.
5. Immerse in water for at least 5 minutes those cubes which have not been cured in water or those cubes where surfaces have dried.
6. Clean the bearing surfaces of the testing machine and clean any loose grit from the two surfaces of the cube which will be loaded.
7. Remove a cube from the water tank and test while still wet.
8. Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite CAST faces of the cube.
9. Apply the load continuously at the following rates

a. Between 2 KN/second and 4 KN/second for 100mm cubes

b. Between 4.5 KN/second and 9 KN /second for 150rnm cubes.

Note:

i. This is achieved by setting the flow control valve to the appropriate value.

10. Record the maximum load applied to the cube.
11. Record the type of failure.

5.4 Calculations

Complete the worksheet as per the sample given in Form 1 in annex.

6. Making Test Beams from Fresh Concrete

BS 1881

6.1 Purpose

This method gives the procedure for making test beams from fresh concrete.

Note:

i. Test beams should be 150mm X 150mm X 750mm long.

6.2 Apparatus

1. Mould
2. Tamping bar (25mm sq) or vibrating hammer
3. Steel float.
4. Sample tray
5. Curing tank

6.3 Sample Preparation

1. Obtain a fresh sample of concrete and thoroughly mix it on the sample tray.

6.4 Procedure

1. Make sure each mould is clean, tightly bolted together and all internal faces thinly coated with oil.
2. Fill the mould in layers approximately 50mm deep and compact each layers by either a) tamping 150 strokes/layer, or b) vibrating each layer until the surface of the concrete becomes smooth and glassy.
3. After the top layer has been compacted, smooth it level with the top of the mould and wipe clean the outside of the mould.
4. Store the beams in their moulds on the floor. Cover them with damp sacks and cover them all with polythene.
5. After 24 hours, remove the beams from the moulds and mark each beam (PERMANENT INK) with a sample No/code No.
6. Submerge each beam in the curing tank until just before testing.

Notes:

ii. The tank should contain clean water which is changed once a month.

iii. The temperature should be kept between 18^0C and 22^0C.

7. Beam Test for Concrete

BS1881 -117

7.1 Purpose

This method gives the procedure for testing hardened concrete beam.

Note:

i. This test determines the tensile strength of concrete in bending - termed the"Flexural Strength".

7.2 Apparatus

1. Flexure testing machine
2. The distance between the upper rollers is 150 mm and the distance between the lower rollers is 45mm.

7.3 Test Procedure

1. Remove any projection fins from the beam
2. Weigh the beam
3. Measure the beam dimensions.
4. A beam stored in water shall be tested immediately on removal from the water whilst still wet.
5. If a beam has been out of water for more than 15 minutes then it must be immersed in water for at least another 12 hours before testing.
6. Clean the bearing surfaces of the rollers and wipe surface water and grit off the beam.
7. Place the beam in the machine correctly centered so that the rollers bear onto the cast sides of the beam.
8. Apply the load continuously at a rate of 450N/second until the beam breaks.
9. Record the maximum load as the breaking load.
10. Only record failures which occur between the inner rollers.

7.4 Calculations

The flexural strength fct (in N/mn^2) is given by the equation

$\mathbf{f_{ct} = (F \times L)/d_1 \times d_2^2}$

Where,

F = breaking load (in N)

d_1 = width of the beam (in mm)= 150 mm

d_2 = depth of the beam (in mm) = 150 mm

L = distance between supporting rollers (in mm)= 45mm

8. Strength of Concrete by Rebound Hammer

BS1881-202

8.1 Purpose

This method gives the procedure to obtain the concrete strength by rebound hammer.

Notes:

i. *The rebound hammer measures the hardness of the concrete surface i.e. to a depth of approximately 30mm.*

ii. *Surface hardness can be related to concrete cube strength (see method of correlation - separate sheets).*

iii. *The hammer should be checked regularly on the reference anvil (see - separate sheet).*

8.2 Apparatus

1. Concrete test hammer

8.3 How to Use the Hammer

1. When the hammer is inside the carrying case, the plunger head (1) is almost totally inside the housing, To eject the plunger, press the plunger head (ii) against a hard surface until it is released
2. To obtain a reading:

a. Rest the plunger head (ii) at right angles to the surface to be tested,

b. Press the hammer smoothly against the surface until the internal hammer (7) strikes.

c. After striking, the hammer (7) rebounds moving the reference pointer (6) with it. (The harder the concrete the more the pointer moves)

d. Keeping the hammer pressed against the surface, press the Push button (19) - this keeps the reference pointer (6) fixed at the correct value and allows the reading to be taken.

8.4 Test Area Selection

1. If possible test verticals surfaces.
2. Avoid testing parts of a structure less than 10 cm thick.
3. At each point where the strength is required an area of about 20 cm X 20cm requires to be cleaned and smooth.

a. Remove any plaster covering the concrete

b. Smooth uneven surfaces using the carhorundum stone supplied with the hammer.

c. Old (and therefore hardened) concrete needs to be ground down to a depth of 10mm (use a grinding wheel).

d. Rough surfaces resulting from incomplete compaction, loss of grout, spalling or fooled surfaces should not be tested.

4. The moisture condition of the surface should be the same as for correlation.

Note:

iv. *The surface should be dry. Provided surface water is wiped from the concrete, saturated concrete can be tested.*

5. At each area to be tested

a. No point should be closer than 25mm to the edge of the area.
b. No point should be closer than 25 mm to any other point.
c. No point should be tested more than once.

8.5 Calculations

1. The average reading is calculated using all readings including very high and very low readings, unless there is a good reason to about a particular reading.
2. To obtain the concrete strength either
   a. Use the calibration obtained experimentally (if any).
   b. Use the manufacture’s calibration.

9. Checking Concrete Rebound Hammer Using Reference Anvil

9.1 Purpose

This method provides procedure for checking rebound hammer using reference anvil.

Note:

i. The hammer should be checked regularly.

9.2 Apparatus

1. Calibration anvil

9.3 Test procedure

1. Place the anvil on the concrete floor.
2. Insert the hammer into the seat and take a reading.
3. If properly working the reading should be between 78 and 82
4. If the reading is below 78 the hammer will probably need cleaning (see manufacturer's booklet).
5. If, after cleaning the hammer still records below 78 then either.
   a. Use central lab calibration for hammer in this condition.

or

   b. Use controls calibration but adjust the results as follow.

$$R = \frac{S}{n} \times \frac{80}{Ra}$$

where:

R = corrected hammer reading
S = sum of the readings taken at a point
n = number of readings taken (usually 10)
Ra = the hammer reading on the anvil (i.e. below 78)

10. Correlation between Concrete Strength and Rebound Number

10.1 Purpose

This method provides procedure for correlation between concrete strength and rebound number.

Notes:

i. The easiest way is to obtain the rebound number of a cube and then to crush the cube.

ii. Cubes with varied mix proportions to give different strength should be tested.

10.2 Test Procedure

1. Take a 150mm cube and place it in the compression machine as for a cube test with 2 cast faces being accessible for testing by the rebound hammer.
2. Apply a load of 190 KN to the cube.
3. Take 9 hammer readings on each of the 2 cast faces that are accessible.
   a. The points of impact should not be nearer than 20mm to an edge
   b. The points of impact should not be nearer than 20mm to each other.
   c. The same point should not be struck more than once
4. Crush the cube and determine the cube strength.
5. Draw a graph of average reading against cube strength.

11. Making Test Cubes of Cement Mortar

BS12

11.1 Purpose

This method provides procedure for making test cubes of cement mortar.

11.2 Apparatus

1. Scales - 2 kg capacity with an accuracy of 1 cm.
2. Measuring cylinders - 200 ml capacity with an accuracy of 2ml.
3. Specimen moulds - at least 3 No
4. Mortar mixer, bowl and paddle
5. Vibration machine for cement mortar cube moulds
6. Steel Straight edge.
7. Storage tank for mortar cubes. The tank contains clean water at 20°C.

11.3 Temperature and Humidity

1. The temperature of the laboratory should be between 20°C and 27.5°C.
2. The temperature of the mixing water, moist closet and water in the storage tank should be between 19°c and 21°c.
3. The humidity of the laboratory should be greater than 50%.
4. The humidity of the moist closet should be greater than 95%.

11.4 Preparation of Cubes

1. Make sure that the cube moulds and base plates are clean. Three cubes should be cast for each test.
2. Coat the interior faces of the Moulds thinly with oil as well as the top surface of the base-plates.
3. Mix the mortar using 555 gms cement for 3 cubes. (1:3 by wt)
   1665 gms standard sand
   222 gms water or give flow =110 (w/c=0.40)
   a. Assemble the mixing bowl and paddle.
   b. Place all the water in the bowl.
   c. Add all the cement to the water and mix at slow speed for 30 seconds.
   d. Add all the sand gradually over the next 30 seconds whilst still mixing at slow speed.
   e. Stop the mixer and change to medium speed and mix for 30 seconds.
   f. Stop the mixer and let the mortar stand for 1 1/2 minutes. During the first 15 seconds of this time scrape down any mortar sticking to the sides of the bowl.
   g. Finish by mixing for 1 minute at medium speed.
4. Clamp a mould and base-plate securely in the vice.

5. The mould, base-plate and vice are now inserted in the vibration machine and the two clamp nuts (at the top of the vibration unit) are tightened.
6. Place mortar in the mould by way of the hopper (above the mould).
7. Switch on the vibration machine and vibrate for 2 minutes keeping adding mortar to the hopper to keep the mould full.
8. Remove the vice and mould from the machine and trim the mortar flush with the top of the mould.
9. Carefully remove the mould and base-plate from the wire and store the cube in its mould and base-plate in a moist closet for 24 hour.
10. After 24 hours remove the cubes from the moulds and store them in the water tank until ready for testing.

12. Ultrasonic Concrete Tester

BS1881

12.1 Setting-up and Calibration

12.1.1 Purpose

This method provides procedure for setting –up and calibration of ultrasonic concrete tester.

Notes:

i. *The speed which high frequency vibrations travel through concrete depends on many variables; density is a major factor.*

ii. *Strength is related to density so this tester gives a useful NON-DESTRUCTIVE Method of determining concrete strength.*

12.1.2 Apparatus

1. Ultrasonic concrete tester

12.1.3 Setting Up

1. Fit a cable to each of the heads using the bayonet sockets (plug in and give a slight turn to the socket ring).
2. Take one cable and fit the free end into the “emitter” socket on top of the control panel.
3. Take the other cable and fit the free end into the “receiver” socket on top of the control panel.
4. Switch on the power and the number 8888.8 should appear in the display window.

a. If this number does not appear then the battery will need recharging (see below).

b. The heads should be kept well apart because if they get too close, the vibrations will be omitted and received through the air.

12.1.4 Calibration

1. This operation is best carried out by 2 people
2. Apply a thin coating of contact paste to the two heads and to both ends of the calibrating bar.
3. The contact paste supplied is a petroleum jelly but grease, soft soap and glycerin paste can also be used. Staining may be a problem.
4. Place one head on the bench, put the Calibration bar vertically on it and the second head at the top.
5. Press together firmly and take the reading on the display.
6. The reading should be the same as the number stamped on the side of the calibration bar.
7. If the reading is not the same, insert a thin screw-driver in the hole marked “Zero” and turn slowly until the reading coincides with the number on the calibration bar.
8. The tester is now calibrated.

12.1.5 Recharging Battery

1. The tester will work continuously for about 8 hours on one charging of the battery.
2. To recharge the battery, connect the recharging cable to its socket and plug it into the mains

supply for 10 hours.

12.2 Measuring Pulse Velocity

12.2.1 Purpose

This method provides procedure for measuring pulse velocity using ultrasonic concrete tester.

Notes:

i. *The pulse velocity V is given by:*

V = L / T

Where

L= *path length taken by the pulse (vibration)*

T= *time taken by the pulse (vibration) to travel the path length.*

ii. *The path length should be measured directly or indirectly. If these methods are not possible then the nominal dimension may be used but be careful as this can lead to error*

iii. *The minimum path length is 100 mm for direct transmission 150 mm for indirect transmission*

iv. *The maximum path length is 1500 mm.*

12.2.2 Transducer Arrangement

1. Pulse velocity may be measured by placing, the heads on either
    a. opposite faces of the concrete (direct transmission)
    b. adjacent faces of the concrete (semi-direct transmission)
    c. the same face of the concrete (indirect transmission)
2. The best arrangement is the direct method.
3. In direct transmission is used when
    a. only one face of the concrete is accessible
    b. the depth of a surface crack is to be found
    c. the quality of the surface concrete is to be found.
4. With indirect transmission, the path length is not certain. It is therefore best to
    a. Put the transmission head in contact with the concrete and keep it at the same position throughout the test.
    b. Put the receiving head at fixed intervals (say 150 mm) along chosen line on the surface.
    c. The times recorded at each point are plotted on a graph of distance against time. The slope of the best line joining the points gives the pulse velocity.

Note:

v. *Be careful of discontinuities which can indicate cracks or weak surface layers.*

5. The heads must be seated with good contact with the concrete,
    a. Where possible place the heads in contact with cast surface.
    b. Only a small amount of contact paste spread thinly and press the heads firmly against the concrete.
    c. Smooth off rough areas of concrete.

12.2.3 Shape and Size of Specimen

1. The minimum allowable LATERAL dimension of the concrete is 80mm.
    a. This is a dimension at right angles to the direction of travel of the vibration.

12.2.4 Effect of Reinforcement

1. Bars parallel to path length.
    a. 6mm diameter bars will have no effect on the pulse velocity.
    b. For larger diameter bars do not take measurements points where ‘a’ is less than 0.25 L (Use the Reinforcement Detection Meter)

Where,

a = the offset, measured as the distance from the surface of the bar to the line joining the nearest point of the two transducers (in mm)

L= the length of the direct path between the transducers (in mm)

2. Bars at right angles to path length
    a. The effect of these bars can be ignored.

12.3 Correlation of Pulse Velocity and Strength

12.3.1 Purpose

This method provides procedure for correlation of pulse velocity and strength of concrete while using ultrasonic concrete tester.

12.3.2 Procedure

1. The relationship between pulse velocity and strength depends on
    a. Method of curing
    b. Age
    c. Moisture condition
    d. Mix proportions
    e. Type of aggregate
    f. Type of cement.
2. Concrete cubes are cast with the same mix proportions. aggregates, cement and method of curing as the concrete to be tested in-situ.
3. A number of cubes are cast for each water/cement ratio to be tested.
4. The cubes are cured in the same way as the concrete in-situ.
5. For each cube the pulse velocity is measured at 4 No. points spaced no closer than 40 mm to any edge.
6. For each cube determine the cube strength.
7. Plot the graph of average pulse velocity against average cube strength for each set of 3 cubes.

12.4 Uniformity of Concrete

12.4.1 Purpose

This method provides procedure for checking uniformity of concrete using ultrasonic concrete tester.

12.4.2 Procedure

1. Variations in pulse velocity can indicate changes in concrete quality.
2. The unit to be tested is marked off in a square grid and the pulse velocity found at each intersection point of the grid.
    a. A large unit would be tested on a 1m grid where a small unit would require a finer grid.
3. When tested large areas of concrete e.g. walls and slabs where only one face is accessible then the measurements will be made by indirect transmission. In this case the path length can be kept constant and the measured time can be used to assess uniformity without converting to pulse velocity.

Notes:

i. Be careful of discontinuities which may indicate surface cracks.

ii. Be careful of reinforcement- see instructions on measuring pulse velocity.

12.5 Thickness of surface layers of weak concrete

12.5.1 Purpose

This method provides procedure for checking Thickness of surface layers of weak concrete using ultrasonic concrete tester.

Note:

i. Concrete may have a weak surface layer. This can be caused by:

a. Poor concreting techniques

b. Fire damage

c. Frost damage

d. Sulphate attack.

12.5.2 Procedure

1. The pulse velocity will be lower in the weak surface layer than in the stronger main mass of the concrete.
2. To find the thickness of the weak surface layer Indirect (surface) transmission is used.
    a. Put the transmitter head in contact with the concrete and keep it at the same position throughout the test.
    b. Put the receiving head at fixed intervals (say 500 mm) along a chosen line on the surface.
    c. The times recorded at each point are plotted on a distance/time graph.
3. When the heads are closer together the pulse (vibration) travels through the surface layer. The slope of the graph (at first) gives the pulse velocity in the surface layer.
4. As the heads move further apart, there comes a point where the pulse (vibration) starts to travel through the underlying (higher quality) concrete. The pulse velocity will therefore increase and therefore the slope of the graph will increase.

12.5.3 Calculation

The thickness of the surface layer is found by

$$T = X0 / 2 \sqrt{[(VS-VD)/ (VS + VD)]}$$

Where

T = thickness of the surface layer (mm)

X 0 = distance (mm) at which the slope changes

VD = pulse velocity in surface layer (km/s)

VS = pulse velocity in sound underlying Concrete (km/s)

12.6 Depth of a Surface Crack

12.6.1 Purpose

This method provides procedure for checking Depth of a Surface Crack using ultrasonic concrete tester.

12.6.2 Procedure

1. The transmitter head is placed at 2.5 y (say 375 mm) from the center of the crack.
2. Three (if possible more) readings of the time are taken at distances of Y (150mm), 2Y (300mm), 3Y (450mm) and so on. The distances are measured from the transmitter head in the direction of the crack.
3. The readings are plotted.
4. If the straight through the first 2 readings passes through 0, there are no hidden cracks and the depth of the visible crack is given by:

$$C = Y /2 \sqrt{ [\{ (2T_2^2 + 3\, T_2^2) / (T_2 \times T_3)\}^2 - 25]}$$

Where

T_2 = time for distance 2Y (300mm)

T_3 = time for distance 3Y (450mm)

13. Steel Reinforcement Detector

BS 1881

13.1 Purpose

This method provides procedure for detecting steel bar using steel reinforcement detector.

13.2 Apparatus

1. Detection meter

13.3 Procedure

1. Check that the. 9 volt battery is fitted and connected.
2. Plug detector head cable into socket on panel.
3. Rotate switch on instrument panel to “Test Batt.”
    a. The meter needle should swing to the right and lie within 2 cm of the right-hand end of the scale.
    b. If it does not, the battery needs recharging.
4. Set switch to position A. and adjust the control marked “ Coarse’ until the needle points to the fleet-hand end of the scale. Allow 5 minutes for the meter to warm up.
    a. The detector head must be well clear of any metallic object while the adjustment is being made.
5. The instrument is now ready to detect concealed ferrous object e.g. reinforcement buried up to a distance of 4 cm.
    a. Place the detector head flat on the surface.
    b. Move the detector head around the surface until a reading is obtained on the scale.
    c. If a reading is obtained, keep head at the same place but rotate the detector head until a maximum needle deflection is obtained.
    d. The metal concealed in the material now has its long axis parallel to the detector head.
6. If no reading is obtained with the switch set on position A. change the switch to position B.
    a. Adjust the control marked “Fine’’ until the meter needle points to the left-hand end of the scale.
    b. The detector head must be well clear of any metallic object while the adjustment is being made.
    c. The instrument will now be able to detect a steel bar up to a distance of 10 cm away.
    d. Repeat steps 5a to 5d.

Form 1: Compressive Strength Test of Cubes and Cylinder

Nepal Government
Ministry of Physical Planning and works
Department of Roads

Tel: 5-521605

Central Road Laboratory

Compressive Strength Test of Cubes & Cylinder

Project/Office:-
Operator :-
Date:-
Sample No:-
W/C:-
Max size of Agg:-
Mix Proportion:-
Slump:-
F.M. of Coarse Agg Cement Brand :-
F.M. of fine Agg :-

Cement Brand:-				
Date of casting				
Date of crushing				
Age of cube/cylinder, days				
Dimension of mould, cm				
Surface area, cm^2				
Weight, Kg				
Density. Kg/m^3				
Crushing Load KN				
Crushing Strength Kg/cm^2, N/mm^2				
Average crushing strength Kg/cm^2, N/mm^2				
Date of casting				
Date of crushing				
Age of cube/cylinder, days				
Dimension of mould, cm				
Surface area, cm^2				
Weight, Kg				
Density, Kg/m^3				
Crushing Load KN				
Crushing Strength Kg/cm^2, N.mm^2				
Average crushing strength Kg/cm^2, N.mm^2				
Date of casting				
Date of crushing				
Age of cube/cylinder, days				
Dimension of mould, cm				
Surface area, cm^2				
Weight, Kg				
Density. Kg/m^3				
Crushing Load KN				
Crushing Strength Kg/cm^2, N.mm^2				
Average crushing strength Kg/cm^2, N/mm^2				

Tested by

Checked by

PART - V
TEST ON BITUMEN

Table of Contents

List of Tables:

1. Penetration of Bitumen

ASTM D 5

1.1 Purpose

This method describes a procedure for determining the penetration of Semi- solid and solid bituminous materials.

Notes:

i. This test measures the CONSISTENCY of Bitumen and tar by measuring the penetration of standard needle into the sample in a standard time.

ii. This test is used for the harder grades of bitumen which are known as "Penetration grades".

iii. The higher the penetration then the softer is the bitumen. i.e. Bitumen pen = 200 is softer than Bitumen pen = 150

1.2 Apparatus

1. Penetrometer- (includes electric timing device).
2. Penetration needle: made from fully hardened and tempered stainless steel, grade 44°C, HRC 54 to 60. It shall be approximately 50mm long and 0.001 to 1.02 mm in diameter, symmetrically tapered at one end to a cone whose angle shall be within the range of 8.7 to 9.7 degree over the entire length from full needle diameter and whose axis shall be coincident with the needle axis within 0.0127 mm maximum run out. After tapering, the point shall be ground off to a truncated cone, the smallest base.
3. Sample cup - (55 mm dia x 35 mm) for penetration below 200.
4. Sample cup- (70mm dia x 45mm) for penetrations between 200 and 350.
5. Water bath
6. Transfer dish
7. Thermometer - Range 23°C - 27°C - accuracy 0.1°C.
8. Heater for softening the sample before the test.

1.3 Sample Preparation

1. Heat enough material to provide two cups full of test sample, until the sample is Liquid enough to pour. Do not heat for longer than 30 minutes.
2. Heat the sample carefully, stirring gently to avoid getting bubbles into the sample.
3. Do not raise the temperature of the sample higher than is necessary in order to pour it into the sample cup.
   (D5 states not more than 90°C above the softening point).
4. Pour the sample into two samples cups-full to the top.
5. Protect each sample from dust (use an upturned beaker over it) and allow the samples to cool at room temperature (between 15°C and 30°C for between
   a. 1 hour and 1 1 /2 hours for the small samples.

or

b. 1/2 hours and 2 hours for the large samples.

6. Place the samples and transfer dish in the water bath (25°C) and leave for the times given in 5, above.

1.4 Test Procedure

1. Ensure that the piston (on the penetrometer) carries a 50 gm weight.

Note:

iv. The piston weight 50 gm hence the total weight =100 gm.

2. Level the base of the penetrometer using the level screws.
3. Clean the needle with solvent, dry with a clean cloth and fix it in the piston.
4. Put a sample (in cup) in the transfer dish and cover the sample with water from the water bath.
5. Place the transfer dish on the penetrometer base.
6. Make sure that both the piston and the fine vertical adjustment (knob just behind dial) are at the top of their travel.
7. Loosen the column clamp knob very carefully whilst holding the moving part and gently lower the whole assembly until the needle point is about 5mm above the surface of the sample.
8. Using the fine adjustment, lower the needle point until it just touches its reflection in the surface of the sample (but without penetrating the surface).
9. Press the button on the automatic timer and this will release the piston (with needle) for exactly 5 seconds.
10. Measure the distance penetrated in tenths of a millimeter by pressing down on the spring-loaded rod until its lower end touches the top of the piston.
11. Release the spring-loaded rod and return the piston to the top of its travel. (see Note 5)
12. Return the transfer dish and sample to the water bath.
13. Remove the needle from the piston.
14. Repeat steps 3 to 13 to obtain a total of 3 values of penetration. The points chosen to test the penetration should be at least 10 mm from the side of the cup and at least 10mm from previous points.

Note:

v. If the penetration is greater than 200 then leave the needle in the sample and repeat the test using other needles.

1.5 Calculations

1. The penetration is the average of 3 penetrations whose values do not differ by more than the following:

Penetration value (1/10 mm),	**0-49**	**50-149**	**150-249**	**250-350**
Maximum difference between highest & lowest penetration	2	4	6	8

2. It the differences are exceeded repeat the test using the second sample.
3. If the differences are again exceeded, ignore all the results and repeat the test completely.
4. Complete the calculation on the worksheet (*refer form 1: Penetration of Bitumen in Annex*)

1.6 Maintenance

1. Keep the apparatus clean and very lightly oiled. (too much oil is worse than none).
2. Take care to store the weights and especially the needles to prevent damage.
3. Keep the needles clean and free from rust and make sure they do not get bent.

2. Softening Point of Bitumen

(Ring and Ball Method)

Reference: ASTM D 36

2.1 Purpose

This method describes a procedure for determining the softening point of Bituminous materials using the ring and ball apparatus.

Note:

i. Bitumen do not have a sharply defined melting point, they gradually become softer and less viscous as the temperature rises.

ii. For this reason the test chosen for softening point is arbitrary and the method must be closely followed it results are to be reproducible.

iii. Softening point is useful:

a. to establish uniformity in supply

b. to indicate the tendency of the material to flow at raised temperatures met in service.

2.2 Apparatus

1. Ring and ball apparatus
2. Electric heater
3. Heater for softening the sample before the test
4. Pouring plate - flat smooth brass plate (50mm x 75mm)

2.3 Sample Preparation

1. Do not start unless it is planned to complete preparation and testing within 6 hours.
2. Heat enough material to overfill the two brass rings, until the sample is fluid enough to pour. Do not heat for longer than 2 hours.
3. Heat the sample carefully, stirring frequently and gently to avoid getting bubbles into the sample.
4. Do not raise the temperature of the sample higher than is necessary in order to pour it into the two brass rings (*D 36 states not more than 110^{o}c above the expected softening point of the bitumen*).
5. Heat the two brass rings to the approximate pouting temperature and place them on the pouring plate which has been thinly coated with talc.
6. Pour the heated sample into the two brass rings, so that they are slightly overfull and allow them to cool in air for at least 30 minutes.

Note:

iv. For material which is soft at room temperature try to cool the air temperature with ice to at least 10°C below the expected softening point.

7. The test must be completed in no more than 4 hours from the time that the bitumen was poured into the rings.

8. When the bitumen discs (in the rings) have cooled, cut away the excess bitumen cleanly with a slightly heated knife, so that each disc is flush and level with the top of its ring.

2.4 Test Procedure

1. Assemble the apparatus with the specimen rings, ball centering guides and thermometer in position in the pyrex beaker.
2. Fill the bath (Pyrex beaker) so that the depth of liquid is between 102mm and 108mm.

Notes:

v. The bath liquid to be used is
  - *a. Freshly boiled distilled water for softening points between30°C and 80°C*
  - *b. USP glycerin for softening points between 80°C and 150°C.*

3. Using forceps, place the two steel balls in the bottom of the bath so that they will reach the same starting temperature as the rest of the apparatus.
4. Place the bath in ice water, if necessary, or on the electric heater to reach and stay at the STARTING temperature for 15 minutes.

Notes:

vi. STARTING temperatures
  - *a. for water bath = 4°C to 0°c'*
  - *b. for glycerin bath = 29°C to 31°C*

5. Take care not to contaminate the bath liquid.
6. Using forceps, place a ball from the bottom of the bath in each ball-centering guide.
7. With the bath on the heater, heat the bath gently so that the bath temperature rises at a uniform rate of 5°C /min.

Note:

*vii. After the first 3 minutes the range of temperate increase must be between 4.5°C and 5.5°C. If it is not then test is **NOT VALID** and must be repeated.*

8. Record for each ring and ball the temperature shown by the thermometer at the instant the bitumen surrounding the ball touches the bottom plate. If the difference between the two temperatures exceeds 1°C then repeat the test.

2.5 Calculation

1. The softening point is the average of the two temperatures recorded to the nearest 0.2°C, provided the difference between the temperatures is less than 1°C.
2. Complete the calculation on the worksheet (refer form 2 : Softening Point of Bitumen in Annex)

2.6 Repeat Tests

If a test must be repeated ALWAYS use a fresh sample that has not been heated and start at step 1 of sample preparation.

3. Flash Point and Fire point of Bitumen

By Cleveland Open Cup

Reference: ASTM D92

3.1 Purpose

This method provides the procedure to determine the Flash and Fire point of bitumen.

Notes:

i. The flash point is the lowest temperature at which the test flame causes the vapor above the bitumen to ignite.

ii. The fire point is the temperature at which the test flame causes the bitumen to ignite and burn for at least 5 seconds.

3.2 Apparatus

1. Cleveland open cup apparatus
2. Shield - to keep off draughts of air - 3 sided, 460mm square x 610 mm high. Not needed but recommended.
3. Thermometer - 6°C to 400°C accuracy to 2°C.

3.3 Preparation of Apparatus

1. Place the apparatus on a level steady table top in a draught free lab.
2. Shield the top of the apparatus from strong light.
3. Wash the test cup with solvent. Flush the cup with cold water and dry completely over a hot plate and allow to cool and place in the apparatus.
4. Support the thermometer with its bulb 1/4” (6.4mm) above the bottom of the cup. It should be positioned half way between the center and side of the cup.

3.4 Test Procedure

1. Heat the sample until it can be poured into the cup.
2. Fill the cup so that the top of the meniscus is exactly at the filling line
   a. If too much bitumen has been added, remove the excess using a pipette or medicine dropper.
   b. If any bitumen gets onto the outside of the apparatus then empty the cup, clean off the spillage and refill.
   c. Destroy any air bubbles on the surface of the bitumen.
3. Connect the gas supply to the apparatus and light the test flame. Adjust the test flame to the size of the comparison bead (mounted on the side of the apparatus). Adjust the level of the test flame so that it is less than 2mm above the top of the cup.
4. Heat the sample so that the temperature rise is about 14° to 17°C per minute until the temperature is about 56°C below the expected flash point.

Note:

iii. ASTM D946 gives the minimum flash point for bitumen as follows:

Penetration at 25°C	*40-50*	*60-70*	*85-100*	*120-150*	*200-300*
Flash point °C	*232*	*232*	*232*	*218*	*176*

5. When the sample temperature is about ±56°C below the expected flash point decrease the heat so that the rate of temperature rise for 28°C before the flash point is 5 to 6°C per minute.
6. Starting at 28°C below the expected flash point, pass the test flame across the center of the cup in a smooth continuous motion. The time from edge of cup to opposite edge of cup should be about 1 second.
   a. Repeat this procedure at 2°C intervals but alternate the direction of travel of the flame.
7. Record the temperature when a flash appears at any point on the surface of the bitumen. Record atmospheric pressure (mm Hg)

Note:

iv. Do not confuse the true flash with the bluish halo that may surround the test flame.

8. To find the fire point continue heating the sample so that the temperature rise is still 5° to 6°C per minute and continue applying the test flame, as in step 6, every 2°C interval.
9. Record the temperature when the bitumen catches fire and continues to burn for at least 5 seconds. Record atmospheric pressure. (mm Hg)

3.5 Calculations

1. Corrected flash point = FL + 0.03 (760 - p)
   Where FL = observed flash point
   i. P = observed atmospheric pressure. (mm Hg)
2. Corrected fire point = FI + 0.03 (760 - p)
   Where Fl = observed fire point
   i. P = observed atmospheric pressure. (mm Hg)
3. Complete the calculation on the worksheet (*refer form 3: Flash and Fire Point of Bitumen in Annex*)

3.6 Report

Values of observed and corrected fire/flash points should be reported to the nearest 2°C.

4. Effect of Heat and Air on Bitumen

(Thin Film Oven Test)
Reference: ASTM D1754

4.1 Purpose

This method provides the procedure to determine the effect of heat and air on bitumen.

Notes:

i. A thin film of bitumen is heated in an oven for 5 hours and the effect on the bitumen is determined from the differences in any of the following:

1. viscosity
2. Penetration
3. Ductility
4. Loss on heating

ii. These properties (some or all) are measured before AND after the oven treatment.

iii. This method indicates changes in the bitumen during normal hot mixing, when the bitumen coats the aggregate with a thin film at temperatures about 150°C.

4.2 Apparatus

1. Oven with rotating shelf
2. Thermometer range 15°C to 170°C
3. Aluminum containers 140mm diameter x 9.5mm deep- 4 No. are required.
4. Balance having accuracy of 0.001 gm

4.3 Sample Preparation

1. Heat enough sample for the test to a fluid condition stirring carefully to avoid getting air bubbles into the sample.

Note:

iv. 420 gms is required for each property tested

v. Do not heat the sample above 150°C

2. Weigh 50 gms ± 0.5 gm of sample into each of the 4 aluminum containers which have been previously cleaned and dried. Allow the samples to cool to room temperature.
3. At the same time pour the samples for carrying out the required tests for viscosity, penetration or ductility- see appropriate Laboratory Instruction Sheets to Carry out the tests.
4. Weigh the samples (from step 2) to 0.001 gm.

4.4 Test Procedure

1. Level the oven so that the shelf is horizontal.
2. Thread the mercury thermometer into the proper support connected to the shaft of the rotating shelf.
3. Preset the “VERTEX” thermoregulator to 163°C.

4. Switch on the heating and put the switch to position 4.
5. Switch on the motor with the right hand switch, the shelf will rotate and the pilot lights will come on.
6. When the pilot light for the heater goes off, check the temperature of the oven with the thermometer, and if necessary, adjust the VERTEX with small rotations of the upper knob, in order to reach the test temperature of 163°C.
7. Switch the heater knob to position 3.
8. With the oven at 163°C, stop the motor and place the containers on the shelf, close the oven and start the shelf rotating.
9. Leave the samples in the oven for 5 hours after the temperature has reached 163°C. The samples must not be in the oven for more than 5.25 hours.
10. Remove the samples from the oven, cool to room temperature and weigh to 0.001 gm.
11. Place the samples (in the aluminum containers) on asbestos cement boards and place them back on the shelf of the oven. Rotate the shelf and heat the samples for 15 minutes at 163°C
12. Remove the samples from the oven and transfer the material from each container into an 8oz (o.22L) tin.
13. Stir the material thoroughly using heat if necessary as in step1of sample preparation.
14. Carry out the necessary tests (i. e. viscosity, penetration or ductility) on the material within 72 hours of carrying out this test.

4.5 Calculation

1. Calculate the percentage of loss on heating with respect to the original wt of sample noted in step 4 of sample preparation.
2. Complete the calculation on the worksheet (refer form 4: Loss in Heating(% weight) Annex)

5. Ductility of Bitumenous Materials

Reference: ASTM D113

5.1 Purpose

This method provides the procedure to determine the loss on heating of bituminous materials

Notes:

i. *The ductility of bitumen is measured by the distance it will stretch before breaking.*

ii. *This test provides a measure of the tensile properties of bitumen and is used to measure ductility for specification requirements.*

5.2 Apparatus

1. Mould - 3 No.
2. Brass base plate for mould
3. Water bath.
4. Ductility testing machine
5. Thermometer accuracy to 0.5°C.
6. 0.3mm Sieve

5.3 Sample Preparation

1. Assemble the mould on the brass plate and screw it in position, (A glass plate may be used).
2. Thoroughly coat the inside surfaces of the mould and brass plate with a thin layer of talc to prevent the bitumen from sticking.
3. Carefully heat the sample until it is fluid enough to pour (Enough sample is needed to fill 3 moulds).
4. Strain the sample through a 0.3 mm (No.50) sieve into another container (a glass beaker).
5. After thorough stirring, pour the sample into the moulds.

Notes:

iii. *Take care not to disturb the mould.*

iv. *To fill the mould, pour the bitumen in a thin stream back and forth from end to end of the mould until the mould is slightly overfilled.*

6. Let the moulds cool to room temperature for 30 to 40 minutes and then place them in the water bath at 25°C for 30 minutes.
7. Remove the moulds from water bath and trim the top surface of the sample level with the top of the mould. Use a hot spatula. Take care not to disturb the mould,
8. Replace the moulds, base plate and samples in the water bath for a period between 85 and 95 minutes

5.4 Test Procedure

1. Remove the samples from the bath, remove the base plate from the mould and detach the side pieces from the mould.

2. Attach the samples to the jaws of the testing machine by screws through the holes at the end of each sample clip.

Notes:

v. The testing machine should be full of water maintained at 25°C, full tleast 2.5cm above the samples.

vi. The moveable jaw of the testing machine can be quickly positioned at the Zero point by unlocking the catch/lever on the top of the jaw.

3. Start the motor and adjust the speed so that the jaw moves at 5 cm/minute. This is best done before the samples are in place but should be checked whilst the test is in progress.
4. Record the distance in cm through which the jaw moves to break the samples.

Notes:

vii. A normal test is one in which the sample pulls out to thread which finally breaks.

viii. If the bitumen thread touches the bottom of the tank or the water surface then the test is considered not normal.

ix. (a) If the thread starts to get near the surface add a little methyl alcohol to the water to reduce the SG of the liquid - hopefully to stop the thread touching the surface.

(b) If the thread starts to get near the bottom of the tank add a little sodium chloride (common salt) to the water.

5.5 Calculations

1. The ductility is the average of the distance to breaking of three NORMAL tests.
2. If it is impossible to obtain 3 normal tests (because of shortage of sample) then it should be reported that the ductility as being unobtainable under the conditions of the test.

5.6 Report

Report the ductility as the average of the three NORMAL test (in cm).

6. Solubility of Bituminous Materials in Trichloroethylene

Reference: ASTM D 2042 -81

6.1 Purpose

This method covers the determination of the degree of solubility in Trichloroethylene of Asphalt Materials having little or no mineral matter.

Notes:

i. The portion that is soluble in trichloroethylene represents the active cementing constituents.

ii. Trichloroethylene is toxic and good ventilation should be provided. Trichloroethylene in the presence of heat and moisture may form acids that are extremely corrosive.

6.2 Apparatus and Materials

1. Assembly of Filtering Apparatus consisting of (or any other suitable assembly permitting vacuum Filtration with Gooch crucible):
    a. Gooch Crucible, glazed inside and outside with the exception of outside bottom surface. The approximate dimensions –dia of 44mm at top, tapering to 36mm at bottom and a depth of 28mm.
    b. Glass filter pad – 3.2 cm^2
    c. Filter Flask, heavy-wall with side tube, 250 ml capacity or larger
    d. Filter tube, 40 to 42 mm inside diameter
    e. Rubber Tubing or Adopter, for holding the Gooch crucible on the filter tube
2. Erlenmeyer Flask, 125 ml, or other suitable container
3. Oven, capable of maintaining a temperature of $110^0 \pm 5^0$ C
4. Asbestos, medium or Long fiber, acid washed for Gooch crucibles
5. Desiccator, of suitable size, charged with an effective desiccant
6. Analytical balance class A
7. Muffle Furnace, capable of obtaining temperature of 650^0C (Not required when using the fiber glass filter discs in lieu of asbestos)
8. Solvent – Trichloroethylene of technical grade.

6.2.1 Preparation of Gooch crucible

1. Thoroughly shake a portion of the asbestos fiber in distilled water so as to form a thin suspension in which the asbestos fibers are evenly dispersed.
2. Assemble the filtering apparatus.
3. Fill the crucible with some of the suspension of asbestos in water and allow it partly to settle in the crucible.
4. Apply light suction to draw off the water, leaving a firm mat of asbestos in the crucible.
5. Add more suspended asbestos and repeat the process until a mat is build up that after ignition, will weigh 0.5 ± 0.1 g.

Note:

iii. In the determination, the asbestos apparently irreversibly absorbs a small amount of soluble bitumen (usually 1 to 9 mg per gram of asbestos). The wt of asbestos used should, therefore, be kept within the specified limits to ensure reproducible results.

6. Wash the Asbestos mat thoroughly with water, dry in oven and ignite in a muffle furnace at 600 to 650^0 C.
7. Cool the crucible in desiccators and weigh to the nearest 0.1 g.
8. Repeat the ignition and cooling until constant wt $110^0 \pm 5^0$ C
9. Store the crucible in desiccators until ready for use.

6.2.2 Using fiber glass filter discs:

1. Assemble the filtering apparatus.
2. Place the filter disc in the Gooch crucible.
3. Moisten the disc with solvent and seat firmly in the bottom of the crucible.
4. Place in an oven at $110^0 \pm 5^0$ C for at least 15 minutes.
5. Cool in desiccator and weigh. (A)
6. Repeat the drying and weighing until constant wt. to the nearest 0.1 mg is obtained.
7. Store the crucible in desiccators until ready for use.

6.3 Sample Preparation

If the sample in not fluid, heat to any convenient temperature but in any case not more than100^0 C above softening point. Normally, the temperature at which this test is run is not critical and it may be performed at the laboratory air temperature. For referee tests, however, the flask and sample in solution shall be placed in a water bath maintained at 37.8 ± 0.25^0 C for 1 hr before filtering.

6.4 Procedure

1. Transfer about 2 g of the sample into a tared 125 ml Erlenmeyer flask or other suitable container.
2. Weigh accurately in the nearest I mg. (B)
3. Add 100 ml of Trichloroethylene to the container in small portions with continuous agitation until all lumps disappear and no undiluted sample adheres to the container.
4. Stopper the flask or otherwise cover the container and set aside for at least 15 mints.
5. Place the previously prepared and weighed Gooch crucible in the filtering tube.
6. Wet the glass fiber pad with a small portion of trichloroethylene and decant the solution through the glass fiber pad of the crucible with or without light suction as may be necessary.
7. When the insoluble matter is appreciable, retain as much of it as possible in the container until the solution has drained through the mat.
8. Wash the container with a small amount of solvent and, using a stream of solvent from a wash bottle, transfer all insoluble matter to the crucible.
9. If necessary, use a “police-man” to remove any insoluble matter adhering to the container.

10. Rinse the policeman and container thoroughly.
11. Wash the insoluble matter in the crucible with solvent until the filtrate is substantially colorless, and then apply strong suction to remove the remaining solvent.
12. Remove the crucible from the tube, wash the bottom free of any dissolved matter, and place the crucible on top of an oven or on a steam bath until all odor of the trichloroethylene is removed.
13. Place in an oven at $110^0 \pm 5^0$ C for at least 20 minutes.
14. Cool in desiccator for 30 ± 5 minutes and weigh.
15. Repeat the drying and weighing until constant wt. (± 0.3 mg) is obtained.(A2)

Note:

iv. In order to obtain precise results, the cooling time in the desiccators must be approximately the same (within ± 5 mints) after all heating.

6.5 Calculations

1. Calculate the percentage of the sample soluble in the solvent, trichloroethylene by weight as follows:

   % Insoluble = [(A2 – A1) / B] x 100

   % Soluble = 100 – {[(A2 – A1) / B] x 100}

Where,

B = total wt. of sample

A1 = Wt. of Gooch crucible along with fiber glass filter disc

A2 = Wt. of Gooch crucible along with fiber glass filter disc + insoluble matters

2. Complete the calculation on the worksheet (refer form 5: Solubility in Trichloroethylene in Annex)

6.6 Report

Report the % of Soluble to the nearest 0.01%.

7. Marshal Test

Reference:- ASTM D 1559

7.1 Purpose

This method covers the measurement of the resistance to plastic floor of cylindrical specimens of bituminous pouring mixture loaded on the lateral surface by means of Marshall apparatus.

Notes:

i. This test is used in the laboratory in the mix design of Bituminous Materials.

ii. It is used to determine the strength of mixtures of
   - *a. Bitumen and aggregate (maximum size 25mm)*
   - *b. Cut-back bitumen and aggregate (maximum size 25mm)*
   - *c. Tar and aggregate (maximum size 25 mm)*

iii. The test can also be used to test the strength of cored sample obtained from roads.

7.2 Apparatus

1. Specimen mould assembly
   - a. Mould
   - b. extension collar
   - c. base plate
2. Extruder
3. Compactor
4. Stability mould (Breaking head)
5. Marshall test machine and load ring.
6. Flow meter
7. Mechanical mixer (gas heated)

7.3 Sample Preparation

7.3.1 Number of samples

At least 3 nos are required for each mix

7.3.2 Aggregate preparation

1. Dry aggregates to constant weight in a 110°C oven and cool (approx 1200 gm per sample).
2. Sieve the aggregate into the following fractions

Fraction No	Size range (mm)
1	25.0-19.0
2	19.0-9.5
3	9.5-4.75
4	4.75-2.36
5	2.36-0.600
6	0.600- 0.300

7	0.300- 0.075
8	less than 0.075

7.3.3 Determination of Mixing and Compacting Temperatures

7.3.4 Bitumen

1. Mix at the temperature where Viscosity = 170 ± 20 cSt.
2. Compact at the temperature where Viscosity = 280 ± 30 cSt.

7.3.4.1 Cutback Bitumen

1. Mix at a temperature where Viscosity = 170 ± 20 cSt.
2. Refer to "Composition chart" for the cutback

a. Determine viscosity at 60°C

b. hence (from the chart) find % of solvent by weight.

c. also from the chart find the viscosity at 60°C after it has lost 50% of its solvent

d. Find the temperature (Using a viscosity temperature graph) at which the cut-back (with 50% loss of solvent) has a viscosity = 280 ± 30 cSt. Compact at this temperature.

7.3.4.2 Tar

1. Mix at the temperature where Engler specific viscosity = 25 ± 3 cSt.
2. Compact at the temperature where Engler specific viscosity = 40 ± 5 cSt

7.3.5 Preparation of Mixtures

1. Weigh into separate pans for each test specimen the amount of each fraction required to produce a batch that will result in a compacted specimen 63.5 mm in height (about 1200 gm total is required).
2. Place the pans and heat in a oven to temperature of
   a. Mixing temperature + 25°C for Bitumen and tar mixes.
   b. Mixing temperature + 12°C for cutback Bitumen mixes.
3. Place all the aggregate in the mixing bowl and weigh the bowl, aggregate and mixing blade.
4. Assemble the mixing apparatus and mix the heated aggregates thoroughly.
5. Switch off the mixer, form a crater in the top of the aggregates and pour in the required amount of bitumen, cutback bitumen or tar at the temperature for mixing.
6. Mix thoroughly until all the aggregate is coated.
7. For cutback bitumen mixtures, cure then in an oven (well ventilated) at 10°C above the compaction temperature until 50% solvent loss has occurred.(weigh the bowl, mix and mixing blade at 10 mints interval).

7.3.6 Compaction of Specimen

1. Thoroughly clean the mould assembly and the face of the compaction hammer.
2. Heat them in either boiling water or a 100°C oven.
3. Dry them, assemble them and place a piece of filter paper (cut to size) in the bottom the mould.

4. Place the entire batch in the mould (with extension collar in place) and using a heated trowel or spatula, “Spade” the specimen 15 times round the perimeter and 10 times over the middle.
5. Remove the collar and smooth the surface of the mix to a slightly rounded shape.
6. The temperature of the mix just before, compaction should be within the limits set for compacting temperatures.
7. Replace the collar and clamp the mould assembly to the pedestal.
8. Give 50 blows of the hammer to the top of the sample.
9. Remove the base plate and collar, turn the sample mould upside down and reassemble the mould.
10. Give another 50 blows of the hammer to the sample.
11. Remove the base plate and place the mould and collar in the extruder and force the sample into the collar.
12. Carefully lift the collar from the sample and transfer the sample to a glass plate and allow to stand at room temperature overnight.

Note:

iv. If the sample is too soft to stand unsupported it may be left to cool in the mould until it is hard enough to be extruded.

7.4 Test Procedure

1. Weigh the sample
2. Measure the sample.
3. Bring the sample to the test temperature
    a. For Bitumen - place in a water bath at 60°C for 30 to 40 minutes
    b. For cut-back bitumen - place in AIR BATH at 25°C for 2 hours.
    c. For tar - place in a water bath at 30°C for 30 to 40 minutes.
4. Thoroughly clean the stability mould and oil the guide rods.
5. The temperature of the stability mould should be kept between 21°C and 38°C.

Note:

v. The remainder of the test from the removal of the specimen from its bath to the maximum load determination should be completed within 30 SECONDS.

6. With the stability mould in position on the testing machine, place the sample in the mould.
7. Press down the top part of the mould into contact with the sample and raise the bottom platen so that the stem of the mould contacts the load ring.
8. Set the load dial gauge to zero and place the flow meter over one of the guide rods; adjust it to read zero.
9. Hold the flowmeter firmly against the mould and switch on the machine.
10. Apply the load (while still holding the flowmeter) until the maximum load is reached. At this point record the maximum load reading and remove the flowmeter from the mould.
11. Record the flowmeter reading- to release the dial gauge press the button on the front of the stem.
12. Record the test temperature of the mix.

7.5 Calculations

1. The maximum load is corrected if the height of the sample is not 63.5mm by multiplying the load obtained in the test by the factor in Table 1.
2. The flow value is the deformation at maximum load in mm divided by o.25 mm.
3. Complete the calculation on the worksheet (refer form 6: Marshal Mix design in Annex)

Table 1: Maximum Load Correction Factor

Sample thickness (mm)	**Correction factor**
25.4	5.56
27	5
28.6	4.55
30.2	4.17
31.8	3.85
33.3	3.57
34.9	3.33
36.5	3.03
38.1	2.78
39.7	2.5
41.3	2.27
42.9	2.08
44.4	1.92
46	1.79
47.6	1.67
49.2	1.56
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
64	0.96
65.1	0.93
66.7	0.89
68.3	0.86
71.4	0.83
73.0	0.81
74.6	0.78
76.2	0.76

8. Extraction of Bitumen from Paving Mixture by Centrifuge

Reference: ASTM D 2172 (Method A)

8.1 Purpose

This method covers the quantitative determination of bitumen in hot-mixed paving mixtures and pavement samples. Aggregate obtained by this method may be used for sieve analysis.

Notes:

i. *The bitumen is extracted from the paving mixture using one of the following solvents:*
   a. *Trichloroethylene*
   b. *Methylene Chloride*
   c. *Benzene*

ii. *The above solvents are all POISONOUS and should be used only under a hood or with an exhaust system in a well ventilated area.*

8.2 Sample Preparation

a. If the sample obtained from the field is not soft enough to separate with a trowel, place it in a large flat tray and warm it in a l 10°C oven until it is soft enough to mix.
b. The field sample is reduced in size (by (quartering or riffling) to give a test sample of minimum weight shown below:

Nominal Maximum Size of Aggregate (mm)	Minimum Weight (kg)
12.5	0.65
25.0	1.30
50.0	2.50

c. If a moisture content determination is required then a further test sample of approximately 500 g is needed.

Notes:

iii. *If the bitumen extracted from the sample does not require testing then use TEST PROCEDURE NO. 1*

iv. *If the bitumen extracted from the sample is required to be recovered from the solvent so that it may be tested then use TEST PROCEDURE NO. 2*

8.3 Test Procedure No.1

a. Place a filter ring in a 110°C oven to dry and record the weight ties up the form 7.

b. Place the full test sample in a 110°C oven and dry to constant weight. Record the weight on the worksheet.

c. Place the sample in the centrifuge bowl. Be sure to distribute the sample evenly around the bowl to reduce vibration when the centrifuge is spinning.

d. Cover the sample with solvent and allow enough time for the solvent to break up the sample (not more than one hour)

e. Place the bowl in the centrifuge.

f. Fit the dry filter ring around the edge of the bowl.

g. Clamp the cover on the bowl tightly.

h. Clamp the external cover on the centrifuge and place a beaker under the drain (outlet) to collect the extract (A 2 litre beaker is required).

i. Start the centrifuge and run the machine until the solvent ceases to flow.

j. Stop the machine and add 200 ml of solvent, through the holes in the top cover.

k. Repeat steps i) and j) until the extract is the colour of light straw. The sample may need redistributing as in 2(c) above.

l. Remove the filter ring and allow to dry in air. Carefully brush off any mineral matter into the centrifuge bowl. Dry the ring in a 110°C oven and weigh and record its weight (E).

m. Transfer, carefully, the contents of the bowl to a sample tray, dry in a 110°C oven and record the weights on the worksheet (B).

n. A continuous flow centrifuge is now used to find the amount of mineral matter contained in the solvent (material less than 0.075mm).

o. Weigh the clean empty centrifuge cup and place it in the centrifuge. Assemble the apparatus and put a flask under the outlet.

p. Remove the filters from the top funnel and with the tap closed, pour in the extract. Make sure all the material is transferred to the funnel by washing the flask with small amounts of CLEAN solvent and pouring into the funnel.

q. Start the centrifuge, open the tap and allow the extract to run slowly into the centrifuge (at about 150 ml/minute).

r. After all the extract has run through wash several increments of clean solvent through until the liquid coming out is clear. Stop the machine.

s. Remove the cup, clean the outside with clean solvent and then dry in a 110°C oven and then weigh (I).

8.4 Test Procedure No 2

a. Take the test sample obtained in 1 (b) and carry out the steps 2 (c) to 2 (t) of procedure No. 1

b. Take the moisture content sample obtained in 1 (c) and determine the moisture content (L) of the mixture using the procedure outlined in a separate worksheet - See D1461.

8.5 Calculations

1. Calculate the percentage of bitumen in the test portion as follows:

   Bitumen Content, % = [{(A – M) – (B + E + I)} / (A – M)] x 100

Where:

A = wt of test portion
M = wt of water in the test portion = (L x A)/100
B = wt of extracted mineral aggregates,
E = wt. of aggregates in filter ring and
I = wt of mineral matter in extract

2. Complete the calculations on the worksheet (refer form 7: Extraction of Bitumen in Annex).

9. Water Content of Bitumen Paving Mixtures

Reference: AST M D 1461

9.1 Purpose

This test method covers the determination, by direct measurements, moisture or volatile fractions of the bitumen in bituminous paving mixtures.

9.2 Apparatus

a. Glass distillation flask with a liebig condenser.

Note:

i. The solvent recommended for this test is XYLENE which is not poisonous and so this test does not require a fume cupboard.

9.3 Sample Preparation

a. Thoroughly mix the field sample and weigh out a test sample of approximately 500 g.
b. Break up the test sample to avoid large lumps.

9.4 Test Procedure

a. The apparatus used for this test is a glass distillation flask with a liebig condenser.
b. Place the test sample in the glass flask.
c. Add 200 ml of solvent and quickly stir it into the sample.
d. Assemble the apparatus over the heater and switch on the heater.
e. Continue the distillation until no more water collects in the trap. In no case should the process continue for more than 1 1/2 hours.
f. Allow the contents of the trap to reach room temperature and read the volume of water in the trap to the nearest scale division.

9.5 Calculations

1. Calculate the moisture content as follows:

   Water % = (Volume o water in the trap/ Weight of sample) x 100

2. Complete the calculations on the worksheet (refer form 8: Water content of Bitumen in Annex).

10. Kinematic Viscosity of Bitumen

Reference ASTM D 2170

10.1 Purpose

This test method covers the procedures for the determination of kinematic viscosity of liquid asphalt (bitumen), road oil and distillation residues of liquid asphalt (bitumen) all at 60^0 C and of asphalt cements at 135^0 C in the range from 6 to 100,000 cSt.

Note:

i. *This test method is suitable for use at other temperatures and at lower kinematic viscosities, but the precision is based on determinations on liquid asphalts and road oils at* 60^0*C and of on asphalt cements at* 135^0*C only in the viscosity range from 30 to 6000 cSt.*

10.2 Definition

Kinematic Viscocity is the ratio of the viscosity to the density of a liquid. It is a measure of the resistant of flow of a liquid under gravity. The cgs unit of Kinematic Viscocity is 1 cm2/sec and is called a stoke (St) and customarily used unit is centistokes-1 mm2/sec (cSt).

Viscosity – the ratio of the applied shear stress to the rate of shear is called the coefficient of viscosity. The coefficient is a measure of the resistance to flow of a liquid, commonly called the viscosity of the liquid. The cgs unit of viscosity is 1g/cm-s, called (P).

10.3 Apparatus

1. Viscometer - BS U-Tube modified reverse flow viscometer made of borosilicate glass, annealed, suitable for this test.
2. Thermometer - thermometer calibrated having accuracy 0.2^0C.
3. Bath – suitable for immersion of the viscometer so that the liquid reservoir or the top of the capillary, whichever is uppermost,, is at least 20 mm below the upper bath level, and with provision for visibility of viscometer and thermometer.
4. Timer – A stop watch graduated in divisions of 0.1 s or less having accuracy of 0.05 sec.

10.4 Preparation of Sample

1. Procedure for liquid asphalt (Bitumen) and Road oil

a. Allow the sealed sample, as received, to reach room temperature.

b. Open the sample container and mix the sample thoroughly by stirring for 30 s taking care to avoid the entrapment of air. If the sample is too viscous for such stirring, place the sample in the tightly sealed container in a bath or oven maintained at 63 ± 3^0 C until it becomes sufficiently liquid for stirring.

c. Immediately charge the viscometer, or, if the test is to be made at a later time, pour approximately 20 ml into one or more containers having a capacity of approximately 30 ml and immediately seal with an airtight closure.

d. For materials with kinematic viscosity at 60^0 C above 800 cSt, heat the 20 ml sample in the sealed container in an oven or bath maintained at $63^0 \pm 3^0$ C until it is sufficiently liquid for a convenient transfer into the viscometer. Such heating should not exceed 30 min.

2. Procedure for Asphalt Cement (Semi Solid)

a. Heat the sample with care to prevent local overheating until it has become sufficiently fluid to pour, occasionally stirring the sample to aid heat transfer and to assure uniformity.

b. Transfer a minimum of 20 ml into a suitable container and heat to $135^0 \pm 5.5^0$ C, stirring occasionally to prevent local overheating and taking care to avoid the entrapment of air.

10.5 Procedure

1. Maintain the bath temperature within $\pm 0.1^0$ C for test temperature of 60^0 C and within $\pm 0.3^0$ C for test temperature of 135^0 C. Apply the necessary correction, if any, to all thermometer readings.
2. Mount the BS U – Tube viscometer in the constant temperature bath keeping tube L vertical.
3. Preheat the clean and dry viscometer having efflux time more than 60 s, to test temperature.
4. Pour sample through tube N to a point just above filling mark G.
5. Allow the sample to flow freely through capillary R, taking care that liquid column remains unbroken, until the lower meniscus is about 5 mm below the filling mark H and then arrest/ prevent its flow by closing the timing tube with a cork or rubber stopper in tube L.
6. Add more liquid if necessary to bring the upper meniscus slightly above mark G.
7. After allowing the sample to attain bath temperature and any air bubbles to rise to the surface, gently loosen the stopper allowing the sample to flow to the lower filling mark H and again arrest /prevent flow.
8. Remove the excess sample above filling mark G by inserting a special pipette until its cork rests on top of tube N; apply gentle suction until air is drawn through.
9. The upper meniscus shall coincide with mark G.
10. Allow the viscometer to remain in the constant temperature bath for a sufficient time to ensure that the sample reaches temperature equilibrium (10 min minimum, 30 min maximum).
11. Remove the stopper in tube N and L, respectively, and allow the sample to flow by gravity.
12. Measure to the nearest 0.1 s the time required for the leading edge of the meniscus to pass from first timing mark E to second timing mark F.
13. If the efflux time is less than 60 s, select a viscometer of smaller capillary diameter and repeat the operation.

10.6 Cleaning the Viscometer

1. Upon completion of test, clean the viscometer thoroughly by several rinsing with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent.
2. Dry the tube by passing a slow stream of filtered dried air through the capillary for 2 min, or until the last trace of solvent is removed.
3. Periodically clean the instrument with chromic acid cleaning solution to remove organic deposits, rinse thoroughly with distilled water and residue-free acetone, dry with filtered dried air.
4. Chromic acid cleaning solution may be prepared by adding, with the usual precautions, 800 ml of concentrated sulphuric acid to a solution of 92 g of sodium dichromate in 458 ml of water. The

use of similar commercially available sulphuric acid cleaning solution is acceptable.

5. Use of alkaline glass cleaning solutions may result in a change of Viscometer calibration, and is not recommended.

10.7 Calculation

1. Calculate the Kinematic Viscosity to three significant figures using the following equation:

Kinematic Viscosity, cSt = Ct

Where:

C = calibration constant of the viscometer, cSt/s, and
T = efflux time in s.

2. Complete the calculation on the worksheet (*refer form 9: Kinematic Viscosity Tests in Annex*)

10.8 Report

Always report the test temperature with the result.

10.8.1 Precision

Criteria for judging the acceptability of viscosity test result obtained by this method are given below:

Table 2: Criteria for judging the acceptability of viscosity test result

Material and type Index	Coefficient of variation (% of Mean)	Acceptable Range of Two Results (% of Mean)
Single-Operator Precision		
Asphalt Cement at 135^{0}C	0.64	1.8
Liquid Asphalt at 60^{0}C		
Below 3000 cSt	0.53	1.5
3000 to 6000 cSt	0.71	2.0
6000 cSt and above	3.2	8.9

11. Specific Gravity of Semi-Solid Bituminous Materials

Reference: ASTM D 70

11.1 Purpose

This method covers the determination of the specific gravity of semi – solid bituminous materials, asphalt cements, and soft tar pitches by use of a pycnometer. Values of Sp. Gr. and density are used for converting volumes to units of mass as required.

The specific gravity of semi – solid bituminous materials, asphalt cements, and soft tar pitches is the ratio of the mass of a given volume of the material at 25°C or 15.6°C to that of an equal volume of water at the same temperature, and shall be expressed as SP. Gr., 25°/25°C or 15.6°/15.6° C.

11.2 Density

The density is the mass per unit of volume and is expressed as Density, 25°C or 15.6°C, g/cm3.

11.3 Apparatus

1. Pycnometer: Glass consisting of a cylindrical or conical vessel carefully ground to receive an accurately fitting glass stopper 22 to 26 mm in diameter. The stopper shall be provided with a hole 1.0 to 2.0 mm in diameter, centrally located in reference to the vertical axis. The top surface of the stopper shall be smooth and substantially plane, and the lower surface shall be concave in order to allow all air to escape through the hole. The height of the concave section shall be 4.0 to 6.0 mm at the centre. The stoppered pycnometer shall have a capacity of 24 to 30 ml, and shall weigh not more than 40 g.
2. Water bath, constant temperature, capable of maintaining the temperature within 0.1°C of the test temperature.
3. Thermometer, having a range from -8 to 32°C.
4. Balance

11.4 Materials

1. Distilled water

11.5 Preparation of Equipment

1. Partially fill a 600 ml Griffin low form beaker with freshly boiled and cooled distilled water to a level that will allow the top of the pycnometer to be immersed to a depth of not less than 40mm.
2. Partially immerse the beaker in the water bath to a depth sufficient to allow the bottom of the beaker to be immersed to a depth of not less than 100 mm, while the top of the beaker is above the water level of the bath. Clamp the beaker in place.
3. Maintain the temperature of the water bath within 0.1°C of the test temperature.

11.6 Calibration of Pycnometer

1. Thoroughly clean, dry and weigh the Pycnometer to the nearest 1 mg. (A)
2. Remove the beaker from the water bath. Fill the Pycnometer with freshly boiled distilled water, placing the stopper loosely in the pycnometer. Place the Pycnometer in the beaker and press the stopper firmly in place. Return the beaker to the water bath.
3. Allow the Pycnometer to remain in the water for a period of not less than 30 mints. Remove the pycnometer, immediately dry the top of the stopper with one stroke of a dry towel, and then quickly dry the remaining outside area of the pycnometer and weigh the Pycnomer with water to the nearest 1 mg. (B)

11.7 Preparation of Sample

1. Heat the sample with care, stirring to prevent local overheating, until the sample has become sufficiently fluid to pour.
2. In no case should the temperature be raised to more than 56^0C above the expected softening point for tar, or to more than 111^0C above the expected softening point for asphalt.
3. Do not heat for more than 30 mints and avoid incorporating air bubbles into the sample.

11.8 Procedure

1. Pour enough sample into the clean, dry, warmed Pycnometer to fill it about three fourths of its capacity.
2. Take precautions to keep the material from touching the sides of the Pycnometer above the final level, and to prevent the inclusion of air bubbles.
3. Allow the Pycnometer and its contents to cool to ambient temperature for a period not less than 40 mints.
4. Take weight of the Pycnometer with the stopper plus sample to the nearest 1 mg.(C)
5. Remove the beaker from the water bath.
6. Fill the Pycnometer containing the asphalt with freshly boiled distilled water, placing the stopper loosely in the pycnometer.
7. Don't allow any air bubble to remain in the Pycnometer.
8. Place the Pycnometer in the beaker and press the stopper firmly in place.
9. Return the beaker to the water bath and allow it to remain for a period of not less than 30 mints.
10. Remove the Pycnometer from the water bath.
11. Dry and weigh it in the same way as that employed in 3. of calibration of Pycnometer above.(D)

11.9 Calculation

1. Calculate the Sp. Gr. to the nearest 0.001 as follows:
   Specific Gravity = $(C - A)/[(B - A) - (D - C)]$

Where:

A = wt. of Pycnometer plus stopper
B = Wt. of Pycnometer filled with water
C = Wt. of Pycnometer partially filled with asphalt, and
D = Wt of Pycnometer plus asphalt plus water

2. Calculate Density to the nearest 0.001 as follows:
   Density = Sp. Gr. x WT

Where:

Sp. Gr. = Sp. Gr. as calculated as above and
WT = Density of water at test temperature
= 0.9990 g/cm3 at test Temperature 15.6^{0}C
= 0.9971 g/cm3 at test Temperature 25^{0}C

3. Complete the calculation on the worksheet (*refer form 10: Specific Gravity of Bitumen in Annex*)

Test format (Forms) for bituminous materials

Form 1: Penetration of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory
Penetration of Bitumen, ASTM-D5

Operator____________________________

Date __________________

Project/Offce:__________________

Sample No:____________________________

Contract No: __________________________

Name of Contractor:____________________

Temperature of Water Bath: ☐ °C (STD-25°C)

Weight of Piston: ☐ gms (STD-50gms)

(A)	Decermined No.	1	2	3
(B)	Penetration (1/10mm)			
(C)	Average Penetration			

Range of Penetration (Highest -Lowest) (1/10mm) ☐

IF REQUIRED

(A)	Decermined No.	1	2	3
(B)	Penetration (1/10mm)			
(C)	Average Penetration			

Range of Penetration (Highest -Lowest) (1/10mm) - ☐

Reported Penetration - ☐

Tested by

Checked by

Form 2: Softening point of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory
Softening Point of Bitumen
(Ring & Ball Method)

Operator_____________________ Office/Project___________________________

Date________________________ Sample No______________________________

S.	Expected Softening Point		C

Bath Liquid 1. Water (For S Between 30°C and 80°C) -
2. Glycerine (For S Between 80°C and 15°C)-

Start Temperature 1. Water = 4°C to 6°C
2. Glycerine = 29°C to 31 °C

Time After Start	1	2	3	4	5	6	7	8	Min
Temp of Bath									°C
Temp Increase									°C

Note: Temp Increase Must Be Between 4.5°C/Min and 5.5°C/min

Time After Start	9	10	11	12	13	14	15	16	Min.
Temp of Bath									°C
Temp Increase									°C

Time After Start	17	18	19	20	21	22	23	24	Min.
Temp of Bath									°C
Temp Increase									°C

Time After Start	25	26	27	28	29	30	31	32	Min.
Temp of Bath									°C
Temp Increase									°C

T1	Temp When Ball No. 1 Touches Bottom Plate			°C
T2	Temp When Ball No. 2 Touches Bottom Plate			°C
T	Softening = 1/2 (T1 + T2)			°C

Tested by Checked by Approved by

Form 3: Flash point and Fire point of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory

Flash Point & Fire Point of Bitumen
(Clevelad Open Cup)

Project/Office:- ________________________________

Operator :- ___________________________________ Sample No:- _________________

Date:- _______________________________________

E	Expected Flash Point		^{o}C

AT 50^{o}C Brlow E reduce temprise to 5C/minute
At 56^{o}C Brlow test for flashn & fire points ever ^{o}C

FL	Observed Flash Point		^{o}C
P	Atmosphetic Pressure		mm hg

FL	Observed Flash Point		^{o}C
P	Atmosphetic Pressure		mm hg

Corrected Flash Point = FL + 0.03 x (760-P)
= .... + 0.30 x (760. ....)
= .... ^{o}C (To nearest 2^{o}C)

Corrected Flash Point = FL + 0.03 x (760-P)
= .... + 0.30 x (760. ....)
= .... ^{o}C (To nearest 2^{o}C)

Tested by Checked by

Form 4: Loss on Heating (% Weight)

Nepal Government
Ministry of Physical Infra Structure & Transport
Department of Roads
Central Road Laboratory
Loss on Heating (% Weight)

ASTM D6-80

Operator______________________ Office/Project____________________________

Date_________________________ Sample No______________________________

S.N.	CAN No.	Weight of CAN gm	Wt. of CAN + Bitumen Before heating gm	Wt. of CAN + Bitumen After heating gm	Wt. of Bitumen before heating gm	Wt. of Bitumen After heating gm	Loss on Weight gm	% Loss	Remarks
1									
2									
3									
4									
5									
6									
							Average % Loss		

Tested by

Checked by

Form 5: Solubility in Trichloroethylene

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads
Central Road Laboratory

Solubility In Trichloroethylene

ASHTO-T-44-85
ASTM-D-2042-81

Operator :- ____________________________ Project/Office:- _____________________

Date:- ________________________________ Sample No:- _______________________

Wt. of Beaker (W_1)	gm		Remarks
Wt. of Beaker + Sample (W_2)	gm		
Wt. of Oven Dry Filter Paper (W_3)	gm		
Wt. of Sample (W_2-W_1) = A	gm		
Wt. Oven Dry Filter Paper + Residue (W_4)	gm		
Wt. of Residue (W_4-W_3) = B	gm		
Solubility (B/A x 100)	%		

Tested by

Checked by

Form 6: Marshal Mix Design

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory

Marshal Mix Design

Sample No:-

Project/Office:

Date.....................

Specimen No.	% Bitumen	Thickness (mm)	Wt. in air gm.	Wt. in water gm.	Wt. of SSD Sample gm	Flow		Stability			Correction factor	Remarks
						Initial Div.	Final Div.	Division	Kg	Corrected in Kg		

Tested by

Checked by

Form 7: Extraction of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory

Worksheet for extraction of Bitumen

Procedure No. 2

Operator :- ____________________ Project:- ____________________

Date:- ________________________ Sample No:- _________________

Extraction of Aggregate

A1	Weight of pan + Sample		gm
A2	Weight of pan		gm
A	Weight of sample = A1-A2		gm
B1	Weight of pan + Dry sample from Bowl after Extraction		gm
B2	Weight of pan		gm
B	Weight of dry sample from bowl after Extraction = B1-B2		gm
C	Weight of Dry filter ring after Extraction		gm
D	Weight of dry filter ring before Extraction		gm
E	Weight of Aggreacted in filter ring = C-D		gm
F	Total weight of extracted Aggregate = B + E		gm

MINERAL MATTER IN EXTRACT

G	Weight of dry Centrifuge Cup before centrifuging		gm
H	Weight of dry centrifuge cup after centrifuging		gm
I	Weight of mineral matter in extract = H - G		gm

WATER CONTENT

L	Moisture content of sample from test D1461		%
M	Weight of water in sample = (LxA)÷100		gm

BITUMEN CONTENT

J	Weight of aggregates + minerals in sample - F +I		gm
K	Weight of bitumen in sample = A - J - M		gm
	Bitumen content = $\frac{K}{A}$ x 100% _____ x 1000		%

Form 8: Water Content of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads
Central Road Laboratory
Water Content of Bitumen

Operator :- ____________________ Project/Office:- ____________________

Date:- ________________________ Sample No:- ______________________

Determination No.	1	2	3	4	5
(A) Wt. of Round Bottom Flask (gm)					
(B) Wt. of Round Bottom flask + bitumen (gm)					
(C) Wt. of Bitumen (B-A) (gm)					
(D) Wt. of xylene (gm)					
(E) Vol m of water in Trap (m2)					
(F) Wt. of water in Trap (gm)					
(G) Water Content $\left(\frac{F}{C} \times 100\right)$					

Tested by Checked by

Form 9: Kinematic Viscosity Test

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory

Kinematic Viscosity Test

Office/Project:________________________ Date:______________________

Operator:____________________________ Sample No: ________________

Determination No.	1	2	3
	BSU	TUBE	
Viscometer Type			
% Kerosene Used			
Viscometer No:			
Viscometer Constatnt:			
Temperature of Bath:			
Time taken to reach up to the index mark 'sec'			

Kinematic Viscosity

- Viscometer constant x Time

- .... C st.

Tested by:________________ Checked by:_____________

Form 10 : Specific Gravity of Bitumen

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads
Central Road Laboratory
Specific Gravity of Bitumen

Project/Office:________________________

Sample No: _________________ Date:______________________

Determination No.	**1**	**2**	**3**	**4**
Weight of Pycnometer in air gm				
Weight pycnometer + Bitumen in air gm				
Weight of Pycnometer + Water gm				
Weight of Pycnometer + Bitumen + Water gm				
Temperature of Water 'C				
Specific Gravity				
Average Specific Gravity				
Reported Specific Gravity				

Tested by Checked by

Form 11 : Ductility Test

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads
Central Road Laboratory

Ductility Test

Office/Project:
Date:
Grade of Bitumen ....
Pouring Temperature, °C ....
Test Temperature, °C.....................

Operator:-
Sample No:-
Periods of Cooling, minutes
(a) in air ....
(b) in water bath before trimming ....
(c) in water bath after trimming ....

Test Property	Briquette Number			Mean Value
	(i)	(ii)	(iii)	
1. Ductility value, cm				
2. Repeatability percent				
3. Reproducibility percent				

Tested by

Checked by

PART - VI
TEST ON EMULSION

Table of Contents

1. Determination of Residue on Sieving through 0.710mm Sieve

Reference: BS 434 –Part 1 Appendix C

1.1 Purpose

This method describes the procedures for the determination of the residue on sieving through 0.710 mm sieve.

1.2 Sample

Gently agitate the 4 litre samples taken from the drum, to render them uniform, and sieve immediately as given below.

1.3 Apparatus

1. A circular 0.710mm sieve approximately 100 mm in diameter and 40mm high.
2. A small metal or glass dish about 110mm in diameter
3. Oven controlled to $110^{o} \pm 5^{o}$ C
4. Balance of capacity 250g readable and accurate to 0.01g
5. Balance of capacity 10 kg readable and accurate to 1g
6. A clean, weighed, 4 litre container

1.4 Materials

1.4.1 Solutions

1. For Anionic emulsion: A 2 % solution by mass of potassium or sodium oleate in water
2. For Cationic emulsion: A 1 % solution by mass of cetrimide (a mixture of alkyl trimethylammonium bromides) in N/10 hydrochloric acid.

1.4.2 Solvents

1. Xylene to any grade in BS 458
2. Acetone to BS 509

1.5 Procedure

1. Wash the sieve with Xylene and then Acetone.
2. Place the sieve in the disc, dry in the oven at $110^{o} \pm 5^{o}$C for one hour, cool and weigh, together with the disc to the nearest 0.01g (W1).
3. Remove the sieve from the disc and moisten with the appropriate solution.
4. Render uniform the 4 litre sample, by gentle agitation, and strain immediately through the sieve into the clean, dry, weighed container (W4).
5. When whole of the emulsion has been passed through the sieve, remove the sieve and weigh the container containing the emulsion to the nearest 1 g. (W2)
6. Wash the sieve repeatedly with the appropriate reagent until the washings are no longer discoloured and then wash with distilled water until free from reagent.

7. Place the sieve along with the residue in the small disc and dry for 2 hrs in the oven at $110^o \pm 50^o$ C.
8. Weigh the sieve along with the residue in the small disc to the nearest 0.01g (W3).

1.6 Calculation

Residue retained in percentage = **[(W3 – W1) / (W2 – W4)] x 100**

Where:

W1 *= weight of sieve and small disc (g),*
W2 *= weight of container and emulsion (g),*
W3 *= weight of sieve, small disc and residue (g), and*
W4 *= weight of container (g)*

1.7 Reporting of Results

The result, in percentage, of the residue present in the emulsion retained on 0.710 mm sieve should be reported to the nearest 0.01.

2. Determination of Residue on Sieving through 0.150mm Sieve

Reference: BS 434 –Part 1 Appendix C

2.1 Purpose

This method describes the procedures for the determination of the residue on sieving through 0.150 mm sieve.

2.2 Sample

Gently agitate the 4 litre samples taken from the drum, to render them uniform, and sieve immediately as given below.

2.3 Apparatus

1. A circular 0.150mm sieve approximately 40 mm in diameter and 50mm high.
2. A small metal or glass dish about 60mm in diameter
3. Oven controlled to $110^{o} \pm 5^{o}$ C
4. Balance of capacity 250g readable and accurate to 0.01g
5. A measuring cylinder of 100 ml capacity

2.4 Materials

2.4.1 Solutions

1. For Anionic emulsion: A 2 % solution by mass of potassium or sodium oleate in water
2. For Cationic emulsion: A 1 % solution by mass of cetrimide (a mixture of alkyl trimethylammonium bromides) in N/10 hydrochloric acid.

2.4.2 Solvents

1. Xylene to any grade in BS 458
2. Acetone to BS 509

2.5 Procedure

1. Wash the sieve with Xylene and then Acetone.
2. Place the sieve in the disc, dry in the oven at 110 ± 5^{0} C for one hour, cool and weigh, together with the disc to the nearest 0.01g (W1).
3. Measure 100 ml of emulsion into the cylinder previously moistened with appropriate solution.
4. Pour the emulsion rapidly onto the sieve, previously moistened with appropriate reagent, and maintain a layer of emulsion constantly upon the sieve.
5. Gently tap the sides of the sieve, if necessary, to ensure easy passage of the emulsion.
6. When whole of the emulsion has been passed through the sieve, wash the sieve repeatedly with the appropriate reagent until the washings are no longer discoloured and then wash with distilled water until free from reagent.
7. Place the sieve along with the residue in the disc and dry for 2 hrs in the oven at 110 ± 5^{o} C.

8. Weigh the sieve along with the residue in the disc to the nearest 0.01g (W2).

2.6 Calculation

Residue retained = (W2 – W1)

Where:

W1 *= weight of sieve and disc (g), and*

W2 *= weight of sieve, disc and residue (g).*

2.7 Re porting of Results

Report the residue on sieving through 0.150 mm sieve as "less than 0.1 g" if this is the case, or, if not, as the weight of residue per 100 ml of emulsion to the nearest 0.01 g.

3. Determination of Water and Binder Content

Reference: BS 434 –Part 1 Appendix E

3.1 Purpose

This method describes the procedures for the determination of water and binder content in Emulsion.

3.2 Apparatus

1. Glass or metal still
2. Condenser
3. Receiver
4. Heater

3.3 Materials

Carrier Liquid: A petroleum free from water and yielding not more than 5 % by volume of distillate at 125^0C and not less than 20 % by volume at 160^0C. A suitable carrier liquid is grade 2 or 3 xylene conforming to BS 458.

3.4 Sample

Ensure that the sample is thoroughly representative of the material to be tested.

3.5 Procedure

1. Weigh 30 g to 50 g of the emulsion to the nearest to 0.1 g into distillation flask or still.
2. Add 100 ml of the carrier liquid and one or two glass beads (drops).
3. Assemble the apparatus.
4. Insert a loose plug of cotton wool in the top of the condenser tube to prevent the condensation of atmospheric moisture in the condenser tube.
5. Heat cautiously and regulate so that the condensate falls from the end of the condenser at a rate of 2 drops to 5 drops per second.
6. Continue heating until the volume of water in the receiver is constant.
7. Discontinue heating and cool to room temperature.
8. If any droplets of water are adhering to the sides of the receiver or condenser, dislodge them with a fine wire spiral.
9. Measure the volume of water.

3.6 Calculation

Calculate the water content as follows:

Water content, W (%) = (A / B) x 100

Where:

A = Volume of water in trap (ml), and

B = weight of emulsion sample taken (g)

Binder content (%) = 100 - W

3.7 Reporting

1. Report the result to the nearest 0.1 % for the water content in the emulsion.
2. Report the binder content of emulsion to the nearest 0.1 % by deducting the water content from 100.

4. Determination of Engler Viscosity

Reference: BS 434 –Part 1 Appendix F

4.1 Purpose

This method describes the procedures for the determination of the viscosity of bitumen road emulsion in arbitrary units at 200 C using Engler Viscometer.

Note:

i. *The viscosity of road emulsions may be changed permanently by violent agitation, by heating or chilling, or by long storage at ambient temperature.*

4.2 Summary of method

The time for 200 ml of the emulsion at 20^{O}C to flow from the viscometer into the receiving flask is measured and divided by the time taken for 200 ml of water to flow from the instrument under similar conditions. The ratio is the viscosity of emulsion in Engler degrees.

4.3 Apparatus

1. A standard Engler Viscometer consists essentially of a cup with short jet in the center of the base which may be closed by means of a tapered hard wood stopper, surrounded by a water bath fitted with a stirring device. Thermometers (10^{O}C to 55^{O}C) are carried in both the cup and the water bath.
2. Thermometers (10^{O}C to 55^{O}C)
3. Receiving Flask: 200 ml capacity at 20^{O}C
4. Timing device readable 0.2 s or less.
5. Sieves: 0.710 mm and 0.250 mm

4.4 Calibration

1. Wash the cup and jet with IP petroleum spirit, 40/60, then several times with alcohol and finally with distilled water.
2. Level the viscometer approx and insert a stopper which has been used only for the water test of the apparatus and has never been in contact with oil or emulsion.
3. Fill the receiving flask nearly to the brim with distilled water at 20^{O}C and pour it into the viscometer cup, allowing the flask to drain in an inverted position for 3 min. The cup is thus filled to a little above the pointer.
4. Place the lid and thermometers in position and maintain the temperature of the water in the cup and the water bath at 20^{O} ± 0.5^{O}C.
5. By raising the stopper a few times fill the jet completely with water and wet the surface of the outlet end so that a drop completely covering the surface remains pendant.
6. Set the water surface exactly at the pointers by sucking out excess water with a pipette of if necessary by adding a small quantity of water at 20^{O}C.
7. When the water is completely at rest, place the drained receiving flask underneath the orifice.

8. Lift the stopper right out vertically so that the surface of the water suffers the minimum disturbance and at the same time start the timer.
9. Note the time taken for the receiving flask to fill to the 200 ml mark.
10. Repeat the determination until three consecutive results have been obtained differing by not more than 0.5 s and showing no progressive decrease.
11. Clean the apparatus and make another series of determinations in the same way.
12. If agreement is obtained with the results of the first series, no further tests need be made; if not, carry out further series of determinations until constant times of efflux are found.
13. The mean of the six values of the last two series shall be taken as the time of efflux of water and shall lie between the limits of 47 and 53 s.

4.5 Preparation of sample

Stir the emulsion gently and adjust its temperature to $20^{O} \pm 0.5^{O}C$ in a water bath.

4.6 Procedure

1. Adjust the temperature of the water in the jacket of the viscometer to $20^{O} \pm 0.5^{O}C$ and insert.
2. Insert the stopper in the cleaned cup.
3. Pour the emulsion through sieve of 0.710 mm into the cup until the level makes contact with one or more of the pointers.
4. If necessary, adjust the leveling screws and add more emulsion until the surface of the emulsion just touches all three pointers simultaneously.
5. Remove any excess emulsion with a pipette; do not draw any off by raising the stopper because coagulation of bitumen may occur in the jet when the stopper is re- inserted.
6. When the temperature of the jacket and of the emulsion is steady at $20^{O} \pm 0.5^{O}C$, measure the time of outflow of 200 ml of the emulsion into the receiving flask, allowing the emulsion to flow down the side of the flask to avoid frothing (foaming).
7. Make the measurement at a sufficiently short interval after introducing the emulsion into the viscometer to minimize sedimentation or creaming and maintain the emulsion at $20^{O} \pm 0.5^{O}C$ during the test.
8. Carry out three determinations on three separate portions of the sample and take the mean value.
9. If the three values differ by more than 5 % of the mean value, carry out three further determinations.
10. After each determination wash out the cup with distilled water and remove superfluous water with filter paper. Clean the jet thoroughly by means of a soft filter paper moistened with a solvent such as xylene and dry the bottom of the instrument round the jet with filter paper. If bitumen has been deposited in the viscometer clean by the procedure given above in (1) of Calibration.
11. In case where difficulty is encountered through blockage of the jet of the viscometer, strain the emulsion first through 0.710 mm sieve and then through 0.250 mm sieve

Note:

ii. When gas heating is used, moisture is liable to be deposited and if the bottom of the jet is damp, irregular reading may result.

4.7 Calculation

Viscosity, 0E = TE / TW Engler degrees

Where:

TE = Mean time of efflux of 200 ml of emulsion (s)
TW = Mean time of efflux of 200 ml of water (s)

4.8 Reporting

Report the viscosity to the nearest 0.10 E.

PART - VII
TEST ON GI WIRE

Table of Content

1. Test Method for Mass of Zinc Coating on Wires

(Stripping Method)

Reference: NS 163 – 2045

1.1 Purpose

This method covers the procedure for determining the mass of Zn coating on wires. This test is required to check the compliance with the requirement of the Specification.

Note:

i. During stripping process small amount of poisonous gas stibina (SbH3) may be evolved in hydrochloric acid- Antimony tri-chloride method. So the test should be performed under a hood with exhaust fan.

1.2 Apparatus

1. Glass Container: Internal Diameter 50mm for wire having dia equal or less than 2.8mm and Int. Dia. 75mm for wire having dia. More than 2.8mm
2. Forceps or tongs
3. Balance with accuracy of 0.01 g

1.3 Reagent

1. Antimony Trioxide or Antimony tri-chloride
2. Concentrated Hydrochloric Acid having Sp. Gr. 1.16

1.4 Preparation of Solutions

1.4.1 Preparation of Antimony Chloride Solution

Dissolve 20 g of Antimony Trioxide or 32 g of Antimony Tri-chloride in 1000 ml of concentrated Hydrochloric Acid having Sp. Gr. 1.14.

1.4.2 Preparation of stripping Solution

Immediately before test, prepare the stripping solution by adding 5 ml of the antimony chloride solution prepared under a) above to 100 ml of concentrated hydrochloric acid having Sp. Gr. 1.14.

1.5 Test Piece

1. The length of the test piece shall be not less than 200 mm for the wire having dia. 3mm or more.
2. For test of wires having dia smaller than 3mm, the length of test piece shall be such that the wt of the test piece in gm shall be more than 4 times its dia in mm.
   (Wt of test piece (g) $\geq$ 4 x dia of wire in mm)
3. Three test pieces shall be prepared for each sample.
4. The test pieces shall be washed with solvent like trichloroethylene or any other suitable organic solvent, wipe with clean soft cloth and dried thoroughly.

1.6 Procedure

1. Take wt. of the each test piece to 0.01 g (M1).
2. Put the stripping solution in the glass container.
3. Immerse one test piece at a time in the stripping solution. If the test piece is too long for the container, it shall be either bent or coiled to permit complete immersion in the test solution.
4. When the evolution of hydrogen ceases or a few bubbles are being evolved, the test piece shall be taken out, washed in water, wiped off with clean soft cotton cloth and fully dried.
5. Take weight of the stripped test piece to 0.01g (M2)
6. Measure the dia. of the stripped test piece to 0.01mm at two places at right angles to each other of the same location to obtain the average value.
7. Calculate the mass of Zn coating in g/m2 as follows (refer Form 1: Test for mass of Zinc Coating on Wire and Plate in Annex):

Mass of Zn Coating = 1960 x d x r g/m2

Where,

d = Average dia. of stripped test piece in mm and
r = (M1 – M2)/ M2
M1 = Original mass of the test piece in g.
M2 = Mass of stripped test piece in g

Note:

ii. *The temperature of the stripping solution should not be more than 380 C.*
iii. *The time required for stripping will vary depending upon the coating thickness but should not exceed one minute.*
iv. *The same stripping solution may be repeatedly used without further addition of the Antimony chloride solution until the time for stripping becomes inconveniently long.*
v. *The number of the specimens immersed at any one time shall not exceed three per 100 ml of the stripping solution.*

2. Test Method for Uniformity of Zinc Coating, (Preece Dip Method)

Reference: NS 163 -2045

2.1 Purpose

This method provides the procedure for the determination of Uniformity of Zn coating.

2.2 Apparatus

1. Glass container:
   - i. Internal diameter 50mm and depth 150 mm for testing the wire having diameter equal to or less than 2.8 mm, or
   - ii. Internal diameter 75 mm and depth 150 mm for testing the wire having diameter more than 2.8 mm.
2. Glass rod for stirring
3. Forceps or tongs
4. Thermometer 10 C accuracy

2.3 Reagent

2.3.1 Copper Sulphate Solution

Dissolve 36 gm of copper sulphate crystalline, (Cu SO4, 5 H2O) in 100 ml of distilled water to prepare copper sulphate solution. The process of dissolving can be expedited by heating the water. If it is heated, it should be cooled before neutralization.

2.3.2 Neutralization

Dissolve 1 gm of Cupric hydroxide or 0.7 gm of Cupric Oxide in one liter of Copper sulphate solution prepared as mentioned above. If cupric hydroxide is used, the mixed solution should be kept for more than 24 hrs for neutralization. If cupric oxide is used, the mixed solution should be kept for more than 48 hrs for neutralization. After the neutralization, the mixed solution is ready as test solution. The Sp. Gr. of the test Solution should be 1.186 at 180 C.

2.4 Sample preparation for Test

a. The test samples should be at least 150 mm in length and should be preferably without damage.

b. The test samples may be straightened, if required, by hand and cleaned using volatile organic solvent like trichloroethylene. Then it should be rinsed with water and wiped with soft clothes to make dry.

2.5 Procedure

1. Fill the glass container with the test solution to a depth of minimum 100 mm.
2. The temperature of the test samples and the test solution should be maintained at 18 ± 20 C for the entire test period.
3. No more than 3 test samples should be immersed at one time.

4. Test samples should not touch each other.
5. During test, the test samples and/ or solution should not be shaken or disturbed.
6. The test sample should be dip for exactly one minute and after every dip it should be removed immediately and should be washed with clean water and wiped with soft clothes for dryness.
7. Any black deposits found on the test sample should be removed with the help of fiber brush.
8. The number of one minute dips should be as per the table given below.
9. If the test sample is required for ½minute dip also, one minute dips should be performed first, then only the ½minute dip should be done.
10. If the test sample is from fabricated objects, then the minimum number of dips should be reduced by one ½ minute dip.
11. The test solution should be discarded after testing 6 numbers of samples. Then fresh test solution should be used for the test of other samples.

2.6 Results

1. Record the findings in format provided in Annex (refer Form 2: Test for Uniformity of Zinc Coating)
2. After testing the sample in the copper sulphate solution for the no. of dips as specified in the table, the Zn coating should be able to withstand without any bright deposit of metallic copper upon the base metal at all points more than 25 mm from a cut end.
3. Detection of False End Point
4. If it is possible to remove the bright copper deposit with an ink eraser or to peel the copper deposit with the edge of a blunt tool such as back of a knife blade, and zinc appears underneath of copper, such an appearance of deposit copper shall be construed as false end point.

Note:

i. Abnormal cases: Abnormal cases may arise when, by reason of unusual surface conditions, the copper sulphate solution will not act normally on the Zn – coating, for example, the solution may have no apparent attack on all or part of the surface, or false deposits of copper may appear on the Zn coating. If there is any such abnormality of performance of test pieces, they shall be discarded and new ones selected.

The new test pieces shall be cleaned in trichloroethylene, rinsed and wiped dry and then immersed for 3 minutes in a solution consisting of one part by volume of Ammonium Hydroxide (Sp. Gr. 0.90) and nine parts of distilled water. The test pieces may be scrubbed with cotton cloth during the immersion. After cleaning the test pieces shall be washed and wiped dry. Then test with copper sulphate solution should be performed as mentioned above.

ii. Application of Preece test to weathered and aged galvanized wire: This Preece test is not applicable to aged or weathered materials because of corrosion film present on the Zn coating. If it is desired to test on such materials, the corrosion film should be removed before testing following the procedure as mentioned above Note (i).

iii. If at any time during the test, there is any doubt as to the presence of exposed base metal, as determined by VISUAL INSPECTION, one or more of the tests like microscopic test, water Immersion test and qualitative test for Zn, may be used.

Table 5.1: Table for Wt. of Zn Coating and No. of Dips for Heavy Coated Wires

SWG/mm	6/4.88	7/4.47	8/4.06	9/3.66	10/11 3.25/2.95	12/13 2.64/2.34
Minm Zn Coating-g/ sq.m.	290	290	290	280	270	260
No. of Dips-1minute	3	3	3	3	3	3
No. of Dips-1/2 minute	1	1	1	1	1	-

3. Test Method for Adhesion of Zinc Coating

Reference: NS 163 – 2045

3.1 Purpose

This method provides the procedure for the determination of Adhesion of Zn coating.

3.2 Apparatus

1. Cylindrical Mandrel of different diameters

Nominal diameter of wire (mm)	**Minimum No. of complete turns**	**Diameter of Mandrel**
Up to and including 3.5	10	4 x dia. of wire
over 3.5 up to and including 7.10	10	6 x dia. of wire
over 7.10 up to and including 10.0	¼ (one 900 bend)	6 x dia. of wire

2. A system capable of rotating the mandrel or winding the wire round the mandrel at a rate not more than 15 turns per minute.

3.3 Test Sample

The test sample consists of a piece of wire long enough to allow the test to be carried out properly.

3.4 Procedure

1. The test sample should be wound round a cylindrical mandrel of diameter as mentioned above in the table so as to form close spirals of 10 complete turns.
2. Winding shall be carried out at a rate of not more than 15 turns per minute.

3.5 Test Results

1. When so wound or bent around the mandrel, the Zn coating shall remain adherent to the steel wire.
2. It shall be considered as meeting this requirement if owing to such winding or bending, it does not flake off, nor crack to such an extent that there is possibility of removing any Zn by rubbing with bare fingers.
3. The use of finger nail is not allowed to remove any Zn coating.
4. Record the findings in format provided in Annex (refer Form 3: Test for Adhesion of Zinc Coating)

4. Tensile Test on Wire

4.1 Purpose

This method provides the Procedure for the determination of tensile strength of the wire.

Note:

i. The Machine to be used is a CONTROLS UNITESTER C21 fitted with tensile testing attachments

ii. THE MAXIMUM LOAD IN TENSION IS 50 KN

iii. The maximum load must not be exceeded even if this means ending the test before the wire breaks.

4.2 Apparatus

1. CONTROLS UNITESTER C21
2. Upper and lower sample holders for wire, CONTROLS u350
3. Micrometer gauge, steel rule and marking pen/scriber.

4.3 Test Procedure

4.3.1 Insert sample into machine.

1. Cut a length of the wire to be tested.
    a. A minimum length of about 600 mm is required to go round both rollers and leave space between the rollers for marking the gauge length.
2. Measure and record the diameter of the wire using the micrometer gauge (***at four points along the wire***).
3. Grip the wire securely in the bottom sample holder and tighten the bolts. Wrap the wire around the bottom roller.
4. Adjust the height of the cross beam so that the wire reaches the top sample holder.
5. Wrap the wire round the top roller and clamp tightly in the top jaws.
6. The wire between the sample holders should be vertical.

4.3.2 Set the machine controls

1. Set pressure gauge selector to 1-2. This ensures that gauge No.2 (***50 KN.Max***) will register the load.

Note:

iv. Once the load reaches 45 KN a protection valve will prevent overload of gauge No.2 ***(the load will fall off on gauge NO.2)*** *and the load must be read on gauge No.1. UP TO A MAXIMUM OF 50 KN.*

2. The lever with Red tape selects either load or unloads.

3. The lever with BLACK tape selects speed
   a. Push lever to machine gives TEST SPEED.
   b. Pull lever from machine (***towards you***) gives MAX SPEED.
4. Fine variations of speed are obtained by adjusting the FLOW VALUE (***circular valve with GREEN tape between the red and black levers***).
5. Set the
   a. Red lever to UNLOAD
   b. Black lever to MAX SPEED
   c. Green valve to ZERO

4.3.3 Test

1. Switch on machine.
2. Put RED lever to load and the wire will begin to straighten out as the machine bottom plate moves upwards
3. As soon as the load begins to be applied (***pressure gauge No. 2 starts to register load***). Switch the BLACK lever to TEST SPEED.
4. With the wire straight in the machine (***no bends***) and with no load applied, mark the gauge length on the wire using the rule and marker pen/scriber.

Note:

v. The gauge length should be as long as possible between the jaws say 100mm.

5. Adjust the GREEN valve reading so that the load is steadily applied to the wire and the load increase is registered as a steady increase on gauge No. 2
6. The load will increase until YIELD starts to occur. At this point the load registered on the gauge will remain more of less constant.
7. Record the YIELD load and the MAXIMUM load (***Ultimate load***) if the wire breaks (***fractures***) at a higher load than the yield load (***refer Form 4: Test for Tensile Strength of Wire and Bar in Annex***).
8. Switch off the machine and put the
   a. Red lever to UNLOAD
   b. Black lever to MAX SPEED
   c. Green valve to ZERO
9. Remove the wire from the holders and
   a. Record the diameter of the wire at the point of breaking (***fracture***)
   b. Fit the broken ends together and measure the increase in gauge length (***if the break occurs inside the gauge length***).

Annex

Test Format for GI Wire

Form 1 : Test for mass of Zinc Coating on Wire and Plate

Nepal Government
Department of Roads
Central Road Laboratory

Test For Zinc Coating on Wire & Plate

Project/Office: Material Date:-

S.N.	Sample No		Original diameter of wire (mm)	Original Wt. (gm)	Stripped Wt. (gm)	Stripped diameter of wire (mm)	Wt. of Zn gm/m^2	Remarks
	Field	Lab						

Tested by Checked by

Form 2 : Test for Uniformity of Zinc Coating

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads

Central Road Laboratory

Uniformity of Zinc-Coating Test Sheet

Project/Office:______________________ Date:____________________

Operator: ________________

S.N.	Sample No.		Type of GI Wire	Original diameter of GI Wire (mm)	No. of dips		Result	Remarks
	Field	Lab			1 min	1/2 min		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Tested by:_____________ Checked by:__________

Form 3 : Test for Adhesion of Zinc Coating

Nepal Government
Ministry of Physical Infrastructure and Transport
Department of Roads
Central Road Laboratory

Adhesion test of Zinc-Coating.

Project/Office:________________________
Operator: _________________
Date:______________________

S.N.	Sample No.		Original Diameter (mm)	No. of Turn	Time (Sec)	Dia of Mandrel	Observation	Results
	Lab	Field						
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Remarks :

____
Tested by

____
Checked by

Form 4 : Test for Tensile Strength of Wire and Bar

Nepal Government
Ministry of Physical Infrastructure & Transport
Department of Roads
Central Road Laboratory

Tensile Test on Wire & Bar

Office/Project: Date:

S.N.	Sample No.		Original Diameter (mm)	Load KN	Area of Wire & Bar mm^2	Corrected Load KN	Tensile Strength (N/mm^2)
	Field	Lab					

Tested by

Checked by

11 Test on GI Wire