MADHA
Expertise | Empathy | Excellence
ENGINEERING COLLEGE

DEPARTMENT OF CIVIL ENGINEERING
FIFTH SEMESTER
REGULATION 2021

Highway Engineering

Lab Manual

1. AGGREGATE CRUSHING VALUE TEST

AIM: To determine crushing value of the aggregate.

THEORY

The principal mechanical properties required in road stones are (i) satisfactory resistance to crushing under the roller during construction and (ii) adequate resistance to surface abrasion under traffic. Also surface stresses under rigid tyre rims of heavily loaded animal drawn vehicles are high enough to consider the crushing strength of road aggregates as an essential requirement in India.

Crushing strength of road stones may be determined either on aggregates or on cylinderical specimens cut out of rocks. These two tests are quite different in not only the approach but also in the expression of the results.

Aggregates used in road construction, should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likely to be adversely affected. The strength of coarse aggregates is assessed by aggregates crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.

DESCRIPTION OF THE APPARATUS

The apparatus for the standard aggregate crushing test (Figure 2.1) consists of the following:

(i) Steel cylinder with open ends, and internal diameter 25.2cm, square base plate plunger having a piston of diameter 15 cm, with a hole provided across the stem of the plunger so that a rod could be inserted for lifting or placing the plunger in the cylinder.
(ii) Cylindrical measure having internal diameter of 11.5 cm and height 18 cm.
(iii) Steel temping rod with one rounded end, having a diameter of 1.6 cm and length 45 to 60 cm.
(iv) Balance of capacity 3 Kg. with accuracy upto 1 g.
(v) Compressions testing machine capable of applying load of 40 tonnes, at a uniform rate of loading of 4 tonnes per minute.

PROCEDURE

The aggregate passing 12.5mm sieve and retained on 10 mm IS sieve is selected for standard test. The aggregate should be in surface-dry condition before testing. The aggregate may be dried by heating at a temperature 100 degrees C to 110 degrees C for a period of 4 hours and is tested after being cooled to room temperature.

The cylindrical measure is filled by the test sample of aggregate in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod. After the third layer is tamped, the aggregates at the top of the cylindrical measure is levelled off by using the tamping rod as a straight edge. About 6.5 Kg. of aggregate is required for preparing two test samples. The test sample thus taken is then weighed. The same weight of the sample is taken in the repeat test.

The cylinder of the test apparatus is placed in position on the base plate; one third of the test sample is placed in the cylinder and tamped 25 times by the tamping rod. Similarly, the other two parts of the test specimen are added, each layer being subjected to 25 tampings. The total depth of the material in the cylinder after tamping shall however be 10 cm. The surface of the aggregates Is levelled and the plunger inserted so that it rests on this surface In level position. The cylinder with the test sample and plunger in position is placed on compression testing machine. Load is then applied through the plunger at a uniform rate of 4 tonnes per minute until the total load is 40 tonnes, and then the load is released. Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36 mm IS sieve. The material which passes this sieve is collected.

The above crushing test is repeated on second sample of the same weight in accordance with above test procedure. Thus two tests are made for the same specimen for taking an averagevalue.

CALCULATION

Total weight of dry sample taken=W1 g. Weight of the portion of crushed material passing 2.36 mm IS sieve=W2 g.

The aggregate crushing value is defined as a ratio of the weight of fines passing the specified IS sieve to the total weight of the sample expressed as a percentage. The value is usually recorded up to the first decimal place.

$$\text{Aggregate crushing value} = \frac{100W2}{W1}$$

RESULTS

The mean of the crushing value obtained in the two tests is reported as the aggregate crushing value.

DETERMINATION OF TEN PERCENT FINES VALUE

The "ten percent fines" value is a measure of resistance on the aggregates to the crushing. The apparatus and materials used are the same as for the standard aggregate crushing test. The test sample in the cylinder with the plunger in position is placed in the compression testing machine. The load is applied at a uniform rate so as to cause a total penetration of the plunger of about 20mm for normal crushed aggregates in 10 minutes. But for rounded or partially rounded aggregates, the load required to cause a total penetration of 15mm is applied where as for honeycombed aggregate like expanded shales or slags that for a total penetration of 24 mm is applied in 10 minutes. After the maximum specified penetration is reached, the load is released and the aggregates from the cylinder is sieved on a 2.36 mm IS sieve. The fines passing this sieve is weighed and is expressed as a percentage by weight of the test sample. This percentage normally falls in the range of 7.5 to 12.5; but if it does not fall in this range, the test is repeated with necessary adjustment of the load.

Two tests are carried out at the load (x tonnes) which give the percentage fines between 7.5 and 12.5 and let the mean of the percent fines be '/ for calculating the load required for 10 percent fines.

$$\text{Load for 10 percent fine} = \frac{14x}{(y+4)}$$

DISCUSSION

In general, large size of aggregates used in the test results in higher aggregates crushing value. The relationship between the aggregate sizes and the crushing values will however vary with the type of specimens tested. When non-standard sizes of aggregates are used for the crushing test, (i.e. aggregate larger than 12.5 mm or smaller than 10 mm) the size of the cylinder, quantity of material for preparation of specimen size of IS sieve for separating fines and the amount and rate of compaction shall be adopted as given in Table 1.

The aggregate sample for conducting the aggregate crushing test for the first time is to be taken by volume in the specified cylindrical measure by tamping in a specified manner and the weight of the sample is determined. When the test is repeated using the same aggregate, it is sufficient to directly weigh and take the same weight of sample. This is because it is necessary to keep the volume and height of the test specimens in the aggregate crushing mould constant when testing any aggregate sample so that the test, conditions remain unaltered. If the volume and hence the height may vary depending on the variation in specific gravity and shape factors of different aggregates.

When aggregates are not available, crushing strength test may be carried out on cylindrical specimen prepared out of rock sample by drilling, sawing and grinding. The specimen may be subjected to a slowly increasing compressive load until failure to find the crushing strength in Kg/sq.cm. However, this test is seldom carried out due to difficulty in preparing specimens and not getting reproducible results. On the contrary, the aggregate crushing test is simple, rapid and gives fairly consistent results.

Application of Aggregate Crushing Test:

The aggregate crushing value is an indirect measure of crushing strength of the aggregates. Low aggregate crushing value indicates strong aggregates, as the crushed fraction is low. Thus the test can be used to assess the suitability of aggregates with reference to the crushing strength for various types of pavement components. The aggregates used for the surface course of pavements should be strong enough to withstand the high stresses due to wheel loads, including the steel tyres of loaded bullock carts. However, as the stresses at the base and sub-base courses are low aggregates with lesser crushing strength may be used at the lower layers of the pavement.

Indian Roads Congress and ISI have specified that the aggregate crushing value of the coarse aggregates used for cement concrete pavement at surface should not exceed 30 percent. For aggregates used for concrete other than for wearing surfaces, the aggregate crushing value shall not exceed 45 percent, according to the ISS. However, aggregate crushing values have not been specified by the IRC for coarse aggregates to be used in bituminous pavement construction methods.

TABLE 1 DETAILS FOR AGGREGATE CRUSHING TEST WITH NON-STANDARD SIZES OF AGGREGATE

Aggregate size		*Diameter of cylinder to be used, cm*	*Quantity of material and preparation of test sample*	*Loading*	*Size of IS sieve for separating fiens*
Passive sieve size, mm	*Retained on sieve size, mm*				
25	26	15 *(standard cylinder)	*Standard method loading Standard loading 3.35 mm		+Standard 4.75 mm
20	12.5	15 *(standard cylinder)	Standard method Metal measure 5 cm dia * 9 cm height tamping rod 8 mm dia 30 cm long depth of material in 7.5cm cylinder after tamping 5 cm.	Rate of loading one tonne per min. upto a total load of 10 tonnes	1.70 mm
10	6.3	7.5			
6.3	4.75	7.5	As above	As above	1.18 mm
4.75	3.35	7.5	As above	As above	850 microns
3.35	2.36	7.5	As above	As above	600 microns

*Standard cylinder as given in Fig.2.1.

** Standard method of preparing sample as given in procedure.

+ Standard loading as given in procedure.

OBSERVATION SHEET

SIZE OF THE AGGREGATE

RATE OF APPLICATION OF LOAD

TOTAL LOAD APPLIED

Sample No:

Total weight of dry sample W1 gms

Weight of fines passing 2.36 mm IS sieve W2 gms

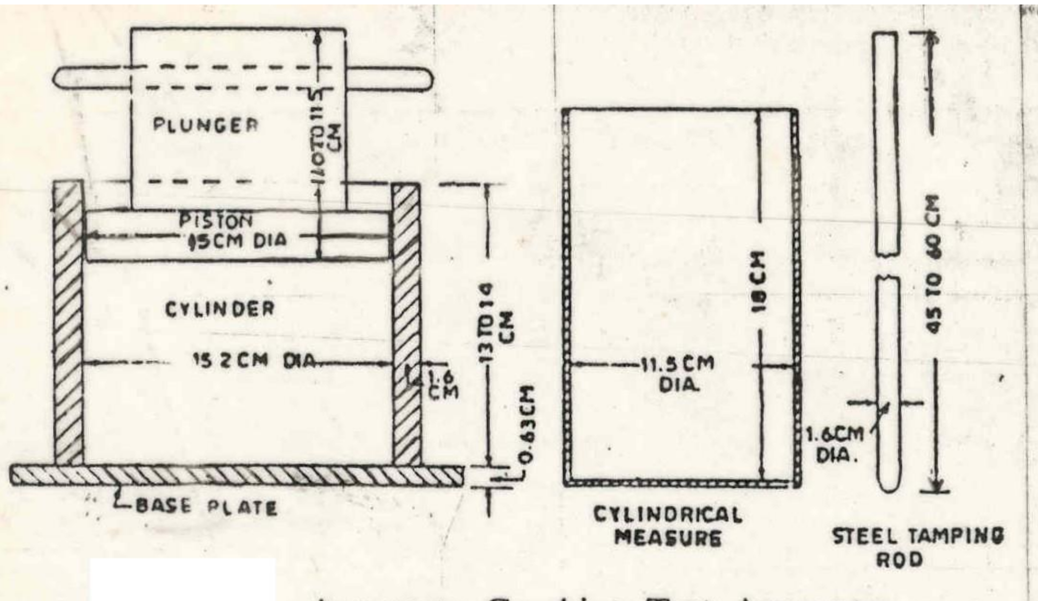
Aggregate crushing value (%)

(W2/W1x100)

Average crushing value percentage

QUESTIONS

1) What is aggregate crushing value ?
2) Why crushing test is to be performed on road aggregates ?
3) What is the size of aggregates to be taken for standard crushing test ?
4) What should be the total depth of the material in the cylinder after tamping ?
5) What is the rate of loading in crushing value test for testing standard size aggregates ?
6) What is the maximum load applied in crushing value test ?
7) Aggregate crushing values for aggregate samples And B are30 and 45 respectively. Which is a better one ? Justify your answer.
8) What is the rate of loading and maximum load to be applied for determining aggregate crushing value of material passing through 10mm sieve and retained on 6.3mm sieve ?
9) What are the applications of aggregate crushing value test ?
10) What is the recommended maximum value of aggregate crushing value for the aggregates to be used in base and surface courses of cement concrete ?



Aggregate Crushing Test Apparatus

2. AGGREGATE IMPACT TEST

AIM : To determine aggregate Impact value.

THEORY

Toughness is the property of a material to resist impact. Due to traffic loads, the road stones are subjected to the pounding action or impact and there is possibility of stones breaking into smaller pieces. The road stones should therefore be tough enough to resist fracture under impact. A test designed to evaluate the toughness of stones i.e. the resistance of the stones to fracture under repeated impacts may be called an impact test for road stones.

Impact test may either be carried out on cylindrical stone specimens as in Page Impact test or on stone aggregates as in Aggregate Impact Test. The Page Impact test is not carried out now-a-days and has also been omitted from the revised British Standards for testing mineral aggregates. The Aggregate Impact test has been standardised by the British Standard Institution and the Indian Standard Institution.

The aggregate impact value indicates a relative measure of the resistance of aggregate to a sudden shock of an impact, which in some aggregates differs from its resistance to a slow compressive load. The method of test covers the procedure for determining the aggregate impact value of coarse aggregates.

APPARATUS

The apparatus consists of an impact testing machine, a cylindrical measure, tamping rod, IS sieve balance and oven.

a) Impact testing machine: The machine consists of a metal base with a plane lower surface supported well on a firm floor, without rocking. A detachable cylindrical steel cup of internal diameter 10.2 cm and depth of 5 cm is rigidly fastened centrally to the base plate. A metal hammer of weight between 13.5 and 14.0 Kg. having the lower end cylindrical in shape, 10cm in diametrer and 5 cm long, with 2mm chamber at the lower edge is capable of sliding freely between vertical guides, and fall concentric over the cup. There is an arrangement for raising the hammer and allowing it to fall freely between vertical guides from a height of 38 cm on the test sample in the cup, the height of fall being adjustable upto 0.5cm. A key is provided for supporting the hammer while fastening or removing the cup. Refer fig.3.1.
b) Measure: A cylindrical metal measure having internal diameter 7.5 cm and depth 5 cm for measuring at one end.
c) Tamping rod: A straight metal tamping rod of circular cross section, 1 cm in diameter and 23 cm long, rounded at one end.
d) Sieve :lS sieve of sizes 12.5 mm, 10 mm and 2.36 mm for sieving the aggregates.
e) Balance: A balance of capacity not less than 500 g. to weigh accurate upto 0.1 g.
f) Oven: A thermostatically controlled drying oven capable of maintaining constant temperature between 100 degrees C and 110 degrees C.

PROCEDURE

The test sample consists of aggregates passing 12.5 mm sieve and retained on 10 mm sieve and dried in an oven for four hours at a temperature 100° C to 110° C and cooled. The aggregates are filled upto about one-third full in the cylindrical measure and tamped 25 times with rounded end of the tamping rod. Further, quantity of aggregates is then added upto about two-third full in the cylinder and 25 strokes of the tamping rod are given. The measure is now filled with the aggregates to over flow, tamped 25 times. The surplus aggregates are struck off using the tamping rod as straight edge. The net weight of the aggregates in the measure is determined to the nearest gram and this weight of the aggregates is used for carrying out duplicate test on the same material. The impact machine is placed with its bottom plate flat on the floor so that the hammer guide columns are vertical. The cup is fixed firmly in position on the base of the machine and the whole of the test sample from the cylindrical measure is transferred to the cup and compacted by tamping with 25 strokes.

The hammer is raised until its lower face is 38cm above the upper surface of the aggregates in the cup, and allowed to fall freely on the aggregates. The test sample is subjected to a total of 15 such blows, each being delivered at an interval of not less than one second. The crushed aggregate is then removed from the cup and the whole of it sieved on the 2.36 mm sieve until no further significant amount passes. The fraction passing the sieve is weighed accurate to 0.1 g. The fraction retained on the sieve is also weighed and if the total weight of the fractions passing and retained on the sieve is added, it should not be less than the total weight is less than the original by over one gram, the result should be discarded and a fresh test made.

The above test is repeated on fresh aggregate sample.

CALCULATION

The aggregate impact value is expressed as the percentage of the fines formed in terms of the total weight of the sample.

Let the original weight of the oven dry sample W_1 g and the weight of fraction passing2.36mm IS sieve be W_2 g.

Aggregate impact value $= \frac{100\boldsymbol{W}_2}{\boldsymbol{W}_1}$

This is recorded correct to the first decimal place.

RESULTS

The mean of the two results is reported as the aggregate impact value of the specimen to the nearest whole number.

Aggregate impact value is to classify the stones in respect of their toughness property as indicated below:

Aggregate Impact Value

< 10%	Exceptionally strong
10-20%	Strong
10-30%	Satisfactorily for road surfacing
> 35%	Weak for road surfacing

DISCUSSION

Chief advantage of aggregate impact test is that test equipment and the test procedure are quite simple and it determines the resistance to impact of stones simulating field condition.

The test can be performed in a short time even at construction site or at stone quarry, as the apparatus is simple and portable.

Well shaped cubical stones provide higher resistance to impact when compared with flaky and elongated stones.

It is essential that the first specimen to be tested from each sample of aggregate is equal in volume; this is ensured by taking the specimen in the measuring cylinder in the specified manner by tamping in three layers. If all the test specimens to be tested in the aggregate impact testing mould are of equal volume, the height of these specimens will also be equal and hence the height of fall of the impact rammer on the specimens will be equal. On the other hand, if equal weight of different aggregate samples are taken, their volume and height may vary depending upon the specific gravity of the aggregates and their shape factors.

There is no definite reason why the specified rate of application of the blows of the impact rammer should be maintained.

Applications of Aggregate Impact Value

The aggregate impact test is considered to be an important test to assess the suitability of aggregates as regards the toughness for use in pavement construction. It has been found that for majority of aggregates, the aggregate crushing and aggregate impact values are numerically similar within close limits. But in the case of fine grained highly siliceous aggregate which are less resistance to impact than to crushing the aggregate impact values are higher (on the average, by about 5) than the aggregate crushing values.

Various agencies have specified the maximum permissible aggregate impact value for the different types of pavements, those recommended by the Indian Roads congress are given in Table 1.

For deciding the suitability of soft aggregates in base course construction, this test has been commonly used. A modified impact test is also often carried out in the case of soft aggregates to find the wet impact value after soaking the test sample. The recommendations given in Table 2 based on work reported by different agencies; have been made to assess the suitability of soft aggregate for road construction.

TABLE 1

Maximum allowable impact value of aggregate in different types of pavement material/layers.

Sl.No.	*Types of pavement material/layer*	*Aggregate impact Value, maximum, %*
1.	Water bound macadam (WBM), sub-based course	50
2.	Cement concrete, base course (as per ISI)	45
3.	i) WBM base course with bitumen surfacing	40
	ii) Built up-spray grout, base course	
4.	Bituminous macadam, base course	35
5.	i) WBM, surfacing course	
	ii) Built-up spray grout, surfacing course	
	iii) Bituminous penetration macadam	
	iv) Bituminous macadam, binder course	
	v) Bituminous surface dressing	
	vi) Bituminous carpet	
	vii) Bituminous / Asphaltic concrete	
	viii) Cement concrete, surface course	30

TABLE 2

Condition of sample	Maximum aggregate impact value, percent	
	Sub-base and base	Surface course
Dry	50	32
Wet	60	39

OBSERVATION SHEET

SIZE OF THE AGGREGATE

NUMBER OF BLOWS

HEIGHT OF FALL

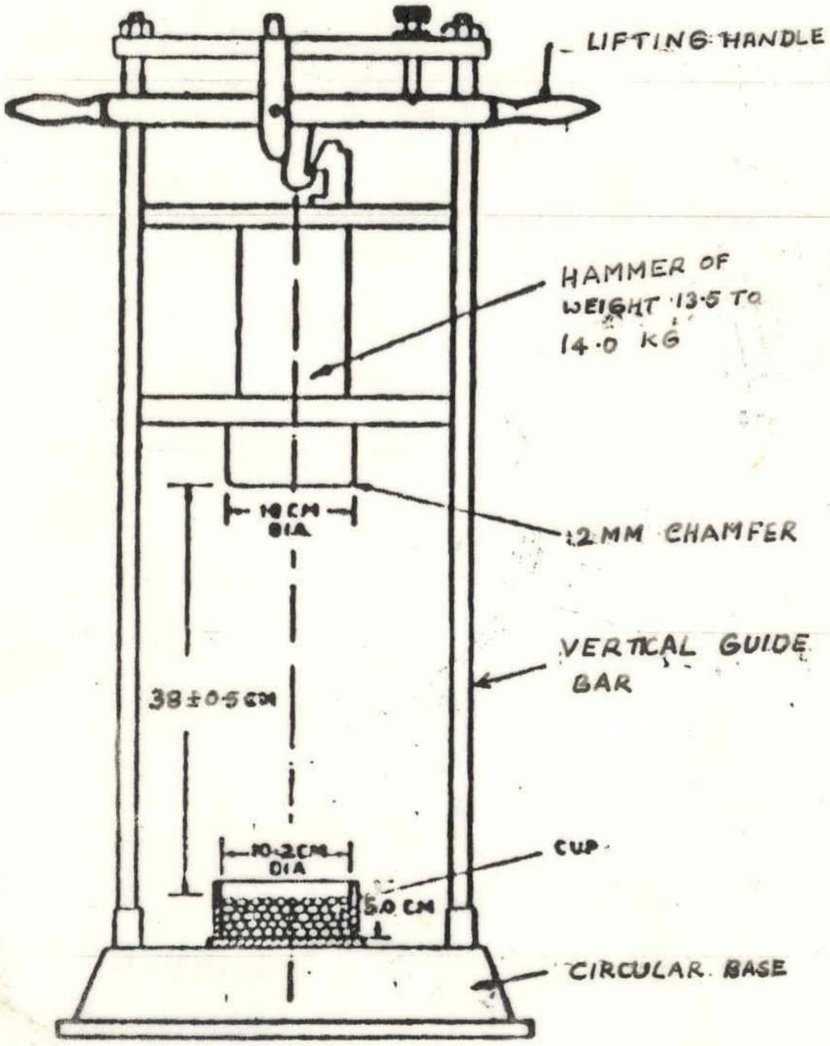
Sample No.				
Total weight of dry sample W_1gms				
Weight of fines passing 2.36mm IS Sieve W_2gms				
Aggregate Impact Value (%) (W_2/W_1)x100				
Aggregate Impact Value percentage				

QUESTIONS

1) What is aggregate impact value?
2) Whyimpact test is to be performed on road aggregates?
3) What is the size of aggregates to be taken for aggregate impact test?
4) What is the height of fall of hammer?

5) How many blows should be given in Impact test?
6) Aggregate Impact values for aggregate samples A and B are 30 and 45 respectively. Which is a better one? Justify your answer.
7) What are the applications of aggregate Impact value test?
8) How do you express aggregate Impact value?
9) What are the desirable limits aggregate impact value specified for different types of pavement surfaces?

AGGREGATE IMPACT TEST



Aggregate Impact Testing Machine

3. Specific Gravity and Water Absorption Tests

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Stones having low specific gravity are generally weaker than those with higher specific gravity values. The specific gravity test helps in identification of stone.

Water absorption gives an idea of strength of rock. Stones having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

Apparatus

The apparatus consists of the following :

(a) A balance of capacity about 3 kg, to weigh accurate to 0.5 g, and of such a type and shape as to permit weighing of the sample container when suspended in water.
(b) A thermostatically controlled oven to maintain temperature of 100° to 110°C.
(c) 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.
(d) A container for filling water and suspending the basket.
(e) An air tight container of capacity similar to that of the basket (referred to in V above).
(f) A shallow tray and two dry absorbent clothes, each not less than 75 x 45 cm.

Procedure

About 2 kg of the aggregate sample is washed thoroughly to remove fines, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22° and 32°C and a cover of atleast 5 cm of water above the top of the basket. 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 25 times at the rate of above one drop per second. The basket and the aggregate should remain completely immersed in water for a period of 24 ± 1/2 hour afterwards.

The basket and the sample are then weighed while suspended in water at a temperature of 22° to 32°C in case it is necessary to transfer the basket and the sample to a different tank for weighing, they should be jolted 25 times as described above in the new tank to remove air before weighing. The weight is noted while suspended in water = W_1 g. The basket and the aggregate are then removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to one of the dry absorbent clothes. The empty basket is then returned to the tank of water, jolted 25 times and weighed in water = W_2g.

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, covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. 10 to 60minutes drying may be needed. The aggregate should not be exposed to the atmosphere, direct sunlight or any other source of heat while surface drying. A gentle current of unheated air may be used during the first ten minutes to accelerate the drying of aggregate surface. The surface dried aggregate is then weighed = W3 g. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110°C for 24 hours. It is then removed from the oven, cooled in an air-tight container and weighed = W4 g.

At least two tests should be carried out, but not concurrently.

Calculations

Weight of saturated aggregate suspended in water with the basket	$=W_1$ g
Weight of basket suspended in water	$= W_2$ g
Weight of saturated aggregate in water	$= (W_1-W_2) = Ws$ g
Weight of saturated surface dry aggregate in air	$= W_3$ g
Weight of water equal to the volume of the aggregate	$= (W_3-Ws)$ g

(1) Specific gravity $= \dfrac{dry\ weight\ of\ aggregate}{weight\ of\ equal\ volume of\ water}$

$$= \frac{W_4}{W_3 - W_s} = \frac{W_4}{W_3 - (W_1 - W_2)}$$

(2) Apparent specific gravity

$$= \frac{dry\ weight\ of\ aggregate}{(weight\ of\ equal\ volume of\ water\ excluding\ air\ voids in aggregate)}$$

$$= \frac{W_4}{W_4 - W_s} = \frac{W_4}{W_3 - (W_1 - W_2)}$$

(3) Water absorption = percent by weight of water absorbed in terms oven dried weight of aggregates.

$$= \frac{(W_3 - W_4)100}{W_4}\ percent$$

Discussion

The size of the aggregates and whether it has been artificially heated should be indicated. ISI specifies three methods of testing for the determination of the specific gravity and water absorption of aggregates, according to the size of aggregates. The three size ranges used are

i) aggregates larger than 10 mm (ii) between 10 mm and 40 mm, and (iii) smaller than 10 mm

The water absorption test does not always give reproducible results with aggregates of high porosity.

Application of Specific Gravity and Water Absorption Test

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average value of about 2.68. Though high specific gravity of an aggregate is considered as an indication of high strength, it is not possible to judge the suitability of a sample of road aggregate without finding the mechanical properties such as aggregate crushing, impact and abrasion values.

Water absorption of an aggregate is accepted as measure of its porosity. Some times this value is even considered as a measure of its resistance to frost action, though this has not yet been confirmed by adequate research.

Water absorption value ranges from 0.1 to about 2.0 percent for aggregate normally used in road surfacings. Stones with water absorption upon 4.0 percent have been used in base courses.' Generally a value of less than 0.6 percent is considered desirable for surface course though slightly higher values are allowed in bituminouous constructions. Indian Roads Congress has specified the maximum water absorption values as 10 percent for aggregates used in bituminous surface dressing and built-up spray grout.

REFERENCES

1. Indian Standard Methods of Test for Aggregate for Concrete, IS : 2386, Part III, *Indian Standards Institution*
2. Soil Mechanics for Road Engineers, *D.S.I.R.,* London.
3. Bituminous Materials in Road Construction, *D.S.I.R.,* H.M.S.O., London.
4. Tentative Specification for Bituminous Surface Dressing, (Single, Two-coats and Pre-coated types),
   IRC : 17, 23 & 48, *Indian Roads Congress.*
5. Tentative Specification for Built-up Spray Grout, IRC : 47, *Indian Roads Congress.*

PROBLEMS

1. Discuss the importance of specific gravity test on road aggregates ?
2. Define true and apparent specific gravity of aggregates ?
3. What is the significance of water absorption test on aggregates ?

OBSERVATION SHEET

DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION

(i) Size of the aggregates =

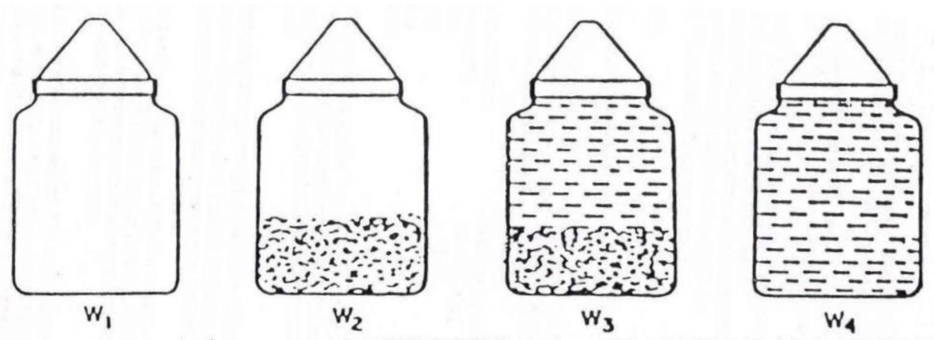
(ii) Aggregate Type =

	Details	*Test number*		
		1	*2*	*Mean value*
1.	Weight of saturated aggregate and basket in water = W_1 g			
2.	Weight of basket in water = W_2 g			
3.	Weight of saturated surface dry aggregates in air = W_3 g			
4.	Weight of oven dried aggregates in air = W_4 g			
5.	Specific gravity $= \dfrac{W_4}{W_3-(W_1-W_2)}$			
6.	Apparent specific gravity $= \dfrac{W_4}{W_4-(W_1-W_2)}$			
7.	Water absorption $= \dfrac{(W_3-W_4)100}{W_4}$ *percent*			

i) Mean value of specific gravity =
ii) Mean value of apparent specific gravity =
iii) Mean value of water absorption =

Report on quality of stone

Remarks:



AGGREGATE ABRASION VALUE TEST INTRODUCTION

Due to the movements of traffic, the road stones used in the surfacing course are subjected to wearing action at the top. Resistance to wear or hardness is hence an essential property for road aggregates, especially when used in wearing course. Thus road stones should be hard enough to resist the abrasion due to the traffic. When fast moving traffic fitted with pneumatic tyres move on the road, the soil particles present between the wheel and road surface causes abrasion on the road stone. Steel tyres of animal drawn vehicles which rub against the stones can cause considerable abrasion of the stones on the road surface. Hence in order to test the suitability of road stones to resist the abrading action due to traffic, tests are carried out in the laboratory.

Abrasion test on aggregates are generally carried out by any one of the following methods:

i) Los Angeles abrasion test
ii) Deval abrasion test
iii) Dorry abrasion test

Of these tests, the Los Angeles abrasion test is more commonly adopted as the test values of aggregates have been correlated with performance of studies. The ISI has suggested that wherever possible, Los Angeles abrasion test should be preferred.

In addition to the above abrasion tests, another test which is carried out to test the extent to which the aggregates in the wearing surface get polished under traffic,is "Polished Stone Value" test. Samples of aggregates are subjected to an accelerated polishing test in a machine and a friction test is carried out on the polished specimen. The results of this test are useful only for comparative purpose and specifications are not yet available.

4. LOS ANGELES ABRASION TEST

AIM: To determine Los Angeles' abrasion value of the aggregate.

THEORY

The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregates and steel balls used as abrasive charge; pounding action of these balls also exist while conducting the test. Some investigators believe this test to be more dependable as rubbing and pounding action simulate the field conditions where both abrasion and impact occur. Los Angeles abrasion test has been standardized by the ASTM, AASHO and also by the ISI. Standard specification of Los Angeles abrasion values are also available for various types of pavement constructions.

APPARATUS

The apparatus consists of Los Angeles machine and sieves.

Los Angeles machine consists of a hollow steel cylinder, closed at both ends, having an inside diameter 70 cm and an inside length of 50 cm, mounted on stub shafts about which it rotates on a horizontal axis. An opening is provided in the cylinder for the introduction of the test sample. A removable cover of the opening is provided in such a way that when closed and fixed by bolts and nut, it is dust-tight and the interior surface is perfectly cylindrical. A removable steel shelf projecting radially 8.8 cm into the cylinder and extending to the full length of it, is mounted onthe interior surface of the cylinder rigidly, parallel to the axis. The shelf is fixed at a distance of 125 cm from the opening, measured along the circumference in the direction of rotation Refer Figure 1. Abrasive charge, consisting of cast iron spheres approximately 4.8 cm in diameter and 390 to 445 g. in weight are used. The weight of the sphere used as the abrasive charge and the number of spheres to be used are specified depending on the gradation of the aggregates tested. The aggregate grading have been standardized as A,B,C,D,E,F, and G for this test and the IS specifications for the grading and abrasive charge to be used are given in Table 1. IS sieve with 1.70mm opening is used for separating the fines after the abrasion test.

PROCEDURE

Clean aggregates dried in an oven at 105-110° C to constant weight, conforming to any one of the grading A to G, as per Table 1 is used for the test. The grading or gradings used in the test should be nearest to the grading to be used in the construction. Aggregates weighing 5 Kg. for grading A,B,C or D and 10 Kg. for grading E,F or G may be taken as test specimen and placed in the cylinder. The abrasive charge is also chosen in accordance with Table 1 depending on the grading of theaggregate and is placed in the cylinder of the machine. The cover is then fixed dust-tight. The machine is rotated at a speed of 30 to 33 revolutions per minute. The machine is rotated for 500 revolution for gradings A,B,C and D, for gradings E,F and G, it shall be rotated for 1,000 revolutions. The machine should be balanced and driven in such a way as to maintain uniform peripheral speed.

After the desired number of revolutions, the machine is stopped and the material is discharged from the machine taking care to take out entire stone dust. Using a sieve of size larger than 1.70 mm IS sieve, the material is first separated into two parts and the finer position is taken out and sieved further on a 1.7 mm IS sieve. The portion of material coarser than 1.7 mm size is washed and dried in an oven at 105 to 110 degrees C to constant weight and weighed correct to one grain.

CALCULATIONS

The difference between the original and final weights of the sample is expressed as a percentage of the original weight of the sample is reported as the percentage wear.

TABLE 1

SPECIFICATIONS FOR LOS ANGELES TEST

Grading	*Weight in grams of each test sample in the size range, mm (Passing and retained on square holes)*										*Abrasive charge of*	
	80-63	63-50	50-40	40-25	25-20	20-12.5	12.5-10	10-6.3	6.3-4.75	4.75-2.36	*Number of spheres*	*Weight of charge, g*
A	-	-	-	1250	1250	1250	1250	-	-	-	12	5000+25
B	-	-	-	-	-	2500	2500	-	-	-	11	4584+25
C	-	-	-	-	-	-	-	2500	2500	-	8	3330+20
D	-	-	-	-	-	-	-	-	5000	-	6	2500+15
E	2500*	2500*	5000*	-	-	-	-	-	-	-	12	5000+25
F	-	-	5000*	5000*	-	-	-	-	-	-	12	5000+25
G	-	-	5000*	5000*	-	-	-	-	-	-	12	5000+25

*Tolerence of +2 percent is permitted.

Let the original weight of aggregate = W_1 g

Weight of aggregate retained on 1.70 mm IS sieve after the test = W_2 g

Loss in weight due to wear = (W_1-W_2)g

Los Angeles abrasion value, % = Percentage wear $= \frac{(W_1 - W_2)}{W_1} \times 100$

RESULT

The result of the Los Angeles abrasion test is expressed as a percentage wear and the average value of two tests may be adopted as the Los Angeles abrasion value.

DISCUSSION

It may seldom happen that the aggregates desired for a certain construction project has the same grading as any one of the specified gradings. In all the cases, standard grading or gradings nearest to the gradation of the selected aggregates may be chosen.

Different specification limits may be required for gradings E, F and G, when compared with A,B,C and D further investigations are necessary before any such specifications could be made.

Los Angeles abrasion test is very commonly used to evaluate the quality of aggregates for use in pavement construction, especially to decide the hardness of stones. The allowable limits of Los Angeles abrasion values have been specified by different agencies based on extensive performance studies in the field. The ISI has also suggested that this test should be preferred wherever possible. However, this test may be considered as one in which resistance to both abrasion and impact of aggregate may be obtained simultaneously, due to the presence of abrasive charge. Also the test condition is considered more representative of field conditions. The result obtained on stone aggregates are highly reproducible.

Application of Los Angeles Abrasion Test

Los Angeles Abrasion test is very widely accepted as a suitable test to assess the hardness of aggregates used in pavement construction. Many agencies have specified the desirable limits of the test, for different methods of pavement construction. The maximum allowable Los Angeles abrasion values of aggregates as specified by Indian Roads Congress for different methods of construction are given in Table 2.

TABLE 2

Maximum Allowable Los Angeles Abrasion Values of Aggregate in different Types of Pavement Layers.

Sl.No.	*Types of pavement material/layer*	*Aggregate impact Value, maximum, %*
1.	Water bound macadam (WBM), sub-based course	60
2.	i) WBM base course with bitumen surfacing	50
	ii) Bituminous Macadam base course	
	iii) Built up-spray grout, base course	
3.	i) WBM, surfacing course	40
	ii) Bituminous Macadam binder course	
	iii) Bituminous penetration macadam	
	iv) Built-up spray grout binder course	
4.	i) Bituminous carpet surface course	35
	ii) Bituminous surface dressing, single or two coats	
	iii) Bituminous surface dressing, using precoated aggregates	
	iv) Cement concrete surface course (as per IRC)	
5.	i) Bituminous/Asphaltic concrete surface course	30
	ii) Cement concrete pavement surface course (as per ISI)	

OBSERVATION SHEET

GRADE OF THE MATERIAL :

NUMBER OF SPHERESUSED:

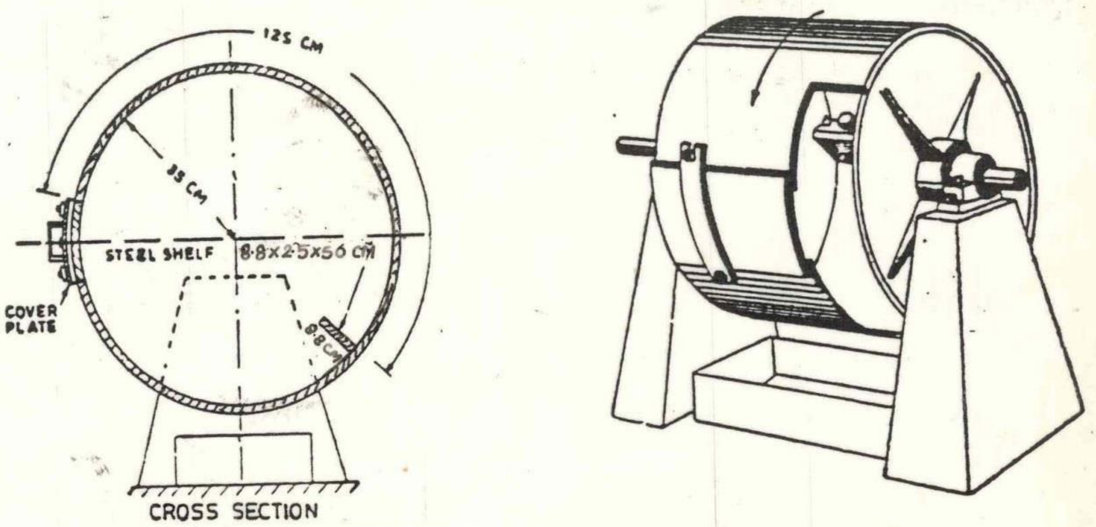
WEIGHT OF CHARGE:

SIZE OF THE AGGREGATE :

NUMBER OF REVOLUTIONS:

SPEED OF ROTATION:

Sample No.				
Total weight of dry sample (W_1gms)				
Weight of fines passing 1.7 mm IS sieve W_2gms				
Los Angele's Abrasion Value (W_2/W_1)x100				
Los Angele's Abrasion Value %				



Los Angeles Machine

-=o0o=-

5. DEVAL’S ATTRITION TEST

AIM : To determine Deval's attrition value of the aggregate.

THEORY

Deval's abrasion test was devised to test rock fragments.Later this test has been standardized by ASTM for finding the rate of wear of stone aggregates by crushing them to tumble one over other in a rattler in presence of abrasive charge. Deval abrasion test has also been standardized by ISI as a test for abrasion of coarse aggregates. In this test also both abrasion and impact take place due to the steel balls used as abrasive charge.

APPARATUS

The apparatus for the test consists of the Deval machine and standard sieve.

The deval abrasion testing machine consists of one or more (generally two) hollow cast iron cylinders closed at one end and provided with iron cover at the other end, capable of fitting tightly. The inside diameter of the cylinder is 20 cm and length is 34 cm. The cylinders are mounted on a shaft at an angle of 30 degrees with the axis of rotation. See fig.4.2. Cast iron or steel spheres of about 4.8 cm diameter and 390 to 445 g weight are used as abrasive charge. Six such spheres are used as abrasive charge, their total weight being 2500 ± 10 g.

IS sieve having 1.70mm square holes are used for sieving the materials after the abrasion test.

PROCEDURE

The test sample consists of dry coarse aggregates made of different percentages of the various sizes conforming to any one of the gradings given in Table 3. The material, is washed dried and separated to different sizes by sieving. The grading adopted for the test should be the one which most nearly represents the coarse aggregate to be used for a particular construction project. Crushed gravel conforming to the above specifications can also be used.

The sample and the abrasive charge of 6 spheres of total weight 2,500+ 10 grams are placed in the Deval abrasion testing machine and the cover is tightly fixed. The machine is rotated at a speed of 30 to 33 rpm for 10,000 revolutions. At the completion of the above number revolutions, the material is removed from the machine and is sieved on a 1.70 mm IS sieve. The material retained on the sieve is washed, dried and weighted to the nearest gram. In Deval's attrition test, the test is performed without using abrasive charge.

TABLE 3

Grading	*Grading of Aggregate for Deval Abrasion Test*		
	Passing IS sieve, mm	Retained on IS sieve mm	Percentage of sample
A	20	12.5	25
	25	20.0	25
	40	25.0	25
	50	40.0	25
B	20	12.5	25
	25	20.0	25
	40	25.0	50
C	20	12.5	50
	25	20.0	50
D	12.5	0.475	50
	20	12.50	50
E	10	04.75	50
	12.5	10.00	50

The weight of the sample to be taken for the test depends on its average specific gravity and is given in Table 4.

Table 4 Weight of Sample for Deval Abrasion Test

Range of specific gravity	Weight of sample, g
Over 2.8	5,500
*2.4 to 2.8	5,000
2.2 to 2.39	4,500
Less than 2.2	4,000

*Most commonly found.

CALCULATIONS

i) The loss in weight by abrasion is the difference between the original weight of the test sample and the weight of material retained on the 1.70 mm IS sieve after the test. The percentage of wear in the loss in weight by abrasion expressed as a percentage of the original weight of the sample.

Let the original weight of the sample be = W_1 g

Weight of material retained on 1.70mm IS sieveafter the abrasion test= W_2g

Therefore, percentage wear or

$$\text{Deval abrasion value, \%} = \left(\frac{W_1 - W_2}{W_1} \right) \times 100$$

ii) In the case of crushed gravel (i.e. fragment of gravel having atleast one fractured face) the percentage by weight of crushed fragments should be determined and the permissible percentage wear is calculated as given below.

$$W = \frac{AL + (100 - A)L'}{100}$$

Where

W = permissible percentage of wear

A = percentage of uncrushed fragments

L = maximum percentage of wear permitted by the specifications for aggregates consisting entirely of crushed fragments.

(100-A) = percentage of crushed fragments.

andL' = maximum percentage of wear permitted by the specifications of gravelconsisting entirely of crushed fragments.

RESULTS

Duplicate test may be carried out simultaneously by placing similar specimens in the second cylinder and the average values of the two tests may be calculated. The report includes (a) percentage of wear, (b) percentage of crushed fragments in the test sample and (c) weight and grading of the test sample.

DISCUSSION

When coarse aggregates furnished for the work contains as much as 25 percent of material finer than 12.5mm but is of such size that either grading A, B or C would be used for the abrasion test, a second abrasion test should be carried out using grading D, if in the opinion of the engineer, the particles lesser than 12.5mm size are not atleast equal in hardness to those particles greater than 12.5mm size.

The British attrition test using Deval's machine is similar to the rattler type of test explained in this experiment with an exception that no abrasive charge is used. Deval abrasion test is in fact a modified Deval's attrition test, using abrasive charge. The attrition test which was formerly standardized by BSI has been omitted, later on as of doubtful value.

Applications of Deval Abrasion Test

It has been recommended by the ISI that wherever possible the Los Angeles abrasion test should be preferred to the Deval abrasion test. The desirable limits of percentage wear by the Deval abrasion test have not been specified by agencies, as this is not a common test. Thus the test has limited uses and applications.

OBSERVATION SHEET

GRADE OF THE MATERIAL

NUMBER OF SPHERES USED

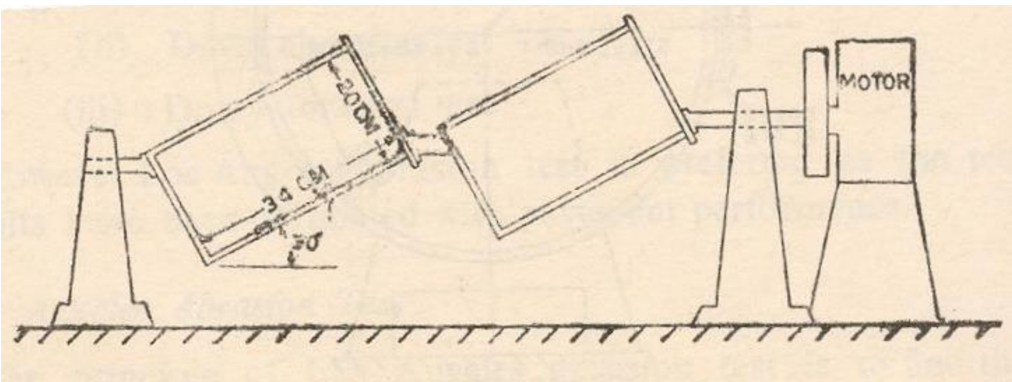
WEIGHT OF CHARGE

SIZE OF THE AGGREGATE

NUMBER OF REVOLUTIONS

SPEED OF ROTATION

Sample No.				
Total weight of dry sample W_1gms				
Weight of fines passing 1.7 mm IS Sieve W_2gms				
Deval’s Attrition value (W_2/W_1)x100				
Deval’s Attrition value percentage				



Deval Abrasion Testing Machine

6. SHAPE TEST

INTRODUCTION

The particle shape of aggregates is determined by the percentage of flaky and elongated particles contained in it. In the case of gravel it is determined by its angularity number. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles are considered undesirable as they may cause inherent weakness with possibilities of breaking down under heavy loads. Rounded aggregates are preferred in cement concrete road construction as the workability of concrete improves. Angular shape of particles are desirable for granular base course due to increased stability derived from the better interlocking. When the shape of aggregates deviates more from the spherical shape, as in the case of angular, flaky and elongated aggregate, the void content in an aggregate of any specified size increases and hence the grain size distribution of a graded aggregate has to be suitably altered in order to obtain minimum voids in the dry mix or the highest dry density. The angularity number denotes the void content of single sized aggregates in excess of that obtained with spherical aggregates of the same size. Thus angularity number has considerable importance in the gradation requirements of various types of mixes such as bituminous concrete and soil-aggregate mixes.

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

FLAKINESS INDEX

AIM : To determine Flakiness index of the given aggregate.

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

APPARATUS

The apparatus consists of a standard thickness gauge shown in Fig. 1, IS sieves of sizes 63, 50,40,31.5, 25,20,16,12.5, 10 and 6.3mm and a balance to weigh the samples.

PROCEDURE

The sample is sieved with the sieves mentioned in Table 1 A minimum of 200 pieces of each fraction to be tested are taken and weighed=W_1 g. In order to separate flaky materials, each fraction is then gauged for thickness on a thickness gauge shown in Fig.1 or in bulk on sieves having elongated slots. The width of the slot used should be of the dimensions specified in column (3) of Table 1 for the appropriate size of material. The amount of flaky material passing the gauge is weighed to an accuracy of at least 0.1 percent of the test sample.

TABLE 1

Dimensions of Thickness and Length Gauges

Size of aggregate		*(a) Thickness gauge (0.6 times the mean sieve) mm*	*(b) Length gauge (1.8 times the mean sieve), mm*
Passing through IS sieve mm	*Retained on IS sieve, mm*		
(1)	(2)	(3)	(4)
63.0	50.0	33.90	-
50.0	40.0	27.00	81.0
40.0	25.0	19.50	58.5
31.5	25.0	16.95	-
25.0	20.0	13.50	40.5
20.0	16.0	10.80	32.4
16.0	12.5	08.55	25.6
12.5	10.0	06.75	20.2
10.0	06.3	04.89	14.70

Calculation and Result

In order to calculate the flakiness index of the entire sample of aggregates first the weight of each fraction of aggregate passing and retained on the specified set of sieves is noted. As an example let 200 pieces of the aggregate passing 50mm sieve and retained on 40mm sieve be = W1 g. Each of the particle from this fraction of aggregate is tried to be passed through the slot of the specified thickness of the thickness gauge; in this example the width of the appropriate gauge of the thickness gauge is

$$= \frac{(50+40)}{2} \times 0.6 = 27.0\, mm\ gauge$$

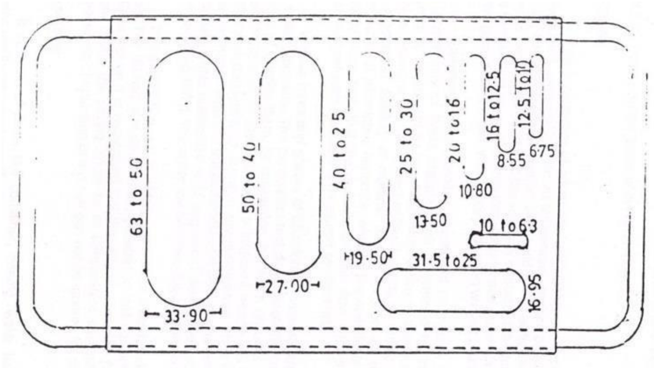
Let the weight of the flaky material passing this gauge be W_1 g. Similarly the weights ofthe fractions passing and retained the specified sieves, W_{1f} W_2 W_3 etc. are weighted and the totalweight $W_1+W_2+W_3+ \ldots = W$ g is found. Also the weights of material passing each of the specifiedthickness gauge are found = w_1, w_2, w_3 and the total weight of material passing the differentthickness gauges = w1+w2+w3+. and the total weight of material passing the different thickness gauges = $w_1+w_2+w_3+ \ldots = w$ g is found. Then the flakiness index is the total weight of the flakymaterial passing the various thickness gauges expressed as a percentage of the total weight of the sample gauged.

$$\text{Flakiness Index} = \frac{(w_1 + w_2 + w_3 + ..)}{(W_1 + W_2 + W_3 + ...)} \times 100$$

OBSERVATION SHEET

Size of aggregate		*Wt. of aggregate in each fraction passing thickness gauge gms*	*Wt. of the aggregate consisting of atleast 200 pieces gms.*
Passing through IS sieve mm	*Retained on IS sieve, mm*		
(1)	(2)	(3)	(4)

Flakiness index of the given aggregate.



THICKNESS GAUGE

ELONGATION INDEX

AIM : To determine Elongation Index of the aggregate.

DEFINITION: The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four fifth times (1.8times) their mean dimension. The elongation test is not applicable to sizes smaller than 6.3 mm.

APPARATUS

The apparatus consists of the length gauge shown in Figure 2, sieves of the sizes specified in Table 1 and a balance.

PROCEDURE

The sample is sieved through the IS sieves as specified Table 1. A minimum of 200 pieces of each fraction is taken and weighed. In order to separate elongated material, each fraction is then gauged individually for length gauge (See Figure 2). The gauge length used should be those specified in column 4 of the Table for the appropriate material. The pieces of aggregates from each fraction tested which could not pass through the specified gauge length with its long side are elongated particles and are collected separately to find the total weight of aggregate retained by the length gauge are weighed to an accuracy of atleast 0.1 percent of the weight of the test sample.

Calculation and Result

In order to calculate the elongation index of the entire sample of aggregates, the weight of aggregates which is retained on the specified gauge length from each fraction is noted. As an example, let 200 pieces of the aggregate passing 40 mm sieve and retained 25 mm sieve weight VV, g. Each piece of these are tried to be passed through the specified gauge length of lengthgauge, which in this example is

$$= \frac{(40+25)}{2} \times 1.8 = 59.5\,\boldsymbol{mm}$$

with its longest side and those elongated pieces which do not pass the gauge are separated and thetotal weight determined = W-, g. Similarly the weight of each fraction of aggregate passing andretained on specified sieves sizes are found, W_1, W_2, W_3... and the total weight of sampledetermined = $W_1+W_2+W3+...$ =Wg. Also the weight of material from each fraction retained on thespecified gauge length are found = X_1, X_2,X_3..and the total weight retained determined=$X_1+X_2+X_3+..$ =Xg.

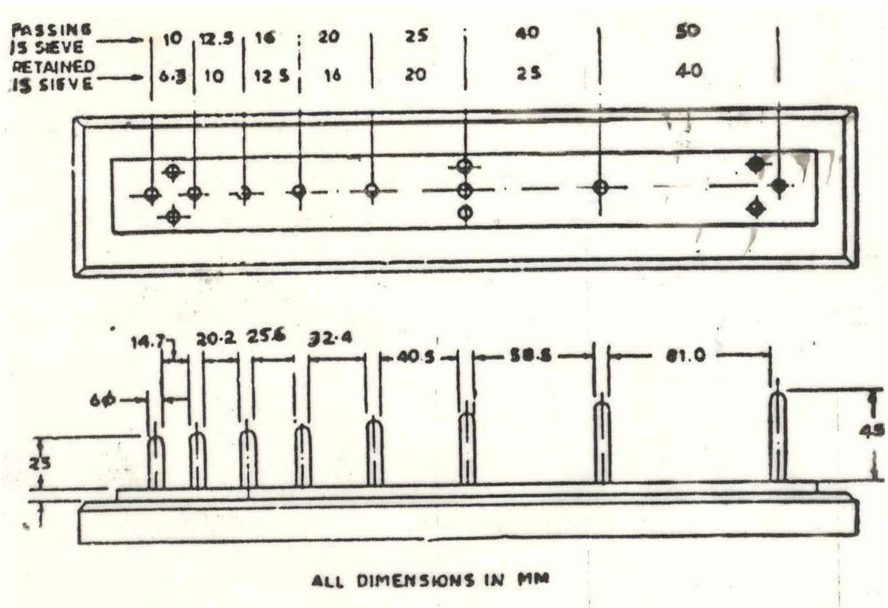
The elongation index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

$$\text{Elongation} = \frac{(X_1 + X_2 + X_3)100}{W_1 + W_2 + W_3 + ...} = 100\frac{X}{W}\ percent$$

OBSERVATION SHEET

Size of aggregate		*Wt. of aggregate in each fraction passing thickness gauge gms*	*Wt. of the aggregate consisting of atleast 200 pieces gms.*
Passing through IS sieve mm	*Retained on IS sieve, mm*		
(1)	(2)	(3)	(4)

Elongation index of the given aggregate.



Length Gauge

ANGULARITY NUMBER

Based on the shape of the aggregate particle, stones may be classified as rounded, angular and flaky Angular particles possess well defined edges formed at the intersection of roughly plane faces and are commonly found in aggregates prepared by crushing of rocks. Sinceweaker aggregates may be crushed during compaction, the angularity number does not apply to any aggregate which breaks down during compaction.

Angularity or absence of the rounding of the particles of an aggregate is a property which is of importance because it affects the ease of handling a mixture of aggregate and binder or the workability of the mix. The determination of angularity number of an aggregate is essentially a laboratory method intended for comparing the properties of different aggregates for mix design purposes and for deciding their gradation requirements.

The degree of packing of particles of single sized aggregate depends on the shape and angularity of the aggregates. If a number of single size spherical particles are packed together in the densest form, the total volume of solids will be 67 percent and the volume of voids 33 percent of the total volume. However if the shape of the particles of the same size deviates from the spherical shape to irregular or angular shape, when they are densely packed the volume of solids decreases resulting in an increase in the volume of voids. Hence, the angularity of the aggregate can be estimated from the properties of voids in a sample of aggregates compacted in a particular manner. The angularity number of an aggregate is the amount by which the percentage voids exceeds 33 after being compacted in a prescribed manner. The angularity number is found from the expression, (67 minus the percent solid volume). Here the value 67 represents the percentage volume of solids of most rounded gravel which would have 33 percent voids.

APPARATUS

The apparatus consists of

(a) a metal cylinder closed at one end and of about 3 litre capacity, the diameter and height of this being approximately equal, i.e. about 15.64 cm dia. x 15.64 cm height.

b) A metal tamping rod of circular cross section, 16mm in diameter and 60 cm in length, rounded at one end.
c) A metal scopp of about one liter heaped capacity of size 20x10x5 cm. and
d) A balance of capacity 10 Kg. weigh up to 1.0 g.

PROCEDURE

The cylinder is calibrated by determining the weight of ater at 27 degrees C required to fill it, so that no meniscus is present above the rim of the container. The amount of aggregate available should be sufficient to provide, after separation on the appropriate pair of sieves, atleast 10 Kg. of the predominent size, as determined by the sieve analysis on the 20, 16, 12.5, 10, 6.3 and 4.75mm IS sieves. The test sample should consist of aggregate retained between the appropriate pair of IS sieves having square holes from the following sets:

20 and 16 mm, 16 and 12.5mm, 12.5 and 10mm, 10 and 6.3 mm, 6.3 and 4.75mm

In case aggregate larger than 20 mm sieve is used for the test the volume of the cylinder should be greater than 3 litres, but when aggregates smaller than 4.75mm size are used, a smaller cylinder may be used. The procedure of the test is the same for each of these except that the amount of compactive effort given by: (weight of the tamping rod x height of fall x number of bios) should be proportional to the volume of the cylinder.

The sample of single-size aggregate retained between the specified pair of sieves is dried in an oven at a temperature 100 degrees C for 24 hours and cooled in an air tight containerprior to testing. The scoop is filled and heapted to overflowing with the aggregate, which is placed in the cylinder by allowing it to slide gently off the scoop from the lowest possible weight. The aggregates in the cylinder are subjected to 100 blows of the tamping rod at a rate of about 2 blows per second. Each blow is applied by holding the rod vertically with its rounded end 5 cm above the surface of the aggregate and releasing it so that it falls vertically and no force is applied to the rod. The 100 blows should be distributed evenly over the surface to the aggregates.

The process of filling and tamping is repeated exactly as described above with a second and third layer of aggregates. The third layer should contain only the aggregate required to just fill up the cylinder level before tamping. After the third layer is tamped, the cylinder is filled to over flowing, and the aggregates are struck off level with the top using tamping rod as a straight edge.

Individual pieces of aggregates are then added and rolled in to the surface by rolling the tamping rod across the upper edge of the cylinder, and this finishing process is continued as long as the aggregate do not lift the rod off the edge of the cylinder on either side, during rolling. The aggregate should not be pushed in or forced down and no downward pressure should be applied to the tamping rod, which is only rolled in contact with the top of the cylinder on both sides.

The aggregate with cylinder is then weighed to the nearest 5 g. The separate determinations are made and the mean weight of the aggregate in the cylinder is calculated. If the result of any one of the determination differs from the mean by more than 25 g, there additional determinations are immediately made on the same material and the mean of all the six determinations is calculated.

Calculation and Results

The angularity number is calculated from the formula:

Angularity number = 67-100 W/CG

Where W = mean weight of aggregates in the cylinder.g

C = Weight of water required to fill the cylinder.g

G = Specific gravity of aggregate

The angularity number is expressed to the nearest whole number.

DISCUSSION

The shape tests give only a rough idea of the relative shape of the aggregates. Particular care has to be taken while carrying out the test for angularity number.

Applications of Shape Tests

The pavement construction flaky and elongated particles are to be avoided, particularly in surface course. If flaky and elongated aggregates are present in appreciable proportions, the strength of the pavement layer would be adversely affected due to possibility of breaking down under loads. In cement concrete the workability is also reduced. However, the reduction in strength in cement concrete depends on the cement content and water-cement ratio.

Indian Raods Congress has recommended the maximum allowable limits of flakiness index values for various types of construction, as given in Table 2

TABLE 2.

Maximum Allowable Flakiness Index of Aggregates in Different Types of Pavement Construction.

Sl.No.	*Types of pavement construction*	*Maximum limits of Flakiness Index %*
1.	Bituminous Carpet	30
2.	i) Bituminous / Asphaltic concrete	
	ii) Bituminous penetration macadam	
	iii) Bituminous surface dressing (single coat, and precoated)	
	iv) Built-up spray grout	25
3.	i) Bituminous macadam	
	ii) Water bound macadam, base and surfacing courses	15

Though elongated shape of the aggregates also affects the compaction and the construction of pavements, there are no specified limits of elongation index values as in the case of flakiness index for different methods of pavement construction.

The angularity number measures the percent voids in excess of 33 percent which is obtained in the case of the most rounded gravel particles. The angularity number of aggregates generally ranges from zero for highly rounded gravel to about 11 for freshly crushed angular aggregates. Slightly higher values of angularity number also may be obtained in the case of highly angular and flaky Aggregates. Thus higher the angularity number more angular and less workable is the aggregate mix. In cement concrete mix, rounded aggregates may be preferred because of better workability, lesser specific surface and higher strength for a particular cement content. But in flexible pavement construction methods using hard aggregates such as the bituminous construction methods, water bound macadam, etc. angular aggregates are preferred because of higher stability due to better interlocking and friction. However in dense bituminous mixes such as the bituminous concrete, the gradation requirement may have to be suitably modified during mix design in the case of aggregates with high angularity number so as to obtain well designed mix.

QUESTIONS:

1) What is the significance of the shape tests ?
2) Why flaky or elongated particles are avoided in pavement construction ?
3) What are the applications of shape tests ?
4) Define flakiness index ?
5) Define elongation index ?

7. PENETRATION TEST

AIM: To determine the grade of the given bitumen.

THEORY

The consistency of bituminous materials vary depending upon several factors such as constituents, temperature, etc. At temperature ranges between 25 and 50° C most of the paving bitumen grades remain in semi-solid or in plastic states and their viscosity is so high that they do not flow as liquid. But the viscosity of most of the tars and cutbacks are sufficiently low at this temperature range to permit these bituminous materials to be in a liquid state, enabling some of the grades to be mixed with aggregates even without heating.

Determination of absolute viscosity of bituminous materials is not so simple. Therefore the consistency of these materials are determined by indirect methods; the consistency of bitumen is determined by penetration test which is a very simple test; the viscosity of tars and cutback bitumens are determined indirectly using an orifice viscometer in terms of time required for a specified quantity of material to flow through an orifice. There is a certain range of consistency of bituminous materials, wherein the material is too soft for penetration test, but the viscosity is so high that the material can not flow through the orifice of the viscometer; the consistency of such materials is measured by 'float test'.

Various types and grades of bituminous materials are available depending on their origin and refining process. The penetration test determines the consistency of these materials for the purpose of grading them, by measuring the depth (in units of one tenth of a millimeter or one hundredth of a centimeter) to which a standard needle will penetrate vertically under specified conditions of standard load, duration and temperature. Thus the basic principle of the penetration test is the measurement of the penetration (in units of one tenth of a mm) of a standard needle in a bitumen sample maintained at 25° C during five seconds, the total weight of the needle assemblybeing 100 g. The softer the bitumen, the greater will be the penetration.

The penetration test is widely used world over for classifying the bitumen into different grades. The ISI has standardized the penetration test equipment and the test procedure, Figure 1. Even though it is recognised that the empirical test like penetration, softening point etc. can not fully qualify the paving binder for its temperature susceptibility characteristics, the simplicity and quickness of operation of this test can not be ignored for common use.

APPARATUS

It consists of items like container, needle, water bath penetrometer, stop watch etc. Following are the standard specifications as per ISI for the above apparatus.

a) Container. A flat bottomed cylindrical metallic container 55 mm in diameter and 35 mm or 57 mm in height.
b) Needle: A straight, highly polished cylindrical hard steel needle with conical end, having the shape and dimensions as given in Figure 2. The needle is provided with a shank approximately 3.0 mm in diameter into which it is immovably fixed.
c) Water-bath: A water bath is maintained at 25 + 1° C confining not less than 10 litres of water, the sample is immersed to depth not less than 100 mm from the top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.
d) Penetrometer: It is an apparatus which allows the needle assembly of gross weight 100 g to penetrate without appreciable friction for the desired duration of time. The dial is accurately calibrated to give penetration value in units of one tenth of a mm. Electrically operated automatic

penetrometers are also available. Typical sketch of penetrometer is shown in Figure 3.

e) Transfer tray: A small tray which can keep the container fully immersed in water during the test.

PROCEDURE

The bitumen is softened to a pouring consistency between 75° and 100° C above the approximate temperature at which bitumen softens. The sample material is thoroughly stirred to make it homogenous and free from air bubbles and water. The sample material is then poured into the container to a depth at least 15 mm more than the expected penetration. The sample containers are cooled in atmosphere of temperature not lower than 13° C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25° C for a period of one hour.

The sample container is placed in the transfer tray with water from the water bath and placed under the needle of the penetrometer. The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g. Using the adjusting screw, the needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample; the needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle. The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is taken before releasing the needle. The needle is released exactly for a period of 5.0 sees by pressing the knob and the final reading is taken on the dial. At least three measurements are made on this sample by testing at distance of not less than 100mm apart. After each test the needle is disengaged and cleaned with benzene and carefully dried. The sample container is also transferred in the water bath before next testing done so as to maintain a constant temperature of 25° C. The test is repeated with sample in the other containers.

RESULTS

The difference between the initial and final penetration readings is taken as the penetration value. The mean value of three consistent penetration measurements is reported as the penetration value. It is further specified by ISI that results of each measurement should not vary from the mean value reported above by more than the following:

Penetration grade	*Repeatability*
0-80	4 percent
80-225	5 percent
Above 225	7 percent

DISCUSSION

It may be noted that the penetration value is influenced by any inaccuracy as regards: i) pouring temperature ii) size of needle iii) weight placed on the needle iv) test temperature v) duration of releasing the penetration needle

It is obvious to obtain high values of penetration if the test temperature and/or weight (place over the needle) are/is increased. Higher pouring temperature than that specified may result in hardening of bitumen and may give lower penetration values. Higher test temperaturesgive considerably higher penetration values. The duration of releasing the penetration needle be exactly 5.0 secs. It is also necessary to keep the needle clean before testing in order to get consistent results. The penetration needle should not be placed closer than 10mm from the side of the dish.

Applications of Penetration Test:

Penetration test is the most commonly adopted test on bitumen to grade the material in terms of its hardness. Depending upon the climatic condition and type of construction, bitumen of different penetration grades are used, 80/100 bitumen denotes that the penetration value ranges between 80 and 100. The penetration values of various types of bitumen used in pavement construction in this country range between 20 and 225. For bituminous macadam and penetration macadam Indian Roads Congress suggests bitumen grades 30/40, 60/70 and 80/100. In warmer regions lower penetration grades are preferred and in colder regions bitumen with higher penetration values are used.

The penetration test is not intended to estimate the consistency of softer materials like cutback or tar, which are usually graded by a viscosity test in an orifice viscometer.

The Indian Standards Institution has classified paving bitumen available in this country into the following six categories depending on the penetration values. Grades designated 'A' (such as A 35) are from Assam Petroleum and those designated 'S' (such as S 35) are from other sources.

Bitumen grade	A25	A35 & S35	A45 & S45	A65 & S65	A90 & S90	A200 & S200
Penetration value	20 to 30	30 to 40	40 to 50	60 to 70	80-100	175-225

OBSERVATION SHEET

POURING TEMPERATURE:

PERIOD OF COOLING IN ATMOSPHERE:

PERIOD OF COOLING IN WATER BATH :

ROOM TEMPERATURE :

DURATION OF RELEASING THE PENETRATION NEEDLE:

TEST TEMPERATURE:

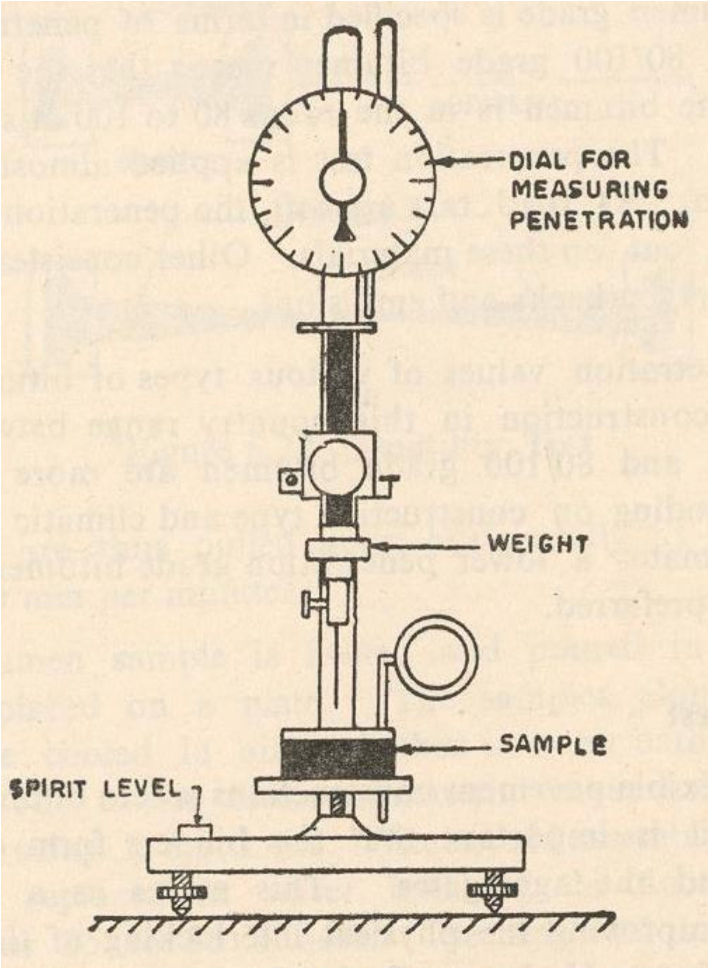
Penetrometer dial reading

	Test 1	*Test 2*	*Test 3*	
Initial				
Final				

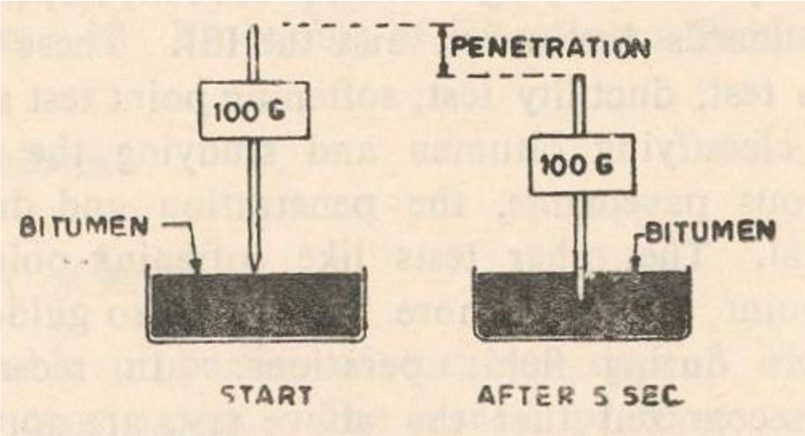
Grade of the Bitumen:

QUESTIONS

1) Define penetration value of the bitumen?
2) How the value of penetration is expressed?
3) What do you understand by 80/100 bitumen?
4) Among 30/40 and 80/100 grades which is harder bitumen?
5) What is the effect of higher test temperature?
6) What is the effect of higher pouring temperature?
7) What is the effect of duration of releasing the penetration needle?
8) How does the size of the needle affect the penetration value of the bitumen?
9) What is the standard load and time specified for penetration test?



Penetrometer



Penetration Test Concept

-=o0o=-

8. DUCTILITY TEST

AIM: To determne ductility of the given bitumen.

THEORY

In the flexible pavement construction where bitumen binders are used, it is of significant importance that the binders form ductile thin films around the aggregates. This serves as a satisfactory binder in improving the physical interlocking of the aggregates. The binder material which does not possess sufficient ductility would crack and thus provide previous pavement surface. This in turn results in damaging effect to the pavement structure. It has been stated by some agencies that the penetration and ductility properties, go together; but depending upon the chemical composition and the type of crude source of the bitumen's, sometimes it has been observed that the above statement is incorrect. It may hence be mentioned that the bitumen may satisfy the penetration value, but may fail to satisfy the ductility requirements. Bitumen paving engineer would however want that both test requirements are satisfied in the field jobs. Penetration or ductility can not in any case replace each other. The ductility is expressed as the distance in centimeters to which a standard briquette of bitumen can be stretched before the thread breaks. The test is conducted at 27°±0.5° C and a rate of pull of 50+2.5 mm per minute. The test has been standardized by the ISI. The ductility test concept is shown in Figure1.

APPARATUS

The ductility test apparatus consists of items like sample (briquette) moulds water bath square-end trowel or putty knife sharpened on end and ductility machine. Standard specifications as per ISI being:

(a) Briquette mould: Mould is made of brass metal with shape and dimensions as indicated in Figure 2. Both ends called clips possess circular holes to grip the fixed and movableends of the testing machine. Side pieces when placed together form the briquette of the followingdimensions:

Length	…. 75 mm
Distance between clips	…. 30 mm
Width at mouth of clips	…. 20 mm
Cross section at minimum width	…. 10 mm x 10 mm

(b) Ductility machine: It is an equipment which functions as constant temperature waterbath and a pulling device at a pre-calibrated rate. The central rod of the machine is threaded andthrough a gear system provides movement to one end where the clip is fixed during initialplacement. The other clip end is hooked at the fixed end of the machine. Two dips are thus pulledapart horizontally at a uniform speed of 50+2.5 mm per minute. The machine may have provisionto fix two or more mould so as to test these specimens simultaneously.

PROCEDURE

The bitumen sample is melted to a temperature of 75°C to 100°C above the approximate softening point until it is fluid. It is strained through IS sieve 30, poured in the mould assembly and placed on a brass plate, after a solution of glycerin and dextrin is applied at all surfaces of the mould exposed to bitumen. Thirty to forty minutes after the sample is poured into the moulds, the plate assembly alongwith the sample is placed in water bath maintained at 27°C for 30 minutes. The sample and mould assembly are removed from water bath and excess bitumen is cut if by levelling the surface using hot knife. After trimming the specimen, the mould assembly containingsample is replaced in water bath maintained at 27°C for 85 to 95 minutes. The sides of the mould are now removed and the clips are carefully booked on the machine without causing any initial strain. Two or more specimens may be prepared in the moulds and clipped to the machine so as to conduct these tests simultaneously.

The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally. While the test is in operation, it is checked whether the sample is immersed in water at depth of at least 10 mm. The distance at which the bitumen thread of each specimen breaks, is recorded(in cm) to report as ductility value.

RESULTS

The distance stretched by the moving end of the specimen upto recorded as ductility value. It is recommended by ISI that test results should not differ from mean value by more than the following:

Repeatability	:	5 percent
Reproducibility	:	10 percent

DISCUSSION

The ductility value gets seriously affected if any of the following factors are varied:

(i) pouring temperature
(ii) dimensions of briquette
(iii) improper level of briquette placement
(iv) rate of pulling

Increase in minimum cross section of 10 sq mm and increase in test temperature would record increased ductility value.

Applications of Ductility Test

A certain minimum ductility is necessary for a bitumen binder. This is because of the temperature changes in the bituminous mixes and the repeated deformations that occur in flexible pavements due to the traffic loads. If the bitumen has low ductility value, the bituminous pavement may crack,especially in cold weather. The ductility values of bitumen vary from 5 to over 100. Several agencies have specified the minimum ductility values for various types of bituminous pavement. Often a minimum ductility value of 50 cm is specified for bituminous construction.

The minimum ductility values specified by the Indian Standards Institution for various grades of bitumen available in India are given below:

Source of paving bitumen and penetration grade	*Minimum ductility value, cm*
Assam petroleum A 25	5
A 35	10
A 45	12
A 65, A 90 & A 200	15
Bituminous from sources other than Assam Petroleum S 35	50
S 45, S 65 & S 90	75

OBSERVATION SHEET

POURING TEMPERATURE:

PERIOD OF COOLING IN ATMOSPHERE:

PERIOD OF COOLING IN WATER BATH BEFORE TRIMMING:

PERIOD OF COOLING IN WATER BATH AFTER TRIMMING:

ROOM TEMPERATURE:

RATE OF PULLING:

TEST TEMPERATURE:

DIMENSIONS OF BRIQUETTE:

i) LENGTH
ii) DISTANCE BETWEEN THE CLIPS
iii) WIDTH AT MOUTH OF CLIPS
iv) CROSS SECTION AT MINIMUM WIDTH

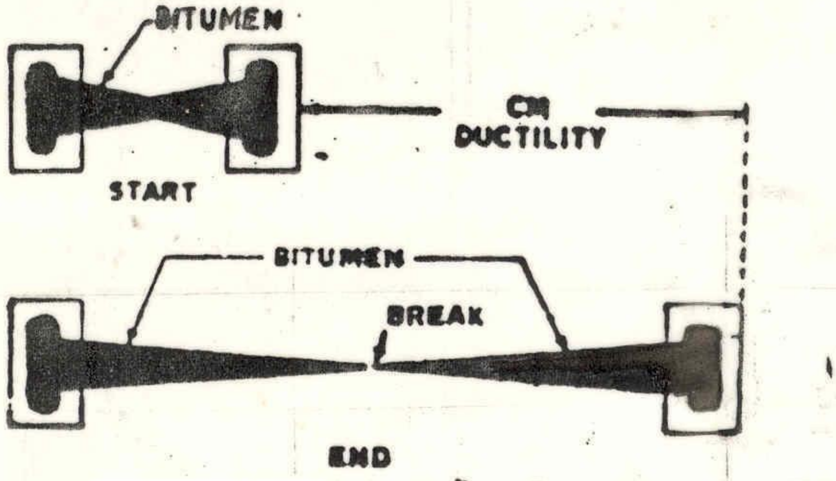
BRIQUETTE NUMBER	I	II	III	
INITIAL				
FINAL				
MEAN DUCTILITY VALUE				

QUESTIONS

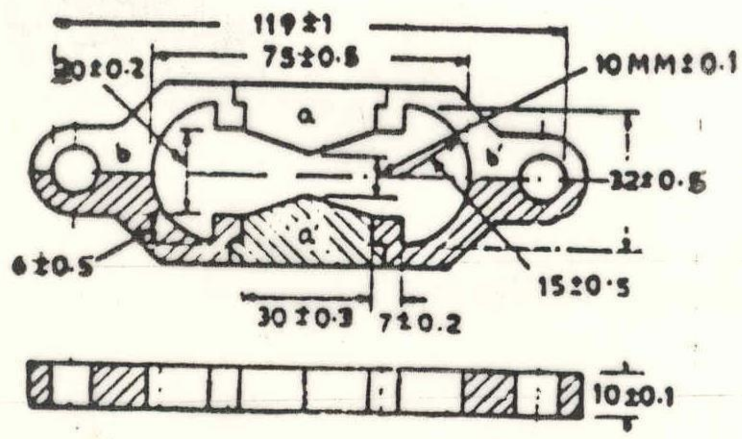
1) Define ductility value of the bitumen ?
2) How is ductility value expressed ?
3) What are the precautions to be taken while test is conducted?
4) what is the distance between clips of ductility mould ?
5) What is the length of the briquttemould ?
6) What is the effect of pouring temperature ?
7) What is the effect of improper level of briquette placement ?

8) What is the effect of rate of pulling on ductility value ?
9) What is the effect of dimensions of the briquette on ductility value ?

Length 75 MM
Distance between clips 30 MM
Width at mouth of clips 20 MM
Cross section at minimum width 10MM X 10MM



Ductility Test Concept



Briquette Mould

9. SOFTENING POINT TEST

AIM: To determine the softening point of the bitumen.

THEORY

Bitumen does not suddenly change from solid to liquid state, but as the temperature increases, it gradually becomes softer until it flows readily. All semi-solid state bitumen grades need sufficient fluidity before they are used for application with the aggregate mix. For this purpose bitumen is sometimes cut back with a solvent like kerosene. The common procedure however is to liquify the bitumen by heating. The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. For bitumen, it is usually determined by Ring and Ball test. A brass ring containing the test sample of bitumen is suspended in liquid like water or glycerine at a given temperature. A steel ball is placed upon the bitumen and liquid medium is then heated at a specified distance below the ring is recorded as the softening point of a particular bitumen. The apparatus and test procedure are standardized by ISI. It is obvious that harder grade bitumenposses higher softening point than softer grade bitumen. The concept of determining the softening point by ring and ball apparatus is shown in Figure 1.

APPARATUS

It consists of Ring and Ball apparatus.

a) Steel Balls:They are two in number. Each has a diameter of 9.5mm and weight 2.5+ .05 g.
b) Brass Rings: There are two rings of the following dimensions.

Depth	6.4 mm
Inside diameter at top	17.5 mm
Inside diameter at bottom	15.9mm
Outside diameter	20.6 mm

Brass rings are also placed with ball guides as shown in Fig.2

c) Support: The metallic support is used for placing pair of rings.
The upper surface of the rings is adjusted to be 50 mm below the surface of water or liquid contained in the bath. A distance of 25mm between the bottom of the rings and top surface of the bottom plate of support is provided. It has a housing for a suitable thermometer.

d) Bath and Stirrer A heat resistance glass container of 85mm diameter and 120mm depth is used. Bath liquid is water for material having softening point below 80°C and glycerine for materials having softening point above 80°C. Mechanical stirrer is used for ensuring uniform heat distribution at all times throughout the bath.

PROCEDURE

Sample material is heated to a temperature between 75 and 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on metal plate. To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerine and dextrine. After cooling the rings in air for 30 minutes, the excess bitumen istrimmed and rings are placed in the support as discussed in item (c) above. At this time the temperature of distilled water is kept at 5°C. This temperature is maintained for 15 minutes after which the balls are placed in position. The temperature of water is raised at uniform rate of 5°C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls. At least two observations are made. For material whose softening point is above 80°C, glycerine is used as a heating medium and the starting temperature is 35°C instead of5°C.

RESULTS

The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening value. The mean of duplicate determinations is noted. It is essential that the mean value of the softening point (temperature) does not differ from individual observations by more than the following limits.

Softening point	Repeatability	Reproducibility
Below 30°C	2°C	4°C
30°Cto80°C	1°C	2°C
Above 80°C	2°C	4°C

DISCUSSION

As in the other physical tests on bitumens, it is essential that the specifications discussed above are strictly observed. Particularly, any variation in the following point would affect the result considerably.

i) quality and type of liquid
ii) weight of balls
iii) distance between bottom of ring and bottom base plate
iv) rate of heating

Impurity in water or glycerine has been observed to affect the result considerably. It is logical to observe lower softening point if the weight of ball is excessive. On the other hand, increased distance between bottom of ring and bottom plate increases the softening point.

Applications of Softening Point Test

Softening point is essentially the temperature at which the bituminous binders have an equal viscosity. The softening point of tar is therefore related to the equiviscous temperature (e.v.t.) The softening point found by the ring and ball apparatus is approximately 20°C lower than the e.v.t.

Softening point, thus gives an idea of the temperature at which the bituminous material attains a certain viscosity. Bitumen with higher softening point may be preferred in warmer place. Softening point is also sometimes used to specify hard bitumen and pitches.

The ranges of softening point specified by the Indian Standards Institution for various grades of bitumen are given below:

Bitumen Grades	Softening point, °C
*A 25 & A 35	55 to 70
*S 35	50 to 65
A 45, S 45 & A 65	45 to 60
S 65	40 to 55
A 90 & S 90	35 to 50
A 200 & S 200	30 to 45

*'A' denotes bitumen from Assam Petroleum and "S" denotes bitumen from sources other than from Assam Petroleum. Also see Table under "Application of penetration test'.

OBSERVATION SHEET

POURING TEMPERATURE:

PERIOD OF COOLING IN ATMOSPHERE:

PERIOD OF COOLING IN WATER BATH :

ROOM TEMPERATURE :

RATE OF HEATING:

TEST TEMPERATURE:

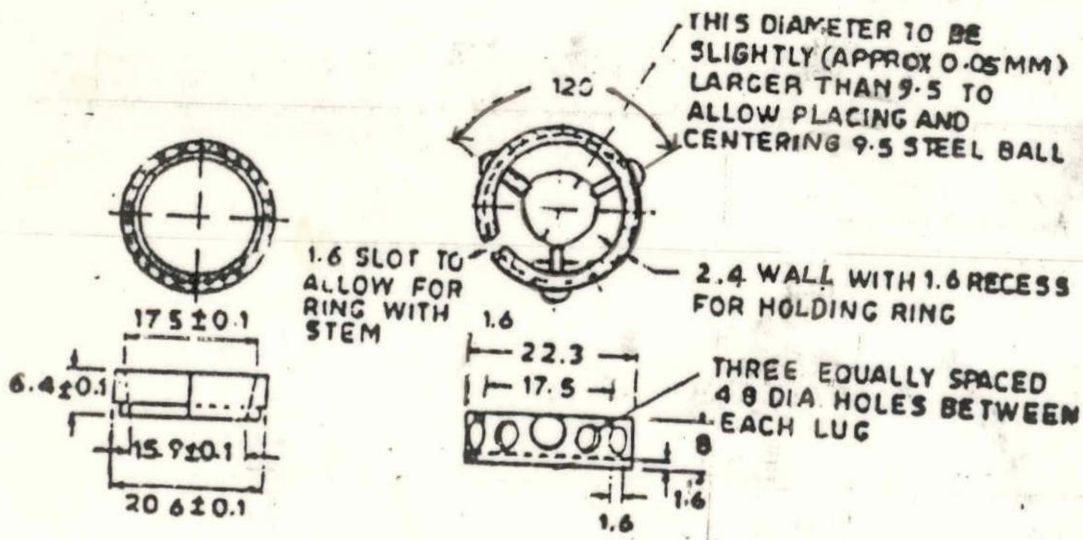
LIQUID USED IN WATER BATH: WATER / GLYCERINE

RATE OF HEATING

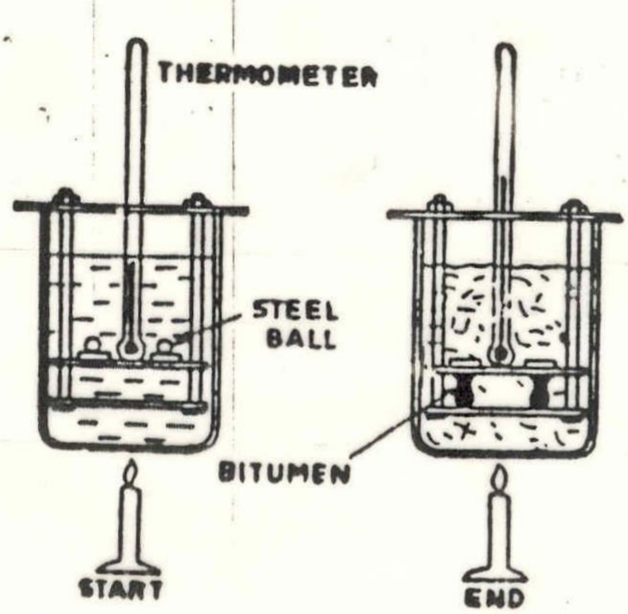
TIME IN MINUTES	TEMPERATURE ^{O}C	

QUESTIONS:

1) What is softening point?
2) What are the applications of softening point?
3) What is the rate of heating in softening point test?
4) When glycerin is used as liquidin Ring and Ball apparatus?
5) How does the weight of Ball affect the Softening point?



Ring and Ball Guides



Softening Point Test Concept

10. FLASH AND FIRE POINT TEST

AIM: To determine the flash point and fire point of the bitumen.

THEORY

Bituminous materials leave out volatiles at high temperatures depending upon their grade. These volatile vapours catch fire causing a flash. This condition is very hazardous and it is therefore essential to qualify this temperature for each bitumen grade, so that the paving engineers may restrict the mixing or application temperatures well within the limits. The flash point is the lowest temperature at which flash occurs due to the ignition of the volatile vapours when a small flame is brought in contact with the vapours of a bituminous product, gradually heated under standardised conditions. As mentioned above, this test gives an indication of the critical temperature at and above which suitable precautions should be taken to eliminate fire hazards during its application. When the bituminous material is further heated to a higher temperature, the material itself catches fire and continues to burn; the lowest temperature causing this condition is the fire point. The fire point is always higher than the flash point of a material. ISI vide specifications I.S.: 1209-1958 gives the following definitions.

Flash point (Fig.1)-The flash point of a material is the lowest temperature at which the vapour of substance momentarily takes fire in the form of a flash under specified condition of test".

Fire point -'The fire point is the lowest temperature at which the material gets ignited and burns under specified condition of test".

APPARATUS

(i) Pensky-Martens Closed Tester consists of cup, lid, stirring device, cover shutter, flame exposure device etc. See Fig.2 and 3.

(ii) Pensky-Marten open Tester as above with the modification, that the cover of the cup is replaced by a clip which encircles the upper rim of the cup and carries thermometer and test flame.

PROCEDURE

All parts of the cup are cleaned and dried thoroughly before the test is started. The material is filled in the cup upto a filling mark. The lid is placed to close the cup in a closed system. All accessories including thermometer of the specified range are suitably fixed. The bitumen sample is then heated. The test flame is lit and adjusted in such a way that the size of a beed is of 4mm diameter. The heating is done at the rate of 5° to 6°C per minute. The stirring is done at a rate of approximately 60 revolutions per minute. The test flame is applied at intervals depending upon the expected flash and fire points. First application is made atleast 17°C below the actual flash point and then at every 1 degree to 3°C. The stirring discontinued during the application of the test flame.

RESULTS

The flash point is taken as the temperature read on the thermometer at the time of the flame application that causes a bright flash in the interior of the cup in closed system. For open cup it is the instance when flash appears first at any point on the surface of the material. Theheating is continued until the volatile ignites and the material continues to burn for 5 seconds. The temperature of the sample material when this occurs is recorded as the fire point.

DISCUSSION

It is specified that in closed cup system, the test results should not differ from the mean by more than 3°C for materials flashing above 104°C and not more than 1°C from the mean for material flashing below 104°C. Sometimes bluish halo that surrounds the test flame is confused with true flash. For open cup system, it is specified by IS that the mean value should not differ from the individual values by more than 3°C for flash point, and by 6°C for fire point.

Applications of flash and fire point test:

Different bituminous materials have quite different values of flash and fire points. When the bitumen or cut back is to be heated before mixing or application, utmost care is taken to see that heating is limited to a temperature well below the flash point. This is essential from safety point of view.

The minimum value of Flash point by Pensky Marten's Closed type apparatus specified by the ISl is 175°C for all the grades of bitumen (for both Assam petroleum and those from other sources).

The minimum specified flash point for rapid curing cutback bitumen of all grades is 26°C and that for medium curing type is 38° for grades 0 and 1 and 65° for grades 2 to 5. Slow curing cutbacks have minimum values ranging from 65 to 121°C.

OBSERVATION SHEET

TYPE OF CUP:

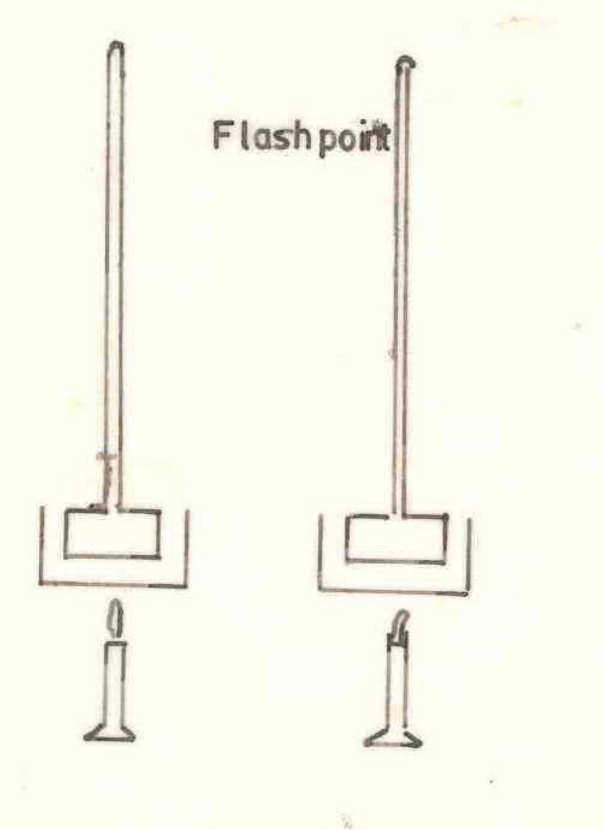
RATE OF HEATING:

TIME IN MINUTES	TEMPERATURE ^{O}C

FLASH POINT: FIRE POINT:

QUESTIONS:

1) Define flash point and fire point?
2) What are the applications of flash and fire point test?
3) Differentiate between flash point and fire point?
4) Briefly out line the test procedures of Flash point and Fire point.



Flash Point Test Concept

11. Normal Consistency of fineness of cement.

OBJECT: To determine standard consistency of cement paste.

THEORY: The object of conducting this test is to find out the amount of water to be added to the cement to get a paste of normal consistency, i.e. the paste of a certain standard solidity, which is used to fix the quantity of water to be mixed in cement before performing tests for tensile strength, setting time and soundness.

APPARATUS: The consistency of the paste is measured by the Vi-cat's apparatus, using a 10 mm diameter plunger fitted into the needle-holder;vicat mould, guaging trowel, measuring jar, Balance with weight-box, glass plates, stop watch, mixing tray, sample of cement.

PROCEDURE: The standard consistency of a cement paste (the amount of water expressed as percentage by weight of the dry cement) which permits the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the vicat mould when the cement paste is tested as described below:

1) Take 300gm of cement and prepare a paste of cement with a weighed quantity of water (100ml) taking care that the time of gauging is between 3 minutes to 5 minutes. The guaging time is counted from the time of adding water to the dry cement until commencing to fill the mould.
2) Fill the vicat mould testing upon non-porous plate with this paste. Water completely filling the mould, smooth off the surface of the paste by single movement of palm making it level with the top of the mould, the mould may be slightly shaken to expel air.
3) Place the mould with the non-porous resting plate under the rod attached with the plunger. Lower the plunger gently to touch the surface of the test block and quickly release, allowing it to sink into the paste. Note down the height not penetrated by plunger in vicat's mould.
4) Prepare the trial paste with varying percentages of water (firstly an interval of 4%, that is of 24%, 28% and 32% and then at an interval of 1% and 0.25% between the percentage range determined by the previous test) and test as described above until the amount of water necessary for making up the standard consistency as defined is found.

OBSERVATIONS AND CALCULATIONS

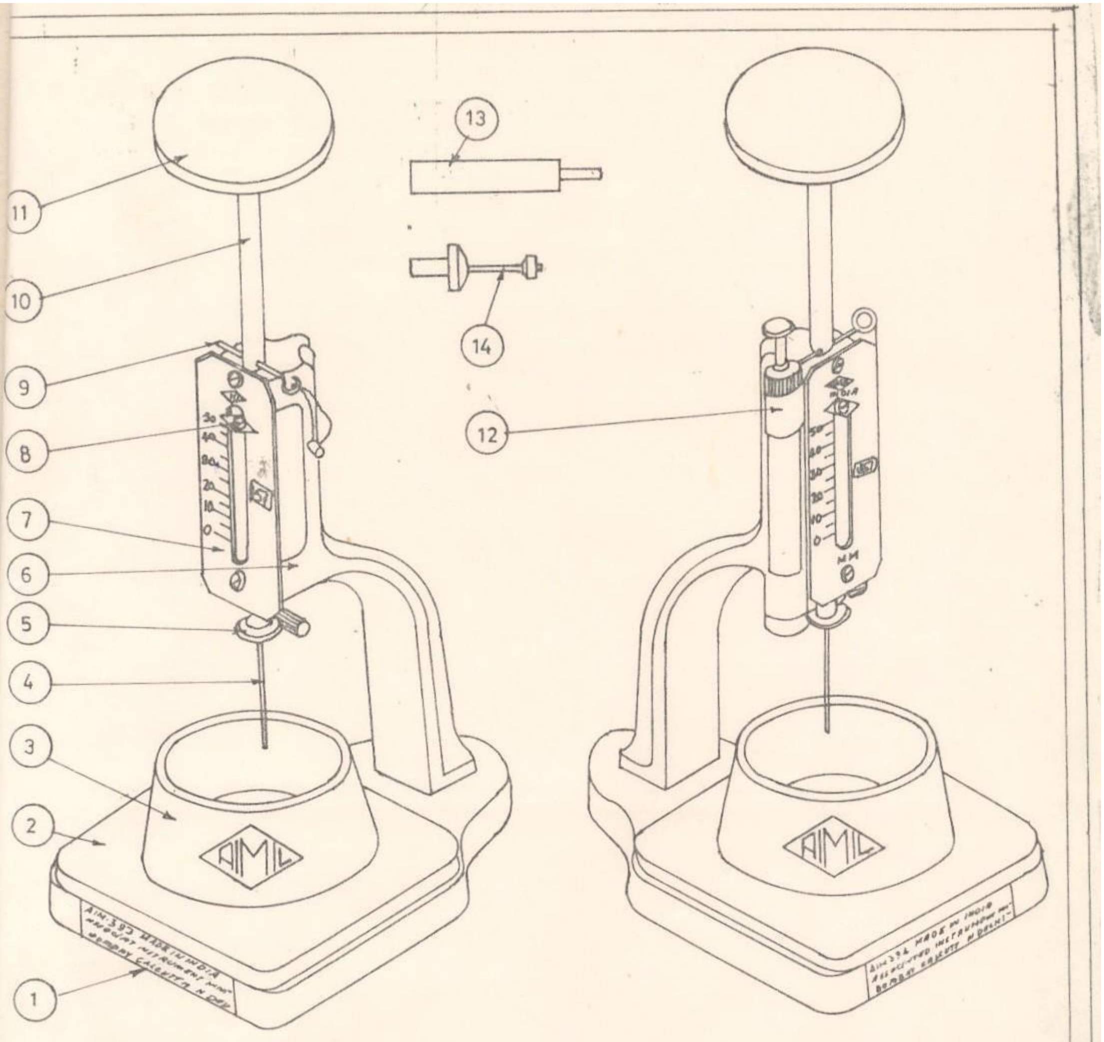
Weight of cement taken for one mould=

Trial No.	*Percentage of water added*	*Height not penetrated by plunger in Vicat's mould mm*

Standard consistency of cement =

PRECAUTIONS:

1) The experiment should be conducted at a room temperature of 25° to 30" at a relative humidity of 90%.
2) After a half minute from the instant of adding water, it should be thoroughly mixed with fingers for atleast one minute. A ball of this paste is prepared and then it is pressed into the test mould, mounted on the non-porous plate.
3) The plunger should be released quickly without pressure or jerk, after the rod is brought down to touch the surface of the test block.
4) For each repetition of the experiment fresh cement is to be taken.
5) Plunger should be cleaned during every repetition and make sure that it moves freely and that there are no vibrations.



AIM-393 VICAT NEEDLE APPARATUS

AIM-394 VICAT NEEDLE APPARATUS WITH DASHPOT

S.No	DESCRIPTION
1	BASE
2	GLASS PLATE
3	VICAT MOULD
4	INITIAL NEEDLE
5	CLAMP SCREW
6	FRAME
7	GRADUATED SCALE

S.N	DESCRIPTION
8	INDICATOR
9	RELEASE PIN
10	BEARING ROD
11	BEARING ROD CAP
12	DASH POT
13	PLUNGER
14	FINAL NEEDLE

12. SETTING TIMES TEST

GENERAL: In order that the concrete may be placed in position conveniently, it is necessary that the initial setting of cement is not too quick and after it has been laid, the hardening should be rapid so that the structure can be made use of as early as possible. The initial .set is a stage on the process of hardening after which may cracks that may appear will not reunite. The concrete is said to be finally set when it has attained sufficient strength and hardness.

OBJECT: To determine the Initial and Final setting times of cement.

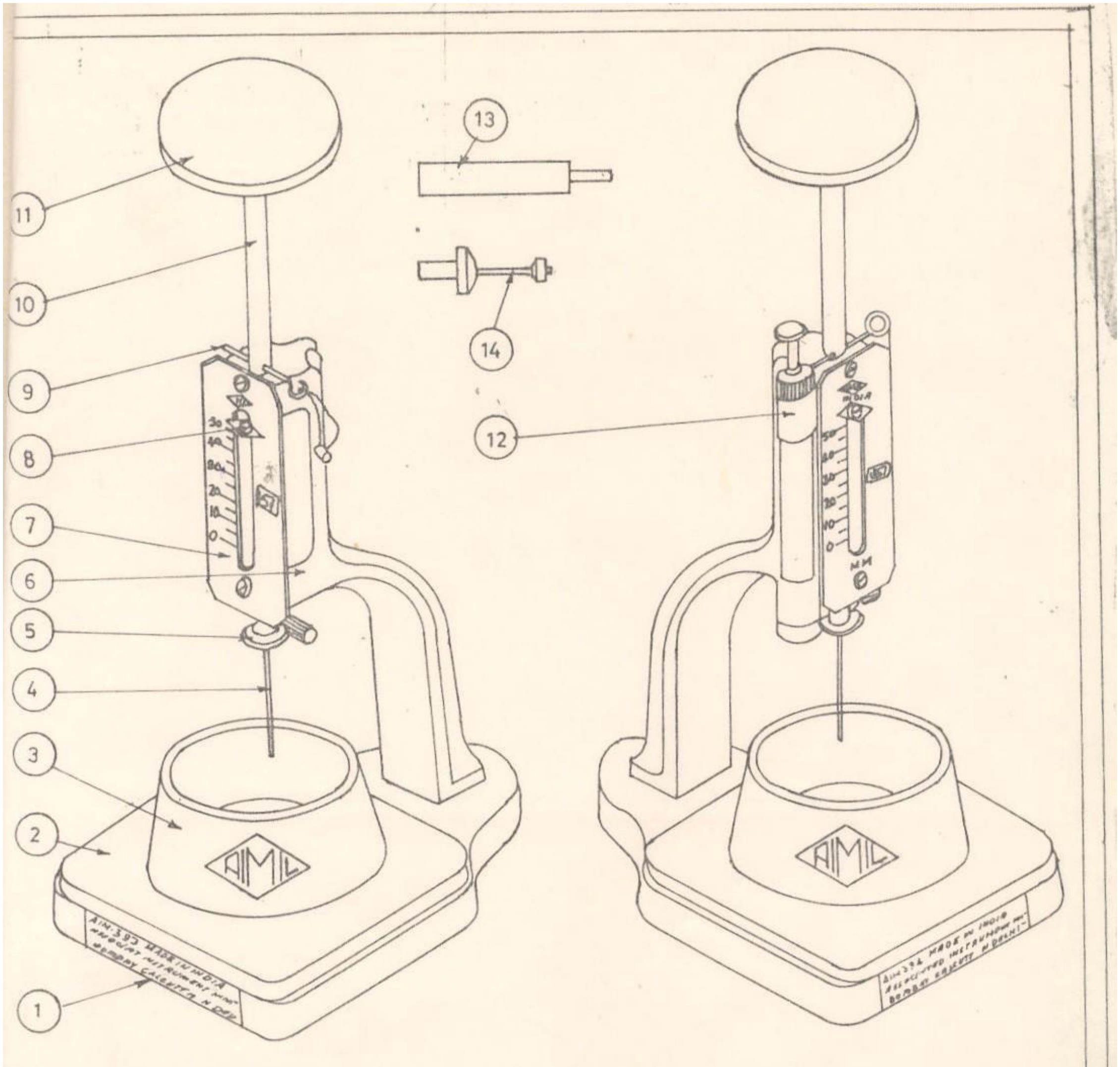
APPARATUS:

1. Vicat apparatus with initial and final setting needles.
2. Stop clock.
3. Measuring cylinder.
4. Trowel

PROCEDURE:

1. Weigh out 300 gms of the given sample of cement on to a non-porous platform and stack it into a heap with a depression in the centre.
2. Add 0.85 times the water required to give a paste of standard consistency to the heap and simultaneously start a stop clock.
3. Guage the cement and water in the same manner as in the standard consistency test and fill the mould completely with the cement paste. Strike the top level with the trowel and slightly jar the mould to the extent necessary to drive all the entrappedair.
4. Place the mould under the Vicat needle apparatus with the 1 mm square needle in position. Lower the needle gently in contact with the surface of the test block and quickly release, allowing it to penetrate into the test block. Note the reading against the index. Now raise the moving rod, clean off the cement paste and wipe the needle clean.
5. In the beginning, the needle will completely pierce the test block and the index reads zero. Report the step no.4 at regular intervals of 1/2 minute till the index reads 5 ± 0.5mm.
6. Note the time elapsed from the moment of adding water to the dry cement to the moment when the index reads 5 ± 0.5 mm which gives the Initial setting time of given cement.
7. Now replace the 1 mm needle by the needle with annular attachment meant for determining the final set.
8. As before allow the moving rod to trowel downwards at every 2 minutes intervals till the needle makes a mark on surface of the cement paste but the annular attachment fails to do so. Note the time at this instant. The total time elapsed from the time of adding water to the dry cement gives the Final' setting time of cement.

Sl.No.	*Consistency of cement*	*% of water added*	*Time taken at water added*	*Time taken at initial setting*	*Time taken at final setting*	*Initial setting time in minutes*	*Final setting time in minutes*



AIM-393 VICAT NEEDLE APPARATUS

AIM-394 VICAT NEEDLE APPARATUS WITH DASHPOT

S.No	DESCRIPTION
1	BASE
2	GLASS PLATE
3	VICAT MOULD
4	INITIAL NEEDLE
5	CLAMP SCREW
6	FRAME
7	GRADUATED SCALE

S.N	DESCRIPTION
8	INDICATOR
9	RELEASE PIN
10	BEARING ROD
11	BEARING ROD CAP
12	DASH POT
13	PLUNGER
14	FINAL NEEDLE

-=o0o=-

13. SPECIFIC GRAVITY OF CEMENT

REF: I.S 4031 - 1988

AIM: To determine the specific gravity of cement

DEFINITION: Specific gravity of cement is defined as the ratio of weight of a given volume of cement at a given temperature to the weight of an equal volume of distilled water at the same temperature both weights being taken in air.

APPARATUS: Specific gravity bottle, weighing balance

MATERIAL: Kerosene free of water, naphtha having a specific gravity not less than 0.7313 shall be used in the specific gravity determination.

PROCEDURE:
1. Wt. of empty dry specific gravity bottle = W_1
2. Wt. of bottle + Cement (filled 1/4 to 1/3) = W_2
3. Wt. of bottle + Cement (Partly filled) + Kerosene = W_3
4. Wt. of bottle + Kerosene (full). = W_4.
5. Wt. of bottle + water (full) = W_5

Specific gravity of kerosene $S_k = (W_4 - W_1) / (W_5 - W_1)$

$$\text{Specific gravity of Cement} = \frac{(W_2 - W_1) \times S_k}{(W_4 - W_1) - (W_3 - W_2)}$$

RESULT: Specific Gravity of cement =

SPECIFICATIONS:

INFERENCE:

14. DETERMINATION OF COMPRESSIVE STRENGTH OF CEMENT

OBJECT: Determination of the compressive strength of cement.

THEORY: The compressive strength of hardened cement is the most important of all the properties of cement. Cement has the maximum strength in compression and is weaker in tension. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportions. Standard Ennore sand is used for finding strength of cement.

APPARATUS: Compression testing machine, cube mould of side 7.06cm (sectional area of 50 sq.cm.), Vibrator, Crucible for mixing cement and sand, measuring cylinder, trowels, non-porous plate and balance with weights-box.

PROCEDURE:

1) Take 555 gms of standard sand, 185 gms of cement (in, ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute. Then add water of quantity (P/4 + 3.5) percent of combined weight of cement and sand and mix the ingredients until the mixture is of uniform color. The mixing time should not be less than 3 minutes nor more than 4 minutes.
2) Place the assembled mould on the table of the vibrating machine and firmly hold it in position by means of a suitableclamp. Securely attach the hopper at the top of the mould tofacilitate filling and this hopper shall not be removed untilcompletion of vibration period.
3) Immediately after mixing the mortar as explained above, fillthe entire quantity of mortar in the hopper of the cube mould andcompact by vibrating. The period of vibration shall be 2 minutesat the specified speed of 12000 ± 4 cycles per minute.
4) Remove the mould from the machine and keep it at a temperature of 27 degrees C in an atmosphere of atleast 90% relative humidity for 24 hours after completion of vibration.
5) At the end of this period, remove the cubes from the moulds and immediately submerge in clean and fresh water and keep there until taken out just before testing.

TESTING: Test three cubes at the periods mentioned below, the periods being reckoned from the completion of vibrations. The compressive strength shall be the average of the strengths of the 3 cubes for each period, respectively.

O.P.C. – 3 and 7 days

Rapid hardening Portland cement---- 1 and 3 days

Low heat Portland cement --- 3, 7 and 28 days

The cubes shall be tested, the load being applied at the rate of 35 N/sq.mm/minute.

OBSERVATIONS:

Sl. No.	*3-days strength*		*7-days strength*	
	Load in KN	*Strength in N/sq.mm*	*Load in KN*	*Strength in N/Sq.mm*

PRECAUTIONS

1) The mortar shall not be compressed into the moulds with hand.
2) Neglect the results which fall outside 15% of the average results on either side.
3) Cubes should be tested on their sides and not on their faces.
4) The inside of the cube mould should be oiled to prevent the mortar from adhering to the sides of the mould.
5) The size of sand particles should be such that not more than 10% by weight shall pass IS:60 micron sieve.
6) The time of wet mixing shall not be less than 3 minutes. If the time of mixing exceeds 4 minutes to bring a uniform color, the mixture shall be rejected and fresh mortar should be prepared.
7) The cubes shall not be allowed to dry until they are broken.

DISCUSSION

IS-269-1976 specifies the following strengths in compression for the standard mortar cubes. Strength in N/sq.mm.are as follows:

Age	*O.p.C.*		*(Change units) Rapid Hardening. Portland cement*	*Low heat cement*
1 day	—		16.0 (11.5)	—
3 days	16.0	(11.5)	2.75 (21.0)	10.0 (7.0)
7 days	22.0	(17.5)	--	16.0 (11.5)
20 days	—			35.0 (26.5)

The values given in brackets are the strength requirements of mortar cubes when locally available sand is used in place of standard ennore sand.

NOTE STANDARD SAND: As per the revised specifications, 100 percent passes through 2 mm sieve and 100 percent retained on a 90-micron sieve. Particle size distribution is as under.

Size	Percentage
Greater than 1mm	33.33
Smaller than 1 mm and greater than 500 microns	33.33
Below 500 microns	33.33

-=o0o=-

15. DETERMINATION OF WORKABILITY OF CONCRETE BY SLUMP CONE TEST

OBJECT: To determine, by the slump test, the workability (consistency) of concrete mixes of given proportions.

THEORY: Unsupported concrete, when it is FRESH, will flow to the sides and a sinking in height will take place. This vertical settlement is known as SLUMP. Slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. A concrete is said to be workable if it can be easily mixed and easily placed, compacted and finished. A workable concrete should not show any segregation or bleeding. Slump increases as water-cement ratio increases.

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or in site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor it is always representative of the place-ability of concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Repeated batches of the same mix, *brought to*the same slump, will have the same water content and W/c ratio, provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits.

APPARATUS: Slump cone, tray for mixing concrete, trowel, tamping *rod, steel* rule, measuring jar, weighing platform machine, spatula. The apparatus for conducting the slump test essentially consists of metallic mould in the form of a frustum of a cone having the dimensions as under:

Bottom diameter = 20cm

Top diameter = 10 cm

Height = 30 cm

The thickness of the metallic sheet for the mould should not be thinner than 1.6mm. For tamping the concrete, a steely tamping rod 16mm diameter; 0.6m long with bullet end is used.

PROCEDURE: Four mixes are to be prepared with W/c ratio (by weight) of 0.5, 0.6, 0.7 and 0.8 respectively and for each mix take 10 Kg. of coarse aggregate, 5 Kg. of sand and 2.5 Kg. of cement. Then the mix proportions are 1:2:4 (Cement:Sand:Coarse Aggregate). If needed, slump values of other mixes i.e. mixes of different proportions can also be found.

1) The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and any old set concrete before commencing the test. Fix slump cone to the base. The base should be smooth, horizontal, rigid and non-absorbent surface. Apply lubricating oil to the inside walls of slump cone so that concrete is prevented from sticking to the walls of the slump cone.
2) Measure the height of the slump cone. Let it be "h1" cm.
3) Preparation of concrete mix: First mix cement and sand in dry state till a mixture of uniform colour is obtained and to this mixture add coarse aggregate and again mix all the three ingredients. Then add water according to the given W/c ratio and prepare a homogeneous mix.
4) The mould is then filled in four layers, each approximately (1/4) of the height of the mould. Each layer is tamped 25 timesby the tamping rod taking care to distribute the strokes evenly over the cross-section. For the second and subsequent layers, the tamping rod should penetrate into the underlying layer.
5) After the top layer has been rodded, strike off the top with a trowel, so that the mould is exactly

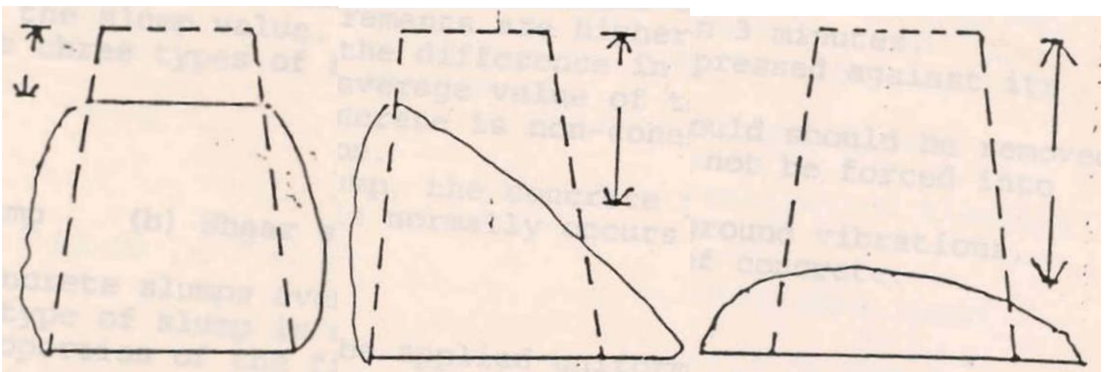
filled.

6) The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction.
7) As soon as the concrete settlement comes to a stop, measure the subsidence of concrete i.e. the difference in level between the height of the mould and that of the highest point of the subsided concrete (OR) measure the height of the concrete and let it be "h2" cm. The difference between (hi) and (h2) gives the slump.
8) Repeat the procedure for different W/c ratios.

NOTE: Any slump specimen which collapses or shears off laterally gives incorrect results and if this occurs, the test is repeated.

OBSERVATIONS:

Sl.No.	*W/C Ratio*	*Height of slump cone (h1) cm*	*Height of concrete after removing cone (h2)*	*Slump value= (h1-h2) cm*
1.	0.5			
2.	0.6			
3.	0.7			



TRUE SLUMP SHEAR SLUMP COLLAPSE SLUMP

PATTERN OF SLUMP: It indicates the characteristics of concrete in addition to the slump value. During the slump test, one often comes across three types of slumps.

(a) True slump (b) Shear slump (c) Collapse slump

a) If the concrete slumps evenly (uniformly), it is called true slump. This type of slump is obtained normally in rich mixes and where the proportion of the fine aggregate is higher.
b) If one half of the cone slides down, it is called shear slump. This normally happens in leaner mixes such as 1:6 or 1:8 and where the slump requirements are higher. In this case, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence. Shear slump indicate that the concrete is non-cohesive and shows the characteristic of segregation.
c) In this type of slump, the concrete just collapse and spread over a large area. This normally occurs in very wet mixes.

PRECAUTIONS:

1) The strokes are to be applied uniformly through the entire area of concrete section.
2) The cone should be removed very slowly by lifting it upwards without disturbing the concrete.
3) The experiment should be completed within 3 minutes.
4) During filling the mould must be firmly pressed against its base.
5) The surplus concrete on the top of the mould should be removed carefully with a trowel. The surplus should not be forced into the mould.
6) Test should be made beyond the range of ground vibrations, because they might increase the subsidence of concrete.

Recommended slump values for concrete for various jobs.

Degree of workability	*Slump in mm*	*Use for which concrete is suitable*
Very low	0-25	i) Roads vibrated by power-operated machines.
		ii) Vibrated concrete in large sections.
Low	25-50	i) Roads vibrated by hand-operated machines.
		ii) Mass concrete foundations without vibration or lightly reinforced sections with vibration
Medium	50-100	i) Manually compacted flat slabs using crushed aggregates.
		ii) Normal reinforced work without vibration and heavily reinforced sections with vibration.
High	100-175	For sections with congested reinforcement which is not normally suitable for vibration.

QUESTIONS:

1) Write down the slump range for concrete used for the followingpurposes:
   (a) Beams, slabs and stair cases.

   (b) Columns and retaining walls,

   (c) Mass concrete in foundation.

2) What do you mean by the workability of freshly mixed concrete?
3) If the concrete can be rammed hard, will the slump value be decreased or increased?
4) What are the dimensions of slump cone and tamping rod?
5) Define segregation and bleeding of concrete.
6) What are the undesirable effects of segregation and bleeding?
7) How can the bleeding of concrete be prevented?
8) Name some admixtures that may increase the slump.
9) For which type of mix, slump test is more suitable (Lean mix/Rich mix) and why?
10) Why slump cone test is still-popular inspite of the fact thatmany other workability tests are in vogue?

-=o0o=-

COMPACTION FACTOR TEST

OBJECT: To determine workability of concrete mixes of given proportions by compaction factor test.

THEORY: The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete in the sensitive to slump test.

This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compaction factor is measured by the density ratio i.e. the ratio of the density actually achieved in the test to the density of same concrete fully compacted.

APPARATUS: Compaction factor apparatus, trowels, graduated cylinder, weighing machine, tamping rod and trays.

PROCEDURE:

1) Keep the compaction factor apparatus on a level ground and add oil in the inner surface of the hoopers and cylinder.
2) Fasten the hopper doors.
3) Weigh the empty cylinder accurately and note the weight (W1).
4) Fix the cylinder on the base with fly nut and bolt in such a way that the central points of hoopers and cylinder lie on one line. Cover the cylinder with a plate.
5) Three mixes are to be prepared with w/c ratio (by weight) 0.50, 0.60, 0.70 respectively. For each mix take 10 Kg. of coarse aggregate, 5 Kg. of sand and 2.5 Kg. of cement. With each mix proceed as follows:
    (a) Mix sand and cement dry, until a mixture of uniform colour is obtained. Now mix the coarse aggregate and cement sand mixture until coarse aggregate is uniformly distributed through out the batch.
    (b) Add the required percentage of water to the above mixture and mix it thoroughly until concrete appears to be homogeneous.
6) Fill the freshly mixed concrete in upper hopper gently and carefully with hand scoop without compacting.
7) After two minutes, release the trap door so that the concrete is allowed to fall into the lower hopper bringing the concrete into standard compaction.
8) Immediately after the concrete has come to rest, open the trap door of lower hopper and allow the concrete to fall into thecylinder bringing the concrete into standard compaction.
9) Remove the excess concrete above the top of the cylinder bypair of trowels, one in each hand, with blades horizontal slidethem from the opposite edges of the mould inward to the centrewith a sawing motion.
10) Clean the cylinder from all sides properly. Find the weight (W2) of partially compacted concrete thus filled in the cylinder.
11) Refill the cylinder with the same sample of concrete in approximately 5 cm layers, vibrating each layer heavily so as to expel all the air and to obtain full compaction of concretes.
12) Level up mix and weigh (W2) the cylinder filled with fully compacted concrete.

11.5 OBSERVATIONS AND CALCULATIONS

Weight of cylinder W1 =

Sl. No.	*W/C ratio*	*Wt.of cylinder with partially compacted concrete W2*	*Wt.of cylinder with fully compacted concrete W3*	*Wt.of partially compacted concrete W2-W1*	*Wt.of compacted concrete W3-W1*	*Compaction factor* = $\left[\frac{W2 - W1}{W3 - W1}\right]$
01.	0.50					
02.	0.60					
03.	0.70					

PRECAUTIONS

1. The test should be carried out on a level ground.
2. The top hopper must be filled gently and to the same extent on each occasion and the time between the end of mixing and release of concrete from top hopper must be constant, two minutes will be convenient.
3. The outside of mould must be wiped clean before weighing and weights should be recorded to the nearest 10 gm.
4. The hoppers and cylinder must be washed clean and wiped before reuse.
5. The mix should not be pressed or compacted in the upper"hopper”.
6. If the concrete in the hopper does not fall through, when the trap door is released, it should be freed by passing a metal rod, similar to that used in slump test, vertically through its centre. A single steady penetration will usually affect release.

DISCUSSIONS: Compaction factor test is adopted to determine the workability of concrete, where the nominal maximum size of aggregate does not exceed 4 0mm and is primarily used in laboratory. It is more sensitive and precise than slump test and is particularly, useful for concrete mixes of low workability as are normally used when the concrete is to be compacted by vibration, such concrete may constantly fail to slump. The compaction factor (C.F.) test is able to indicate small variations of workability over a wide range.

LIMITATIONS OF THE METHOD

1. When maximum size of aggregate is large as compared with more particle size, the drop into bottom container will produce segregation and give unreliable comparison with other mixes of smaller maximum aggregate size.
2. The method of introducing concrete into mould bears no relationship to any of the more common methods of placing and compacting high quality concrete.
3. Compaction factor test establishes the fact that with increase in the size of coarse aggregate the workability decreases.

SUGGESTED RANGES OF WORKABILITY OF CONCRETE

MEASURED IN ACCORDANCE WITH IS;13,99-1958

(I.S : 456-1973 THIRD REVISION)

Placing conditions	*Degree of workability*	*Values of workability*
Concreting of small sections with vibration	Very low	20-10 seconds, vee-bee time or. 0-75-0.80 compacting factor
Concreting of lightly reinforced sections with vibration	Low	10.5 seconds, vee-bee time.
Concreting of lightly reinforced section without vibration	Medium	5.2 seconds Vee-Bee time or 0.85-0.92 compacting factor or 25075 mm, slump
Concreting of heavily reinforced sections without vibration	High	Above 0.92 C.F. or 75-125 mm slump

-=o0o=-

VEE BEE CONSISTENCY TEST

OBJECT: To determine the workability of the concrete mix of given proportion by Vee-Bee consistometer test.

APPARATUS: Vibration table, Metal pot, Slump cone. Swivel arm, graduated rod, Perspex disc, and Tamping rod.

PRINCIPLE: It is based on the principle of measuring the energy required to transform a concrete specimen in the shape of a conical frustum into a cylinder.

PROCEDURE:

Position the metal cone over the slump cone.

Place the concrete inside the slump cone, in four layers each approximately one quarter of the height of the slump cone. Tamp each layer with twenty five strokes of the rounded end of the tamping rod.

Distribute the strokes in a uniform manner over the cross section of the mould. For the first layer tamp it thoroughly through its depth. For subsequent layers penetrate screw into the underlying layer.

After the top layer has been rodded, position the metal cone of the swivel arm away and strike off the concrete level with the top of the cone using a trowel so that the mould is filled level to the top of the cone.

Remove any material spilled inside the metal pot or sticking on to the side of the slump cone.

Position the perspex disc over the cone and note down the reading on the graduated rod (1^) carefully lift the slump cone vertically and remove it after keeping the disc away. Position the disc over the concrete.

Note down the reading on the graduated rod (1_2). The difference in two readings gives the slump in centimeters. Switch on the vibrator starting a stop watch simultaneously. Allow the concrete to spread out in the pot. When the whole concretesurface uniformly adheres to the perspex disc stop the watch simultaneously switching off the vibrator. Note down the time in seconds. Note the reading on the graduated rod 1_3).

The consistency of the concrete is expressed in Vee-Bee degrees which are equal to the time in seconds.

CONCLUSIONS:

Vee-Bee test is preferable for stiff concrete mixes having "low" or "very low" workability. Compared to the other two tests, (Slump test and compaction factor test).Vee-Bee test has the advantage that the concrete in the test receives a similar treatment as it would be in actual practice. Since the end point of the test is to be ascertained visually, it introduces a source of error which is more pronounced for concrete mixes of high workability and consequently records low Vee-Bee time. The test is therefore, not suitable for concrete of higher workability that is slump of 75 mm or above.

16. COMPRESSIVE STRENGTH OF CONCRETE

AIM: To determine the compressive strength of concrete by crushing test on cubes and cylinders.

APPARATUS: Compression Testing Machine, Specimen, Scale.

THEORY: In design of R.C.C. sections allowable, stress is taken for the design. This allowable stress is a fraction of the ultimate (crushing) strength of concrete. As per I.S.456, a factor of safety of 3.0 is adopted for obtaining allowable comp. stresses. The permissible stresses are specified with reference to cube strength.

The testing of concrete cube (or cylinder) are required (i) to verify the strength of concrete mix used in actual construction and (ii) to verify the strength of trial mixes as in the case of design of mixes. I.S. code has specified the strength on cubes of 150 x 150 xl50 mm. Alternatively if test results on cylinder strengths (150 x 300 mm) are available the results shall satisfy:

Minimum cylinder compressive strength = 0.8 x compressive strength specified on cubes.

TABLE : PROPORTIONS FOR NOMINAL MIX, CONCRETE

Grade of concrete	*Total quantity of dry aggregates by mass per 50 Kg. of cement to be taken as the sum of the individual masses of fine and coarse aggregates max.*	*Proportion of fine aggregate to coarse aggregate (By mass)*	*Quantity of water per 50 Kg. of cement*
(1)	*(2)*	*(3)*	*(4)*
	Kg.		*Liters*
M.5	800	Generally 1:2 but subject to upper limit of 1:1 ½ and a lower limit of 1:2 ½	60
M.7.5	625		45
M.10	480		34
M.15	350		32
M.20	250		30

NOTE: The proportions of the fine to coarse aggregates should be adjusted from upper limit to lower limit progressively as the grading of the fine aggregates becomes finer and the maximum size of coarse aggregate becomes larger. Graded coarse aggregate shall be used.

EXAMPLE: For an average grading of fine aggregate (that is. Zone 14 of table 4 of IS 383-1970), the proportions shall be 1:1 1/2, 1:2 and 1:2 1/2 for maximum size of aggregates 10mm, 20mm, and 40mm respectively.

PREPARATION OF SAMPLES

1) Take the required quantities of materials from the table depending upon the mix under preparation.
2) Cement and sand are thoroughly mixed until the mixture is of uniform colour.
3) The coarse aggregate is then added and mixed dry.
4) Add water and mix the whole mass for minimum two minutes so that the resulting concrete is uniform in colour.
5) The moulds, both cubes (150mm x 15 0mm x 150mm) and cylinders (150mm dia and 3 0 0mm height) should be oiled to prevent the concrete from sticking.
6) The concrete should be filled in the mould in three equal layers. Each layer should be compacted 35 times with a 16mm diameter, rod, 600mm long and bullet pointed at lower end. When cylinder is used the strokes for each layer should not be less than 3 0.

7) Strike off the surface with a trowel.
8) Place the moulds containing the test specimen in moist air of atleast 90% humidity and at temperature (27° ± 2°)C for 24 hours.
9) Next day, the specimens are taken out from the moulds and cured under clean, fresh water at temperature (27° ± 2°)C.
10) The curing is done until the required days of testing and the specimens shall be taken out just prior to the test.

TESTING

1) Tests shall be conducted at the end of 7 days and 2 8 days. The tests should **be** carried out immediately upon the removal of specimens from water.
2) Measure the dimensions of the given specimen.
3) Keep the specimen in compression testing Machine so that the load is applied to the transverse sides as cast and not to the top and bottom as cast. The rate of loading should be 14 0 Kg/sq.cm./minute.
4) Note the mode of failure and angle of plane (if any) on which the specimen fails. Record the ultimate load reached during the test.

OBSERVATIONS AND CALCULATIONS

Size of specimen =

Area of cross section A =

Sl. No.	*Identification No.*	*Date of casting*	*Date of testing*	*Ultimate load P(Newtons).*	*Ultimate compressive strength P/A N/mm^2*
1.					
2.					
3.					
4.					

Average =

NOTE: The test strength of sample shall be the average of the strength of three specimens. The individual variation should not be more than ± 15 percent of the average.

DISCUSSIONS & CONCLUSIONS

I.S.456: 1978 classified concrete mixes according to its strength. The concrete is classified into seven grades, and the grades are based on the basis of compressive strength of 15 cm cubes at 28 days mixed and cured under prescribed conditions. The strength requirements of each grade of concrete as specified by ISI are given in the following table.

REQUIREMENTS

Grade of concrete	STRENGTH REQUIREMENTS OF CONCRETE Compressive strength of 15 cm cube of 28 days after mixing conducted in accordance with IS:516-1959	
	Preliminary test (min) Kg/sq.cm.(N/sq.mm)	Working test (min) Kg/ Sq.cm. (N/sq.mm)

NOTE: Preliminary Test: A test conducted in a Laboratory on the trial mix of the concrete produced in the laboratory with the object of

(1) Designing of concrete mix before the actual concreting operations start.
(2) Determining the adjustments required in the materials used during the execution of work.
(3) Verifying the strength of concrete mix.

WORK TEST: A test conducted either in the field or in a laboratory on the specimen made on the works, out of the concrete being used on the works. The above table mentions seven grades of concrete and specifies both the preliminary test strength and work-cube strength. These strength requirements are applicable to both controlled (design mix) concrete and ordinary (nominal) concrete. But for ordinary concrete preliminary tests are not obligatory according to the IS code. IS.456 also specified that where the strength of the concrete for any two grades specified in the above table, such ^concrete shall be classified for all purposes as concrete belonging to the lower of the two grades between which its strengths lies.

-=o0o=-

17. BULKING OF FINE AGGREGATE

OBJECT: Determination of adjustment for bulking of fine aggregate and to draw curve between water content and bulking.

THEORY: In concrete mix design, the quantity of fine aggregate used in each batch should be related to the known volume of cement. The difficulty with measurement of fine aggregate by volume is the tendency of sand to vary in bulk according to moisture contents. The extent of this variation is given by this test.

If sand is measured by volume and no allowance is made for bulking, the mix will be richer than that specified because for given mass, moist sand occupies a considerably larger volume than the same mass of dry sand, as the particles are less closely packed when the sand is moist.

Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension, which keeps the neighboring particles away from it. Similarly, the force exerted by surface tension keeps every particle away from each other. Therefore, no point contact is possible between the particles. This causes bulking of the volume. The extent of surface tension and consequently how far the adjacent particles are kept away will depend upon the percentage of moisture content and the particle size of fine aggregate. It is interesting to note that the bulking increases with the increase in moisture content upto a certain limit and beyond that the further increase in the moisture content results in the decrease in the volume and at a moisture content representing saturation point, the fine aggregate shows no bulking. Fine sand bulks more and coarse sand bulks less. From this it follows that the coarse aggregate also bulks but the bulking is so little that it is always neglected. For sand, the volume goes on increasing until the moisture content is about 8% by weight of sand. The bulking of sand may be as large as 30 to 40%.

APPARATUS: Balance, weights box, graduated cylinder, cylindrical container, beaker, metal tray, steel rule, oven.

PROCEDURE:

1) Weigh the empty container (W1).
2) Put sufficient quantity of the oven-dried sand loosely into the container until it is about two-third full. Level off top of sand and weight the container (W2). Calculate the weight of sand (dry) W by deducting the weight of the container.
3) Push a steel rule vertically down through the sand at the middle to the bottom and measure the height of sand. Let it be(h) cm.
4) Empty the sand out into a clean metal tray without anyloss.
5) Add 1% of water by weight of sand. Mix the sand and waterthoroughly by hand.
6) Put the wet sand loosely into the container without tamping it.
7) Level the top surface of the inundated sand and measure its depth at the middle with a steel rule. Let it be "H" cms.
8) Repeat the above procedure with 2%, 3%, 4% etc. of water by weight till bulking is maximum and starts falling down and ultimately bulking is zero i.e. saturated sand occupies the same volume as dry sand.

OBSERVATIONS & CALCULATIONS:

Weight of empty container W1 = ---grams

Weight of containers-sand, W2 =..gms.

Weight of dry sand, W = (W2-Wl) = --gms.

Height of dry sand, h =...cm.

Total % of water added	Quantity of water added in ml.	Height of moist sand in cm H	Bulking in % $= \frac{(H - h)}{h} \times 100$

GRAPH: Draw a graph between bulking percent and moisture content percent.

PRECAUTIONS:

i) There should not be any wastage of sample
ii) Water should be measured accurately
iii) iii) Vessel should be clean and dry.

QUESTIONS:

1) Is "bulking of sand" test actually needed in the field? If so, why?
2) "Fine sand bulks more and coarse sand bulks less" why?
3) Explain"bulking phenomenon".
4) Why the bulking takes place only in sand and why not in coarse aggregate?
5) If no allowance is made for bulking of sand, how is it going to effect the mix proportions?
6) For production of quality and controlled concrete,______batching is adopted. (Volume batching/weigh batching).

DEPARTMENT OF CIVIL ENGINEERING

S.R.M NAGAR, KATTANKULATHUR - 603203.

SOIL MECHANICS LABORATORY MANUAL

(FIFTH SEMESTER)

REGULATION 2021

REGULATION 2021

SOIL MECHANICS LABORATORY

COURSE OBJECTIVES:

- To study the particle size distribution of different soil.
- To enhance the knowledge on various index properties of soil.
- To gain knowledge about the compaction characteristics of soil.
- To learn about the shearing properties of soil.
- To study about the bearing capacity of soil.

COURSE OUTCOME:

On the completion of the course, the students will be able to:

1. Students are able to classify the soil based on IS Code
2. Students are able to conduct tests to determine both the index properties
3. Students are able to conduct tests on engineering properties of soils
4. Students are able to conduct tests on characterization of the soil based on their properties.
5. Students are able to conduct field tests on soil.

TOTAL: 60 PERIODS

List of Experiments:

1. **DETERMINATION OF INDEX PROPERTIES** **20**
    a. Specific gravity of soil solids
    b. Grain size distribution of cohesionless soil – Sieve analysis
    c. Grain size distribution of cohesive soil - Hydrometer analysis
    d. Liquid limit and Plastic limit tests on cohesive soil
    e. Shrinkage limit and Differential free swell tests for cohesive soil

2. **DETERMINATION OF INSITU DENSITY AND COMPACTION CHARACTERISTICS** **12**
    a. Field density Test (Sand replacement method)
    b. Determination of moisture – density relationship using standard Proctor compaction test.
    c. Determination of relative density for the given sample

3. **DETERMINATION OF ENGINEERING PROPERTIES** **28**
    a. Constant Head Permeability determination for given sample.
    b. Falling Head Permeability determination for given sample.
    c. One dimensional consolidation test (Demonstration only)
    d. Direct shear test in cohesionless soil
    e. Unconfined compression test in cohesive soil
    f. Laboratory vane shear test in cohesive soil
    g. Tri-axial compression test in cohesionless soil (Demonstration only)
    h. California Bearing Ratio Test for the given soil

LABORATORY SAFETY PROCEDURES

DO'S

- Know the potential hazards of the materials used in the laboratory.
- Wear personal protective apparel when working.
- Wash skin promptly if contacted by any chemical.
- Handle Heavy Equipment with utmost care.
- Be cautious when working with electricity.
- Shoes must cover the entire foot. Open toed shoes and sandals are inappropriate footwear in laboratories.
- Restrain and confine long hair and loose clothing. Pony tails and scarves used to control hair must not present a loose tail that could get caught in moving parts of machinery.
- Clean all the apparatus before and after the experiment.
- Wash your hands thoroughly once you complete the experiments.

DON'T

- Don't Eat, drink, chew gum, or apply cosmetics in laboratory.
- Don't handle heavy weights carelessly.
- Don't use Golden Ornaments While Handling Mercury.

CONTENTS

Ex.No:1

Date: **Determination of Specific gravity of soil solids**

AIM

To determine the specific gravity of soil solids.

THEORY

Specific gravity of soil solids is the ratio of weight, in air of a given volume; of dry soil solids to the weight of equal volume of water at 4ºC.Specific gravity of soil grains gives the property of the formation of soil mass and is independent of particle size. Specific gravity of soil grains is used in calculating void ratio, porosity and degree of saturation, by knowing moisture content and density. The value of specific gravity helps in identifying and classifying the soil type.

APPARATUS REQUIRED

1. Pycnometer
2. 450 mm sieve
3. Weighing balance
4. Oven
5. Glass rod
6. Distilled water

PROCEDURE

1. Dry the pycnometer and weigh it with its cap. (W_1)
2. Take about 200gmof oven dried soil passing through 4.75mm sieve into the pycnometer and weigh again (W_2).
3. Add sufficient de-aired water to cover the soil and screw on the cap.
4. Shake the pycnometer well and remove entrapped air if any.
5. After the air has been removed, fill the pycnometer with water completely.
6. Thoroughly dry the pycnometer from out side and weigh it (W_3).
7. Clean the pycnometer by washing thoroughly.
8. Fill the cleaned pycnometer completely with water up to its top with cap screw on.
9. Weigh the pycnometer after drying it on the outside thoroughly (W_4).

10. Repeat the procedure for three samples and obtain the average value of specific gravity.

OBSERVATIONS AND CALCULATIONS

Determine the specific gravity of soil grains (G) using the following equation

$$G = (W_2 – W_1) / \{ (W_2 – W_1) - (W_3 – W_4) \}$$

Where

W1 = Empty weight of pycnometer.

W2 = Weight of pycnometer + oven dry soil

W3 = Weight of pycnometer + oven dry soil+ water

W4 = Weight of pycnometer + water

OBSERVATION FOR SPECIFIC GRAVITY DETERMINATION			
	TRIAL 1	**TRIAL 2**	**TRIAL 3**
Empty weight of pycnometer. **W1 in gms**			
Weight of pycnometer + oven dry soil **W2 in gms**			
Weight of pycnometer + oven dry soil+ water **W3 in gms**			
Weight of pycnometer + water **W4 in gms**			
Specific Gravity, G (No Unit)			

RESULT

Average specific gravity of soil solids G =

Specific Gravity and Moisture Content of soil solids

1. What is meant by Specific Gravity?

    The ratio of unit weight of Soil solids to the unit weight of the water is called specific gravity of soil solids.

2. What are the different types of specific gravity?

    Specific Gravity of Soil Solids

    Apparent Specific Gravity

3. What is meant by Apparent specific gravity?

    The ratio of Bulk unit weight of soil to the unit weight of the water is called Apparent gravity of soil solids

4. What are the Different methods to find Specific Gravity?

    Pycnometer Method

    Density Bottle Method

5. Different name of Specific Gravity of Soil Solids?

    True specific Gravity

6. Different name of Bulk Specific Gravity?

    Apparent Specific Gravity

7. Range of Specific Gravity of Soil Solids

    It range from 2.65 to 2.70 for soil

8. Range of Specific Gravity of Soil Solids

    It range from 1.25 to 1.50 for soil.

9. What is meant by capillary water?

    The water which move up / down due to the surface tension is called as capillary water.

10. What is meant by Hygroscopic water?

    The water which bind/held around the soil particle is known as Hygroscopic water.

11. What is meant by Water Content?

    The ratio of Mass of water to the mass of soil solid is called Water content

12. What are the different methods to find water content?

    Calcium Carbide Method

    Torsion Balance Method

    Sand Bath Method

    Hot Air Oven Method

13. How the water content measured from Oven Method?

    The wet soil is kept in oven at the temperature on 105 degree for 24 hours. The weight of water and the weight of dry weight observed. With that water content to be found.

14. Explain Calcium Carbide Method?

    In this method, the wet sample is kept in the flask with calcium carbide chemical. The closed flask to be shake and the carbon dioxide will form and the pressure due to formed gas is measured with pressure gauge attached with flask.

15. Explain Calcium Carbide Method?

    In this method, the wet soil if weighed and fried in the hot pan. After few minutes the dry weight to be found. With this water content to be found

16. What are the different types of soil water?

    Free water

    Structural Water

    Capillary water

    Hygroscopic water

17. What is meant by free water?

    The water which flow under gravity between the voids is called free water.

18. What is structural water?

    The water present inside the structure of the soil which cant dry with oven is called structural water

19. What is meant by capillary water?

    The water which move up / down due to the surface tension is called as capillary water.

Ex.No:2

Date: **Determination of Grain Size Distribution (Sieve Analysis)**

AIM

To conduct sieve analysis of soil to classify the given coarse grained soil.

THEORY

Grain size analysis is used in the engineering classification of soils. Particularly coarse grained soils. Part of suitability criteria of soils for road, airfield, levee, dam and other embankment construction is based on the grain size analysis. Information obtained from the grain size analysis can be used to predict soil water movement. Soils are broadly classified as coarse grained soils and fine grained soils. Further classification of coarse grained soils depends mainly on grain size distribution and the fine grained soils are further classified based on their plasticity properties. The grain size distribution of coarse grained soil is studied by conducting sieve analysis.

APPARATUS REQUIRED

1. A set of Sieves 4.75 mm, 2.36 mm ,1.18 mm ,0.60mm, 0.425 mm, 0.30 mm 0.15 mm 0.075mm including lid and pan
2. Tray
3. Weighing Balance
4. Sieve Shaker
5. Brush

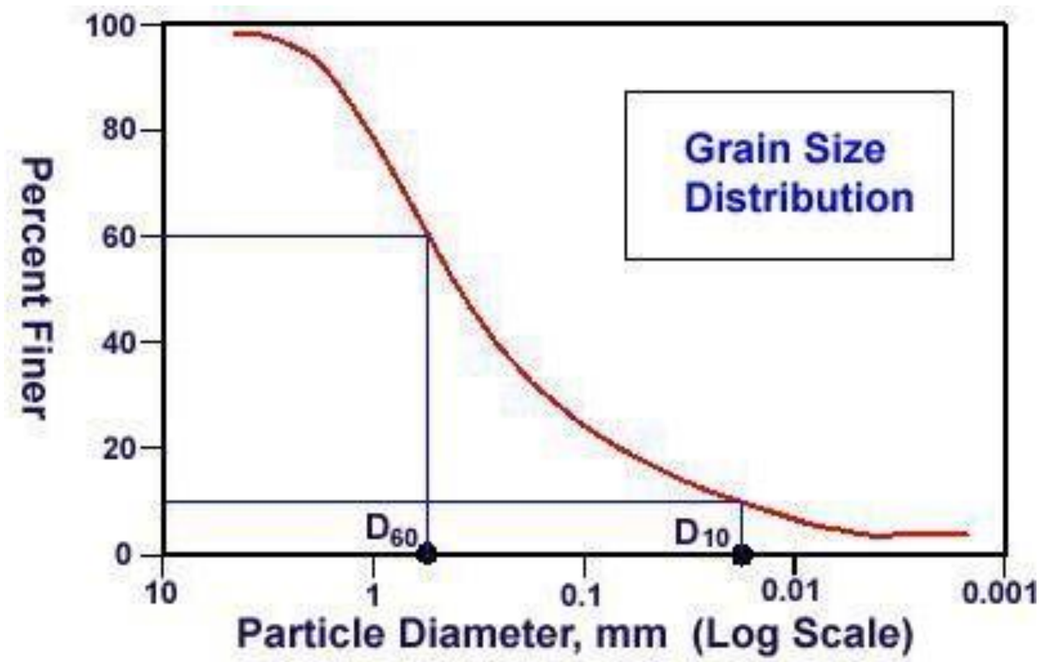
PROCEDURE

1. Weigh 500gms of soil sample, of which grain size distribution has to be studied.
2. Clean the sieve set so that no soil particles were struck in them.
3. Arrange the sieves in order such that coarse sieve is kept at the top and the fine sieve is at the bottom. Place the closed pan below the finest sieve.
4. Take the soil obtained into the top sieve and keep the lid to close the top sieve.
5. Position the sieve set in the sieve shaker and sieve the sample for a period of 10 minutes.
6. Separate the sieves and weigh carefully the amount of soil retained on each sieve, This is usually done by transferring the soil retained on each sieve on a separate sieve of paper and weighing the soil with the paper.
7. Enter the observations in the Table and calculate the cumulative percentage of soil retained on each sieve.

8. Draw the grain size distribution curve between grain size on log scale on the abscissa and the percentage finer on the ordinate.

OBSERVATIONS & CALCULATIONS					
Weight of the soil taken for testing (W) =					
Sl.No	Aperture size of sieve in mm	Weight of soil retained (gm)	% Weight Retained	Cumulative Percentage Retained	Percentage Finer
1	4.75mm				
2	2.36mm				
3	1.18mm				
4	0.600mm				
5	0.425mm				
6	0.300mm				
7	0.150mm				
8	0.075mm				

Plot the graph between percentage finer and logarithmic grain size (mm).From the graph, obtain the percentage of coarse, medium and fine sands.



Uniformity coefficient $C_u = D_{60} / D_{10}$

Coefficient of Curvature $C_c = (D_{30})^2 / D_{60} \times D_{10}$

RESULT

Percentage of gravel (>4.75mm) =

Percentage of coarse sand (4.75mm – 2.00 mm) =

Percentage of medium sand (2.00mm – 0.425 mm) =

Percentage of fine sand (0.425mm – 0.0.075 mm) =

Percentage of fines (<0.075 mm) =

Uniformity Coefficient C_u =

Coefficient of Curvature C_c =

Ex.No:3

Date: **Determination of Grain Size Distribution (Hydrometer Analysis)**

AIM

To determine the grain size distribution of soil sample containing appreciable amount of fines by hydrometer analysis test.

THEORY

For determining the grain size distribution of soil sample, usually mechanical analysis (sieve analysis) is carried out in which the finer sieve used is 63 micron or the nearer opening. If a soil contains appreciable quantities of fine fractions in (less than 63 micron) wet analysis is done. One form of the analysis is hydrometer analysis. It is very much helpful to classify the soil as per ISI classification. The properties of the soil are very much influenced by the amount of clay and other fractions.

APPARATUS REQUIRED

1. Hydrometer
2. Glass measuring cylinder-Two of 1000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1000 ml volume. Thermometer- To cover the range 0 to 50º C with an accuracy of 0.5 º C.
3. Water bath.
4. Stirring apparatus.
5. I.S sieves apparatus.
6. Balance-accurate to 0.01 gm.
7. Oven-105º to 110º.
8. Stop watch.
9. Desiccators
10. Centimeter scale.
11. Porcelain evaporating dish.
12. Wide mouth conical flask or conical beaker of 1000 ml capacity.
13. Thick funnel-about 10 cm in diameter.
14. Filter flask-to take the funnel.
15. Measuring cylinder-100 ml capacity.
16. Wash bottle-containing distilled water.

17. Filter papers.
18. Glass rod-about 15 to 20 cm long and 4 to 5 mm in diameter.
19. Hydrogen peroxide-20 volume solution.
20. Hydrochloric acid N solution-89 ml of concentrated hydrochloric acid.(specific gravity 1.18) diluted with distilled water one litre of solution.
21. Sodium hexametaphosphate solution-dissolve 33 g of sodium hexametaphosphate and 7 gms of sodium carbonate in distilled water to make one litre of solution.

PROCEDURE

Volume

(a) Volume of water displaced: Approximately 800 ml of water shall be poured in the 1000 ml measuring cylinder. The reading of the water level shall be observed and recorded.

The hydrometer shall be immersed in the water and the level shall again be observed and recorded as the volume of the hydrometer bulb in ml plus volume of that part of the stem that is submerged. For practical purposes the error to the inclusion of this stem volume may be neglected.

(b) From the weight of the hydrometer: The hydrometer shall be weighed to the nearest 0.1 gm. The weight in gm shall be recorded as the volume of the bulb plus the volume of the stem below the 1000 ml graduation mark. For practical purposes the error due to the inclusion of this stem may be neglected.

Calibration

(a) The sectional area of the 1000 ml measuring cylinder in which the hydrometer is to used shall be determined by measuring the distance between the graduations. The sectional area is equal to the volume include between the two graduations divided by the measured distance between them.

1. The distance from the lowest reading to the center of the bulb is (R_h) shall be recorded ($R_h = H_L + L/2$).

2. The distance from the highest hydrometer reading to the center of the bulb shall be measured and recorded.

3. Draw a graph hydrometer readings vs H_H and R_H. A straight line is obtained. This calibration curve is used to calibrate the hydrometer readings which are taken with in 2 minutes.

4. From 4 minutes onwards the readings are to be taken by immersing the hydrometer each time. This makes the soil solution to rise, there by rising distance of free fall of the particle. So correction is applied to the hydrometer readings.

5. Correction applied to the R_h and H_H

V_h= Volume of hydrometer bulb in ml.

A=Area of measuring cylinder in cm^2.

From these two corrected readings draw graph (straight line)

Calculation

Total weight of dry soil taken, W =

Specific Gravity of soil, G =

Wt. Of soil gone into solution ,Ws =

Meniscus correction, Cn =

Dispersion agent correction =

Reading in water RW =

Temperature correction =

% finer for wt. Of soil Ws gone into solution N= [(100G)/ {Ws x (G)}] x R

OBSERVATIONS & CALCULATIONS

Elapsed Time in Sec	Hydrometer reading upper Meniscus Rh 1000	Corrected hydrometer Reading (1-lower meniscus Cm)	N(%finer For soil)

RESULT

Grain size distribution of soil is done by Hydrometer Analysis.

Grain Size Distribution:

1. What is meant by Cc?

   Cc if defined as Coefficient of Curvature. It depend on D10, D30 & D60 value from the grain size distribution Curve

2. What is meant by Cu?

   Cc if defined as Coefficient of Uniformity. It depend on D10& D60 value from the grain size distribution Curve

3. What is meant by Grain Size Distribution curve?

   The curve drawn in semi log sheet between the size of particles in X Axis and the % Finer in the Y Axis is called as grain size distribution curve.

4. What are the test to be done for drawing GSD?

   Sieve Analysis

   Sedimentation Analysis

5. What are the classification in sieve analysis?

   Coarse Soil Fraction

   Fine Soil Fraction

6. What are the correction to be carried out in Sedimentation Analysis?

   Correction due to Meniscus, Chemicals and Temperature

7. What to judge from Cc??

   If the value of Cc between 1 to 3 means, the soil is "Well Graded Soil" Else "Poorly Graded Soil"

8. What to judge from Cu?

If the value of Cu > 4 means, the soil is "Well Graded Sand" & Cu > 6 means, the soil is "Well Graded Gravel". Else "Poorly Graded Soil"

Ex.No:4

Date: **Determination of Liquid Limit and Plastic Limit**

AIM

To determine the liquid limit and plastic limit of the given soil sample

THEORY AND APPLICATION

Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil can be considered as soft if the moisture content is lesser than liquid limit. The soil is brittle and stiffer. The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

The moisture content expressed in percentage at which the soil has the smallest plasticity is called the plastic limit. Just after plastic limit the soil displays the properties of a semi solid. For determination purposes the plastic limit it is defined as the water content at which a soil just begins to crumble when rolled into a thread of 3mm in diameter. The values of liquid limit and plastic limit are directly used for classifying the fine grained soils. Once the soil is classified it helps in understanding the behaviour of soils and selecting the suitable method of design construction and maintenance of the structures made-up or and resting on soils.

APPARATUS REQUIRED:

1) Measuring balance
2) Liquid limit device (Casagrandes)
3) Grooving tool
4) 425 micron sieve
5) Glass plate
6) Spatula

7) Mixing bowl

8) Wash bottle

9) Mositure content bins

10) Drying oven

Procedure for liquid limit:

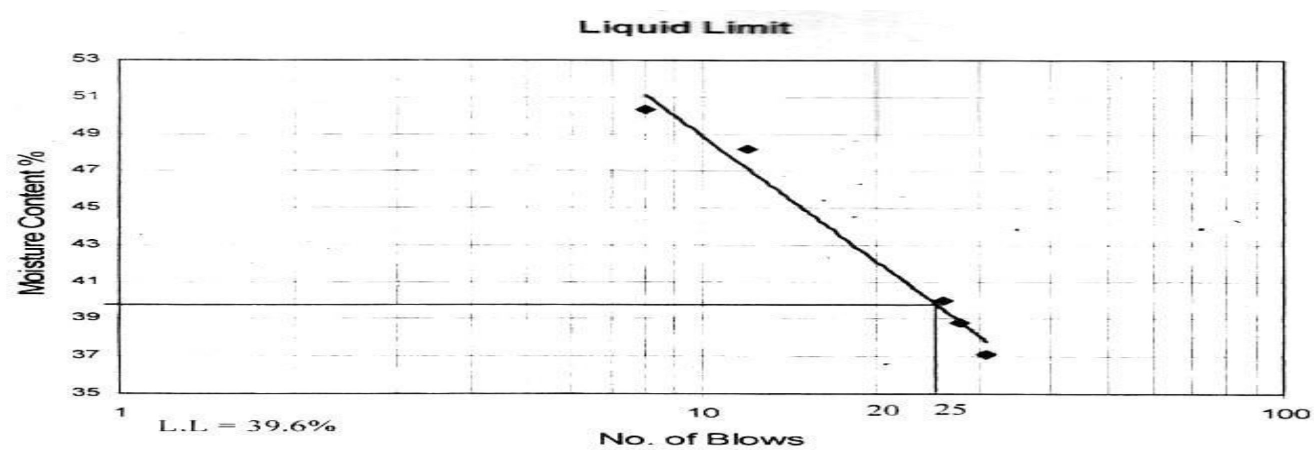
- About 120 gm of air dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is to be obtained.
- Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.
- A portion of the paste is placed in the cup of LIQUID LIMIT device and spread into portion with few strokes of spatula.
- Trim it to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.
- The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimension is formed
- Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only.
- The number of blows required to cause the groove close for about 1 cm shall be recorded.
- A representative portion (15gm) of soil is taken from the cup for water content determination by oven drying.
- Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

S.NO	PERCENTAGE OF WATER CONTENT	NO. OF BLOW
1		
2		
3		
4		
5		

S.No	Description	Test 1	Test 2	Test 3
1	No of blows (N)			
2	Container number			
3	Weight of the container + wet soil			
4	Weight of the container + dry soil			
5	Weight of the water (3 – 4)			
6	Weight of the container			
7	Weight of the dry soil (4 – 6)			
8	Moisture content (%), W = {(5 / 7)*100}			

Use the above table for recording number of blows and calculating the moisture content

- Use semi-log graph paper. Take number of blows on log scale (X –Axis) and water content on nominal scale (Y – axis). Plot all the points. (Flow curve)
- Read the water content at 25 blows which is the value of liquid limit.



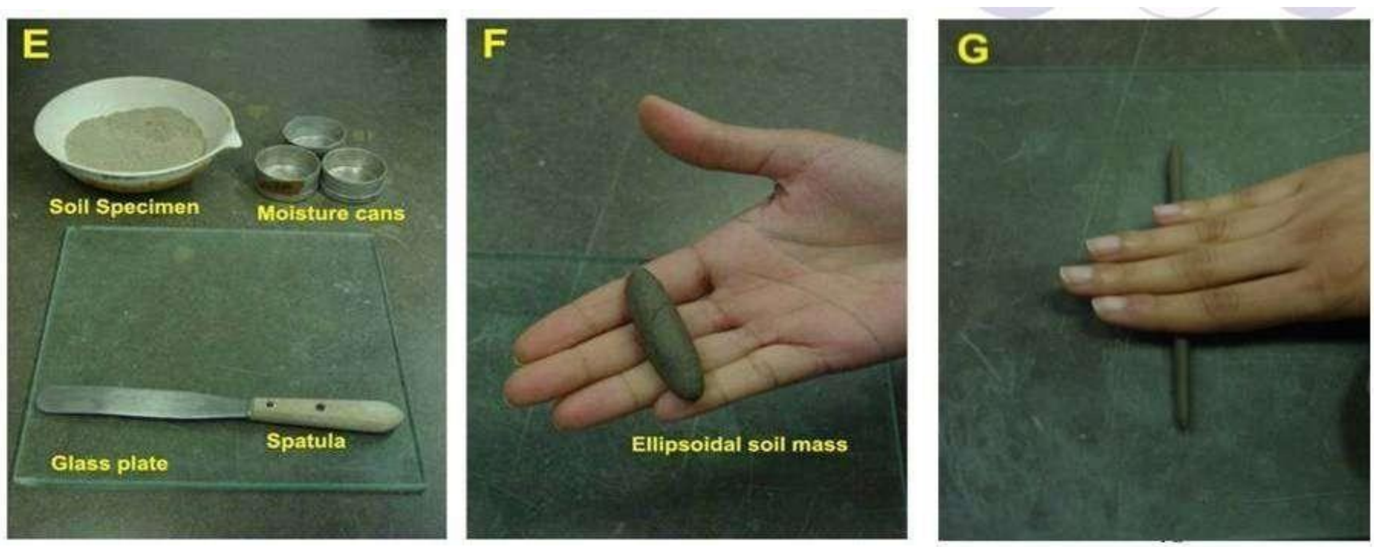
From graph,

Flow Index, IF = (W2 – W1) / log 10 (N2 – N1) =

Liquid Limit (LL) =

Procedure for plastic limit:

- Take about 20gm of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (part 1).
- Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily molded with fingers.
- Allow it to season for sufficient time (for 24 hrs) to allow water to permeate throughout the soil mass
- Take about 10gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 strokes per minute.
- Continue rolling till you get a threaded of 3 mm diameter.
- Kneed the soil together to a uniform mass and reroll.
- Continue the process until the thread crumbles when the diameter is 3 mm.
- Collect the pieces of the crumbled thread in air tight container for moisture content determination.
- Repeat the test to at least 3 times and take the average of the results calculated to the nearest whole number.
- Note: Compare the diameter of thread at intervals with the rod. When the diameter reduces to 3 mm, note the surface of the thread for cracks.



S.No	Description	Test 1	Test 2	Test 3
1	Container number			
2	Wt. container + Lid, W1			
3	Wt. container + Lid + Wet sample, W2			
4	Wt. container + Lid + Dry sample, W3			
5	Wt. of dry sample = W3 – W1			
6	Wt. of water in the soil = W3 – W2			
7	Water content (%) = [(W3 – W2) / (W3 – W1)] * 100			

Calculations for Plastic Limit:

- Collect the pieces of the crumbled thread in air tight container for moisture content determination and record the result as the plastic limit.

  Plastic Limit (PL) =

  Plasticity Index (IP) = (LL - – PL) =

  Toughness Index = (IP / IF) =

Results:

Liquid Limit =

Plastic Limit =

Flow Index =

Plasticity Index =

Toughness Index =

Ex.No:5

Date: Determination of Shrinkage Limit and Differential Free Swell Index

AIM:

To determine the shrinkage limit, shrinkage ratio and volumetric shrinkage for the given soil

THEORY:

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory it changes from liquid state to plastic state, from plastic state to semisolid state and then to solid state. Volume changes also occur with changes in water content. But there is particular limit at which any moisture change does not cause soil any volume change.

APPARATUS REQUIRED:

1. Evaporating Dish (Porcelain, about 12cm diameter with flat bottom).
2. Spatula
3. Shrinkage Dish (Circular, porcelain or non-corroding metal dish having a flat bottom and 45mm in diameter and 15 mm in height internally).
4. Straight Edge (Steel, 15 cm in length).
5. Glass cup (50 to 55 mm in diameter and 25 mm in height, the top rim of which is ground smooth and level).
6. Glass plates (Two, each 75 mm one plate shall be of plain glass and the other shall have prongs).
7. Sieves (2mm and 425micron IS sieves).
8. Oven thermostatically controlled.
9. Graduate Glass (having a capacity of 25 ml and graduated to 0.2 ml and 100 cc one mark flask).
10. Balance (Sensitive to 0.01 g minimum).
11. Mercury(Clean, sufficient to fill the glass cup to over flowing)
12. Wash bottle containing distilled water.

Procedure:

Preparation of soil paste

- Take about 100 gm of soil sample from a thoroughly mixed portion of the material passing through 425micron I.S. sieve.
- Place about 30 gm the above soil sample in the evaporating dish and thoroughly mixed with distilled water and make a creamy paste.
- Use water content somewhere around the liquid limit

Filling the shrinkage dish

- Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.
- Fill the dish in three layers by placing approximately 1/3 rd of the amount of wet soil with the help of spatula. Tap the dish gently on a firm base until the soil flows over the edges and no apparent air bubbles exist. Repeat this process for 2nd and 3rd layers also till the dish is completely filled with the wet soil.
- Strike off the excess soil and make the top of the dish smooth. Wipe off all the soil adhering to the outside of the dish.
- Weigh immediately, the dish with wet soil and record the weight.
- Air-dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven dry them to constant weight at 1050C to 1100C say about 12 to 16 hrs.
- Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.
- Determine the weight of the empty dish and record.
- Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows.
- Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly.
- Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.
- Volume of the Dry Soil Pat
- Determine the volume of dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the following manner.
- Place the glass cup in a larger one and fill the glass cup to overflowing with mercury. Remove the excess mercury by covering the cup with glass plate with prongs and pressing it. See that no air bubbles are entrapped. Wipe out the outside of the glass cup to remove the adhering mercury. Then, place it in another larger dish, which is, clean and empty carefully.
- Place the dry soil pat on the mercury. It floats submerge it with the pronged glass plate which is again made flush with top of the cup. The mercury spills over into the larger plate. Pour the mercury that is displayed by the soil pat into the measuring jar and find the volume of the soil pat directly.
- Caution: Do not touch the mercury with gold rings.

OBSERVATION

WEIGHT OF CONTAINER, gms	
Wt. Of wet sample + Container, gms	
Wt. Of dry sample + Container, gms	
Wt. Of Water	
Wt. Of wet soil pat	
Wt. Of dry soil pat	
Water content,in %	
Wt. Of mercury container, gms	
Wt. Of mercury displaced, gms	
Volume of displaced mercury = Volume of dry soil pat, Vd cm3	
Volume of container, V cm3	
Shrinkage Limit	
Shrinkage Ratio	

Results:

Shrinkage limit =

Shrinkage ratio =

Volumetric shrinkage =

ATTERBERG'S Limit:

1. What is meant by LL?

   The water content at the boundary limit between the plastic state and the liquid state is called Liquid limit

2. What is meant by PL?

   The water content at the boundary limit between the Semi solid state and the plastic state is called plastic limit

3. What is meant by SL?

   The water content at the boundary limit between the solid state and the semi solid state is called shrinkage limit

4. What are the methods to find Liquid Limit?

   Casagrande Liquid Limit Test, One Point Method

5. How to find Shrinkage Limit in Lab?

   It is found by using Mercury Displacement Method. Because, SL can't be find by directly.

6. What are the characteristics of Degree of saturation at different states?

   Degree of Saturation is 0 to 100 % at in Solid State. After that, Degree of saturation is 100%. At LL, PL & SL, Degree of saturation is 100%

7. How to find the consolidation of clay in soil

   Consolidation of clay is found using the Cc value, Initial Void ratio, Effective Vertical Stress over the soil

8. How to Judge the soil based on A Line.

   If soil falls above A Line, it is Inorganic Clay and the Soil falls below A line, soil is Organic Clay.

9. What is the purpose of finding LL, Pl & SL?

   To Classify the fine Grained Soil based on BIS classification. If LL<35%, Soil is Low Compressibility. If LL is between 35 to 50%, soil Medium Compressibility. If the LL > 50%, Soil is High Compressibility.

10. What is meant by A Line?

    In consistency Chart, to classify the soil A Line is needed. A Line equation is

    $I_p = 0.73 (LL – 20)$

Ex.No:6

Date: **Determination of Field Density (Sand Replacement Method)**

AIM:

To determine the field density of soil at a given location by sand replacement method.

THEORY:

In core cutter method the unit weight of soil obtained from direct measurement of weight and volume of soil obtained from field. Particularly for sandy soils the core cutter method is not possible. In such situations the sand replacement method is employed to determine the unit weight. In sand replacement method a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand, whose density is known, is filled into the pit. By measuring the weight of sand required to fill the pit and knowing the density of soil , volume of the pit is calculated .Knowing the weight of soil excavated from the pit and the volume of pit the density of soil is calculated. Therefore in this experiment there are two stages (1) Calibration of sand density and (2) Measurement of soil density.

APPARATUS

1. Moisture content cups
2. Sand pouring Cylinder
3. Calibrating can
4. Metal tray with a central hole
5. Dry sand (Passing through 600 micron sieve)
6. Balance
7. Metal tray
8. Scraper tool
9. Glass plate

PROCEDURE

CALIBRATION OF SAND DENSITY

- Measure the internal dimensions diameter (d) and height (h) of the calibrating can and compute its internal volume V.
- Fill the sand pouring cylinder (SPC) with sand with 1 cm top clearance to avoid any spillover during operation and find its weight (W1)

- Place the SPC on a glass plate, open the slit above the cone by operating the valve and allow the sand to run down. The sand will freely run down till it fills the conical portion. When there is no further downward movement of sand in the SPC, close the slit.
- Find the weight of the SPC along with the sand remaining after filling the cone (W2)
- Place the SPC concentrically on top of the calibrating can. Open the slit to allow the sand to rundown until the sand flow stops by itself. This operation will fill the calibrating can and the conical portion of the SPC. Now close thes lit and find the weight of the SPC with the remaining sand(W3)

MEASUREMENT OF SOIL DENSITY

- Clean and level the ground surface where the field density is to be determined.
- Place the tray with a central hole over the portion of the soil to be tested.
- Excavate a pit into the ground, through the hole in the plate , approximately 12cm deep (Close the height of the calibrating can) The hole in the tray will guide the diameter of the pit to be made in the ground.
- Collect the excavated soil into the tray and weigh the soil (W)
- Determine the moisture content of the excavated soil.
- Place the SPC, with sand having the latest weight of W3, over the pit so that the base of the cylinder covers the pit concentrically.
- Open the slit of the SPC and allow the sand to run into the pit freely, till there is no downward movement of sand level in the SPC and then close the slit.
- Find the weight of the SPC with the remaining sand W4.

OBSERVATION – SAND REPLACEMENT METHOD

S.No	Description	Test 1
	CALIBERATION OF APPARATUS	
1	Weight of sand + cylinder before pouring (W1) (g)	
2	Mean weight of sand pouring cylinder with remaining sand after filling in cone (W2)	
3	Volume of calibrating container (V) cc	

4	Mean weight of sand pouring cylinder with remaining sand after filling in cone and	
5	Weight of sand filling calibrating containers, Wa = (W1 – W3 – W2) (g)	
6	Calibrated Bulk density of sand, ρS = (5/3) (g/cc)	
	MEASUREMENT OF INSITU SOIL DENSITY	
7	Weight of wet soil from the hole or Wt. of excavated Soil (Ws or WW) (g)	
8	Weight of sand + cylinder after pouring in the hole and cone (W4) (g)	
9	Weight of sand in the hole, Wh = (W1 – W4 – W2) (g)	
10	Bulk density of soil, ρ W / Wh)* ρS (g/cm3)	
11	Bulk unit weight of soil, γ 9.8 * ρ kN/m3)	
12	Container Number	
13	Weight of container + wet soil (g)	
14	Weight of container + dry soil (g)	
15	Weight of container (g)	
16	Weight of dry soil (g)	
17	Weight of water (g)	
18	Water content, W = (R17/R16)*100 (%)	

RESULT

1. **Dry unit weight of the soil =**
2. **Wet unit weight of the soil =**
3. **Void ratio of the soil =**
4. **Porosity of the soil =**
5. **Degree of saturation =**

Ex.No:7

Date: **Determination of Moisture Density Relationship (Proctor Compaction)**

AIM:

To determine Optimum Moisture Content and Maximum dry density for a soil by conducting standard proctor compaction test

THEORY:

Compaction is the process of densification of soil mass, by reducing air voids under dynamic loading. On the other hand though consolidation is also a process of densification of soil mass but it is due to the expulsion of water under the action of continuously acting static load over a long period.The degree of compaction of a soil is measured in terms of its dry density. The degree of compaction mainly depends upon its moisture content during compaction, compaction energy and the type of soil. For a given compaction energy, every soil attains the maximum dry density at a particular water content which is known as optimum moisture content (OMC).Compaction of soil increases its dry density, shear strength and bearing capacity. The compaction of soil decreases its void ratio permeability and settlements. The results of this test are useful in studying the stability earthen structures like earthen dams, embankments roads and airfields. In such constructions the soils are compacted. The moisture content at which the soils are to be compacted in the field is estimated by the value of optimum moisture content determined by the Proctor compaction test.

APPARATUS REQUIRED:

1) Proctor mould having a capacity of 1000 cc with an internal diameter of 100 mm and a height of 127.3 mm. The mould shall have a detachable collar assembly and a detachable base plate.

2) Rammer: A mechanical operated metal rammer having a 5.08 cm diameter face and a weight of 2.5 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 30 cm.

3) Sample extruder.

4) A balance of 15 kg capacity.

5) Sensitive balance.

6) Straight edge.

7) Graduated cylinder.

8) Mixing tools such as mixing pan, spoon, towel, spatula etc.

9) Moisture tins.

PROCEDURE:

- Take about 3 kg of air dried soil
- Sieve the soil through 20mm sieve.Take the soil that passes through the sieve for testing.
- Take 2.5 kg of the soil and add water to ti to bring its moisture content to about 4% in coarse grained soils and 8% in case of fine grained soils.
- Clean , dry and grease the mould and base plate .Weigh the mould with base plate. Fit the collar.
- Compact the wet soil in three equal layers by the rammer with 25 evenly distributed blows in each layer.
- Remove the collar and trim off the soil flush with the top of the mould. In removing the collar rotate it to break the bond between it and the soil before lifting it off the mould.
- Clean the outside of the mould and weigh the mould with soil and base plate.
- Remove the soil from the mould and obtain a representative soil sample from the bottom, middle and top for water content determination
- Repeat the above procedure with 8,12,16 and 210 % of water contents for coarse grained soil and 14,18,22 and 26 % for fine grained soil samples approximately.
- The above moisture contents are given only for guidance. However, the moisture contents may be selected based on experience so that, the dry density of soil shows the increase in moisture content.Each trial should be performed on a fresh sample.

OBSERVATION

Dia. of the mould, D (cm) = Vol. of the mould, V (cm^3) =

Ht. of the mould, H (cm) = Wt. of the mould, W1 (g) =

S.No	Description	Test 1	Test 2	Test 3	Test 4
(a) Density					
1	Weight of the mould + compacted soil (W2) (g)				
2	Weight of mould (W1) (g)				
3	Weight of compacted soil, W (W2 – W1) (g)				
4	Bulk density (g/cm^3)				
5	Dry density (g/cm^3)				

6	Water content %,w				
	Zero void ratio (Gsϒw)/(1 + (wGs/100))				
	Void ratio, e = ((Gsϒw)/(ϒd)) - 1				
(b) Water content					
	Container number				
7	Empty weight of container (g)				
8	Weight of container + wet soil (g)				
9	Weight of container + dry soil (g)				
10	Weight of dry soil (R8 – R7) (g)				
11	Weight of wet soil (R9 – R7) (g)				
12	Weight of water (R8 – R9) (g)				
13	Moisture content, W [(R12 / R10)*100] (%)				

Results:

Optimum Moisture Content (OMC) % =

Maximum dry density (g/cc) =

Field Density Test

1. What is meant by Density of soil?

   The Ratio of Mass of the soil to the volume of the soil is called as density of soil.

2. What are the different forms of Density of soil?

   Dry Density

   Wet / Bulk Density

   Saturated Density

   Submerged Density

3. What are the methods to find Field Density of Soil?

   Sand Replacement Method

   Core Cutter Method

4. What are the importances of finding field density?

   To confirm the achievement of compaction during sub grade preparation.

5. What are the different Field Methods to compact the soil?

   Rollers, Tampers ,Vibrators ,Terra Probe method

6. What are the Disadvantages of Core Cutter Test?

   While taking out the core cutter from the ground, the soil present at the bottom portion may get collapse and fall down

7. What are the disadvantages of sand replacement test?

   Generally, it gives good results. But if the calibration of clean sand gets error, final finding also will be error

8. What is the range of Permeability for Course sand?

   More Than 10-3 mm/sec

9. How to classify the permeability of soil?

   High, Medium, Low, Very Low & Impervious

10. What is meant by Permeability?

    The flow of water inside the soil pores is called as Permeability

Ex.No:8

Date: Determination of Relative Density of Cohesion less Soils (Demonstration)

AIM:

To determine the relative density of cohesion less soil.

THEORY

Relative density is also known as density index. It is defined as the ratio of difference between the void ratio of cohesion less soil in the loosest state and any given void ratio to the difference between its void ratios in the loosest and in the densest states. The concept of density index gives a practically useful measure of compactness of such soils. The compactive characteristics of cohesion less soils and the related properties of such soils are dependent on factors like grain size distribution and shape of individual particles. The compactive characteristics of cohesion less soils s and the related properties of such soils are dependent on factors like grain size distribution and shape of individual particles. Relative density is also effected by these factors and serves as a parameter to correlate properties of soils. Various soil properties such as penetration resistance, compressibility, compaction , friction angle , permeability and CBR has been found to have simple relationships with relative density.

APPARATUS REQUIRED

1. Vibratory table: A steel table with cushioned steel vibrating deck about 75 x 75 cm. The vibrator should have a net weight of over 45 kg. The vibrator should have frequency of 3600 vibrations per minute, a vibrator amplitude variable between 0.05 and 0.65 mm under a115 kg load.

2. Moulds: Cylindrical metal density moulds of 3000cc 150mm dia and 169.77 mm high.

3. One guide sleeve: With clamp assembly should be provided with lock nuts.

4. Surcharge base plate: 10mm thick with handle for each mould.

5. One dial gauge holder

6. Dial gauge: A dial gauge with 50mm travel and 0.02 mm least count.

7. Pouring devices : Consisting of funnels 12mm and 25 mm in diameter and 150 mm long with cylindrical spots and lipped brims for attaching to 150mm and 300 mm high metal cans.

8. Mixing pans: Two mixing pans

`

PROCEDURE

The test procedure to determine the relative density of soil involves the measurement of density of soil in its loosest possible state ( ) and densest possible state ( ) .Knowing the specific gravity of soil solids (G) the void ratios of the soil in its loosest (emax) and densest state (emin) are computed. The density of soil in the field () (natural state) is used to compute void ratio (e) in the field. After obtaining the three void ratios the relative density is computed. For 4.75mm size particles 3000cc mould is used. Moulds are first calibrated, Then the densities of the soil are obtained.

CALIBRATION OF MOULDS

To calibrate the mould should be filled with water and a glass plate should be slide carefully over the top surface of the mould in such a manner as to ensure that the mould is completely filled with water. The volume of the mould should be calculated in cc by dividing the weight of water in the mould by the unit weight of water.

PREPARATION OF SOIL SAMPLE

A representative sample of soil should be selected. The weight of soil sample to be taken depends upon the maximum size of particles in the soil .The soil sample should be dried in an oven at a temperature of 105ºc to 110ºc .The soil sample should be pulverized without breaking the individual soil particles and sieved through the required sieve.

PROCEDURE FOR THE DETERMINATION OF MINIMUM DENSITY

1. The pouring device and mould should be selected according to the maximum size of particle. The mould should be weighed and weight recorded. Oven dry soil should be used.

2. Soil containing particles smaller than 10mm should be placed as loosely as possible in the mould by pouring the soil through the spout in a steady stream. The spout should be adjusted so that the height of free fall of the soils always 25mm.While pouring the soil the pouring device should be moved in a spiral motion from the outside towards the centre to form a soil layer of uniform thickness without segregation. The mould should be filled approximately 25mm above the top and leveled with the top by making one continuous pass with steel straight edge. If all excess material is not removed an additional continuous pass should be made. Great care shall be exercised to avoid jarring during the entire pouring and trimming operation.

3. The mould and the soil should be weighed and the weight recorded.

4. Soil containing particles larger than 10mm should be placed by means of a large scoop held as close as possible to and just above the soil surface to cause the material to slide rather than fall into the previously placed soil. If necessary large particles may be held by hand to prevent them from rolling offs the scoop.

5. The mould should be filled to overflowing but not more than 25mm above the top. The surface of the soil should be leveled with the top of the mould using the steel straight edge in such a way that any slight projections of the larger particles above the top of the mould shall approximately balance the large voids in the surface below the top of the mould.

6. The mould and the soil should be weighed and the weight recorded.

OBSERVATION:

Weigh of the mould =

Volume of the mould =

Sl.No	**Description**	**Trial 1**	**Trial2**	**Trial3**
1	Weight of the mould , gms			
2	Weight of the soil + mould gms			
3	Weight of the soil W gms			
4	Calibrated volume of mould V_c			
5	Minimum density			

RESULT

Minimum density =

Ex.No:9

Date: **Determination of Permeability of Soil (Constant Head Method)**

AIM:

To determine the coefficient of permeability of the soil by conducting constant head method.

THEORY

The property of the soil which permits water to percolate through its continuously connected voids is called its permeability .Water flowing through the soil exerts considerable seepage forces which has direct effect on the safety of hydraulic structures. The quantity of water escaping through and beneath and earthen dam depends on the permeability of the embankment and the foundation soil respectively. The rate of settlement of foundation depends on the permeability properties of the foundation soil.

APPARATUS REQUIRED

1. Permeability apparatus with accessories
2. Stop watch
3. Measuring jar

PROCEDURE – Constant Head Method

- Compact the soil into the mould at a given dry density and moisture content by a suitable device. Place the specimen centrally over the bottom porous disc and filter paper.
- Place a filter paper, porous stone and washer on top of the soil sample and fix the top collar.
- Connect the stand pipe to the inlet of the top plate.Fill the stand pipe with water.
- Connect the reservoir with water to the outlet at the bottom of the mould and allow the water to flow through and ensure complete saturation of the sample.
- Open the air valve at the top and allow the water to flow out so that the air in the cylinder is removed.
- When steady flow is reached, collect the water in a measuring flask for a convenient time intervals by keeping the head constant. The constant head of flow is provided with the help of constant head reservoir
- Repeat the for three more different time intervals

OBSERVATIONS AND CALCULATIONS – Constant Head Method

Calculate the coefficient of permeability of soil using the equation

$$K = QL / Ath$$

Where

K = Coefficient of permeability

Q = Quantity of water collected in time t sec (cc)

t = Time required (sec)

A = Cross sectional area of the soil sample (sq.cm)

h = Constant hydraulic head (cm)

L = Length of soil sample (cm)

DIA OF SPECIMEN , D=
Length of Specimen L =
Head =
Area of specimen =

S.no.	Time, t sec	Quantity of discharge, Q cm^3	K_T cm/sec

RESULT:

Coefficient of permeability of the given soil sample by

Constant Head Method =

Ex.No:10

Date: **Determination of Permeability of Soil (Variable Head Method)**

AIM:

To determine the coefficient of permeability of the soil by conducting falling head method.

THEORY

The property of the soil which permits water to percolate through its continuously connected voids is called its permeability .Water flowing through the soil exerts considerable seepage forces which has direct effect on the safety of hydraulic structures. The quantity of water escaping through and beneath and earthen dam depends on the permeability of the embankment and the foundation soil respectively. The rate of settlement of foundation depends on the permeability properties of the foundation soil.

APPARATUS REQUIRED

1. Permeability apparatus with accessories
2. Stop watch
3. Measuring jar

PROCEDURE – Falling Head Method

- Compact the soil into the mould at a given dry density and moisture content by a suitable device. Place the specimen centrally over the bottom porous disc and filter paper.
- Place a filter paper, porous stone and washer on top of the soil sample and fix the top collar.
- Connect the stand pipe to the inlet of the top plate. Fill the stand pipe with water.
- Connect the reservoir with water to the outlet at the bottom of the mould and allow the water to flow through and ensure complete saturation of the sample.
- Open the air valve at the top and allow the water to flow out so that the air in the cylinder is removed.
- Fix the height h1 and h2 on the pipe from the top of water level in the reservoir
- When all the air has escaped, close the air valve and allow the water from the pipe to flow through the soil and establish a steady flow.
- Record the time required for the water head to fall from h1 to h2.
- Change the height h1 and h2 and record the time required for the fall of head.

OBSERVATIONS AND CALCULATIONS – Variable Head Method

Calculate the coefficient of permeability of soil using the equation.

$$K = 2.303\ Al / At\ Log_{10}(h1/h2)$$

Where

K = Coefficient of permeability

a = Area of stand pipe (sq.cm)

t = Time required for the head to fall from h1 to h2 (sec)

A = Cross sectional area of the soil sample (sq.cm)

L = Length of soil sample (cm)

h1 = Initial head of water in the stand pipe above the water level in the reservoir (cm)

h2 = final head of water in the stand pipe above the water level in the reservoir (cm)

(i) Diameter of the stand pipe (cm) =

(ii) Cross sectional area of stand pipe (sq.cm) =

(iii) Length of soil sample (cm) =

(iv) Area of soil sample (sq.cm) =

S.no.	Time, t sec	Initial head , h1 cm	Final head , h2 cm	$\log_{10}$ h1/h2	K_T cm/sec

RESULT:

Coefficient of permeability of the given soil sample by

Falling Head Method =

Co-efficient of Permeability:

1. What is meant by Permeability?

   The flow of water inside the soil pores is called as Permeability.

2. What are the methods to find Permeability?

   Direct Method

      Constant Head Permeability Test Method

      Falling Head Permeability Test Method

      Pumping Out Test

      Pumping In Test

   Indirect Method

      Found using Soil Particle Size

3. Which method is suitable for Sandy Soil?

   For Sandy soil, the Constant Head permeability Test to be adopted

4. Which method is suitable for Clayey Soil?

   For Clayey soil, the Variable Head permeability Test to be adopted

5. What is the range of Permeability for Clay?

   Less Than 10^{-9} mm/sec.

6. What is the range of Permeability for Silt?

   10^{-7} mm/sec to 10^{-9} mm/sec

7. What is the range of Permeability for Fine Clay?

   10^{-5} mm/sec to 10^{-7} mm/sec

8. What is the range of Permeability for Clean Sand?

   10-^{3} mm/sec to 10^{-5} mm/sec

9. What is the range of Permeability for Course sand?

   More Than 10^{-3} mm/sec

10. How to classify the permeability of soil?

    High, Medium, Low, Very Low & Impervious

Ex.No:11

Date: **Determination of Coefficient of Consolidation**

AIM

To determine the coefficient of consolidation of a given clay soil.

THEORY

When a load is applied on a saturated soil, the load will initially be transferred to the water in pores of the soil .This results in development of pressure in pore water which results in the escape of water from voids and brings the soil particles together. The process of escape of water under applied load, leads to reduction in volume of voids and hence the volume of soil. The process of reduction of volume of voids due to expulsion of water under sustained static load is known as consolidation. The magnitude of consolidation depends on the amount of voids or void ratio of the soil. The rate of consolidation depends on the permeability properties of soil. The two important consolidation properties of soil are (i) co-efficient of consolidation (Cv) and (ii) Compression index (Cc). The coefficient of consolidation reflects the behaviour of soil with respect to time under a given load intensity. Compression index explains the behaviour of soils under increased loads.

APPARATUS REQUIRED

1. Consolidometer consisting of specimen ring.
2. Guide ring
3. Porous stones
4. Dial gauges
5. Stop watch

PROCEDURE

Preparation of specimen

Sufficient thickness of the soil specimen is cut from undisturbed sample. The consolidation ring is gradually inserted into the sample. The consolidation ring is gradually inserted into the sample by pressing and carefully removing the material around it. The specimen should be trimmed smooth and flush to the ends of the ring. Any voids in the specimen caused due to removal of gravel or limestone pieces should be filled back by pressing completely the loose soil in the voids. The ring should be wiped clean and weighed again with the soil. Place wet filter paper on top and bottom faces of the sample and two porous stones covering it should be in place. Place this whole assembly in the loading frame. Over the porous stone a perforated plate with loading ball is placed

The sample is put for saturation both from top and bottom. After allowing time for saturation the load is applied through the loading frame. The settlement in sample is measured using a dial gauge. The stepwise procedure for observing reading is as follows:

1. Apply the required load intensity (stress) at which Cv is to be determined.

2. As the loading is applied, the stop watch should be started.

3. Take the readings of the dial gauge at different time interval from the time of loading and record them in the table.

OBSERVATION AND CALCULATIONS

(a) Square root method

1. Record the dial gauge readings at different time interval from the point of loading in Table.

2. Plot a graph between √t on X axis and dial gauge reading on Y axis .Where t is time in minutes.

3. The curve drawn reflects three components of settlement (i) Immediate settlement or elastic compression. This will be reflected in the form of steep settlements in a small time interval and a nearly vertical line at the initial portion of the curve represents it. This is followed by (ii) Primary consolidation curve, which will be nearly a straight line with a reduced sloe. The majority of consolidation will be in this zone. After primary consolidation (iii) Secondary consolidation takes place that is marked by a curve nearly parallel to time axis.

4. Draw a straight line through a primary consolidation zone. Identification of primary consolidation zone depends on experience and eye judgement. Extent the straight line to meet Y- axis at Oc. Oc is the corrected zero.

5. Draw another straight line through Oc , with a slope equal to 1.15 times the slope of the earlier straight line.

6. The Straight line so drawn (with 1.15 times the slope of primary consolidation line will intersect the originally plotted curve at a point. The X co ordinate of this point will give √t90. Where t90 is the time required for 90% consolidation (in minutes)

7. The coefficient of consolidation is calculated as follows

$$Cv = 0.848\ H2 / (t90 \times 60)\ \ cm^2/sec.$$

Where H = length of drainage path (cm)

H = half thickness of soil sample for double drainage and H = thickness of soil sample for single drainage

t_{90} = time required for 90% consolidation in minutes.

(b) Log - method

1. The compression dial readings should be plotted against the log of time and a smooth curve drawn to pass through the points.

2. The two straight portions of the curve should be extended to intersect at a point , the ordinate of which gives d_{100} corresponding to 100% primary compression.

3. The corrected zero point ds shall be located by the laying of above point in the neighbourhood of 0.1 minute a distance equal to the vertical distance between this point and one at a time which is four times this value

4. The 50% compression point which is halfway between the corrected zero point and the 100% compression point, shall be marked on the curve and the readings on the time axis corresponding to this point t_{50}, time to 50% primary compression, shall be noted. The readings on the dial gauge reading axis, corresponding to 100% compression gives d_{100}.

5. Coefficient of consolidation is calculated as follows

$$C_v = 0.197\ H^2/\ t_{50}.$$

TABULATION

Dimensions of sample: Diameter = Thickness =

Unit weight of soil =

Elapsed time In minutes, t	√t	Dial gauge reading
1	2	3
0		
0.25		
2.25		
4.00		
6.25		

9.00		
12.25		
16.00		
20.25		
25.00		
36.00		
49.00		
64.00		
81.00		
100.00		
121.00		
144.00		
169.00		
225.00		
256.00		

RESULT

Co efficient of Consolidation of the given soil sample Cv =

Ex.No:12

Date: **Direct shear test in cohesion-less soil**

AIM:

To determine the shearing strength of the soil using the direct shear apparatus.

THEORY:

Shear strength of a soil is its maximum resistance to shearing stresses. It is equal to the shear stress at failure on the failure plane. Shear strength is composed of (i) internal frictions, which is the resistance due to the friction between the individual particles at their contact points and inter locking of particles. (ii) cohesion which is the resistance due to inter particle forces which tend to hold the particles together in a soil mass. Coulomb has represented the shear strength of the soil by the equation :

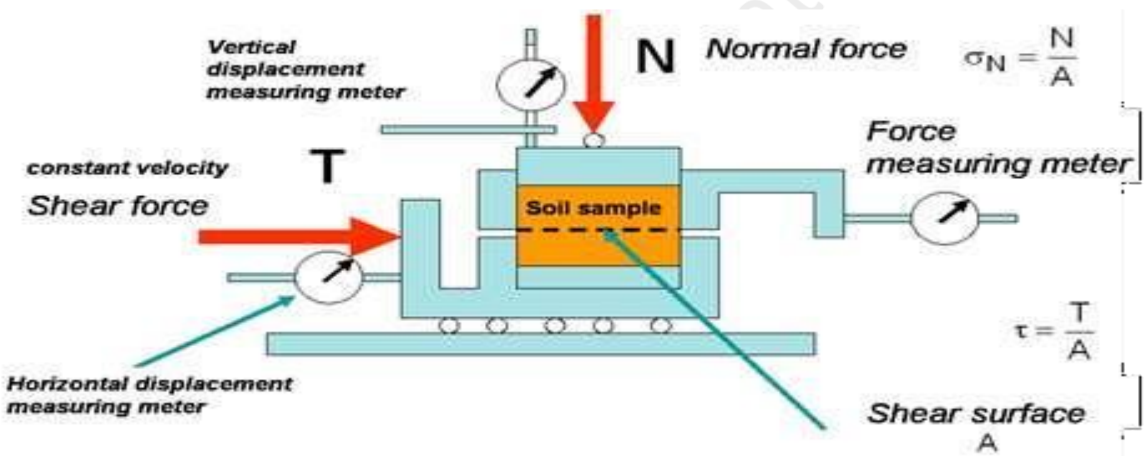
APPARATUS REQUIRED:

1) Direct shear box apparatus
2) Loading frame (motor attached).
3) Dial gauge.
4) Proving ring.
5) Tamper.
6) Straight edge.
7) Balance to weigh upto 200 mg.
8) Aluminum container.
9) Spatula.

PROCEDURE:

- Check the inner dimension of the soil container.
- Put the parts of the soil container together.
- Calculate the volume of the container. Weigh the container.
- Place the soil in smooth layers (approximately 10 mm thick). If a dense sample is desired tamp the soil.
- Weigh the soil container, the difference of these two is the weight of the soil. Calculate the density of the soil.
- Make the surface of the soil plane.
- Put the upper grating on stone and loading block on top of soil.
- Measure the thickness of soil specimen.
- Apply the desired normal load.

- Remove the shear pin.
- Attach the dial gauge which measures the change of volume.
- Record the initial reading of the dial gauge and calibration values.
- Before proceeding to test check all adjustments to see that there is no connection between two parts except sand/soil.
- Start the motor. Take the reading of the shear force and record the reading.
- Take volume change readings till failure.
- Add 5 kg normal stress 0.5 kg/cm2 and continue the experiment till failure.
- Record carefully all the readings. Set the dial gauges zero, before starting the experiment



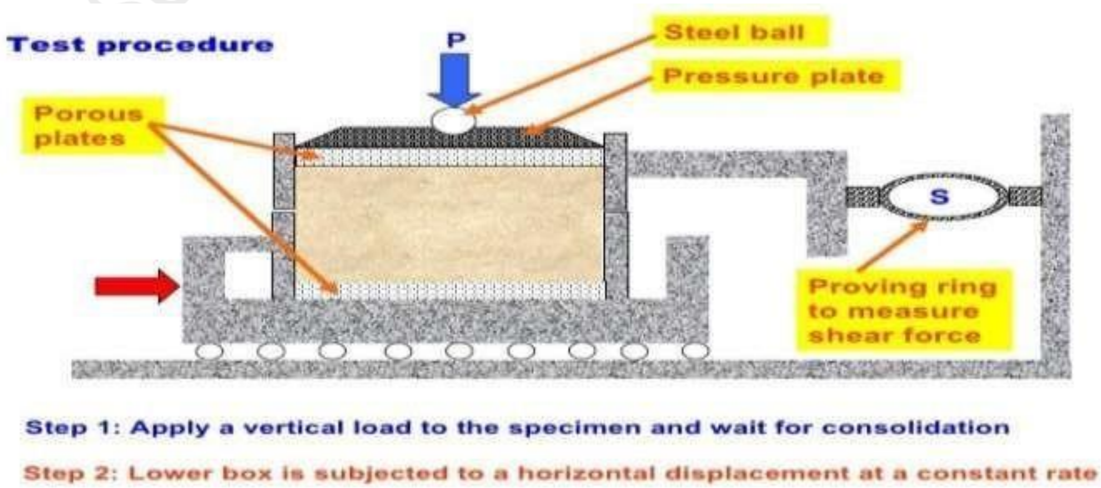


Table: Observation for Direct Shear test (Table 1: Normal stress 0.5 kg/cm^2)

Least count of the dial : Proving ring constant :

Horizontal Gauge reading (1)	Vertical dial gauge reading (2)	Proving ring reading (3)	Hor. Dial gauge reading Initial reading div. Gauge (4)	Shear deformation col. (4) X Least count of dial (5)	Vertical gauge reading Initial reading (6)	Vertical deformation = div. In col. (6) X L.C of dial gauge (7)	Proving reading Initial reading (8)	Shear stress = div. Col. (8) X Proving ring constant area of the specimen (kg/cm^2) (9)
0								
25								
50								
75								
100								
125								
150								
175								
200								
250								
300								
400								
500								
600								
700								
800								
900								

Table: Observation for Direct Shear test (Table 1: Normal stress 1 kg/cm^2)

Least count of the dial : Proving ring constant :

Horizontal Gauge reading (1)	Vertical dial gauge reading (2)	Proving ring reading (3)	Hor. Dial gauge reading Initial reading div. Gauge (4)	Shear deformation col. (4) X Least count of dial (5)	Vertical gauge reading Initial reading (6)	Vertical deformation = div. In col. (6) X L.C of dial gauge (7)	Proving reading Initial reading (8)	Shear stress = div. Col. (8) X Proving ring constant area of the specimen (kg/cm^2) (9)
0								
25								
50								
75								
100								
125								
150								
175								
200								
250								
300								
400								
500								
600								
700								
800								
900								

Table: Observation for Direct Shear test (Table 1: Normal stress 1.5 kg/cm^2)

Least count of the dial : Proving ring constant :

Horizontal Gauge reading (1)	Vertical dial gauge reading (2)	Proving ring reading (3)	Hor. Dial gauge reading Initial reading div. Gauge (4)	Shear deformation col. (4) X Least count of dial (5)	Vertical gauge reading Initial reading (6)	Vertical deformation = div. In col. (6) X L.C of dial gauge (7)	Proving reading Initial reading (8)	Shear stress = div. Col. (8) X Proving ring constant area of the specimen (kg/cm^2) (9)
0								
25								
50								
75								
100								
125								
150								
175								
200								
250								
300								
400								
500								
600								
700								
800								
900								

Calculations:

Sample Size =

Area of sample , Ao =

Volume of sample, V =

Weight of sample, w =

Density of sample =

S.NO	PROVING RING READING		SHEAR FORCE, Pn, kg	Applied Load ,kg	Normal force, Pv	Normal Stress	Shear stress , T = Pn/ A
	Initial Div	Final Div					
1							
2							
3							

RESULT

The shear strength parameters of the given soil sample,

τ =

Ex.No:13

Date: **Determination of Unconfined Compression in Cohesive Soil**

AIM

To determine the shearing strength of the cohesive soil.

THEORY:

The unconfined compression test is a special case of tri axial compression test in which σ2, σ3 = 0. The cell pressure in the tri axial cell is also called the confining pressure. Due to the absence of such a confining pressure, the uniaxial test is called the unconfined compression test. The cylindrical specimen of soil is subjected to major principal stress σ1 till the specimen fails due to shearing along a critical plane of failure.

APPARATUS REQUIRED:

1) Loading frame of capacity of 2 t, with constant rate of movement.
2) Proving ring.
3) Soil trimmer.
4) Frictionless end plates of 75 mm diameter (Perspex plate with silicon grease coating).
5) Evaporating dish (Aluminum container).
6) Soil sample of 75 mm length.
7) Dial gauge (0.01 mm accuracy).
8) Balance of capacity 200 g and sensitivity to weigh 0.01 g.
9) Oven, thermostatically controlled with interior of noncorroding material to maintain the temperature at the desired level. What is the range of the temperature used for drying the soil.
10) Sample extractor and split sampler.
11) Dial gauge (sensitivity 0.01mm).
12) Vernier calipers to find out the diameter and length of the specimen.

PROCEDURE:

- In this test, a cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called Unconfined compressive strength of the soil.

Preparation of specimen for testing

A. Undisturbed specimen

- Note down the sample number, bore hole number and the depth at which the sample was taken.
- Remove the protective cover (paraffin wax) from the sampling tube.
- Place the sampling tube extractor and push the plunger till a small length of sample moves out.
- Trim the projected sample using a wire saw.
- Again push the plunger of the extractor till a 75 mm long sample comes out.
- Cutout this sample carefully and hold it on the split sampler so that it does not fall.
- Take about 10 to 15 g of soil from the tube for water content determination.
- Note the container number and take the net weight of the sample and the container.
- Measure the diameter at the top, middle, and the bottom of the sample and find the average and record the same.

B. Moulded sample

- For the desired water content and the dry density, calculate the weight of the dry soil Ws required for preparing a specimen of 3.8 cm diameter and 7.5 cm long.
- Add required quantity of water Ww to this soil.
- Ww = WS * W/100 gm
- Mix the soil thoroughly with water.
- Place the wet soil in a tight thick polythene bag in a humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
- After 24 hours take the soil from the humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
- Place the lubricated moulded with plungers in position in the load frame.
- Apply the compressive load till the specimen is compacted to a height of 7.5 cm.
- Eject the specimen from the constant volume mould.
- Record the correct height, weight and diameter of the specimen.

TEST PROCEDURE

- Take two frictionless bearing plates of 75 mm diameter.
- Place the specimen on the base plate of the load frame (sandwiched between the end plates).
- Place a hardened steel ball on the bearing plate.
- Adjust the center line of the specimen such that the proving ring and the steel ball are in the same line.
- Fix a dial gauge to measure the vertical compression of the specimen.
- Adjust the gear position on the load frame to give suitable vertical displacement.
- Start applying the load and record the readings of the proving ring dial and compression dial for every 5 mm compression.

- Continue loading till failure is complete.
- Draw the sketch of the failure pattern in the specimen.

Table: Observation for UCC test

Specific gravity, G : Bulk density (Initial) :

Initial water content : Degree of saturation :

Initial diameter of the specimen (D_O) cm :

Initial Length of the specimen (L_O) mm :

Initial area of cross section (A_O) cm^2 :

S.No	Elapsed time (min)	Axial load, P (kg)	Compression dial reading, ΔL (mm)	Strain, ϵ (%)	Area, A (cm^2)	Compressive stress, σ (kg/cm^2)
1						
2						
3						
4						

Calculations:

The axial strain, ϵ is determined by, ϵ Δ / O)*100

The average c/s area, A at particular strain is determined by, A = (A_O/[1-ϵ])

Plot is made between σ and ϵ. The maximum stress from this curve gives the values of the unconfined compressive strength qu. Where no maximum occurs, the unconfined compressive strength is taken as the stress at 20% axial strain.

RESULTS:

Unconfined compression strength of the soil, qu =

Shear strength of the soil, qu/2 =

Sensitivity = (qu for undisturbed sample) / (qu for remoulded sample) =

Ex.No:14

Date: **Laboratory Vane Shear Test in Cohesive Soil**

AIM

To determine the undrained shear strength of the cohesive soil using vane shear.

THEORY:

Vane shear test is a quick test, used either in the laboratory or in the field, to determine the undrained shear strength of cohesive soil. The vane shear tester consists of four thin steel plates, called vanes, welded orthogonally to a steel rod. A torque measuring arrangement, such as a calibrated torsion spring, is attached to the rod which is rotated by a worm gear and worm wheel arrangment, After pushing the vanes gently into the soil, the torque rod is rotated at a uniform speed (usually at 1O per minute). The rotation of the vane shears the soil along a cylindrical surface. The rotation of the spring in degrees is indicated by a pointer moving on a graduated dial attached to the worm wheel shaft. The torque T is the calculated by multiplying the dial reading with the spring constant.

APPARATUS REQUIRED:

1) Vane shear apparatus.
2) Specimen.
3) Specimen container.
4) Callipers.

PROCEDURE:

- Prepare two or three specimens of the soil sample of dimensions of at least 37.5 mm diameter and 75 mm length in specimen.(L/D ratio 2 or 3).
- Mount the specimen container with the specimen on the base of the vane shear apparatus. If the specimen container is closed at one end, it should be provided with a hole of about 1 mm diameter at the bottom.
- Gently lower the shear vanes into the specimen to their full length without disturbing the soil specimen.
- The top of the vanes should be atleast 10 mm below the top of the specimen. Note the readings of the angle of twist.
- Rotate the vanes at an uniform rate say 0.1O/s by suitable operating the torque application handle until the specimen fails.
- Note the final reading of the angle of twist.
- Find the value of blade height and width in cm.

OBSERVATION

S.No	Initial reading (Deg)	Final reading (Deg)	Difference (Deg)	Spring constant (kg – cm)	T = (Spring constant/180) X Difference (kg – cm)	Shear strength, τ_f (kg – cm^2)
1						
2						
3						
4						
5						

CALCULATIONS:

The shear strength of the soil sample using vane apparatus is given by formula,

Shear strength, $S = T / \pi(D^2 H / 2 + D^3)$

Where S = shear strength of soil in kg/cm2

T = torque in cm kg

D = overall diameter of vane in cm

T = spring constant / 180o x difference in degrees.

RESULT:

Undrained Shear strength of the given cohesive soil sample is

Ex.No:14

Date: Tri-axial compression test in cohesion-less soil (Demonstration Only)

AIM:

To determine the undrained shear strength of the cohesive soil using vane shear.

THEORY:

The strength test more commonly used in a research laboratory today is the triaxial compression test, first introduced in the U.S.A. by A. Casagrande and Karl Terzaghi in 1936 – 37. The soil specimen, cylindrical in shape, is subjected to direct stresses acting in three mututally perpendicular directions. In the common solid cylindrical specimen test, the major principal stress σ1 is applied in the vertical direction, and the other two principal stresses σ2 and σ3 σ2 σ3) are applied in the horizontal direction by the fluid pressure round the specimen

APPARATUS REQUIRED:

KNOWLEDGE OF EQUIPMENT

1) A constant rate of strain compression machine of which the following is a brief description of one is in common use.

a) A loading frame in which the load is applied by a yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor.

b) A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials.

2) A triaxial cell to take 3.8 cm dia and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a nonferrous metal top and base connected by tension rods and with walls formed of perspex.

Apparatus for preparation of the sample:

1) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.

2) Rubber ring.

3) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.

4) Stop clock.

5) Moisture content test apparatus.

6) A balance of 250 gm capacity and accurate to 0.01 gm.

PROCEDURE:

- The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.

- The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

- When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.

- The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

- The handle wheel of the screw jack is rotated until the under side of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.

- The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test

TABLE: OBSERVATION AND RECORDING

The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to give a rate of strain 2% per minute. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken the corresponding proving ring chart. The load applied is known. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15% strain.

Soil specimen measurement:

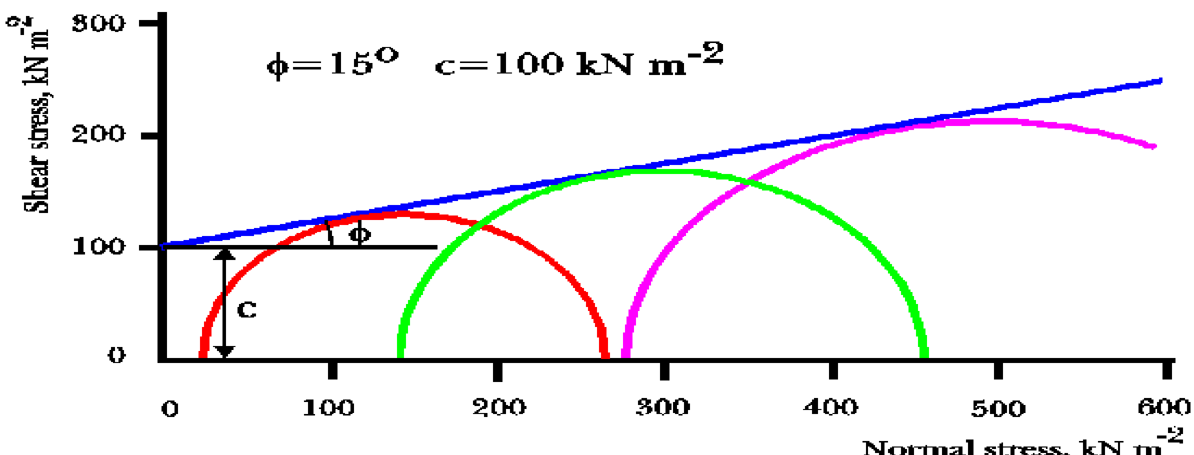
Height	:	Area	:
Volume	:	Diameter	:
Initial mass	:	Initial water content	:
Final mass	:	Final water content	:

Cell pressure σ3) kg/cm^2 :

Load gauge reading 1	Strain 2	Proving ring reading 3	Load on sample (kg) 4	Corrected area (cm^2) 5	Vertical stress σ_1) (R4/R5) 6	Deviator stress σ_d) (R6 – σ_3) 7

CALCULATIONS:

The shear parameters are obtained from a plot of Mohr circles for which purpose peak value of principal stress difference σ1 – σ3) or principal stress-ratio σ1/σ3) or the ultimate value as desired may be used.



Results of triaxial tests

RESULT:

Shear parameter of the given soil sample is

Ex.No:15

Date: **California Bearing Ratio Test**

AIM

To determine the California bearing ratio by conducting a load penetration test in the laboratory.

THEORY:

This method was originally devised by O.J. Porter, the of the California State Highway Department, but it has since been developed and modified by other authorities in U.S.A., notably the U.S. Corps of Engineers. The method combines a load penetration test perfomed in the laboratory or in-situ with the empirical design charts to determine the thickness of pavement and of its constituent layers. This is probably the most widely used method for the design of flexible pavement. The thickness of the different elements comprising a pavement is determine by CBR values. The CBR test is a small scale penetration test in which a cylindrical plunger of 3 in 2 c/s area is penetrated into a soil mass at the rate of 0.05 in. per minute (1.25mm/min).The CBR is defined as the ratio of the test load to the standard load, expressed as percentage, for a given penetration of the plunger, CBR = (Test load/Standard load)*100

The test may be performed on undisturbed specimens and on remoulded specimens which may be compacted either statically or dynamically

APPARATUS REQUIRED:

1) Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.
2) Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3) Metal rammers. Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4) Weights. One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5) Loading machine. With a capacity of atleast 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with Load indicating device.
6) Metal penetration piston 50 mm dia and minimum of 100 mm in length.
7) Two dial gauges reading to 0.01 mm.
8) Sieves. 4.75 mm and 20 mm I.S. Sieves.

9) Miscellaneous apparatus, such as a mixing bowl, straight edge, scales soaking or pan, drying oven, filter paper and containers.

PROCEDURE:

PREPARATION OF TEST SPECIMEN

Undisturbed specimen

Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in . When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot.

Determine the density Remoulded specimen

Prepare the remoulded specimen at Proctor's maximum dry density or any other density at which C.B.R is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S. sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

Dynamic Compaction

- Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
- Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.
- Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer.
- For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
- Remove the collar and trim off soil.
- Turn the mould upside down and remove the base plate and the displacer disc.
- Weigh the mould with compacted soil and determine the bulk density and dry density.
- Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

Static compaction

- Calculate the weight of the wet soil at the required water content to give the desired density when occupying the standard specimen volume in the mould from the expression.
- W =desired dry density * (1+w) * V
- Where W = Weight of the wet soil w = desired water content
- V = volume of the specimen in the mould = 2250 cm3 (as per the mould available in laboratory)
- Take the weight W (calculated as above) of the mix soil and place it in the mould.

- Place a filter paper and the displacer disc on the top of soil.
- Keep the mould assembly in static loading frame and compact by pressing the displacer disc till the level of disc reaches the top of the mould.
- Keep the load for some time and then release the load. Remove the displacer disc.
- The test may be conducted for both soaked as well as unsoaked conditions.
- If the sample is to be soaked, in both cases of compaction, put a filter paper on the top of the soil and place the adjustable stem and perforated plate on the top of filter paper.
- Put annular weights to produce a surcharge equal to weight of base material and pavement expected in actual construction. Each 2.5 kg weight is equivalent to 7 cm construction. A minimum of two weights should be put.
- Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Remove the mould from tank.
- Note the consolidation of the specimen
- Procedure for Penetration Test
- Place the mould assembly with the surcharge weights on the penetration test machine.
- Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
- Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
- Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
- Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

Observation and Recording

1. Compaction characteristics:

   (a) Dynamic compaction:

   Optimum water content (%):

   Weight of mould + compacted specimen (g):

   Weight of empty mould (g) :

   Weight of compacted specimen (g) :

   Volume of specimen (cm3):

   Bulk density (g/cc) :

   Dry density (g/cc) :

(b) Static compaction:

Dry density (g/cc) :

Moulding water content (%):

Wet weight of compacted specimen, W (g) :

2. Penetration test:

Surcharge weight used (g) :

Water content after penetration test :

Penetration dial		**Load dial**		**Corrected load (kg)**
Readings	Penetration (mm)	Readings	Load (kg)	
	0			
	0.5			
	1.0			
	1.5			
	2.0			
	2.5			
	3.0			
	4.0			
	5.0			
	7.5			
	10.0			
	12.5			

CALCULATIONS:

1. Expansion ratio:

The expansion ratio may be calculated as follows,

Expansion ratio = {(df – di)/h}*100 df = final dial gauge reading (mm) di = initial gauge reading (mm) h = initial height of specimen (mm)

2. LOAD PENETRATION:

Plot the load penetrating curve. If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding to each penetration.

Corresponding to the penetration value at which the C.B.R. is desired, correct load values are found from the curve and C.B.R. is calculated as follows;

C.B.R. = (PT/PS) * 100 Where,

PT = Corrected test load corresponding to the chosen penetration from the load penetration curve.

PS = Standard load for the same penetration taken from the table below.

Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater that at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design

RESULT:

C.B.R. of specimen at 2.5 mm penetration =

C.B.R. of specimen at 5.0 mm penetration =

Engineering Properties of Soil

1. What is meant Unconfined in UCC Test?

   There will no Confining Pressure given to make the soil to fail. Minor Principal Stress is Zero

2. What are the called Shear strength parameters?

   Cohesion

   Angle of Internal Friction

3. How to classify the soil based on shear strength parameters?

   Purely Cohesive soil

   Cohesive soil

   Cohesion less Soil

4. What are the tests available to find shear strength parameters?

   Direct Shear Test

   Triaxial Compression Test

   Unconfined Compression Test

   Vane shear Test.

5. What are the different Drainage Condition to be consider in Triaxial Test?

   CD Test (consolideted drained Test)

   CU Test (consolideted Undrained Test)

   UU Test (Unconsolideted Undrained Test)

6. What are the advantages of UCC Test?

   This test is most applicable for clayey soil. It will give accurate result shear strength

7. What is meant by Unconfined cohesion?

   It is represented by Cu. Half of the Unconfined Compression Strength Qu is called as Unconfined Cohesion

8. What is the disadvantages of UCS test?

   Soil must be free from fissures and there should not presence of silt content

9. What is meant by Angle of failure plane?

   Angle of failure plane (α) = 45 + Ø/2. The angle made by failure plane depends on angle of internal friction Ø.

10. What is meant by Principal Plane and principal stress?

    The plane at which shear stress is Zero is called as Principal Plane and the stress acts on the principal plane is called as principal stress

11. What is meant by Dilation?

    Dilation Occurs in Dense sand, there will be volume change in soil under shear. The phenomenon at which the volume initially decreases and then increases after the certain strain for dense soil is called Dilation.

12. What are the advantages of Direct Shear Test?

    The Test is Simple and Convenient for sandy soil

13. What are the disadvantages of Triaxial Compression Test?

    The Test is Elabrate, Time Consuming and Skilled person to be take care.

14. How to arrive Angle of internal friction from test?

    The observed value of Shear load for applied Normal load for different trial is drawn in Graph. The angle of the line connecting all failure points gives angle of internal friction.

15. What is the advantages of Direct Shear test?

    This test is suitable for all types of soil. Can measure the pore water pressure at any time. It gives most accurate results

16. What is the disadvantages of Direct Shear test?

    Failure plane is predefined as Horizontal. It will be suitable only for cohesionless soil

17. What is meant by Angle of failure plane?

    Angle of failure plane (α) = 45 + Ø/2.

    The angle made by failure plane depends on angle of internal friction Ø.

18. What is meant by Principal Plane and principal stress?

    The plane at which shear stress is Zero is called as Principal Plane and the stress acts on the principal plane is called as principal stress.

19. What are the different types of settlement?

Primary Settlement (Immediate Settlement)

Consolidation Settlement

Tertiary Settlement

20. What is the purpose of consolidation?

    To Calculate the Future settlement of the Building or any other structure

21. What is meant by Degree of Consolidation?

    The ratio of the settlement at the time to the final settlement of soil is called Degree of Consolidation.

22. What are the methods to find coefficient of consolidation?

    Log T Method

    Root T Method

23. What are the disadvantages of Triaxial Compression Test?

    The Test is Elaborate, Time Consuming and Skilled person to be take care.

24. How to arrive Angle of internal friction from test?

    The observed value of Minor principal stress and Major Principal stress for different trial to be drawn as mohr circles. The angle of the common tangent line touching all mohr's circle.

25. What is the advantages of Direct Shear test?

    This test is suitable for all types of soil. Can measure the pore water pressure at any time. It gives most accurate results

TOPIC BEYOND SYLLABUS

Ex.No:16

Date: Determination of Moisture Content of Soil

AIM

To determine the moisture content (water content) of a given soil sample.

THEORY

A soil is an aggregate of soil particles having a porous structure. The pores may havewaterand/orair.Theporesarealsoknownasvoids.Ifvoidsarefullyfilledwithwater.Thesoil iscalledsaturated soil and if voids have only air, the soil is called dry.

Moisture content is defined as the ratio of the mass/weight of water to the mass/weight of soil solids

$$W = W_w / W_s$$

Where, W=water content

Ww=Weight/mass of water

Ws =Weight/mass of soil solids (mass of oven dry soil)

The temperature at which only pore water is evaporated. This temperature was standardized105^{0}C to110^{0}C.Soils having gypsum are dried at 600ºC to800ºC.

The quantity of soil sample needed for the determination of moisture content depends on the gradation and the maximum size of particles. Following quantities are recommended.

S.No.	Soil	Max. quantity used(gm)
01	Coarse gravel	1000to2000
02	Fine gravel	300to500
03	Coarse sand	200
04	Medium sand	50
05	Fine sand	25
06	Silt and clays	10to25

The methods to determine moisture content in the laboratory are oven-drying, pycnometer, infrared lamp with torsion balance moisture meter. The approximate methods are alcohol burning method and calcium carbide method.

APPARATUS REQUIRED

1. Containers
2. Balance of sufficient sensitivity.
3. Hot Oven
4. Desiccators.

PROCEDURE

- Clean, dry and weigh the container with lid.
- Take the required quantity of the soil specimen in the container and weigh with lid.
- Maintain the temperature of the oven between105ºC to110ºC for normal soils and 600ºC to 800ºC for soils having loosely bound hydration water or/and Organic matter.
- Dry the sample in the oven till its mass becomes constant. In normal conditions the sample is kept in the oven for not more than24hours.
- After drying remove the container from the oven, replace the lid and cool in the desiccators.
- Weigh the dry soil in the container with lid.

OBSERVATIONS

S.No.	Determination No.	1	2	3
1	Container No.			
2	Mass of container with lid. W_1(gm)			
3	Mass of containerwithlid+wetsoil,W_2(gm)			
4	Mass of containerwithlid+dry soil,W_3(gm)			
5	Mass of water,$W_w=W_2-W_3$(gm)			
6	Mass of dry soil,$W_s=W_3-W_1$(gm)			
7	Moisture content, $W=W_2-W_3/W_3-W_1 x100$,(%)			

RESULT:

The moisture content of the given soil sample =

TOPIC BEYOND SYLLABUS

Ex.No:17

Date: Determination of Specific Gravity Using Density Bottle

AIM:

Determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by density bottle.

THEORY:

The knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc.Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

APPARATUS REQUIRED

1. Density bottle of 50 ml with stopper having capillary hole.
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water.
4. Alcohol and ether.

PROCEDURE

- Clean and dry the density bottle
- wash the bottle with water and allow it to drain.
- Wash it with alcohol and drain it to remove water.
- Wash it with ether, to remove alcohol and drain ether.
- Weigh the empty bottle with stopper (W1)
- Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W2).
- Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
- Again fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature water baths.
- Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W3).
- Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W4.
- Repeat the same process for 2 to 3 times, to take the average reading of it.

OBSERVATIONS

S. No.	Observation Number	1	2	3
1	Weight of density bottle (W1 g)			
2	Weight of density bottle + dry soil(W2 g)			
3	Weight of bottle + dry soil + water(W3 g)			
4	Weight of bottle + water (W4 g)			
5	Specific Gravity			

CALCULATIONS

$$\textit{Specific gravity of soil} = \frac{\text{Density of water at 27 C}}{\text{Weight of water of equal volume}}$$

$$= \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

$$= \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Unless or otherwise specified specific gravity values reported shall be based on water at 27ºC.

The specific gravity of the soil particles lie with in the range of 2.65 to 2.85. Soils containing organic matter and porous particles may have specific gravity values below Soils having heavy substances may have values above 3.0.

RESULT:

Specific gravity of soil =

Ex.No:19

Date: **Determination of Field Density-Core Cutter Method**

AIM:

To determine the field density of soil at a given location by core cutter method

THEORY:

In core cutter method the unit weight of soil obtained from direct measurement of weight and volume of soil obtained from field. Particularly for sandy soils the core cutter method is not possible. In such situations the sand replacement method is employed to determine the unit weight. In sand replacement method a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand, whose density is known, is filled into the pit. By measuring the weight of sand required to fill the pit and knowing the density of soil , volume of the pit is calculated .Knowing the weight of soil excavated from the pit and the volume of pit the density of soil is calculated. Therefore in this experiment there are two stages (1) Calibration of sand density and (2) Measurement of soil density.

APPARATUS

1. Cylindrical core cutter
2. Steel rammer
3. Steel dolly
4. Balance
5. Moisture content cups

PROCEDURE

CORE CUTTER

- Measure the height (h) and internal diameter (d) of the core cutter and apply grease to the inside of the core cutter.
- Weigh the empty core cutter (W1).
- Clean and level the place where density is to be determined.
- Drive the core cutter, with a steel dolly on its top in to the soil to its full depth with the help of a steel rammer.
- Excavate the soil around the cutter with a crow bar and gently lift the cutter without disturbing the soil in it.
- Trim the top and bottom surfaces of the sample and clean the outside surface of the cutter.

- Weigh the core cutter with soil (W2).
- Remove the soil from the core cutter , using a sample ejector and take a representative soil sample from it to determine the moisture content (w).

OBSERVATIONS - CORE CUTTER METHOD

Internal diameter of the core cutter (d)

Height of the core cutter (h)

Volume of the core cutter (V)

Specific gravity of solids (G)

RESULT

1. **Dry unit weight of the soil =**
2. **Wet unit weight of the soil =**
3. **Void ratio of the soil =**
4. **Porosity of the soil =**
5. **Degree of saturation =**