ORISSA SCHOOL OF MINING ENGINEERING, KEONJHAR

DIPLOMA IN CIVIL ENGINEERING

CIVIL ENGINEERING LABORATORY-I

(LAB MANUAL)

3RD SEMESTER

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CIVIL ENGINEERING LABORATORY-I – SYLLABUS

Exp.No	Name Of The Experiments
	Material Testing Laboratory-
01	Determination Of Young's Modulus Of Steel In Tensile Testing Machine.
02	Determination Of Fineness Of Cement By Sieving.
03	Determination Of Normal Consistency, Initial And Final Setting Time Of Cement.
04	Determination Of Soundness Of Cement By Le-Chatelier Apparatus.
05	Determination Of Compressive Strength Of Cement.
06	Determination Of Compressive Strength Of Burnt Clay, Fly Ash Bricks And Blocks.
07	Grading Of Fine And Coarse Aggregate By Sieving For Concrete.
08	Determination Of Specific Gravity And Bulking Of Sand.
09	Determination Of Specific Gravity And Bulk Density Of Coarse Aggregate.
10	Grading Of Road Aggregates.
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12	Determination Of Crushing Value Test Of Aggregates.
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15	Determination Of Soundness Test Of Road Aggregates.
	Concrete Laboratory-
16	Determination Compressive Strength Of Concrete Cube.
17	Determination Of Workability Of Concrete By Slump Cone Method.
18	Determination Of Workability Of Concrete By Compaction Factor Method.
19	Non Destructive Test- Demonstration On Rebound Hammer.
20	Non Destructive Test- Ultrasonic Pulse Velocity Measuring Instrument.

Experiment – 01

Determination of Young's Modulus of Steel in a Tensile Testing Machine

Aim:

To conduct a tensile test on a mild steel specimen and determine the Young's modulus of elasticity

Apparatus Required:

1. Universal Testing Machine (UTM)
2. Mild steel specimens
3. Graph paper
4. Scale
5. Vernier Caliper

Theory:

The tensile test is most applied one, of all mechanical tests. In this test ends of test piece are fixed into grips connected to a straining device and to a load measuring device. If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original form as soon as load is removed. However, if the load is too large, the material can be deformed permanently. The initial part of the tension curve which is recoverable immediately after unloading is termed. As elastic and the rest of the curve which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformations essentially entirely elastic is known as the yield strength of material. In some material the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and a lower yield point. However, some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. This stage the "ultimate strength"‟ which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Further loading will eventually cause „neck‟ formation and rupture.

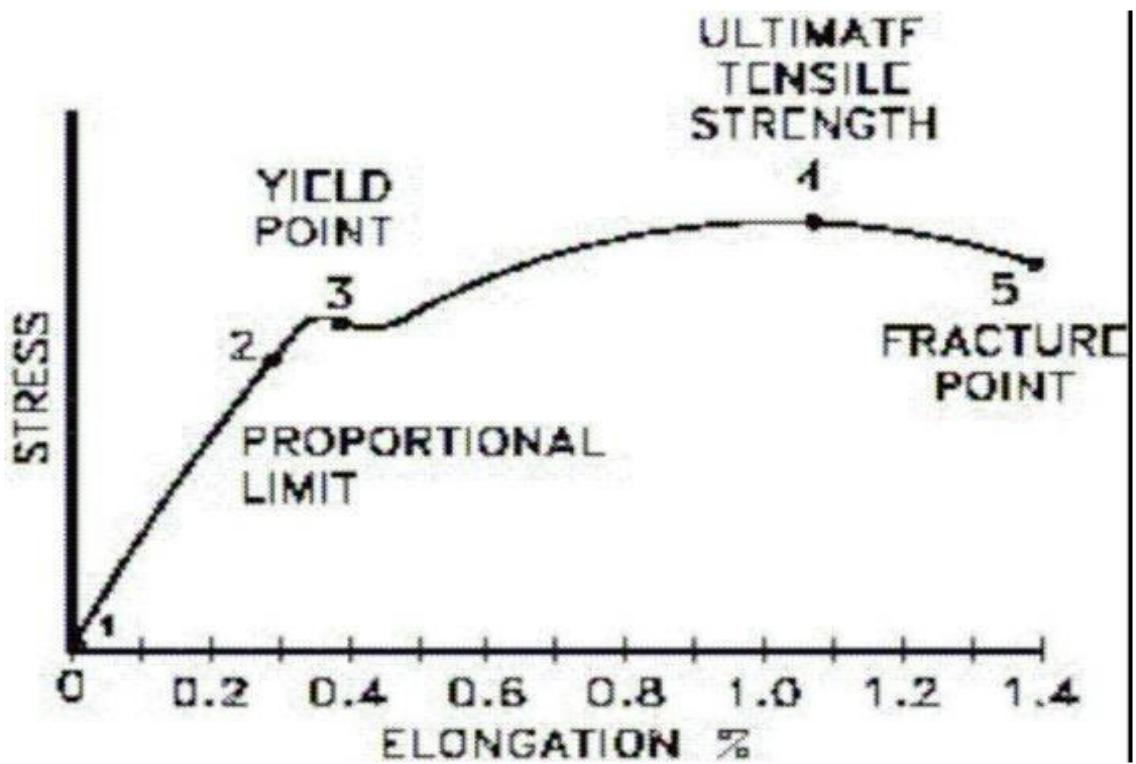
Procedure:

1. Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen.
2. Insert the specimen into grips of the test machine and attach strain-measuring device to it.
3. Begin the load application and record load versus elongation data.
4. Take readings more frequently as yield point is approached.
5. Measure elongation values with the help of dividers and a ruler.
6. Continue the test till Fracture occurs.
7. By joining the two broken halves of the specimen together, measure the final length and diameter of specimen.

Working Of the Instrument:

The required gauge length (between 30 to 120mm) is set by adjusting the upper knife edges. A scale is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp to press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjusts screws. Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damaged. As a safety, while testing the instrument may be kept hanging from a fixed support by a slightly loose thread.

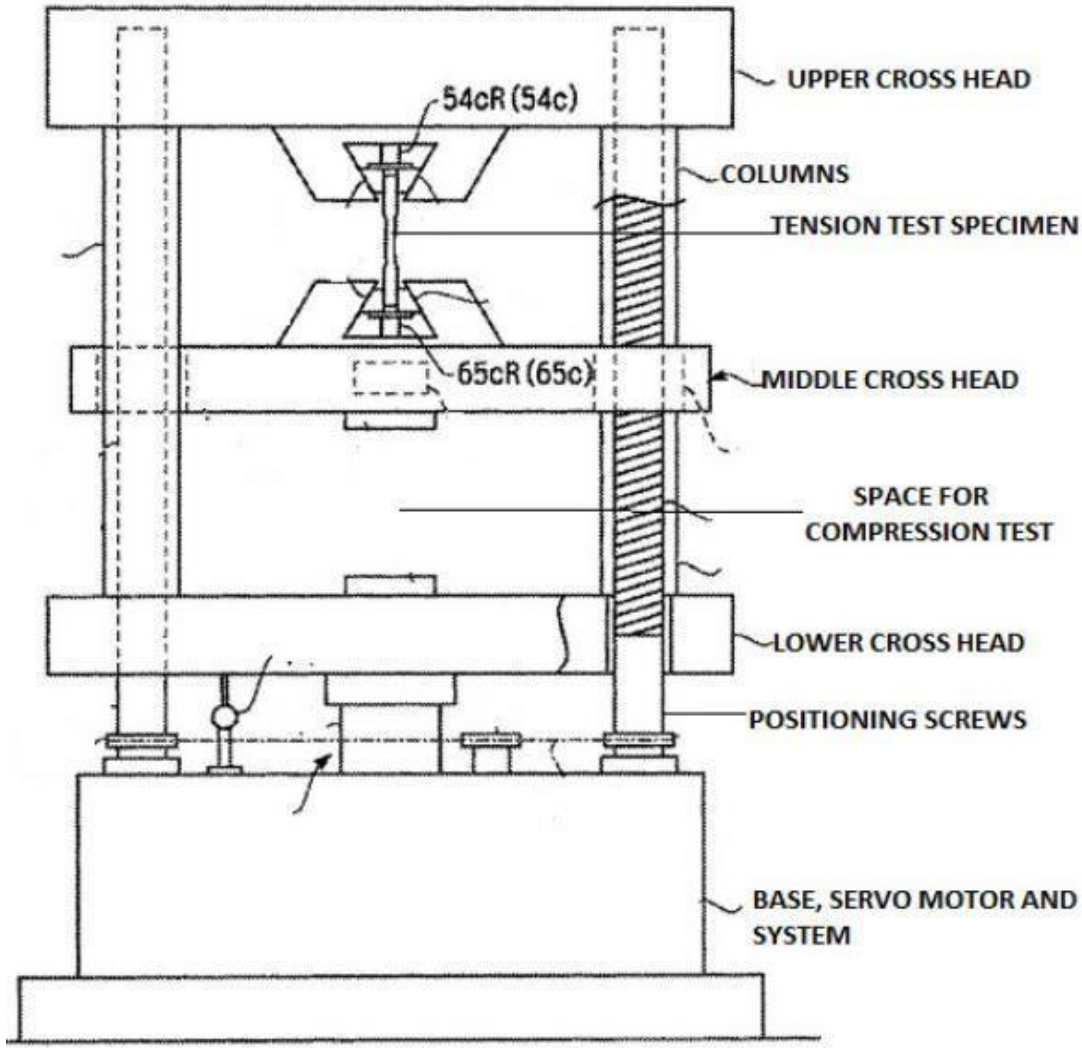
Stress And Strain Curve:

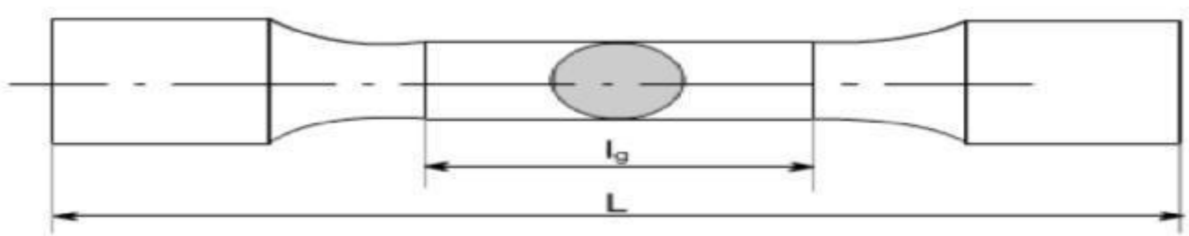


Result:

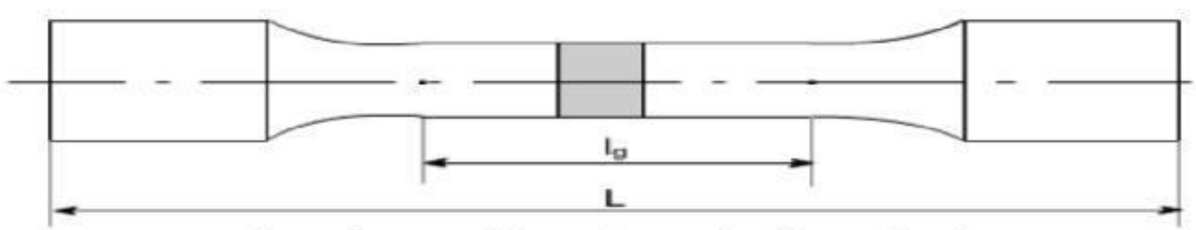
The young's modulus of steel is __________________N/mm^2

Diagram:





[specimen with circular X-section]



[specimen with rectangular X-section]

Observation:

(A) Original dimensions-

Gauge Length = ___________________mm

Diameter = ___________________ mm

Area = ___________________mm^2

(B) Final Dimensions-

Gauge Length = ___________________mm

Diameter = ___________________mm

Area = ___________________mm^2

Calculation:

Young's Modulus (E) = Tensile Stress / Tensile Strain

= P . L / A . change in length

Where - P - Applied Force in N
L – Initial Length in mm
A – Area in mm^2

Tabulation:

Sample No.	Applied force in (N)	Change in Length in (mm)	Young's modulus (E) in N/mm^2
1			
2			
3			
4			
5			

Experiment – 02

Determination of Fineness of Cement by sieving Method`

Aim:

To determine the fineness value of cement by using dry sieving method.

Apparatus Required:

1. Standard weigh balance with 100gm. Weighing capacity
2. IS -90 Micron sieve
3. Dry cement sample

Procedure:

1. Break down any air-set lumps present in the cement sample with fingers.
2. Weigh accurately 100gms of the cement and place it on a standard micron IS-90 sieve.
3. Starts continuously sieve the sample for 15 minutes by manually.
4. Weigh the residue left after 15 minutes of sieving. This complete the test

Result:

The fineness value of cement is _______________%

Limits:

The percentage of residue should not exceed 10%.

Precautions:

Sieving shall be done holding the sieve in both hands gentle wrist motion; this will involve no danger of spilling the cement, which shall be kept well spread out on the screen. More or less continuous rotation of the sieve shall be carried out throughout sieving.

Washers, shots and slugs shall not be used on the sieve. The underside of the sieve shall be lightly brushed with a 25 or 40 mm Bristle brush after every 5 minutes of sieving.

Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method

Diagram:

IS- 90 micron sieve

Observation:

Original weight of the cement sample (A) = ______________gm.

Weight of the sample retained on the sieve (B) = ______________gm.

Calculation:

The percentage weight of the residue over the total sample

$$= \frac{\text{Weight of the sample retained on the sieve x 100}}{\text{Total weight of the sample}}$$

$$= \frac{A \times 100}{B}$$

= __________%

Experiment – 03

Determination of Normal Consistency, Initial and Final Setting Time of Cement

Determination of Normal Consistency-

Aim:

To determine percentage of water required to produce a standard cement paste.

Apparatus required:

1. Vicat's apparatus
2. Balance
3. Measuring cylinder
4. Stop watch
5. Glass plate
6. Enamel tray
7. Trowel

Procedure:

1. Keep the Vicat apparatus on a level base (when using Vicat apparatus with dashpot, keep the bearing movable rod to its highest position and pin it.) Unscrew the top of the dashpot. Half fill the dashpot with any suitable oil of viscosity and screw the top. Work the plunger a number of times.
2. Attach the plunger for determining standard consistency to the movable rod. Work the plunger a number of times.
3. Take 400 gm of cement in a pan and a weighed quantity of water in a beaker.
4. Prepare a paste with the water added to cement. Start a stopwatch at the time of adding water to cement.
5. Keep the Vicat mould on a non porous plate and fill the cement paste in it.
6. After completely filling the mould, shake it slightly to expel the air. Smooth off the surface of the paste making it level with the top of the mould. The cement paste thus prepared is the test block.
7. Place the test block resting on the non porous plate under the movable rod, bearing the needle.
8. Lower the plunger gently to touch the surface of the cement paste and quickly release; (when Vicat apparatus with dashpot is used, place the mould filled with cement paste and the non absorbent plate on the base plate of the Vicat apparatus. Raise the plunger of the dash pot and bring it in contact with the top cap of the movable bearing rod.
9. Remove the pin holding the movable bearing rod to the surface of the cement paste and quickly release by pushing down the plunger to sink in to the paste). This operation shall be done immediately after filling the mould.
10. Prepare trial test specimens with varying percentages of water until plunger penetrates to a point 5 to 7mm from the bottom of the Vicat mould, which is read on the scale. Express the water required as percentage by weight of the dry cement.

Observations:

1. Weight of cement taken (g) = __________
2. Initial percentage of water added to cement = ___________
3. Quantity of water added to cement =________

Tabulation:

SL. NO.	QUANTITY OF WATER ADDED(ml)	DEPTH OF PENETRATION(mm)

Calculation:

$$\text{Standard Consistency of Cement} = \frac{\text{Quantity of water for 5-7 mm penetration x 100}}{\text{Weight of cement}}$$

Points to be noted:

1. The time of gauging should not be less than 3 minutes and not more than 5 minutes. Gauging time is the time elapsing from the time of adding water to the dry cement until commencing to fill the mould.
2. The test should be conducted at room temperature $27^{o}C$ +/- $2^{o}C$
3. There should be no vibration on the working table.
4. The plunger should be cleaned during every repetition.

Result:

Percentage of water content for standard consistency = ____________ %

1. Vicat Apparatus:
The Vicat apparatus consists of a frame having a movable rod with a cap at one end and at the other end any one of the following attachment, which are interchangeable:

1. Needle for determining the initial setting time
2. Needle for determining the final setting time
3. Plunger for determining the standard consistency

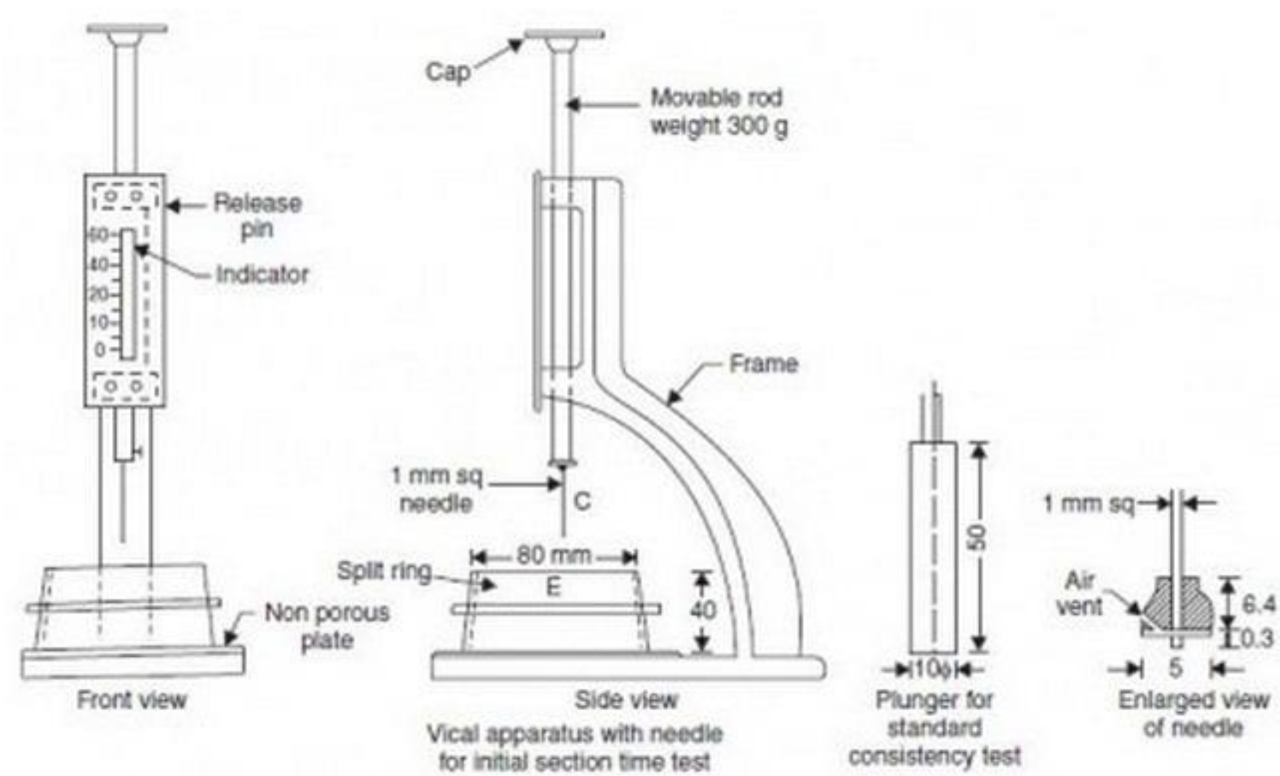
2. Needles:
Needle for Initial Setting Time-
The needle is having a cross sectional area of 1mm^2. The end of the needle is flat.
Needle for Final Setting Time-
The needle is circular having a cross sectional area of 1mm^2. The needle is fitted with a metal attachment. The end of the needle projects beyond the cutting edge of the hollowed out metal attachment.
Plunger for Standard Consistency-

It is of polished brass 10 ± 0.05mm in diameter with a projection at the upper end for insertion into the movable rod. The lower end is flat.

3. Movable Rod:
Movable rod carries an indicator which moves over a graduated scale attached to the frame (certain models have an additional attachment of dash pot, which facilitates lowering of movable rod slowly).

4. Graduated Scale:
Graduated scale is 40mm in length and the smallest division of scale is 1mm.

5. Vicat Mould:
The Vicat mould is in the foam of a frustum of a cone having an internal diameter of 60+/-0.5mm at the top, 70 +/- 0.5mm at the bottom and height 40 +/_ 0.5mm.



Determination of Initial and final Setting Time:

Aim:

To determine the initial and final setting time of cement.

Apparatus Required:

8. Vicat's apparatus
9. Balance
10. Measuring cylinder
11. Stop watch
12. Glass plate
13. Enamel tray
14. Trowel

Procedure:

Initial Preparation:

1. Consistency test to be done before starting the test procedure to find out the water required to give the paste normal consistency (P).
2. Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
3. Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (T_1).
4. Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.

Test for Initial Setting Time:

1. Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
2. Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
3. In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (T_2).

Test for Final Setting Time:

1. For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
2. The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (T_3).

Observations:

1. Weight of cement taken = ____________ gm
2. Weight of water added = ____________ gm
3. Time at which water is mixed with water T_1 = ____________ am/pm
4. Time when initial setting time needle penetrated 5-7mm T_2 = ____________ am/pm
5. Time when collar of final setting time needle stopped to make impression T_3 = __________am/pm

Calculations:

Initial setting time = T_2-T_1=__________ - __________ = ____________ minutes

Final setting time = T_3-T_1=__________ - __________ = ____________ minutes

Where-

T_1 =Time at which water is first added to cement.
T_2 =Time when needle fails to penetrate 5 mm to 7 mm from bottom of the mould.
T_3 =Time when the needle makes an impression but the attachment fails to do so.

Result:

Initial setting time for given sample of cement, is found to be = __________ minutes

Final setting time for given sample of cement, is found to be = __________ minutes

Needle used for finding
Initial setting time of cement

Needle with annular
attachment used in
Final setting time of cement

Experiment – 04

Determination of Soundness of Cement by Le-Chatelier Apparatus.

Aim:

To determine the excess lime present in cement.

Apparatus required:

1. Le- Chatelier mould.
2. Cement.
3. Glass sheets.
4. Mixing pan.
5. Trowel.
6. Wight.
7. Measuring glass cylinder.

About Le-Chatelier mould:

It consists of a small split cylinder forming a mould having dimensions of internal dia 30mm and height 30mm. On either side of the split cylinder, two parallel indicating arms with pointed ends of length165 mm are attached. Remember, Le-Chatelier mould is a split cylinder (opened Cylinder) Indicator arms determine the expansion of cement.

Procedure:

1) Take 400 gram of cement sample. The mould and the glass plates are oiled before conducting the Test.

2) For this test to be performed we need standard consistency of cement. Water is taken as 0.78 x P (Where P is water required for Standard consistency in percentage)

(For example, Standard consistency is 30% of water, then take water percentage for soundness is 0.78 x 30% = 23.4%. So water to mixed in 400 gm of cement will be 400 x (23.4/100) = 93.6ml.)

3) Make well mixed paste of cement and fill in Le- Chatelier mould taking care to keep the edges of the mould gently together during the operation.

4) Clean upper surface and make it smooth and place a small weight over the cover plate.

5) Put this assembly quickly in water at a temperature of 27º C + 2ºC and keep it there for 24 hours.

6) Take out mould from water and measure distance between the indicators points as Reading-1. (Suppose it is 2 mm)

7) Now, again put this assembly in boiling water for 25 to 30 minutes and keep at boiling for 3 Hours. The mould should be in boiled water during this period

8) Remove the mould from water and allow it to cool at room temperature.

9) Measure the distance between the indicator points as Reading-2. (Suppose it is 10mm)

10) Soundness of cement = (Reading-2) – (Reading-1)

= 10 mm – 2mm

= 8 mm

Result:

The value of soundness of cement obtained = ______________ mm

Limits:

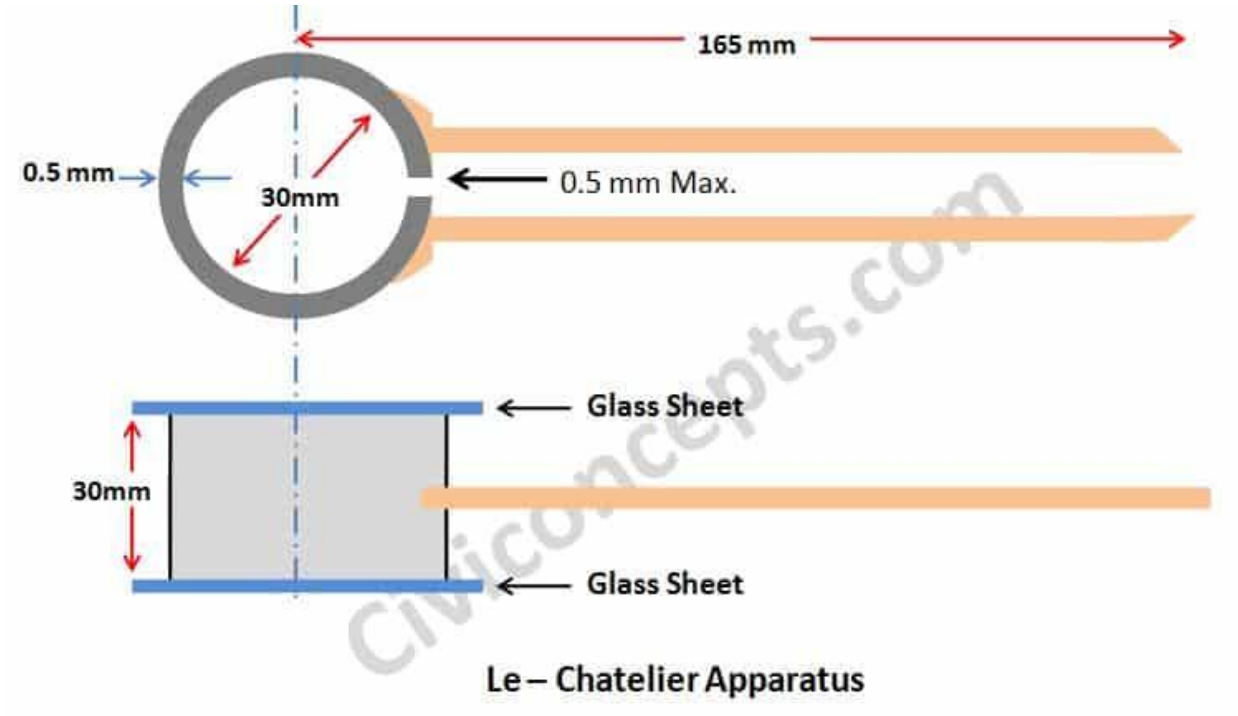
A good cement (OPC, PPC, Rapid hardening etc) should have not more than below expansion limits.

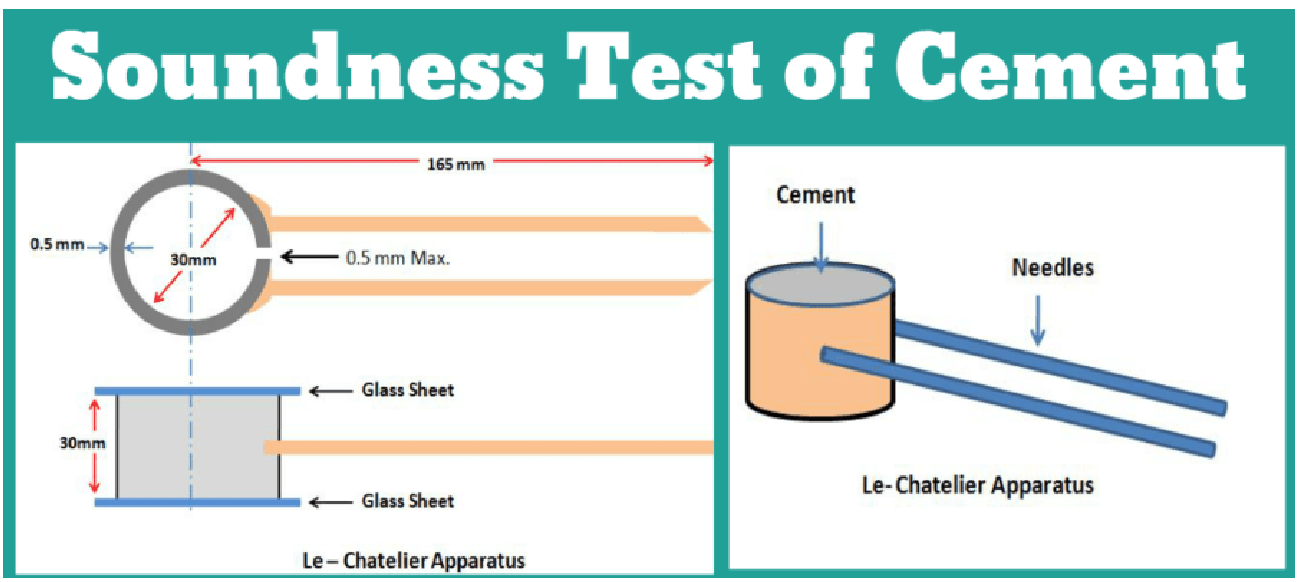
Types of Cement	Expansion Limits
Ordinary Portland cement [OPC] 33 Grade, 43 Grade, 53 grade	10mm
Portland Pozzolona Cement [PPC]	10mm
Rapid Hardening cement	10mm
Low heat cement	10mm
Super sulphated cement	5mm

Precautions:

1. The test is conducted with special care and guidance
2. Filling of moulds must not be done by applying extra pressure.
3. During the process of boiling, the water level must not go below the height of the mould

Diagram:





Calculations:

Expansion= B- A

Here,
A = The measurement taken after 24hours of immersion in water at 27 ± 2degree Celsius
B = The measurement taken after 3hours of immersion in water at boiling temperatur

Experiment – 05

Determination Of Compressive Strength Of Cement.

Aim:

To determine the compressive strength of a cement cube by using compression testing machine.

Apparatus required:

1. Standard sand and cement.
2. Cube mould of 70.6mm x 70.6mm x 70.6mm
3. Vibrating machine.
4. Gauging trowel.
5. Poking/ tamping rod.
6. Balance of capacity 10Kg and sensitivity 1gram.
7. Measuring glass cylinder.
8. Compression testing machine (CTM).

Procedure:

1. Unless otherwise specified this test shall be conducted at a temperature $27^0 + 2^0$ C.
2. Weigh the material required for each cube separately.
3. The quantity of cement, standard sand of 1:3 and water required for each cube are as follows
   Cement = 200gms
   Standard Sand = 600gms, Conforming to IS: 650 –1991.
   Water = (P/ 4+ 3) Percentage of combined mass of cement and sand. P is the consistency of Cement as per IS: 4031 (Part 4) 1988.
4. Place on a nonporous plate, a mixture cement and standard sand.
5. Mix it dry with a trowel for one minute and then with water until the mixture is of uniform colour.
6. The time of mixing shall in any event be not less than 3 minutes and should be the time taken to obtain uniform colour exceeds 4 minutes.
7. In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply a similar coating of petroleum jelly between the contact surface of the bottom of the mould and base plate in order to ensure that no water escapes during vibration.
8. Place the assembled mould on the table of the vibration machine and hold it firmly in position by means of suitable clamp, attach a hopper of suitable size and shape securely at the top of the mould to facilitate filling and hopper shall not be removed until the completion of vibration period.
9. Immediately after fixing the mould in the vibrating machine, place the mortar in the cube mould and prod with the rod.
10. Prod the mortar 20 times in about 8 seconds to ensure elimination of entrapped air and honey combing.
11. Place the remaining mortar in the cube mould and prod again as specified for the first layer and then compact the mortar by vibration.
12. The period of vibration shall be two minutes at the specified speed of 12000 + 400 vibrations per minute.
13. Remove the mould from the vibrating machine and cut of the excess mortar with a straight edge.

14. Store the test specimens in a place free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27 + 20C for 24 + 1/2 hours from the addition of water to the dry ingredients. After this period, mark the specimens and remove from the moulds and unless required for test within 24 hours.
15. Immediately submerge the cubes in a clean, fresh water or saturated lime solution and keep there until taken out just prior to test.
16. Renew the water or solution in which the specimens are submerged for every seven days, and the temperature of water is maintained with the specified limits.
17. Conduct testing at recognized ages of the specimens, the most usual being 7 and 28 days.
18. When it may be necessary to obtain the early strength, tests may be conducted at the age of 72 + 2 hours.
19. Calculate the ages from the addition of water to the dry ingredients.
20. Test at least three specimens preferably from different batches at each selected age.

Result:

The average 3 Days Compressive Strength of a cement mortar cube =___________________ N/mm^2

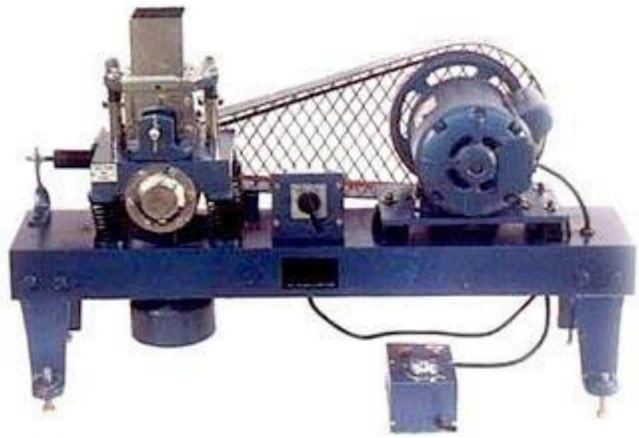
The average 7 Days Compressive Strength of a cement mortar cube =___________________ N/mm^2

The average 28 Days Compressive Strength of cement mortar cube = ___________________N/mm^2

Precaution:

The time of mixing is very important and in no case shall not be less than 3minutes and not to exceed 4 minutes

Diagram:



Vibrating table

Mortar cube 70.6mm x 70.6mm x 70.6mm

Measuring cylinder

Compression testing machine

Tabulation:

Sr. No.	Age of Cube	Load (N)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm^2)	Avg. Compressive Strength (MPa)
1	3 days				
2					
3					
4	7 days				
5					
6					
7	21 days				
8					
9					

Calculations:

Compressive strength = Load / Cross sectional area of the specimen

= --------------------N / mm2

Experiment – 06

Determination Of Compressive Strength Of Burnt Clay, Fly Ash Bricks And Blocks.

Aim:

To determination Of Compressive Strength of Burnt Clay, Fly Ash Bricks and Blocks by using CTM.

Apparatus required:

1. Brick sample
2. Measuring scale
3. Compression testing machine (CTM)

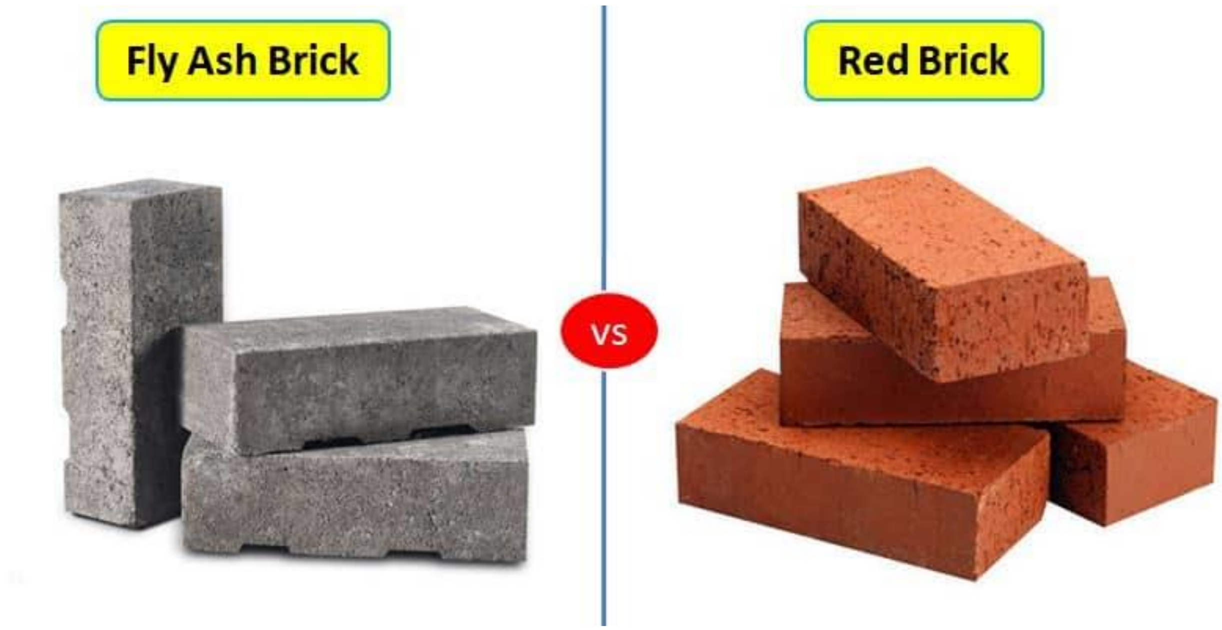
Procedure:

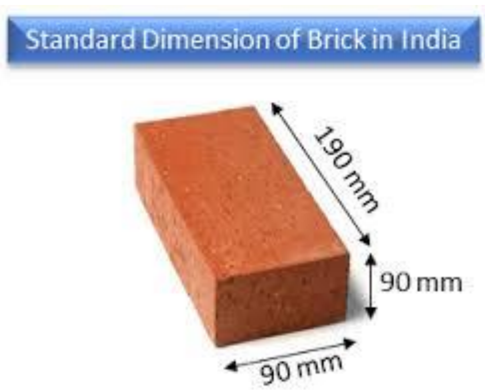
1. Take five random bricks samples and immerse them in water for 24 hours at room temperature.
2. After 24 hours, take them out, allow them to drain and then clean the surplus water.
3. Now, fill their frogs (and any other voids) by a layer of standard 1:1 cement mortar (1 part cement and 1 part sand).
4. Store these bricks under damp sacks for 24 hours (to allow setting of mortar). Place the bricks in water for seven days. (This is to allow the mortar to harden).
5. Take the bricks out of the water, allow the water to drain and remove the surplus water. When surface dry, each brick is tested for compressive strength individually.
6. Place the brick flat-wise, with frog end facing upward, between two plywood sheets.
7. Brick so adjusted between the plywood sheets is placed on the bed of compressive strength of bricks testing machine and load is applied axially and at a uniform rate of 140 kg/cm^2/minute or 14 N/mm^2. (This is very important).
8. Note the load at which the brick fails (gets broken). This load (P) is divided by cross-sectional area (A) of the brick gives the compressive strength (Co). Co=P/A
9. The arithmetic mean of the compressive strength of bricks values of all the five bricks shall be taken as the compressive strength of that lot of bricks represented by the test samples, (and not for all the bricks of a kiln).
10. The brick shall be classified accordingly on the basis of the (Co) obtained as above.

Result

1. Average compressive strength of the given burnt clay bricks =________________ N/mm^2
2. Average compressive strength of the given fly ash bricks = _________________N/mm^2

Diagram:





Compressive Strength of Bricks:

1. Compressive Strength of first class brick is 105 kg/cm^2 or 10.5 N/mm^2
2. Compressive Strength of 2nd class brick is 70 kg/cm^2 or 7 N/mm^2
3. Compressive Strength of common building brick is 35 kg/cm^2 or 3.5 N/mm^2
4. Compressive Strength of sun dried brick is 15 to 25 kg/cm^2 or 2.5 N/mm^2

Tabulation:

Burnt clay or red brick-

Sr. No.	Load (N)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm^2)	Avg. Compressive Strength (MPa)
1				
2				
3				
4				
5				

Fly ash brick-

Sr. No.	Load (N)	Cross Sectional Area(mm^2)	Compressive Strength (N/mm^2)	Avg. Compressive Strength (MPa)
1				
2				
3				
4				
5				

Calculation:

Compressive Strength of Bricks = Maximum Load at Failure (N)/Average area of bed face (mm^2)

= ____________________ / __________________

= __________________ N/mm^2

Experiment – 07

Grading Of Fine And Coarse Aggregate By Sieving For Concrete.

Fine aggregates:

Aim:

To determine the fineness modulus of fine aggregate by grading sieve analysis.

Apparatus required:

1. Sieve sizes of 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm.
2. Dry oven
3. Digital weight scale.
4. Mechanical sieve shaker (optional)

Theory:

Fineness modulus of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fineness modulus. Fine aggregate means the aggregate which passes through 4.75mm sieve. To find the fineness modulus of fine aggregate we need sieve sizes of 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm. Fineness modulus of finer aggregate is lower than fineness modulus of coarse aggregate.

Sample preparation

Take a sample of fine aggregate in pan and placed it in dry oven at a temperature of 100 – 110^{o}C. After drying take the sample and note down its weight.

Procedure:

1. Take the sieves and arrange them in descending order with the largest sieve on top.
2. If mechanical shaker is using then put the ordered sieves in position and pours the sample in the top sieve and then closes it with sieve plate.
3. Then switch on the machine and shaking of sieves should be done at least 5 minutes.
4. If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally.
5. After some time shake the 3rd and 4th sieves and finally last sieves.
6. After sieving, record the sample weights retained on each sieve.
7. Then find the cumulative weight retained.
8. Finally determine the cumulative percentage retained on each sieves.
9. Add the all cumulative percentage values and divide with 100 then we will get the value of fineness modulus.

Values of Fineness Modulus of Sand:

Fineness modulus of fine aggregate varies from 2.0 to 3.5mm. Fine aggregate having fineness modulus more than 3.2 should not considered as fine aggregate. Various values of fineness modulus for different sands are detailed below.

Type of sand	Fineness modulus range
Fine sand	2.2 – 2.6
Medium sand	2.6 – 2.9
Coarse sand	2.9 – 3.2

Fineness modulus limits for various zones of sand according to IS 383-1970 are tabulated below.

Sieve size	Zone-1	Zone-2	Zone-3	Zone-4
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
0.6mm	15-34	35-59	60-79	80-100
0.3mm	5-20	8-30	12-40	15-50
0.15mm	0-10	0-10	0-10	0-15
Fineness modulus	**4.0-2.71**	**3.37-2.1**	**2.78-1.71**	**2.25-1.35**

Result:

The fineness modulus value of fine aggregate=____________________

Observation:

Let us say the dry weight of sample = 1000 gm

Tabulation:

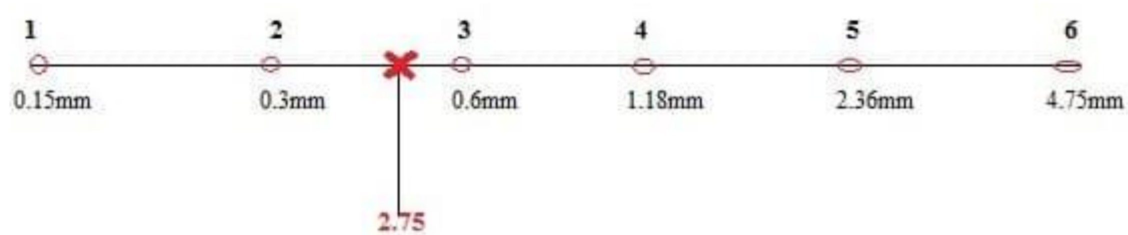
Sieve size	Weight retained (g)	Cumulative weight retained(g)	Cumulative percentage weight Retained (%)
4.75mm	0	0	0
2.36mm	100	100	10
1.18mm	250	350	35
0.6mm	350	700	70
0.3mm	200	900	90
0.15mm	100	1000	100
Total			**275**

Calculation:

Fineness modulus of aggregate = (cumulative % retained) / 100 = (275/100) = 2.75

Fineness modulus of fine aggregate is 2.75.

It means the average value of aggregate is in between the 2nd sieve and 3rd sieve. It means the average aggregate size is in between 0.3mm to 0.6mm as shown in below figure.



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Coarse aggregates:

Aim:

To determine the fineness modulus of coarse aggregate by grading sieve analysis.

Apparatus required:

1. Sieve sizes of 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm..
2. Dry oven.
3. Digital weight scale.
4. Mechanical sieve shaker. (optional)

Theory:

Fineness modulus of coarse aggregates represents the average size of the particles in the coarse aggregate by an index number. It is calculated by performing sieve analysis with standard sieves.

The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate. Higher the aggregate size higher the Fineness modulus hence fineness modulus of coarse aggregate is higher than fine aggregate.

Coarse aggregate means the aggregate which is retained on 4.75mm sieve when it is sieved through 4.75mm. To find fineness modulus of coarse aggregate we need sieve sizes of 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm and 0.15mm.

Fineness modulus is the number at which the average size of particle is known when we counted from lower order sieve size to higher order sieve. **So, in the calculation of coarse aggregate we need all sizes of sieves.**

Sample preparation

Take a sample of coarse aggregate in pan and placed it in dry oven at a temperature of 100 – 110^{o}C. After drying take the sample and note down its weight.

Procedure:

1. Take the sieves and arrange them in descending order with the largest sieve on top.
2. If mechanical shaker is using then put the ordered sieves in position and pours the sample in the top sieve and then closes it with sieve plate.
3. Then switch on the machine and shaking of sieves should be done at least 5 minutes.
4. If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally.
5. After some time shake the 3rd and 4th sieves and finally last sieves.
6. After sieving, record the sample weights retained on each sieve.
7. Then find the cumulative weight retained.
8. Finally determine the cumulative percentage retained on each sieves.
9. Add the all cumulative percentage values and divide with 100 then we will get the value of fineness modulus.

Diagram:

Limits of Fineness Modulus:

Fineness modulus of coarse aggregate varies from 5.5 to 8.0. And for all in aggregates or combined aggregates fineness modulus varies from 3.5 to 6.5. Range of fineness modulus for aggregate of different maximum sized aggregates is given below.

Maximum size of coarse aggregate	Fineness modulus range
20mm	6.0 – 6.9
40mm	6.9 – 7.5
75mm	7.5 – 8.0
150mm	8.0 – 8.5

Result:

The fineness modulus value of fine aggregate=____________________

Observation:

Let us say dry weight of coarse aggregate = 5000 g

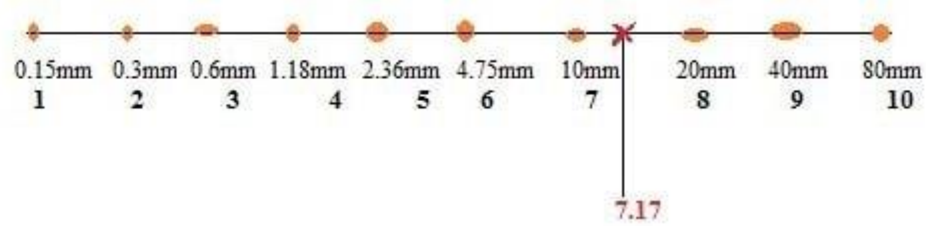
Tabulation:

Sieve size	Weight retained(g)	Cumulative weight retained (g)	Cumulative % retained (g)
80mm	0	0	0
40mm	250	250	5
20mm	1750	2000	40
10mm	1600	3600	72
4.75mm	1400	5000	100
2.36mm	0	5000	100
1.18mm	0	5000	100
0.6mm	0	5000	100
0.3mm	0	5000	100
0.15mm	0	5000	100
Total			**717**

Calculation:

Fineness modulus of coarse aggregates = sum (cumulative % retained) / 100 = (717/100) = **7.17**

Fineness modulus of 7.17 means, the average size of particle of given coarse aggregate sample is in between 7th and 8th sieves, that is between 10mm to 20mm.



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Experiment-08

Determination Of Specific Gravity And Bulking Of Sand.

Specific gravity of fine aggregate:

Aim:

To determine the specific gravity of fine aggregate by using pycnometer method.

Apparatus required:

1. A balance of capacity not less than 3kg ,readable and accurate to 0.5 gm and of such a type as to permit the weighing of the vessel containing the aggregate and water .
2. A well ventilated oven to maintain a temperature of 100ºC to 110ºC
3. Pycnometer of about 1 liter capacity having a metal conical screw top with a 6mm hole at its apex. The screw top shall be watertight.
4. A means supplying a current warm air.
5. A tray of area not less than $32cm^2$.
6. An airtight container large enough to take the sample.
7. Filter papers and funnel.

Specific gravity of fine aggregate (sand) is the ratio of the weight of given volume of aggregates to the weight of equal volume of water.

The specific gravity of sands is considered to be around **2.65.**

Pycnometer bottle

Procedure:

1. Take about 500g of sample and place it in the pycnometer.
2. Pour distilled water into it until it is full.
3. Eliminate the entrapped air by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger.
4. Wipe out the outer surface of pycnometer and weigh it **(W)**
5. Transfer the contents of the pycnometer into a tray, care being taken to ensure that all the fine aggregate is transferred.
6. Refill the pycnometer with distilled water to the same level.
7. Find out the weight **(W1)**
8. Drain water from the sample through a filter paper.
9. Place the sample in oven in a tray at a temperature of 100ºC to 110º C for 24±0.5 hours, during which period, it is stirred occasionally to facilitate drying.
10. Cool the sample and weigh it **(W2)**

Observation:

Weight of sand + water in pycnometer **(W) = ______________**

Weight of pycnometer with water **(W1) = _______________**

Weight of oven dry sample **(W1) =_______________**

C**alculations:**

Apparent specific gravity = (Weight of dry sample/Weight of equal volume of water)

= W2/(W2- (W-W2))

Result:

Specific gravity of fine aggregate = _________________

Bulking of fine aggregate:

1. Laboratory Test for Bulking of Sand-

Aim:

To determine the percentage bulking of fine aggregate.

Apparatus:

1. 250ml measuring cylinder
2. Weighing balance
3. Fine aggregate

Theory:

Bulking of fine aggregate or sand is the phenomenon of increase in sand volume due to the increase of moisture content. Bulking test on fine aggregates has to be performed before using it in construction.

Causes of Bulking of Sand-

The moisture content in the sand makes thin films around sand particles. Hence, each particle exerts pressure. Thus they move away from each other causing increasing in volume. The bulking of the aggregates are dependent on two factors:

1.The fineness of the aggregates

2.Percentage moisture content

As shown in figure-1 below, the bulking of the sand increases with the increase in moisture content. This happens up to a limit beyond which any moisture addition will decrease the volume.

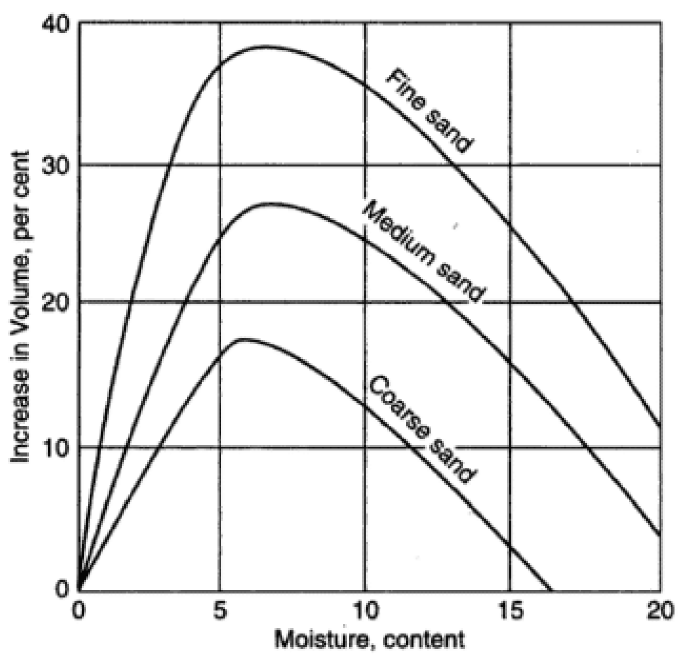


Fig.1: Variation of Bulking of sand with moisture content

A fully saturated fine aggregate does not show any bulking. The rate of bulking is inversely proportional to the size of the aggregates. Hence, fine aggregates bulk more compared to coarse aggregates.

Procedure:

1. Take 500 grams of fine aggregate over dried at a temperature of 100 to 110 degree Celsius for 24 ± 0.5 hours. This weight is measured as W1
2. The cooled sand is taken in an airtight container. This weight is measured as W2.
3. The water content of the sample is calculated as

$$WC = (W1-W2) \times 100/W1$$

4. In a pan, 250 grams of sand is taken
5. To this 2% by weight of water is added. This is properly mixed
6. The mixture is poured into a 250ml cylinder. This is consolidated by shaking
7. The surface is leveled. The reading is measured as Y1.
8. The test is repeated for the remaining quantity of sand for 2% water by weight each time. The readings are taken as Y2, Y3…..etc until a decreasing reading of the volume is observed.
9. After this level, 4% water is added and the test is continued until the sample becomes fully saturated.
10. To the standard sample in the measuring cylinder, add about 50 ml water ore and stir the sample well.
11. Note down the surface level of inundated sand (Y ml).

Calculations:

Percentage Bulking of Sand = (Y1-Y) x100/Y

Results:

A graph is plotted with percentage water content along X -axis and percentage bulking along y-axis. From the graph the following results are obtained:

1. % of bulking occurred =____________
2. % of water content at maximum bulking=______________
3. % of water content when bulking is zero=______________
4. % of bulking for the initial water content (W) of the sample =_______________

2. Field Test for Bulking of Sand:

Apparatus

1. 250ml measuring cylinder
2. Fine aggregate

Procedure:

1. Pour the sand into 250 ml measuring cylinder up to the 200 ml mark.
2. Fill the cylinder with water and stir well (sufficient water should be poured to submerge the sand completely and it can be seen that the sand surface is now below its original level)
3. Take the reading at the sand surface (Y ml)

Calculations:

Percentage Bulking of Sand = [(200/Y) - 1] x100

Result:

Percentage bulking of field sample= _______________

Experiment-09

Determination Of Specific Gravity And Bulk Density Of Coarse Aggregate

Specific Gravity Of Coarse Aggregate:

Aim:

To measure the strength or quality by determining specific gravity of coarse aggregate.

Apparatus required:

1. A balance of capacity about 3kg, to weigh accurate 0.5g, and of such a type and shape as to permit weighing of the sample container when suspended in water.
2. A thermostatically controlled oven to maintain temperature at 100-110° C.
3. A wire **basket of not** more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
4. A container for filling water and suspending the basket
5. An air tight container of capacity similar to that of the basket
6. A shallow tray and two absorbent clothes, each not less than 75x45cm.

Procedure:

1. About 2 kg of aggregate sample is washed thoroughly to remove fines, drained and placed in wire basket and immersed in distilled water at a temperature between 22- 32º C and a cover of at least 5cm of water above the top of basket.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hour afterwards.
3. The basket and the sample are weighed while suspended in water at a temperature of 22° – 32°C. The weight while suspended in water is noted **= W_1g.**
4. The basket and aggregates are removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weighed in water= **W_2 g.**
5. The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates are transferred to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. The surface dried aggregate is then weighed = **W_3 g**
6. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then removed from the oven, cooled in an air tight container and weighted=**W_4 g**.

Diagram:

Observations:

Weight of saturated aggregate suspended in water with basket = W_1**g**

Weight of basket suspended in water = W_2 **g**

Weight of saturated surface dry aggregate in air = W_3g

Weight of oven dry aggregate = W_4 **g**

Weight of saturated aggregate in water = $W_1 – W_2$ **g**

Formulas:

1. Specific gravity = $W_3 / (W_3 – (W_1 – W_2))$
2. Apparent specific gravity = $W_4 / (W_4 – (W_1 – W_2))$

Result:

The specific gravity of coarse aggregate = _________________

Recommended Values of Specific Gravity and Water Absorption for Aggregates:

The specific gravity of aggregates normally used in road construction ranges from about **2.5 to 3.0 with an average of about 2.68.**

Bulk Density Of Coarse Aggregate:

Aim:

To determine the bulk density of coarse aggregate

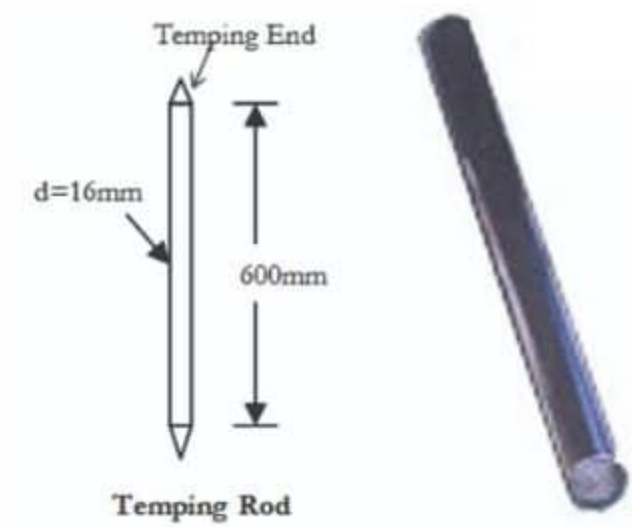
Apparatus required:

1. **Balance**

   A balance sensitive to 0.5% of the weight of the sample to be weighed.

2. **Tamping Rod**

   A straight metal tamping rod of cylindrical cross-section 16 mm in diameters maximum 75 cm long, rounded at one end.



3. **Cylindrical Metal Measure**

   The capacity of cylindrical metal measure conforms to the specifications of Table 1.

Table 1 Capacity of Measures

Nominal Maximum Size of Aggregate, mm	Capacity of Measure, m^3 (L)
12.5	0.0028 (2.8)
25	0.0093 (9.3)
37.5	0.014 (14)
75	0.028 (28)
100	0.070 (70)
125	0.100 [100]

Fig. 2: Cylindrical Measures of Different Sizes

4. **Shovel or Scoop**

   A shovel or scoop of convenient size for filling the measure with aggregate

5. **Equipment for Measuring Volume of Measure**

   It includes plate glass, grease, and thermometer, and balance.

Sample Preparation:

1. The size of the test sample ranges from 125% to 200 % of the amount required to fill the measure.
2. Dry the aggregate sample to constant mass in an oven at 110±5 °C.

Fig. 3: Aggregate Sample

Determination of Volume of Measure:

1. Evaluate the mass of the plate glass and measure the nearest 0.05 kg.
2. Place a thin layer of grease on the rim of the measure to prevent leakage of water.

3. Fill the measure with water and cover it with the plate glass in a manner to remove bubbles and excess water.
4. Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg.
5. Measure the temperature of the water to the nearest 0.5 °C and specify its density from Table 2.
6. Calculate the volume, *V*, of the measure using the following expression:

$$V=(W-M)/D \qquad \text{Equation 1}$$

$$F= D/(W-M) \qquad \text{Equation 2}$$

where:

V: volume of the measure, m^3

W: mass of the water, plate glass, and measure, kg

M: mass of the plate glass and measure, kg

D: density of the water for the measured temperature, kg/m^3, and

F: factor for the measure, 1/m^3

Table 2 Density of Water

Temperature, C	**kg/m^3**
15.6	999.01
18.3	998.54
21.1	997.97
23.0	997.54
23.9	997.32
26.7	996.59
29.4	995.83

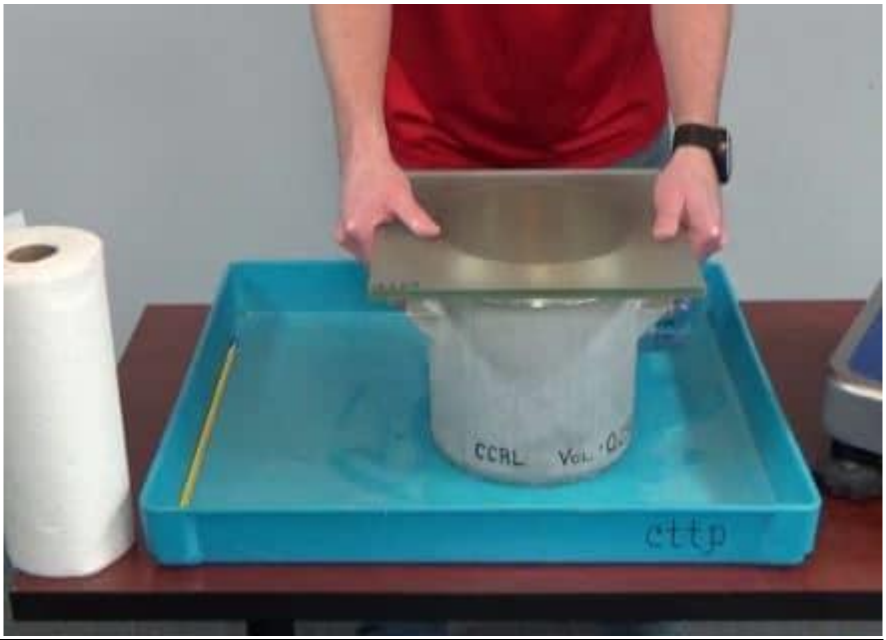


Fig. 4: Determination Volume of Measure

Procedure:

1. Take the weight of the empty measure (W) to the nearest 0.05kg, as per procedure provided above.
2. Fill the measure to in three layers and compact the aggregate in three layers using one of the three methods based on the aggregate size.

Method A - Rodding for maximum aggregates size of 37.5 mm or less,

Method B- Jigging for maximum aggregates size greater than 37.5 mm and not exceeding 125 mm,

Method C- Shoveling to determine the loose bulk density of the aggregate.

Method A: Rodding

Fill the measure with aggregate in nearly equal three layers. Apply 25 evenly distributed strokes of tapping rode to each layer surface. The rode should not hit the bottom of the measure during rodding of the layer, and penetrating the rod to into the first and second layer during rodding second and third layer need to be prevented.

Fig. 5: Rodding Aggregate

Method B: Jigging

Fill the measure with aggregate in nearly equal three layers. Compact each layer by placing the measure on a firm base, raising the opposite sides alternately about 50 mm, and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. Compact each layer by dropping the measure 50 times, 25 times on each side, and finally level the surface of the aggregate.

Method C: Shoveling

Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm above the top of the measure. Prevent segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate.

3. Finally, determine and record the mass of the measure plus its contents to the nearest 0.05 kg.

Calculations:

Compacted Bulk Density of aggregate-

$$Bulk\ density\ (M) = (G-T) / V \quad Equation\ 3$$

Or

$$Bulk\ density\ (M) = (G-T) / F \quad Equation\ 4$$

Where:

M: bulk density of the aggregate, kg/m^3,
G: mass of the aggregate plus the measure, kg,
T: mass of the measure, kg,
V: volume of the measure, m^3,
F: factor for measure, m^3, computed from equation 2.

The bulk density determined by this test method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface-dry (SSD) condition is required, it can be computed using the following formula:

$$Mssd= M [1+ (A/100)] \quad Equation\ 5$$

Where:

MSSD: *bulk density in SSD condition, kg/m^3.*
A: *% absorption,*

Experiment-10
Grading Of Road Aggregates.

Aim:

To determine the grades of (percentage of passing value) coarse aggregates by sieving.

Apparatus required:

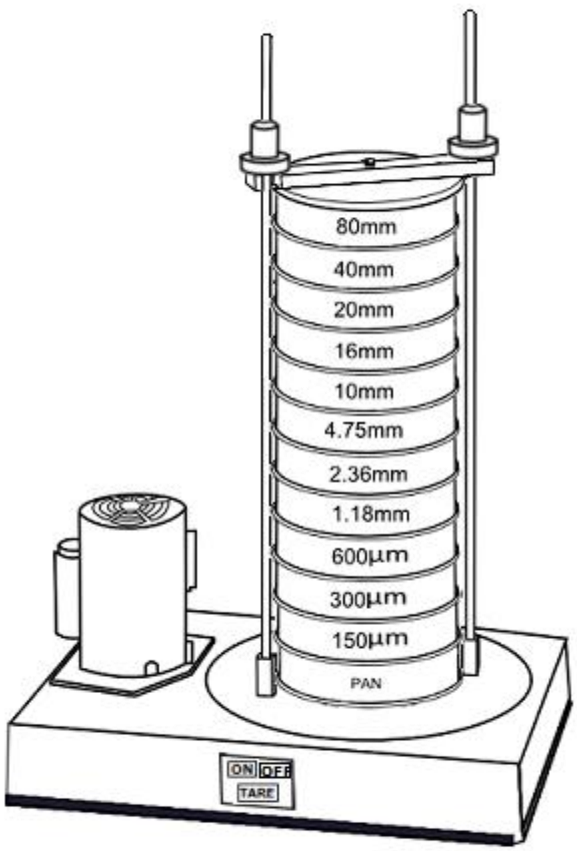
1. Sieves for CA 4.75mm to 80mm.
2. Weigh balance.
3. Test sample.
4. Tray etc.

Sample preparation:

Take a sample of coarse aggregate in pan and placed it in dry oven at a temperature of 100 – 110°C. After drying take the sample and note down its weight.

Procedure:

1. Take the sieves and arrange them in descending order with the largest sieve on top.
2. If mechanical shaker is using then put the ordered sieves in position and pours the sample in the top sieve and then closes it with sieve plate.
3. Then switch on the machine and shaking of sieves should be done at least 5 minutes.
4. If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally.
5. After some time shake the 3rd and 4th sieves and finally last sieves.
6. After sieving, record the sample weights retained on each sieve.
7. Then find the cumulative weight retained.
8. Finally determine the cumulative percentage retained on each sieves.
9. Finally determine the percentage of passing on each sieve.
10. Finally we compare the values as per IS-383 Code.



Observation and Tabulation:

Weight of aggregate sample taken = **1000 g**

Sieve size	Weight of aggregates retained on sieve			Avg. weight aggregates (A) Avg.- $\frac{1+2+3}{3}$	% of total weight retained(B) $\frac{A \times 100}{1000}$	Cumulative Percentage of total weight(C) = B +	% of passing (result) (D) = 100-C	Permissible value as per IS-383
	Sample 1	Sample 2	Sample 2					
20 mm								
12.5 mm								
10mm								
6.3mm								
4.75mm								
pan								

IS – 383: Values :

IS Sieve Designation	Percentage Passing for Single-Sized Aggregate of Nominal Size						Percentage Passing for Graded Aggregate of Nominal Size			
	63 mm	40 mm	20 mm	16 mm	12·5 mm	10 mm	40 mm	20 mm	16 mm	12·5 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
80 mm	100	—	—	—	—	—	100	—	—	—
63 mm	85 to 100	100	—	—	—	—	—	—	—	—
40 mm	0 to 30	85 to 100	100	—	—	—	95 to 100	100	—	—
20 mm	0 to 5	0 to 20	85 to 100	100	—	—	30 to 70	95 to 100	100	100
16 mm	—	—	—	85 to 100	100	—	—	—	90 to 100	—
12·5 mm	—	—	—	—	85 to 100	100	—	—	—	90 to 100
10 mm	0 to 5	0 to 5	0 to 20	0 to 30	0 to 45	85 to 100	10 to 35	25 to 55	30 to 70	40 to 85
4·75 mm	—	—	0 to 5	0 to 5	0 to 10	0 to 20	0 to 5	0 to 10	0 to 10	0 to 10
2·36 mm	—	—	—	—	—	0 to 5	—	—	—	—

Result:

Analysis the grading of aggregates the followings -

1.
2.

Experiment-11

Determination Of Flakiness, Elongation Of Road Aggregates.

Aim:

To determine flakiness index and elongation index by conducting shape test of aggregates.

Apparatus required:

1. A standard thickness gauge. (Flakiness Gauge)
2. A standard length gauge. (Elongation Gauge)
3. IS sieves of sizes 63, 50 40, 31.5, 25, 20, 16, 12.5,10 and 6.3mm
4. A balance of capacity 5kg, readable and accurate up to 1 gm.

Theory:

The particle shape of aggregates is determined by the percentages of flaky and elongated particles contained in it. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles are considered undesirable as these cause inherent weakness with possibilities of breaking down under heavy loads.

Thus, evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary.

The Flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three- fifths (0.6times) of their mean dimension. This test is not applicable to sizes smaller than 6.3mm.

The Elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than nine-fifths (1.8times) their mean dimension. This test is not applicable for sizes smaller than 6.3mm.

Procedure:

1. Sieve the sample through the IS sieves (as specified in the table).
2. Take a minimum of 200 pieces of each fraction to be tested and weigh them.
3. To separate the flaky materials, gauge each fraction for thickness on a thickness gauge. The width of the slot used should be of the dimensions specified in column (4) of the table for the appropriate size of the material.
4. Weigh the flaky material passing the gauge to an accuracy of at least 0.1 per cent of the test sample.

5. To separate the elongated materials, gauge each fraction for length on a length gauge. The width of the slot used should be of the dimensions specified in column (6) of the table for the appropriate size of the material.
6. Weigh the elongated material retained on the gauge to an accuracy of at least 0.1 per cent of the test sample.

Results:

1. Flakiness Index =________________________
2. Elongation Index =_______________________

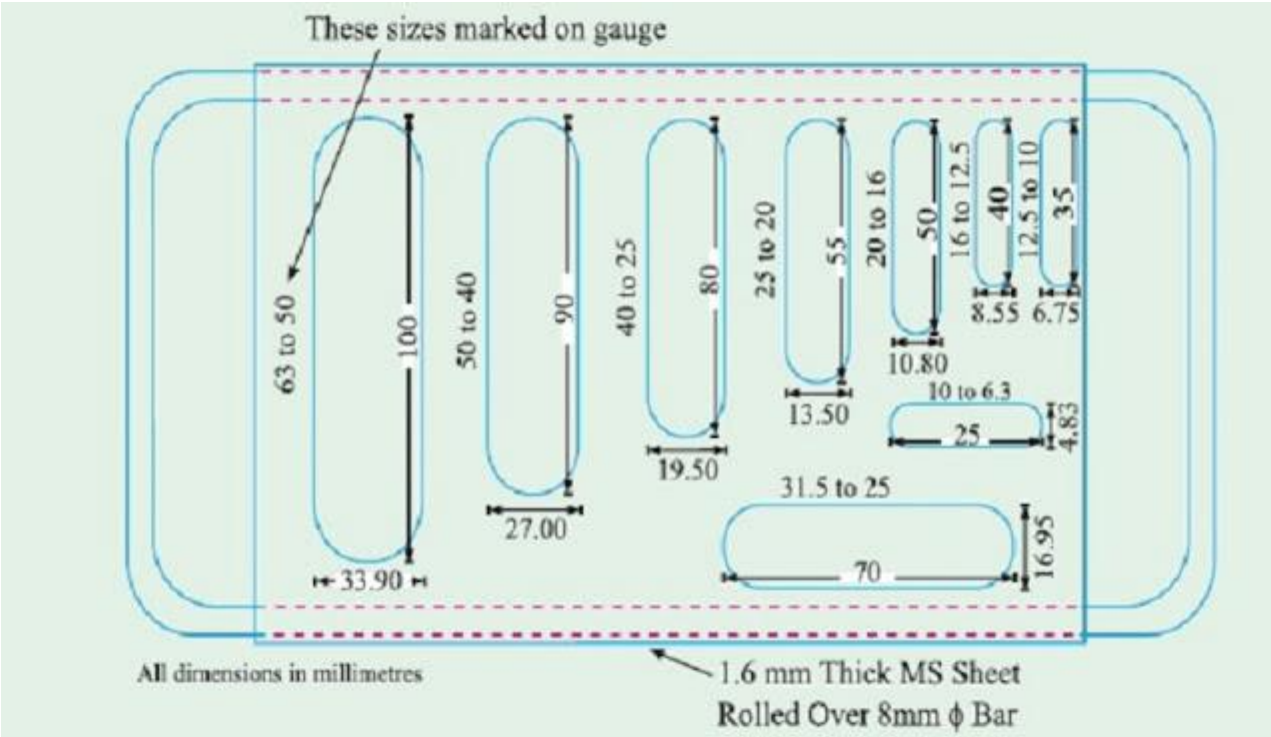
Recommended Values of Flakiness Index and Elongation Index:

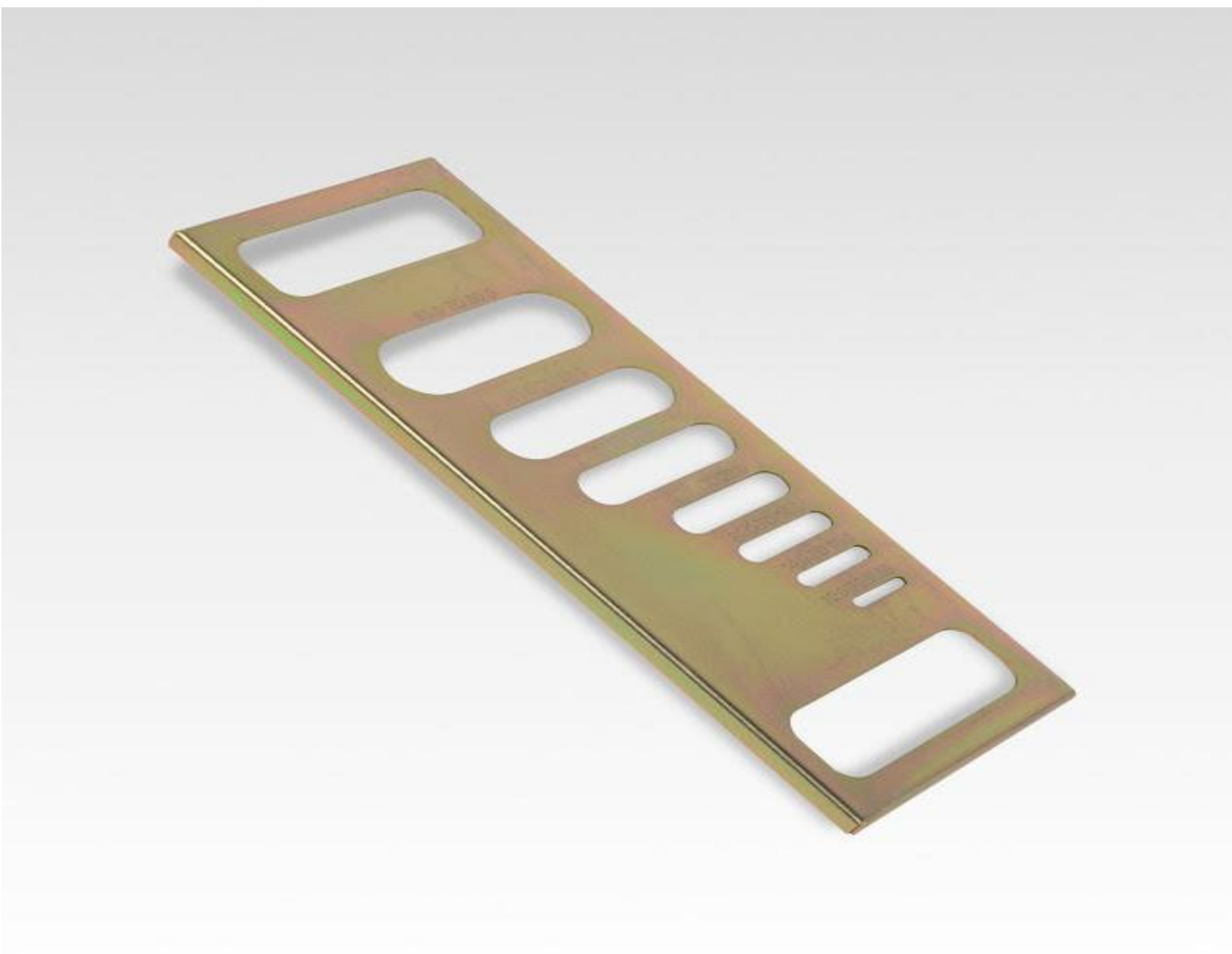
The shape tests give only a rough idea of the relative shapes of aggregates. Flaky and elongated particles should be avoided in pavement construction, particularly in surface course.

If such particles are present in appreciable proportions, the strength of pavement layer would be adversely affected due to possibility of breaking under loads. Workability is reduced for cement concrete. IRC recommendations for maximum limits of flakiness index are as given-

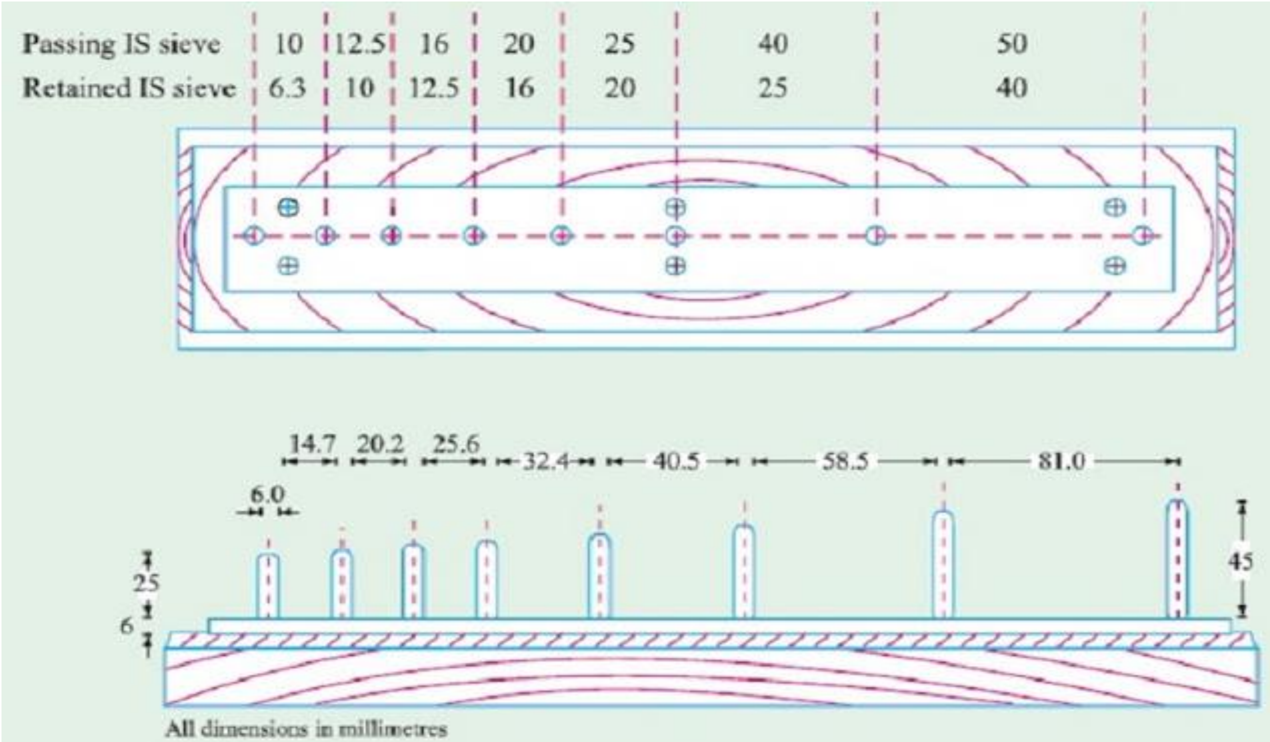
SI No.		Type of pavement	Maximum limits of flakiness index, %
1		Bituminous carpet	30
2	(i)	Bituminous / Asphaltic concrete	25
	(ii)	Bituminous Penetration macadam	
	(iii)	Bituminous surface dressing (single coat, two coats & precoated)	
	(iv)	Built up spray grout	
3	(i)	Bituminous macadam	15
	(ii)	WBM base course and surface course	

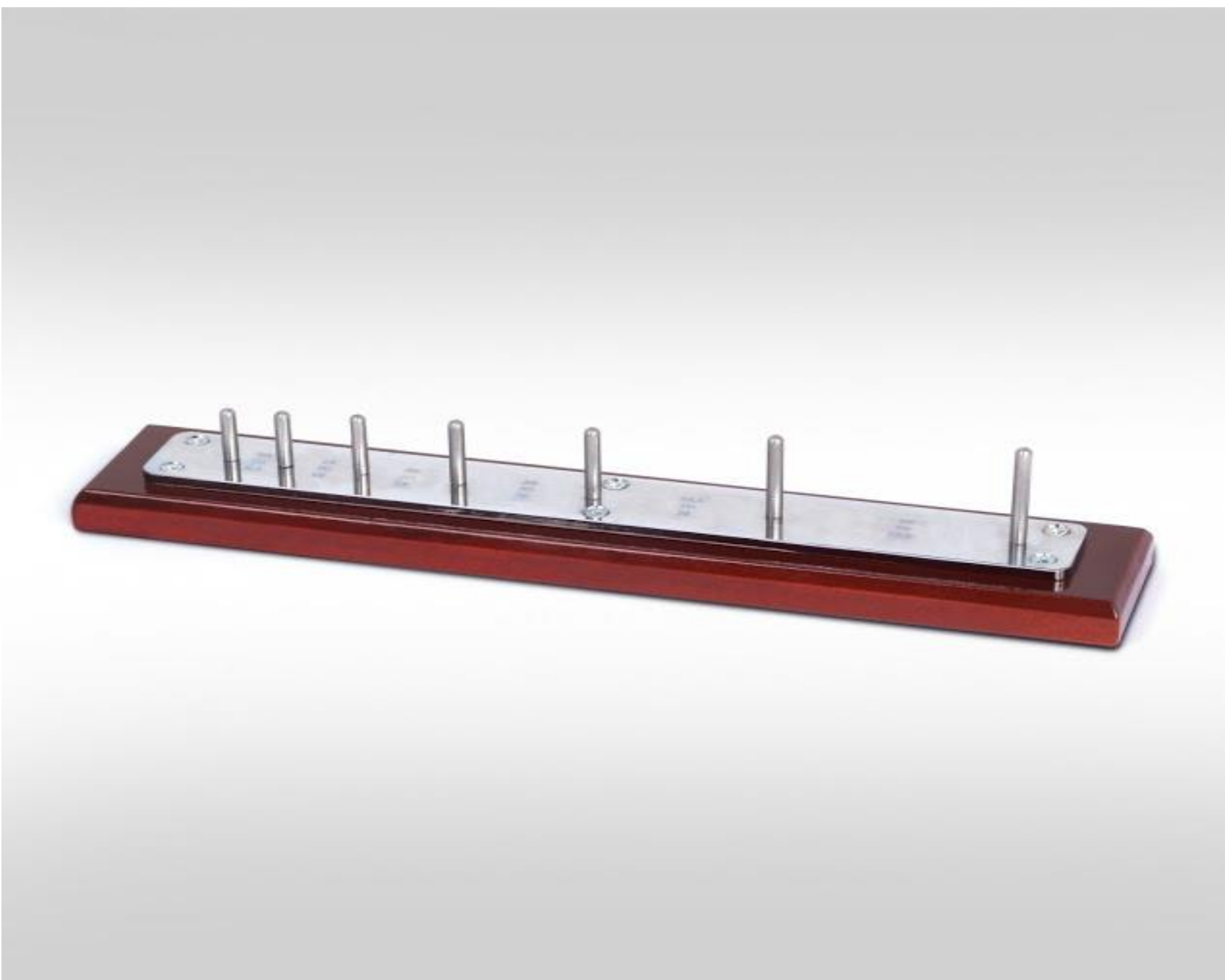
Diagram:





Flakiness gauge





Elongation gauge

Tabulation:

Size of aggregates		Weight of fraction consisting of at least 200 pieces in gm	Thickness gauge size, mm	Weight of aggregates in each fraction passing thickness gauge,mm	Length gauge size, mm	Weight of aggregates in each fraction retained on length gauge,mm
Passing through IS Sieve, mm	Retained on IS Sieve,mm					
1	**2**	**3**	**4**	**5**	**6**	**7**
63	50	W_1=	23.90	X_1=	–	–
50	40	W_2=	27.00	X_2=	81.00	Y_1=
40	31.5	W_3=	19.50	X_3=	58.00	Y_2=
31.5	25	W_4=	16.95	X_4=	–	–
25	20	W_5=	13.50	X_5=	40.5	Y_3=
20	16	W_6=	10.80	X_6=	32.4	Y_4=
16	12.5	W_7=	8.55	X_7=	25.5	Y_5=
12.5	10	W_8=	6.75	X_8=	20.2	Y_6=
10	6.3	W_9=	4.89	X_9=	14.7	Y_7=
Total	**W =**		**X =**		**Y=**	

Calculation:

1. The Flakiness Index on an aggregate is = Total weight passing Flakiness Gauge x 100 / Total weight of test sample =__________ (%)

   Flakiness Index = $(X_1 + X_2 + \ldots..) / (W_1 + W_2 + \ldots.) \times 100$

2. The Elongation Index on an aggregate is = Total weight retained on Elongation Gauge x 100 / Total weight of test sample =_________ (%)

   Elongation Index = $(Y_1 + Y_2 + \ldots) / (W_1 + W_2 + \ldots.) \times 100$

Experiment-12

Determination Of Crushing Value Test Of Aggregate

Aim:

1. To determine the aggregate crushing value of coarse aggregates
2. To assess suitability of aggregates for use in different types of road pavement

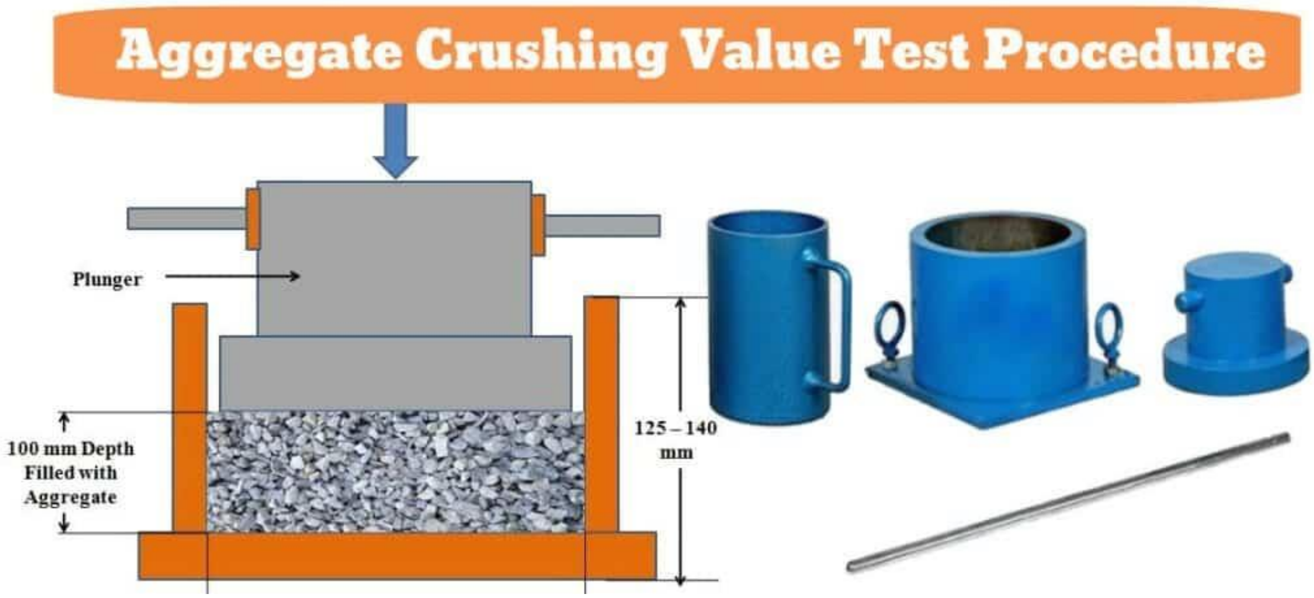
Theory:

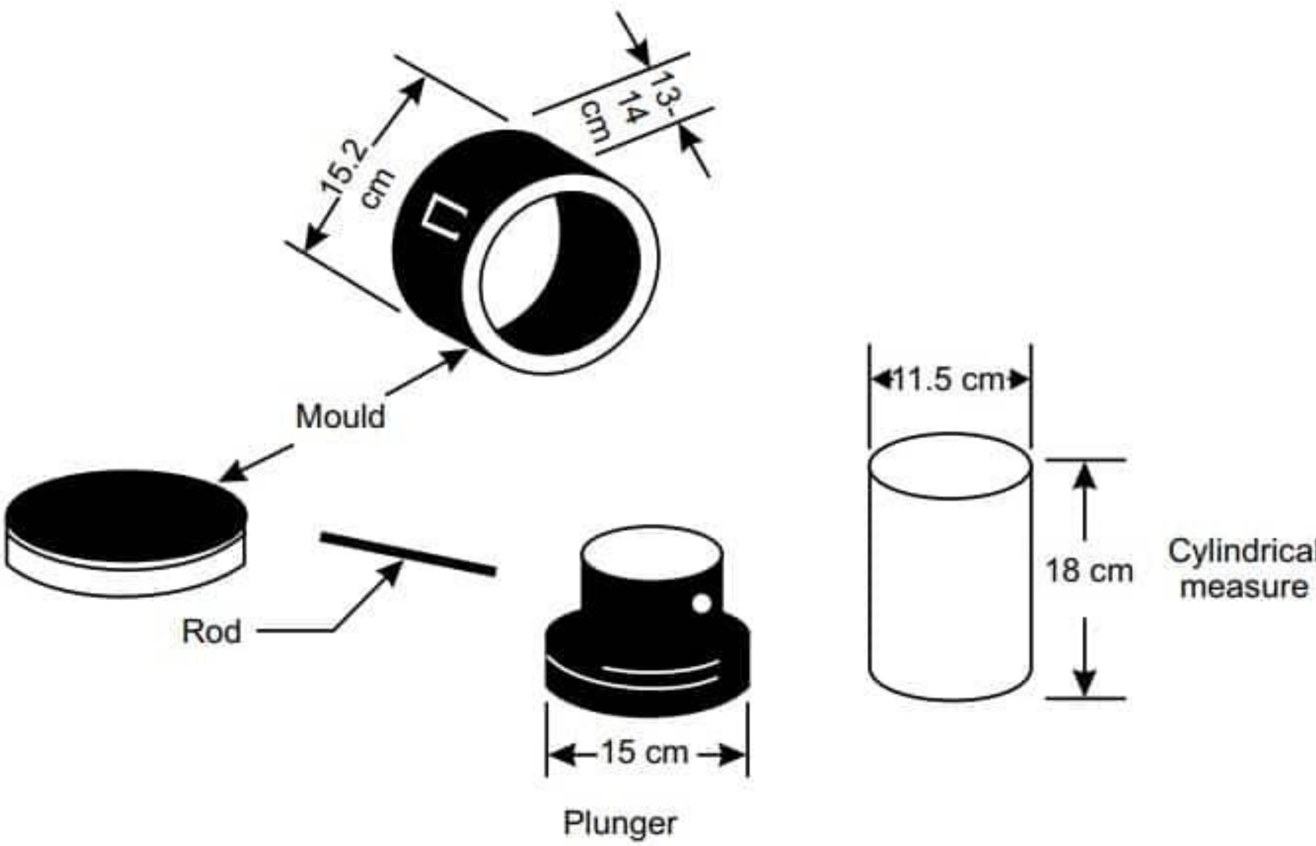
The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. It is the percentage by weight of the crushed or finer material obtained when the test aggregates are subjected to a specified load under standardized conditions, and is a numerical index of the strength of the aggregate used in road construction. Aggregates with lower crushing value indicate a lower crushed fraction under load and would give a longer service life to the road and hence a more economical performance. Weaker aggregates if used would get crushed under traffic loads, would produce smaller pieces not coated with binder and these would be easily displaced or loosened out resulting in loss of the surface/layer. In short the aggregates used in road construction must be strong enough to withstand crushing under roller and traffic. Crushing value is a measure of the strength of the aggregate. The aggregates should therefore have minimum crushing value.

Apparatus:

The apparatus of the aggregate crushing value test as per IS: 2386 (Part IV) – 1963 consists of:

1. A 15cm diameter open ended steel cylinder with plunger and square base plate, of the general form and dimensions as shown in Fig 1.
2. A straight metal tamping rod of circular cross-section 16mm diameter and 45 to 60 cm long, rounded at one end.
3. A balance of capacity 5kg, readable and accurate up to 1 gm.
4. IS Sieves of sizes 12.5 mm, 10 mm and 2.36 mm.
5. A compression testing machine capable of applying a load of 40 tones and which can be operated to give a uniform rate of loading so that the maximum load is reached in 10 minutes. The machine may be used with or without a spherical seating.
6. For measuring the sample, cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of the following internal dimensions: Diameter: 11.5 cm, Height: 18.0cm





Aggregate Crushing apparatus

Procedure:

The test sample: It consists of aggregates sized 12.5 mm - 10.0 mm (minimum 3kg). The aggregates should be dried by heating at 100-110^0 C for a period of 4 hours and cooled.

1. Sieve the material through 12.5 mm and 10.0 mm IS sieves. The aggregates passing through 12.5 mm sieve and retained on 10.0 mm sieve comprises the test material.
2. The cylinder of the test shall be put in position on the base-plate and the test sample added in thirds, each third being subjected to 25 gentle blows with the rounded end of tamping rod.
3. The surface of the aggregate shall be carefully leveled.
4. The plunger is inserted so that it rests horizontally on this surface, care being taken to ensure that the plunger does not jam in the cylinder
5. The apparatus, with the test sample and plunger in position, shall then be placed between the plates of the testing machine.
6. The load is applied at a uniform rate as possible so that the total load is reached in 10 minutes. The total load shall be 40 tones.
7. The load shall be released and the whole of the material is removed from the cylinder and sieved on 2.36mm IS Sieve.
8. The fraction passing the sieve shall be weighed and recorded.

Precautions:

1. The plunger should be placed centrally and rest directly on the aggregates. Care should be taken that it does not touch the walls of the cylinder so as to ensure that the entire load is transferred onto the aggregates.
2. In the operation of sieving the aggregates through 2.36mm sieve and weighing care should be taken to avoid loss of fines. The sum of weights of fractions retained and passing the sieve should not differ from the original weight of the specimen by more than 1gm.
3. The tamping should be done properly by gently dropping the tamping rod and not by hammering action. Also it should be uniform over the surface of the aggregates taking care that the tamping rod does not frequently strike against the walls of mould.

Observation Table:

	Sample - I	Sample - II
Total weight of dry sample taken = W1 gm		
Weight of portion passing in 2.36 mm sieve = W2 gm		
Aggregate crushing value = (W2/W1)*100 (per cent)		
Aggregate Crushing Mean Value = %		

Result:

Aggregate Crushing test value =____________________ %

Experiment-13

Los Angeles Abrasion Test Of Aggregates

Aim:

1. To determine Los Angeles abrasion value.
2. To find out the suitability of aggregates for its use in road construction.

Theory:

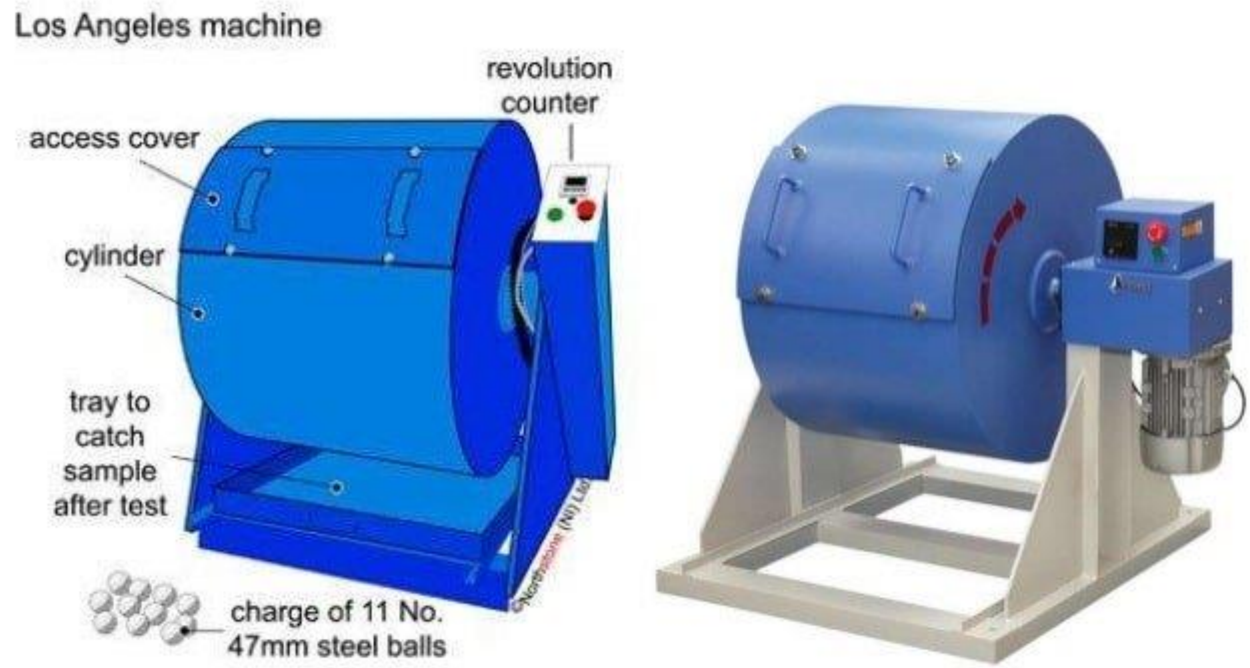
The aggregates used in surface course of the highway pavements are subjected to wearing due to movement of traffic. When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface causes abrasion of road aggregates. The steel reamed wheels of animal driven vehicles also cause considerable abrasion of the road surface. Therefore, the road aggregate should be hard enough to resist the abrasion. Resistance to abrasion of aggregates is determined in laboratory by Los Angeles test machine.

The principle of Los Angeles abrasion test is to produce the abrasive action by use of standard steel balls which when mixed with the aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates. The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value.

Apparatus:

The apparatus as per IS: 2386 (Part IV) – 1963 consists of:

1. Los Angeles Machine.
2. Abrasive charge: Cast iron or steel balls, approximately 48 mm in diameter and each weighing between 390 to 445 g; 6 to 12 balls are required.
3. Sieve: 1.70, 2.36, 4.75, 6.3, 10, 12.5, 20, 25, 40, 50, 63, 80 mm IS Sieves.
4. Balance of capacity 5 kg or 10 kg.
5. Drying oven.
6. Miscellaneous like tray etc.



Los Angeles abrasion test setup

Procedure:

The test sample consists of clean aggregates dried in oven at 105° – 110°C. The sample should conform to any of the grading shown in table 1.

1. Select the grading to be used in the test such that it conforms to the grading to be used in construction, to the maximum extent possible.
2. Take 5 kg of sample for grading A, B, C & D and 10 kg for grading E, F & G.
3. Choose the abrasive charge as per Table 2 depending on grading of aggregates.
4. Place the aggregates and abrasive charge on the cylinder and fix the cover.
5. Rotate the machine at a speed of 30 to 33 revolutions per minute. The number of revolutions is 500 for grading A, B, C & D and 1000 for grading E, F & G. The machine should be balanced and driven such that there is uniform peripheral speed.
6. The machine is stopped after the desired number of revolutions and material is discharged to a tray.
7. The entire stone dust is sieved on 1.70 mm IS sieve.
8. The material coarser than 1.7mm size is weighed correct to one gram.

Table 1: Grading of Test Samples – *Tolerance of ± 12 percent permitted.

Sieve size (square hole)	Weight of test sample in gm	Grades of aggregate in gm						
Passing (mm)	**Retained on (mm)**	**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			

Table 2: Selection of Abrasive Charge

Grading	No of Steel balls	Weight of charge in gm.
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

Observations and tabulation:

	Sample - I	Sample - II
Total weight of dry sample taken = W1 gm		
Weight of portion passing in 1.75 mm sieve = W2 gm		
Aggregate Abrasion value = (W2/W1)*100 (per cent)		
Aggregate Abrasion Mean Value = %		

Results:

Los Angeles Abrasion Value =________________________ %

Precautions:

1. The cover should be fixed tightly before rotating the machine.
2. All material should be discharged from the cylinder after the conduct of test.

Recommended Los Angeles Test Values for Pavements:

Depending upon the value, the suitability of aggregates for different road constructions can be judged as per IRC specifications as given:

Sl. No.	**Type of Pavement**	**Max. permissible abrasion value in %**
1	Water bound macadam sub base course	60
2	WBM base course with bituminous surfacing	50
3	Bituminous bound macadam	50
4	WBM surfacing course	40
5	Bituminous penetration macadam	40
6	Bituminous surface dressing, cement concrete surface course	35
7	Bituminous concrete surface course	30

Experiment-14

Impact Test Of Coarse Aggregates

Aim:

1. To determine the impact value of the road aggregates
2. To assess suitability of aggregates for use in different types of road pavement

Theory:

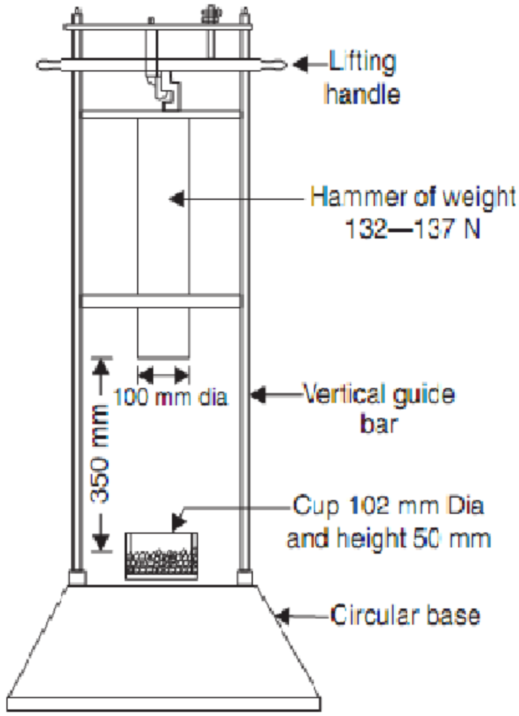
The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Apparatus:

The apparatus of the aggregate impact value test as per IS: 2386 (Part IV) – 1963 consists of:

1. A testing machine weighing 45 to 60 kg and having a metal base with a plane lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.
2. A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm.
3. A metal hammer weighing 13.5 to 14.0 kg the lower end is cylindrical in shape, is 50 mm long, 100.0 mm in diameter, with a 2 mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup. The free fall of the hammer should be within 380 ± 5 mm.
4. A cylindrical metal measure having internal diameter of 75 mm and depth 50 mm for measuring aggregates.
5. Tamping rod 10 mm in diameter and 230 mm long, rounded at one end.
6. A balance of capacity not less than 500 g, readable and accurate up to 0.1 g.

AGGREGATE IMPACT TESTING MACHINE



Aggregate Impact Testing Machine

Procedure:

The test sample: It consists of aggregates sized 10.0 mm to 12.5 mm. The aggregates should be dried by heating at 100-110o C for a period of 4 hours and cooled.

1. Sieve the material through 12.5 mm and 10.0 mm IS sieve. The aggregates passing through 12.5 mm sieve and retained on 10.0 mm sieve comprises the test material.
2. Pour the aggregates to fill about 1/3rd depth of measuring cylinder.
3. Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.
4. Add two more layers in similar manner, so that cylinder is full.
5. Strike off the surplus aggregates.
6. Determine the net weight of the aggregates to the nearest gram (W1).
7. Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.
8. Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.
9. Raise the hammer until its lower face is 380 mm above the surface of the aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.
10. Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1 gm (W2). Also weigh the fraction retained in the sieve.
11. Note down the observations in the Performa and compute the aggregate impact value.
12. The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

Precautions:

1. Place the plunger centrally so that it falls directly on the aggregate sample and does not touch the walls of the cylinder in order to ensure that the entire load is transmitted on to the aggregates.
2. In the operation of sieving the aggregates through 2.36 mm sieve the sum of weights of fractions retained and passing the sieve should not differ from the original weight of the specimen by more than 1 gm.
3. The tamping is to be done properly by gently dropping the tamping rod and not by hammering action. Also the tampering should be uniform over the surface of the aggregate taking care that the tamping rod does not frequently strike against the walls of the mould.

Observation Table:

	Sample - I	Sample - II
Total weight of dry sample taken = W1 gm		
Weight of portion passing in 2.36 mm sieve = W2 gm		
Aggregate Impact Value = (W2/W1)*100 (per cent)		
Aggregate Impact Mean Value = %		

Result:

Aggregate impact test value = ____________________ %

Classification of aggregates using aggregate Impact Value is as given below:

Aggregate Impact Value (%)	**Classification**
< 10	Exceptionally Strong
10 – 20	Strong
20 – 30	Satisfactory for Road Surfacing
> 35	Weak for Road Surfacing

Impact Values For Different Types Of Road Construction By IRC Are Given Below:

SL No.	**Types of Pavement**	**Aggregate Impact Value not more than**
1.	Bituminous Concrete	24
2.	Dense bituminous macadam, Semi-dense bituminous concrete, Surface dressing, Bituminous carpet and cement Concrete wearing course	27
3.	Wearing course	30
4.	Bitumen bound macadam base course	35
5.	WBM base course with bitumen surfacing	40
6.	Cement concrete base course	45

Experiment-15

Determination Of Soundness Test Of Road Aggregates.

Aim:

1. To determine the soundness of coarse aggregates
2. This test is intended to study the resistance of coarse aggregates to weathering action and to judge the durability of the coarse aggregate.

Apparatus Required:

1. Sieves 80 to 4.75 mm for CA
2. Temperature regulation
3. Containers
4. Balance
5. Oven $105^0 – 110^0$ C
6. Sodium sulphate
7. Magnesium sulphate
8. Wire mesh bucket

Sodium sulphate and Magnesium sulphate

Theory:

Soundness is the property of aggregate to resist disintegration when subjected to freezing and thawing. The test is intended to study the resistance of Aggregates to weathering condition in concrete or other applications. It is carried out to judge the durability of soundness of the Aggregate. In order to quicken the effect of weathering due to alternate set-dry and or freeze-thaw cycles in the laboratory, the resistance to disintegration of aggregate is determined by soaking the aggregate specimen in saturated solution of sodium sulphate or magnesium sulphate.

Preparation of Reagent:

Saturated solution of sodium sulphate (the anhydrous Na2SO4 or the crystalline Na2SO4.10 H2O) is prepared in water at a temperature of 250 to 300C. It should be ensured that the solution is saturated and excess salt is present.

The solution is maintained at a temperature of 27° ± 2° C and stirred at frequent intervals until it is used. At the time of using the solution should have a specific gravity of not less than 1.151 and not greater than 1.171 and discolored solution should not be used.

It may be necessary to use not less than 420 gm of anhydrous salt or 1300 gm of the crystalline decahydrate salt per liter of water.

Alternatively saturated solution of magnesium sulphate may be prepared by dissolving either anhydrous (Mg SO4) or crystalline (Mg SO4. 7H2O) magnesium sulphate. At the time of using, the solution should have a specific gravity of not less than 1.295 and not more than 1.308. Not less than 400 gm of the anhydrous salt or 1600 gm of the crystalline hepta hydrate may be used per liter of water.

Preparation of Test Sample for Coarse Aggregate:

- Wash the coarse aggregate through 4.75 mm IS sieve and dry the material retained on the sieve in an oven maintained at a temp of 105 to 110^{0}C, till it attains a constant mass.
- Sieve the dried sample to separate it into different size fractions using sieves of sizes 80 mm, 63 mm, 40 mm, 20 mm, 10 mm, and 4.75 mm.
- The sample should be of such an amount that it will yield not less than the following amount of the different sizes, which shall be available in amounts of 5 percent or more.

Size	Yield
10 mm to 4.75 mm	300 g
20 mm to 10 mm	1000 g (consisting of 12.5 mm to 10 mm = 33% and 20 mm to 12.5 mm = 67%)
40 mm to 20 mm	1500 g (consisting of 25 mm to 20 mm = 33% and 40 mm to 25 mm = 67%)
63 mm to 40 mm	3000 g (consisting of 50 mm to 40 mm = 50% and 63 mm to 50 mm = 50%)
80 mm and larger	3000 g

Take proper weight of sample from each fraction and place it in separate containers for the test.

Procedure:

1. Take individual samples in a wire mesh basket and immerse it in the solution of sodium sulphate or magnesium sulphate for not less than 16 hours nor more than 18 hours, in such a manner that the solution covers them to a depth of at least 15 mm.
2. After completion of the immersion period, remove the samples from solution and allow it to drain for 15 minutes and place it in drying oven.
3. Dry the sample until it attains a constant mass and then remove it from oven and cool it to room temperature.
4. After cooling again immerse it in the solution as described in step-1.
5. The process of alternate immersion and drying is repeated until the specified number of cycles as agreed between the purchaser and the vendor is obtained.
6. After completion of the final cycle and after the sample has been cooled, wash it to free from sodium sulphate or magnesium sulphate solution. This may be determined when there is no reaction of the wash water with barium chloride.
7. Then dry each fraction of the sample to constant temp of 105 to 110^{0}C and weigh it.
8. Sieve the coarse aggregate over the sieve shown below for the appropriate size of particles.

Size of Aggregate	Sieve used to determine loss
63 mm to 40 mm	31.5 mm
40 mm to 20 mm	16.0 mm
20 mm to 10 mm	8.0 mm
10 mm to 4.75 mm	4.0 mm

Result:

Percentage of loss in aggregates = ____________________

Limits:

Soundness of aggregate – Loss with magnesium sulphate - 5 cycles - Max 12%

Loss with sodium sulphate - 5 cycles - Max 18%

Diagram:

Before and After Soundness Test

Tabulation:

Sieve Size (Mm)		Weight Of Aggregate W1- (Kg)	Weight Of Aggregate After Testing (Kg)					Weight Of Aggregate After Testing W2- (Kg)	Percent Loss %
passing	retained	Before Testing	Day 1	Day 2	Day 3	Day 4	Day 5	Washed And Dried	
63	40								
40	20								
20	10								
10	4.75								
Total									

Calculation:

Percentage loss in aggregates = $(W_1 – W_2 / W_1)$ x 100

Where, W_1 = Initial weight of sample

W_{2} = Final retained weight on sample container after 5 cycle

Experiment-16

Determination Compressive Strength Of Concrete Cube.

Aim:

To find compressive strength value of concrete cubes.

Apparatus required:

1. 150 mm Cube Moulds (with IS Mark)
2. Electronic Weighing Balance
3. G.I Sheet (For Making Concrete)
4. Vibrating Needle & other tools
5. Compressions Testing Machine

Procedure:

Cube Casting-

- Measure the dry proportion of ingredients (Cement, Sand & Coarse Aggregate) as per the design requirements. The Ingredients should be sufficient enough to cast test cubes
- Thoroughly mix the dry ingredients to obtain the uniform mixture
- Add design quantity of water to the dry proportion (water-cement ratio) and mix well to obtain uniform texture
- Fill the concrete to the mould with the help of vibrator for thorough compaction
- Finish the top of the concrete by trowel & tapped well till the cement slurry comes to the top of the cubes.

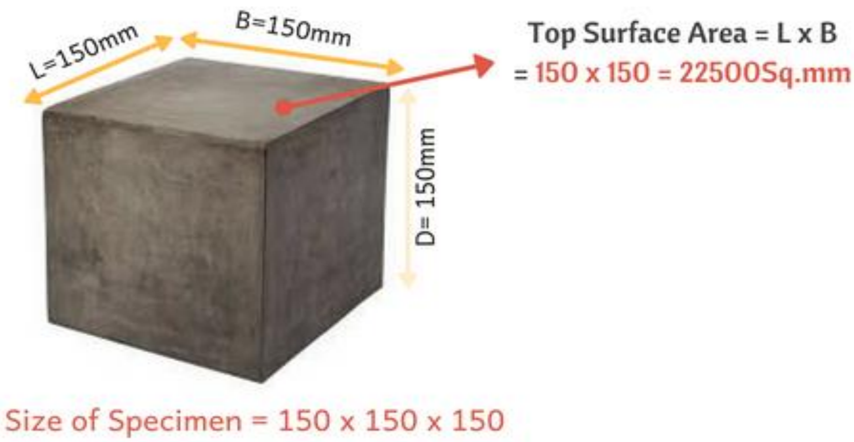
Curing-

- After some time the mould should be covered with red gunny bag and put undisturbed for 24 hours at a temperature of 27 ° Celsius ± 2
- After 24 hours remove the specimen from the mould.
- Keep the specimen submerged under fresh water at 27 ° Celsius. The specimen should be kept for 7 or 28 days. Every 7 days the water should be renewed.
- The specimen should be removed from the water 30 minutes prior to the testing.
- The specimen should be in dry condition before conducting the testing.
- The Cube weight should not be less than 8.1 Kgs

Testing-

- Now place the concrete cubes into the testing machine. (centrally)
- The cubes should be placed correctly on the machine plate (check the circle marks on the machine). Carefully align the specimen with the spherically seated plate.
- The load will be applied to the specimen axially.
- Now slowly apply the load at the rate of 140kg/cm^2 per minute till the cube collapse.
- The maximum load at which the specimen breaks is taken as a compressive load.

Diagram:



Compression Testing Machine

15 cm Cube Mould

Concrete Cube

Tabulation:

Sr.No	Age of cubes	Cross sectional area in mm^2	Load in N (1 KN = 1000N)	Compressive strength (N/ mm^2)	Avg. compressive strength (MPa)
1	3 days				
2					
3					
4	7 days				
5					
6					
7	21 days				
8					
9					

Calculation:

Compressive Strength of concrete = Maximum compressive load / Cross Sectional Area

Cross sectional Area = _________ mm x _________ mm = ____________ mm^2

Result:

1. The average 3 Days Compressive Strength of given cement cube = _______________ N/mm^2
2. The average 7 Days Compressive Strength of given cement cube = _______________ N/mm^2
3. The average 28 Days Compressive Strength of given cement cube = _______________ N/mm^2

<u>Compressive strength as per IS 456-2000:</u>

IS 456 : 2000

Table 2 Grades of Concrete

(*Clause* 6.1, 9.2.2, 15.1.1 *and* 36.1)

Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days in N/mm^2
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

Experiment-17
Determination Of Workability Of Concrete By Slump Cone Method.

Aim:

To determination the Workability of Concrete by conducting Slump Cone Method.

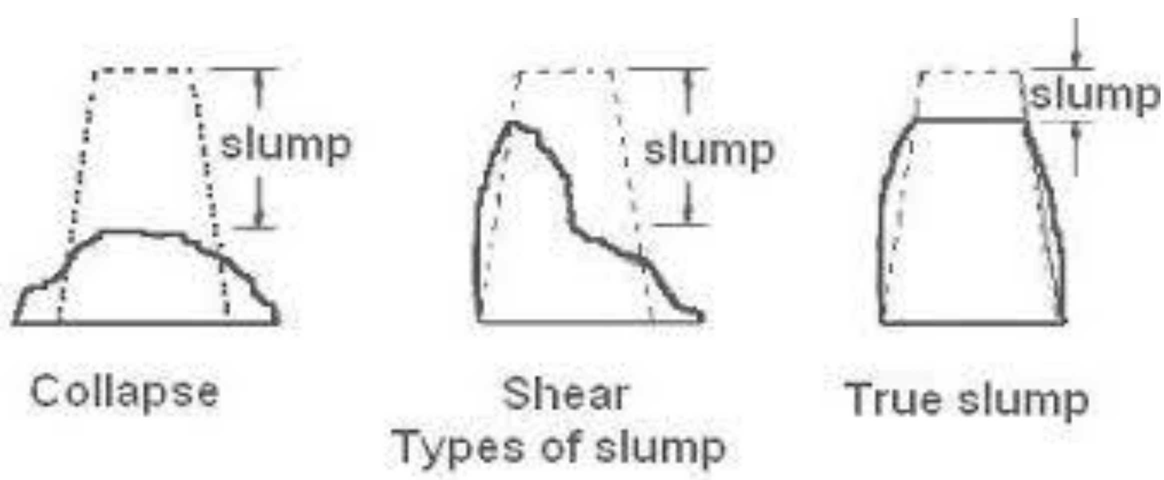
Apparatus required:

1. Slump cone mould.
2. Non porous base plate.
3. Measuring scale, temping rod.

The mould for the test is in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10 cm. The tamping rod is of steel 16 mm diameter and 60cm long and rounded at one end.

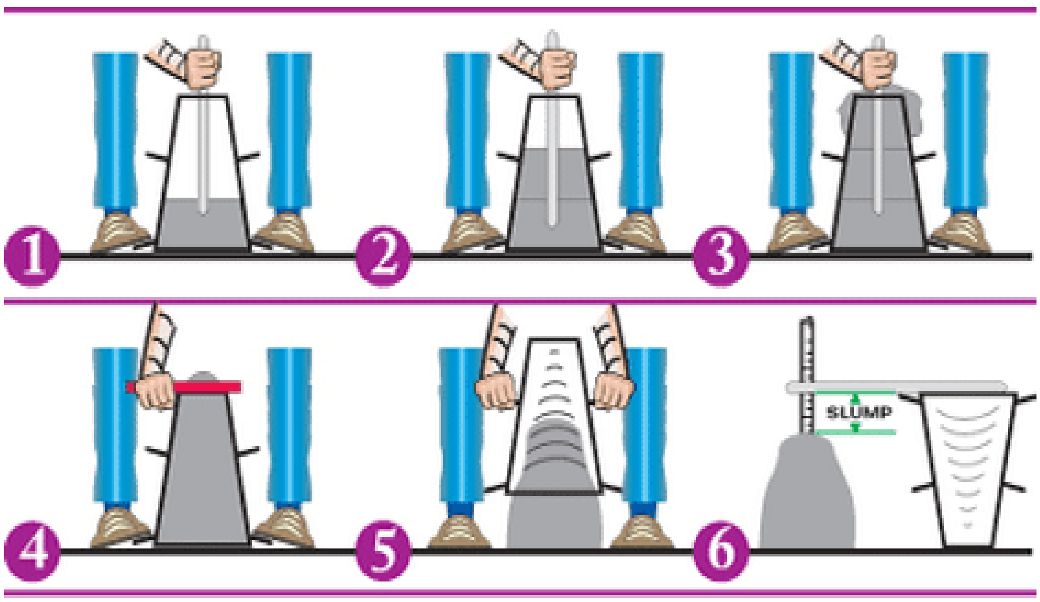
Procedure:

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non- porous base plate.
3. Fill the mould with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.



Slump Measurement

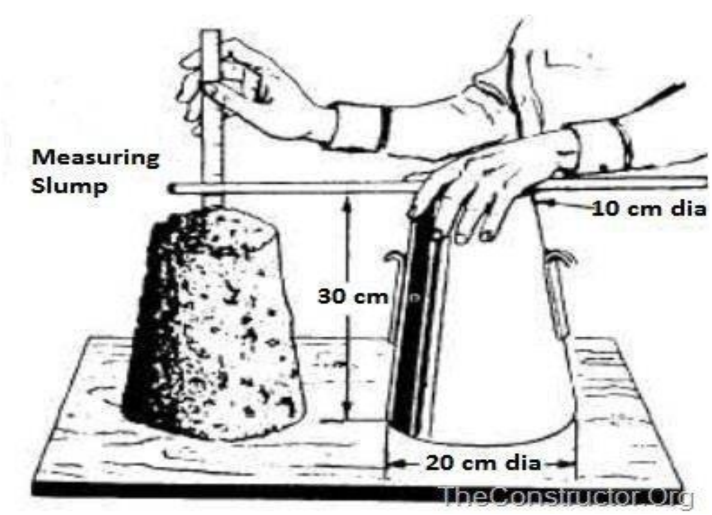
Diagram:



<u>Concrete Slump Test Procedure</u>

NOTE:

The above operation should be carried out at a place free from Vibrations or shock and within a period of 2 minutes after sampling.



<u>Measuring Slump of Concrete</u>

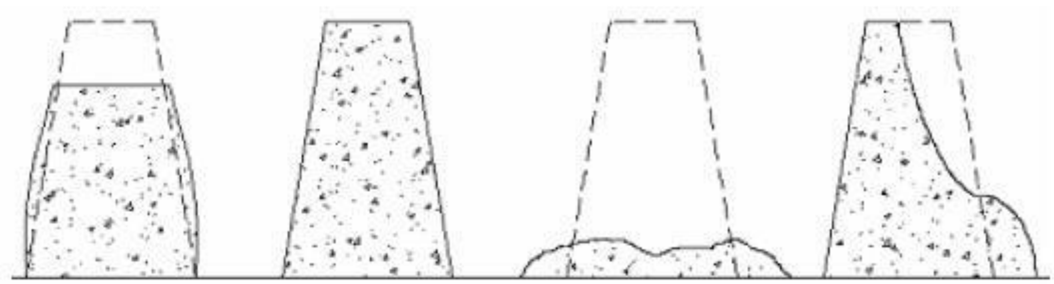
Observation:

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

Results:

Slump for the given sample= _____mm

When the slump test is carried out, following are the shape of the concrete slump that can be observed:



Types of Concrete Slump Test Results

- True Slump – True slump is the only slump that can be measured in the test. The measurement is taken between the top of the cone and the top of the concrete after the cone has been removed as shown in figure-1.

- Zero Slump – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. These type of concrete is generally used for road construction.

- Collapsed Slump – This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.

- Shear Slump – The shear slump indicates that the result is incomplete, and concrete to be tested.

Degree of workability	Slump		Use for which concrete is suitable
	mm	in	
Very low	0-25	0-1	Very dry mixes; used in road making. Roads vibrated by power operated machines.
Low	25-50	1-2	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines.
Medium	50-100	2-4	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations.
High	100-175	4-7	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

Experiment-18

Determination Of Workability Of Concrete By Compaction Factor Test Method.

Aim:

To determine the workability of fresh concrete by compaction factor test.

Apparatus required:

1. Compaction factor apparatus consists of trowels, hand scoop (15.2 cm long), a rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end)
2. Balance.
3. Concrete mix is prepared as per mix design in the laboratory.

Procedure:

1. Take M20 grade concrete.
2. Prepare the mix with 1:1.5:3 by adding required amount water as per Water cement ratio. Now mix the fresh concrete.
3. See that the Inner surfaces of conical hoppers should be free from moisture and apply grease to it. Close the trap door of the upper hopper.
4. Then measure the weight of the empty bottom cylinder and note it as $\mathbf{W_1}$
5. Fill the fresh concrete into the upper conical hopper using trowel without compacting it.
6. Next, trap door of an upper hopper is opened. Thus the concrete falls on the lower hopper.
7. Wait for 2-3 secs and check whether the entire concrete is fallen from the upper hopper to bottom hopper. If not, slight tamping is done until the whole concrete falls to the bottom hopper.
8. Now open the bottom hopper trap door, and entire concrete is fallen to the cylinder. Cut off the excess concrete on the top surface of a cylinder using the trowel.
9. Weight the cylinder with partially filled concrete and note it as $\mathbf{W_2}$.
10. Then the cylinder is emptied, and the concrete sample is filled again by filling it in 3 layers each layer is compacted by giving 25 blows using the tamping rod. Now, the concrete inside the cylinder is fully compacted.
11. Measure the weight of cylinder with fully compacted concrete and note it as $\mathbf{W_3}$.

Note:

The Compaction factor values ranges from **0.7 to 0.95.**

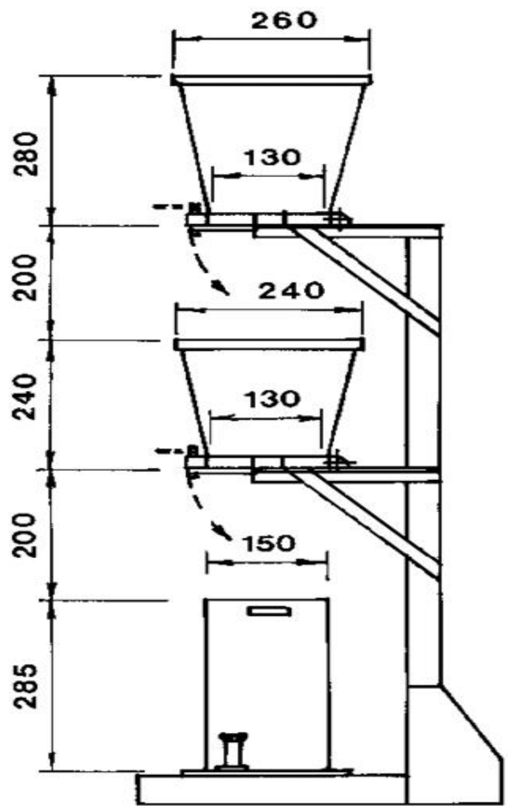
Relation between Workability and Slump as per IS 456-2000:

Description of workability	*Compacting factor*	*Corresponding slump mm*
Very low	0.78	0–25
Low	0.85	25–50
Medium	0.92	50–100
High	0.95	100–175

Result:

Compaction factor of the fresh concrete = ____________

Diagram:



Compacting factor test Apparatus

Tabulation:

Sr.No	Description	Sample-1	Sample-2	Sample-3
1	Weight of empty cylinder- $\mathbf{W_1}$			
2	Weight of empty cylinder + free fall concrete - $\mathbf{W_2}$			
3	Weight of empty cylinder + Hand compacted concrete -$\mathbf{W_3}$			
4	Weight of partially compacted concrete - $\mathbf{W_P = W_2 - W_1}$			
5	Weight of fully compacted concrete - $\mathbf{W_F = W_3 - W_1}$			
6	Compaction factor = $\mathbf{W_P / W_F}$			

Calculation:

$$\text{Compaction factor} = \frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

$$= \frac{W_2 - W_1}{W_3 - W_1}$$

W_1 = Weight of Empty Cylinder.

W_2 = Weight of Partially Compacted Concrete

W_3 = Weight of Fully Compacted Concrete.

Experiment-19

Non Destructive Test- Demonstration On Rebound Hammer.

Aim:

As per the Indian code IS: 13311(2)-1992, the rebound hammer test have the following objectives:

1. To determine the compressive strength of the concrete by relating the rebound index and the compressive strength.
2. To assess the uniformity of the concrete.
3. To assess the quality of the concrete based on the standard specifications.
4. To relate one concrete element with other in terms of quality.

Principle of Rebound Hammer Test:

Rebound hammer test method is based on the principle that the rebound of an elastic mass depends on the hardness of the concrete surface against which the mass strikes. The operation of the rebound hammer is shown in **figure-1**. When the plunger of rebound hammer is pressed against the concrete surface, the spring controlled mass in the hammer rebounds. The amount of rebound of the mass depends on the hardness of concrete surface.

Thus, the hardness of concrete and rebound hammer reading can be correlated with compressive strength of concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

Procedure:

Procedure for rebound hammer test on concrete structure starts with calibration of the rebound hammer. For this, the rebound hammer is tested against the test anvil made of steel having Brinell hardness number of about 5000 N/mm2.

After the rebound hammer is tested for accuracy on the test anvil, the rebound hammer is held at right angles to the surface of the concrete structure for taking the readings. The test thus can be conducted horizontally on vertical surface and vertically upwards or downwards on horizontal surfaces as shown in **figure-2** below

If the rebound hammer is held at intermediate angle, the rebound number will be different for the same concrete.

The impact energy required for the rebound hammer is different for different applications. Approximate Impact energy levels are mentioned in the table-1 below for different applications.

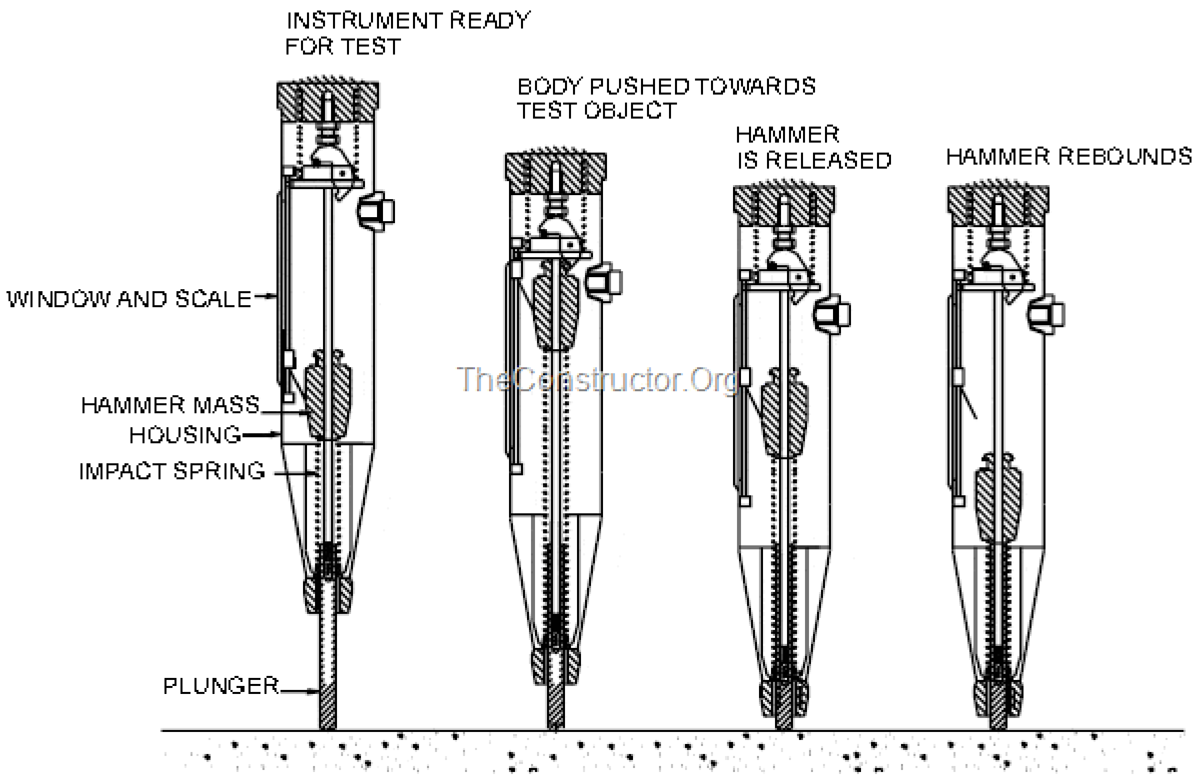


Fig.1.Operation of the rebound hammer

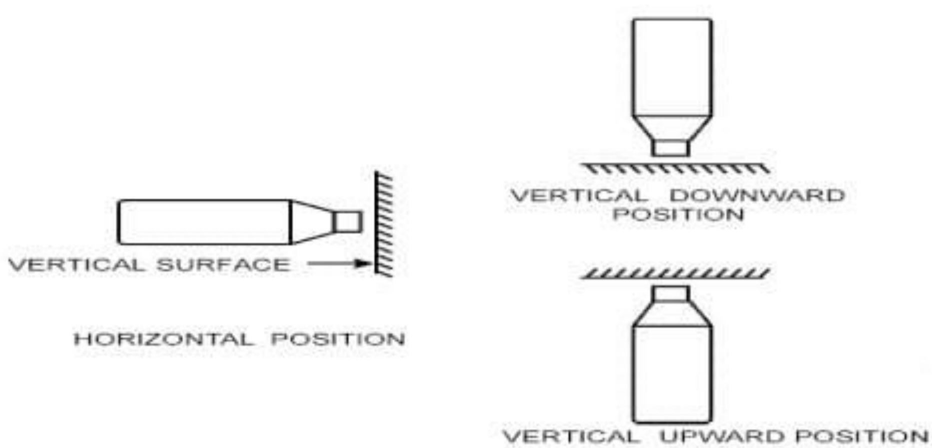


Fig.2.Rebound Hammer Positions for Testing Concrete Structure

Table-1: Impact Energy for Rebound Hammers for Different Applications as per IS: 13311(2)-1992

Sr.No	Applications	Approximate Impact Energy for Rebound Hammer in Nm
1	For Normal Weight Concrete	2.25
2	For light weight concrete / For small and impact resistive concrete parts	0.75
3	For mass concrete testing Eg: In roads, hydraulic structures and pavements	30.00

Points to Remember in Rebound Hammer Test:

1. The concrete surface should be smooth, clean and dry.
2. Ant loose particles should be rubbed off from the concrete surface with a grinding wheel or stone, before hammer testing.
3. Rebound hammer test should not be conducted on rough surfaces as a result of incomplete compaction, loss of grout, spalled or tooled concrete surface.
4. The point of impact of rebound hammer on concrete surface should be at least 20mm away from edge or shape discontinuity.
5. Six readings of rebound number are taken at each point of testing and an average of value of the readings is taken as rebound index for the corresponding point of observation on concrete surface.

Correlation between compressive strength of concrete and rebound number:

The most suitable method of obtaining the correlation between compressive strength of concrete and rebound number is to test the concrete cubes using compression testing machine as well as using rebound hammer simultaneously. First the rebound number of concrete cube is taken and then the compressive strength is tested on compression testing machine. The fixed load required is of the order of 7 N/mm2 when the impact energy of the hammer is about 2.2 Nm.

The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimize the size effect on the test result of a full scale structure. 150mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2.2Nm), whereas for rebound hammers of higher impact energy, for example 30 Nm, the test cubes should not be smaller than 300mm.

The concrete cube specimens should be kept at room temperature for about 24 hours after taking it out from the curing pond, before testing it with the rebound hammer. To obtain a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes and the strength of dry tested cubes on which rebound readings are taken.

A direct correlation between rebound numbers on wet cubes and the strength of wet cubes is not recommended. Only the vertical faces of the cubes as cast should be tested. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20mm and should be not less than 20mm from each other. The same points must not be impacted more than once.

Interpretation of Rebound Hammer Test Results:

After obtaining the correlation between compressive strength and rebound number, the strength of structure can be assessed. In general, the rebound number increases as the strength increases and is also affected by a number of parameters i.e. type of cement, type of aggregate, surface condition and moisture content of the concrete, curing and age of concrete, carbonation of concrete surface etc.

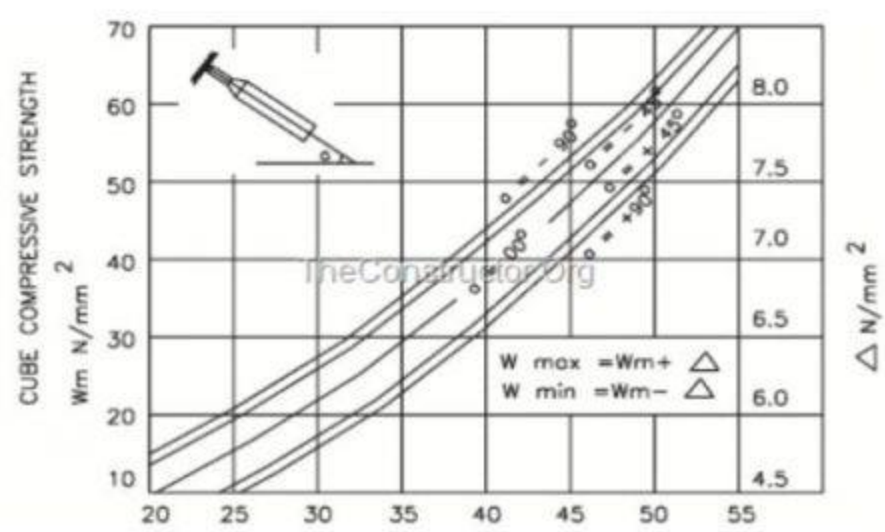


Fig.3.Relationship between Cube Strength and the Rebound Number

Moreover the rebound index is indicative of compressive strength of concrete up to a limited depth from the surface. The internal cracks, flaws etc. or heterogeneity across the cross section will not be indicated by rebound numbers.

Table-2 below shows the quality of concrete for respective average rebound number.

Table.2. Quality of Concrete for different values of rebound number

Average Rebound Number	Quality of Concrete
>40	Very good hard layer
30 to 40	Good layer
20 to 30	Fair
< 20	Poor concrete
0	Delaminated

As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent. If the relationship between rebound index and compressive strength can be found by tests on core samples obtained from the structure or standard specimens made with the same concrete materials and mix proportion, then the accuracy of results and confidence thereon gets greatly increased.

Experiment-20

Non Destructive Test- Ultrasonic Pulse Velocity Measuring Instrument.

Aim:

To determine the following by busing ultrasonic pulse velocity method-

1. The homogeneity of the concrete.
2. The presence of cracks, voids and other imperfections.
3. Changes in the structure of the concrete which may occur with time.
4. The quality of the concrete in relation to standard requirements.
5. The quality of one element of concrete in relation to another.
6. The values of dynamic elastic modulus of the concrete.

Principle:

The ultrasonic pulse is generated by an electro acoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed which includes longitudinal (compression), shear (transverse) and surface (Rayleigh) waves. The receiving transducer detects the onset of the longitudinal waves, which is the fastest.

Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic properties, pulse velocity method is a convenient technique for investigating structural concrete.

The underlying principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of poorer quality, lower velocities are obtained. If there is a crack, void or flaw inside the concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making the path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

Apparatus Required:

Ultrasonic Pulse Velocity Meter.

The apparatus for ultrasonic pulse velocity measurement shall consist of the following:

a) Electrical pulse generator,
b) Transducer - one pair,
c) Amplifier, and
d) Electronic timing device.

Procedure:

1. In this test method, the ultrasonic pulse is produced by the transducer which is held in contact with one surface of the concrete member under test. After traversing a known path length L in the concrete, the pulse of vibrations is converted into an electrical signal by the second transducer held in contact with the other surface of the concrete member and an electronic timing circuit enables the transit time (T) of the pulse to be measured. The pulse velocity (V) is given by:

$$V = L/T$$

2. Once the ultrasonic pulse impinges on the surface of the material, the maximum energy is propagated at right angles to the face of the transmitting transducer and best results are, therefore, obtained when the receiving transducer is placed on the opposite face of the concrete member (direct transmission or cross probing). However, in many situations two opposite faces of the structural member may not be accessible for measurements. In such cases, the receiving transducer is also placed on the same face of the concrete members (surface probing). Surface probing is not as efficient as cross probing, because the signal produced at the receiving transducer has amplitude of only 2 to 3 percent of that produced by cross probing and the test results are greatly influenced by the surface layers of concrete which may have different properties from that of concrete inside the structural member. The indirect velocity is invariably lower than the direct velocity on the same concrete element. This difference may vary from 5 to 20 percent depending largely on the quality of the concrete under test. For good quality concrete, a difference of about 0.5 km/ sec may generally be encountered.
3. To ensure that the ultrasonic pulses generated at the transmitting transducer pass into the concrete and are then detected by the receiving transducer, it is essential that there be adequate acoustical coupling between the concrete and the face of each transducer. Typical couplets are petroleum jelly, grease, liquid soap and kaolin glycerol paste. If there is very rough concrete surface, it is required to smoothen and level an area of the surface where the transducer is to be placed. If it is necessary to work on concrete surfaces formed by other means, -for example toweling, it is desirable to measure pulse velocity over a longer path length than would normally be used. A minimum path length of 150 mm is recommended for the direct transmission method involving one unmolded surface and a minimum of 400 mm for the surface probing method along an unmolded surface.
4. The natural frequency of transducers should preferably be within the range of 20 to 150 kHz. Generally, high frequency transducers are preferable for short path lengths and low frequency transducers for long path lengths. Transducers with a frequency of 50 to 60 kHz are useful for most all-round applications.

5. Since size of aggregates influences the pulse velocity measurement, it is recommended that the minimum path length should be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for concrete in which the nominal maximum size of aggregate is between 20 to 40 mm.
6. In view of the inherent variability in the test results, sufficient number of readings are taken by dividing the entire structure in suitable grid markings of 30 x 30 cm or even smaller. Each junction point of the grid becomes a point of observation.
7. Transducers are held on corresponding points of observation on opposite faces of a structural element to measure the ultrasonic pulse velocity by direct transmission, i.e., cross probing. If one of the faces is not- accessible, ultrasonic pulse velocity is measured on one face of the structural member by surface probing.
8. Surface, probing in general gives lower pulse velocity than in case of cross probing and depending on number of parameters, the difference could be of the order of about 1 km/sec.

Influence of Test Conditions-

1. Influence of Surface Conditions and Moisture Content of Concrete-

Smoothness of contact surface under test affects the measurement of ultrasonic pulse velocity. For most concrete surfaces, the finish is usually sufficiently smooth to ensure good acoustical contact by the use of a coupling medium and by pressing the transducer against the concrete surface. When the concrete surface is rough and uneven, it is necessary to smoothen the surface to make the pulse velocity measurement possible.

In general, pulse velocity through concrete increases with increased moisture content of concrete. This influence is more for low strength concrete than high strength concrete. The pulse velocity of saturated concrete may be up to 2 percent higher than that of similar dry concrete. In general, drying of concrete may result in somewhat lower pulse velocity.

2. Influence of Path Length, Shape and Size of the Concrete Member-

As concrete is inherently heterogeneous, it is essential that path lengths be sufficiently long so as to avoid any error introduced due to its heterogeneity. In field work, this does not pose any difficulty as the pulse velocity measurements are carried out on thick structural concrete members. However, in the laboratory where generally small specimens are used, the path length can affect the pulse velocity readings.

The shape and size of the concrete member do not influence the pulse velocity unless the least lateral dimension is less than a certain minimum value, for example the minimum lateral dimension of about 80 mm for 50 kHz natural frequency of the transducer. Table 1 gives the guidance on the choice of the transducer natural frequency for different path lengths and minimum transverse dimensions of the concrete members.

3. Influence of Temperature of Concrete-

Variations of the concrete temperature between 5 and 30°C do not significantly affect the pulse velocity measurements in concrete. At temperatures between 30 to 60°C there can be reduction in pulse velocity up to 5 percent. Below freezing temperature, the free water freezes within concrete, resulting in an increase .in pulse velocity up to 7.5 percent.

4. Influence of Stress-

When concrete is subjected to a stress which is abnormally high for the quality of the concrete, the pulse velocity may be reduced due to the development of micro-cracks. This influence is likely to be the greatest when the pulse path is normal to the predominant direction of the planes of such micro-cracks. This occurs when the pulse path is perpendicular to the direction of a uniaxial compressive stress in a member.

This influence is generally insignificant unless the stress is greater than about 60 percent of the ultimate strength of the concrete.

5. Effect of Reinforcing Bars-

The pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition. This is because, the pulse velocity in steel is 1.2 to 1.9 times the velocity in plain concrete and, under certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel.

The apparent increase in pulse velocity depends upon the proximity of the measurements to the reinforcing bar, the diameter and number of the bars and their orientation with respect to the path of propagation.

Result:

1. The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. This in turn, depends upon the materials and mix proportions used in making concrete as well as the method of placing, compaction and curing of concrete.

   For example, if the concrete is not compacted as thoroughly as possible, or if there is segregation of concrete during placing or there are internal cracks or flaws, the pulse velocity will be lower, although the same materials and mix proportions are used.
2. The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc, indicative of the level of workmanship employed; can thus be assessed using the guidelines given in Table 2, which have been evolved for characterizing the quality of concrete in structures in terms of the ultrasonic pulse velocity.

S. No.	Pulse velocity by Cross Probing (km/sec)	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

Table 1: Velocity Criterion for Concrete Quality Grading.

3. Since actual values of the pulse velocity obtained, depend on a number of parameters, any criterion for assessing the quality of concrete on the basis of pulse velocity as given in Table 2 can be held as satisfactory only to a general extent. However, when the comparison is made amongst different parts of a structure, which have been built at the same time with supposedly similar materials, construction practices and supervision, the assessment of quality becomes more meaningful and reliable.
4. The assessment of compressive strength of concrete from ultrasonic pulse velocity values is not adequate because the statistical confidence of the correlation between ultrasonic pulse velocity and the compressive strength of concrete is not very high. The reason is that a large number of parameters are involved, which influence the pulse velocity and compressive strength of concrete to different extents. However, if actual concrete materials and mix proportions adopted in a particular structure are available, then estimate of concrete strength can be made by establishing suitable correlation between the pulse velocity and the compressive strength of concrete specimens made with such materials and mix proportions, under environmental conditions similar to that in the structure. The estimated strength may vary from the actual strength by 20 percent. The correlation so obtained may not be applicable for concrete of another grade or made with different types of materials.