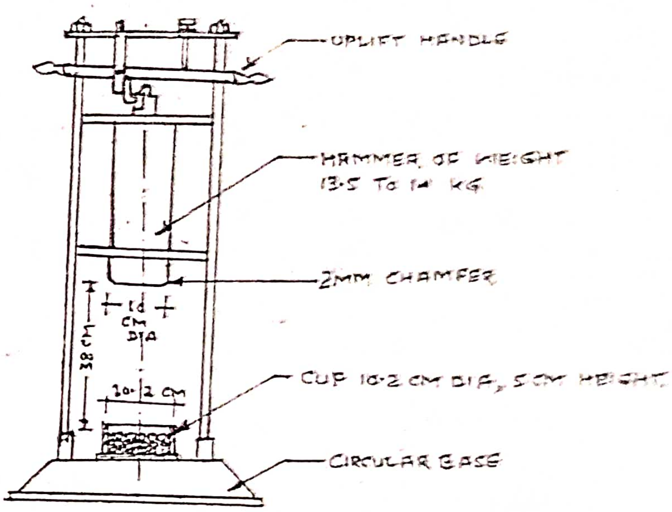
1. EXPERIMENT :: To conduct the aggregate impact value test .

APPARATUS ::

1. Impact testing machine
2. cylindrical measure having internal diameter 7.5 cm and depth 5 cm for measuring aggregates.
3. Tamping rod
4. IS Sieves of sizes 12.5 mm ,10 mm and 2.36 mm .
5. Weighing balance
6. Thermostatically controlled drying oven

DIAGRAM ::



AGG. IMPACT TESTING MACHINE

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 in to smaller pieces . The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or an impact and the designed to evaluate the toughness of stones i.e. the resistance of the stones to fracture under repeated impacts may be called as impact test for road aggregates.

PROCEDURE ::

The test specimen consists of aggregates passing 12.5 mm sieve and retained on 10 mm sieve and dried in an oven for 4 hours at a tempe ure of 100-110 degree centigrade and cooled. Test aggregates are filled up to 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 up to about 2 / 3 rd full in the cylinder and 25 strokes of the tamping rod are given . The measure is now filled with the aggregates to overflow ,tamped 25 times . The surplus aggregates are struck off with the help of tamping rod as straight edge. The net weight of the aggregates in the measure is determined . 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 whole of the test sample from cylindrical measure is transferred to the cup and compacted by tamping with 25 strokes .

The hammer is raised until its lower face is 38 cm above the upper surface of 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 aggregates is then removed from the cup and whole of it sieved on 2.36 mm sieve .

OBSERVATION SHEET :

Sample no.	Total weight of dry sample (W1) gm	Weight of fines passing 2.36 mm IS sieve , (W2) gm	Aggregate impact value = (W2 / W1) * 100 (%)	Average aggregate Impact value
1.				
2.				

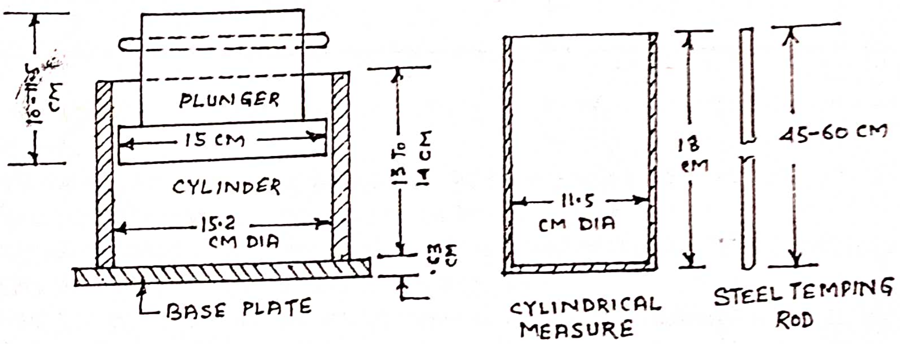
RESULT : Average impact value = %

2. EXPERIMENT :: To conduct the aggregate crushing value test.

APPARATUS ::

1. Steel cylinder with open ends, and internal diameter 15.2 cm, square base plate, plunger having a piston of diameter 15 cm.
2. Cylindrical measure having internal diameter of 11.5 cm and height 18 cm.
3. Steel tamping rod with one end rounded, having a diameter of 1.6 cm and height 45-60 cm.
4. Balance of capacity 3 Kg. with accuracy up to 1 gm.
5. Compression testing machine capable of applying load of 40 tons at a uniform rate of loading of 4 tons per min.

DIAGRAM ::



AGG. CRUSHING TEST APPARATUS

THEORY ::

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 effected. 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.

PROCEDURE ::

The aggregates passing 12.5 mm IS Sieve and retained on 10 mm IS Sieve is selected for standard test. The aggregates should be in surface dry condition before testing. 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 leveled off by using the tamping rod as a straight edge.

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 tapped 25 times by the tamping rod. Similarly the other two parts of the test specimen are added, each layer being subjected to 25 blows. The total depth of the material in the cylinder after tamping shall however be 10 cm. The surface of the aggregates is leveled and the plunger inserted so that it rests on this surface in level position. The cylinder with the test sample and the plunger in position is placed on the compression testing machine.

Load is then applied through the plunger at a uniform rate of 4 tons per min until the total load is 40 tons , 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 test is repeated on second sample of the same weight in accordance with above test procedure . The two tests are made for the same specimen for taking an average value .

OBSERVATION SHEET ::

Sample Number	Total weight of dry sample (W1) gm	Weight of fines passing 2.36 mm IS sieve (W2) gm	Aggregate crushing value = (W2 / W1) * 100 (%)	Average crushing value
1.				
2.				
3.				

RESULT :: Aggregate crushing value = %

QUESTIONS:

(1)Explain the aggregate crushing value.How would you express it?

(2)Briefly explain the aggregate crushing value test procedure.

(3)Aggregaate crushing value of material A is 40 and that of B is 25. Which one is better?

(4)What are the applications of aggregate crushing test?

(5)What are the recommended maximum value of aggregate crushing value for the aggregates to be used in base & surface courses of cement concrete.

< 10 ; >35

3. TO DETERMINE THE FLAKINESS AND ELONGATION INDEX OF AGGREGATES.

INTRODUCTION

The particle shape of aggregates is determined by the percentages 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 aggregates, 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

The *flakiness index* of aggregates is the percentages 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 Figure , IS sieves of sizes 63, 50, 40,

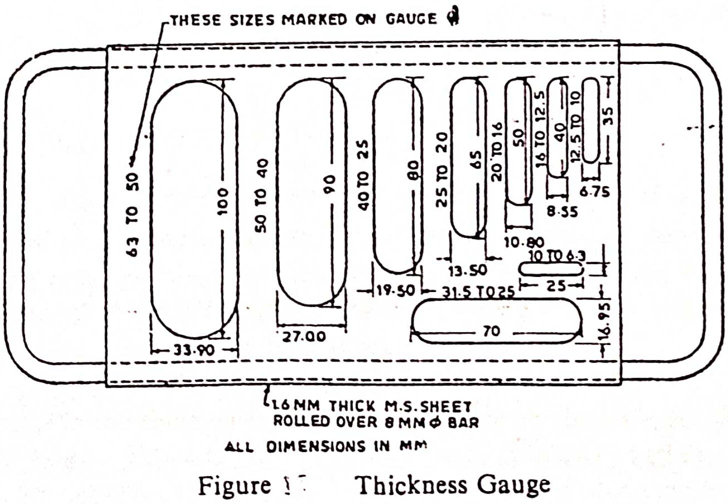


Figure 1 Thickness Gauge

ELONGATION INDEX

The *elongation index* of an aggregate is the percentage by weight of particles whose greatest dimensio (length) is greater than one and four fifth times (1.8 times) their mean dimension. The elongation test is no applicable to sizes smaller than 6.3 mm.

Apparatus

The apparatus consists of the length gauge shown in Figure 15.2, sieves of the sizes specified in Tabl 15.1 and a balance.

Procedure

The sample is sieved through the IS sieves specified in Table 15.1. A minimum of 200 pieces of eac fraction is taken and weighed. In order to separate elongated material, each fraction is then gauge individually for length in a length gauge (See Figure 15.2) The gauge lengths used should be tho: specified in column 4 of the Table for the appropriate material. The pieces of aggregates from eac fraction tested which could not pass through the specified gauge length with its long side are elongate particles and are collected separately to find the total weight of aggregates retained on the length gau from each fraction. The total amount of elongated material retained by the length gauge are weighed to a accuracy of atleast 0.1 percent of the weight of the test sample.

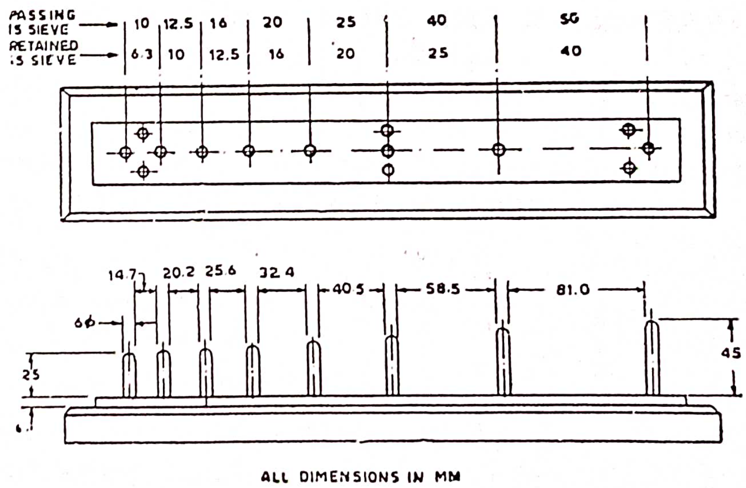


Figure 15.2 Length Gauge

Calculation and Result

In order to calculate the elongation index of the entire sample of aggregates, the weight of aggrega which is retained on the specified gauge length from each fraction is noted. As an example, let 200 piec of the aggregate passing 40 mm sieve and retained 25 mm sieve weight W_1 g. Each piece of these are tri to be passed through the specified gauge length of the length gauge, which in this example is

$$= \frac{(40 + 25)}{2} \times 1.8 = 58.5 \text{ mm}$$

with its longest side and those elongated pieces which do not pass the gauge are separated and the total wei determined $= w_1$ g. Similarly the weight of each fraction of aggregate passing and retained on specifi sieves sizes are found, W_1, W_2, W_3 ...and the total weight of sample determined $= W_1 + W_2 + W_3 \ldots = W$g. Also the weight of material from each fraction retained on the specified gauge length found $= x_1, x_2, x_3 \ldots$ and the total weight retained determined $= x_1 + x_2 + x_3 + \ldots = X$ g.

used. The procedure of the test is the same for each of these except that the amount of compactive ef given by : (weight of the tamping rod × height of fall × number of blows) should be proportional to volume of the cylinder.

The samples of single-size aggregate retained between the specified pair of sieves is dried in an ove a temperature 100° to 110°C for 24 hours and cooled in an air tight container prior to testing. The scoc filled and heaped to overflowing with the aggregate, which is placed in the cylinder by allowing it to s gently off the scoop from the lowest possible height. The aggregates in the cylinder are subjected to blows of the tamping rod at a rate of about 2 blows per second. Each blow is applied by holding the vertically with its rounded end 5 cm above the surface of the aggregate and releasing it so that it vertically and no force is applied to the rod The 100 blows should be distributed evenly over the sur to the aggregates.

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

Individual pieces of aggregate are then added and rolled in to the surface by rolling the tamping across the upper edge of the cylinder, and this finishing process is continued as long as the aggregate do lift the rod off the edge of the cylinder on either side, during rolling. The aggregate should nc pushed in or forced down and no downward pressure should be applied to the tamping rod, whic 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. Three separate determinations made and the mean weight of the aggregate in the cylinder is calculated. If the result of any one of determination differs from the mean by more than 25 g, three additional determinations are immedia 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 shapes of the aggregates. Particular care ha be taken while carrying out the test for angularity number.

Application of Shape Tests

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

Indian Roads Congress has recommended the maximum allowable limits of flakiness index value various types of construction, as given in Table 15.2.

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FLAKINESS INDEX

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Apparatus

The apparatus consists of a standard thickness gauge shown in Figure [illegible], IS sieves of sizes 63, 50, 40,

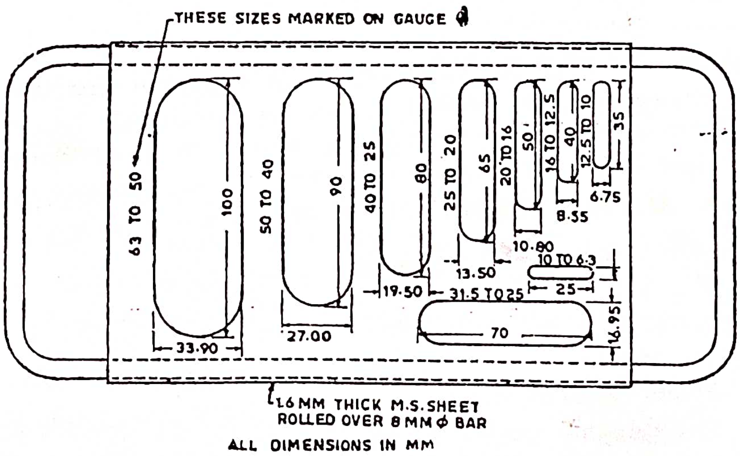


Figure [illegible] Thickness Gauge

31.5, 25, 20, 16, 12.5, 10 and 6.3 mm and a balance to weigh the samples.

Procedure

The sample is sieved with the sieves mentioned in Table 15.1. 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 Figure 15.1 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 15.1 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 15.1

Dimensions of Thickness and Length Gauges

Size of aggregate: Passing through IS sieve mm	Size of aggregate: Retained on IS sieve, mm	(a) Thickness gauge (0.6 times the mean sieve), mm	(b) Length gauge (1.8 times the mean sieve), mm
1	2	3	4
63.0	50.0	33.90	—
50.0	40.0	27.00	81.0
40.0	31.5	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	8.55	25.6
12.5	10.0	6 75	20.2
10.0	6.3	4.89	14.7

alculation and Result

In order to calculate the flakiness index of the entire sample of aggregates first the weight of each action of aggregate passing and retained on the specified set of sieves is noted. As an example let 200 eces of the aggregate passing 50 mm sieve and retained on 40 mm sieve be = W_1 g. Each of the particle om this fraction of aggregate is tried to be passed through the slot of the specified thickness of the thickness uge; in this example the width of the appropriate gauge of the thickness gauge is

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

Let the weight of the flaky material paassing this gauge be w_1 g. Similarly the weights of the actions passing and retained the specified sieves, W_1, W_2, W_3 etc. are weighed and the total weight $_1 + W_2 + W_3 + \ldots = W$ g is found. Also the weights of material passing each of the specified thickness uge are found = $w_1, w_2, w_3 \ldots$ 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 flaky material ssing the various thickness gauges expressed as a percentage of the total weight of the sample gauged.

$$\text{Flakiness Index} = \frac{(w_1+w_2+w_3+\ldots)\,100}{W_1 + W_2 + W_3 + \ldots} \text{ percent} = 100\,\frac{w}{W} \text{ percent,}$$

ELONGATION INDEX

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 (1.8 times) their mean dimension. The elongation test is no applicable to sizes smaller than 6.3 mm.

Apparatus

The apparatus consists of the length gauge shown in Figure 15.2, sieves of the sizes specified in Tabl 15.1 and a balance.

Procedure

The sample is sieved through the IS sieves specified in Table 15.1. A minimum of 200 pieces of eaci fraction is taken and weighed. In order to separate elongated material, each fraction is then gauge individually for length in a length gauge (See Figure 15.2) The gauge lengths used should be thos specified in column 4 of the Table for the appropriate material. The pieces of aggregates from eac fraction tested which could not pass through the specified gauge length with its long side are elongate particles and are collected separately to find the total weight of aggregates retained on the length gaug from each fraction. The total amount of elongated material retained by the length gauge are weighed to a accuracy of atleast 0.1 percent of the weight of the test sample.

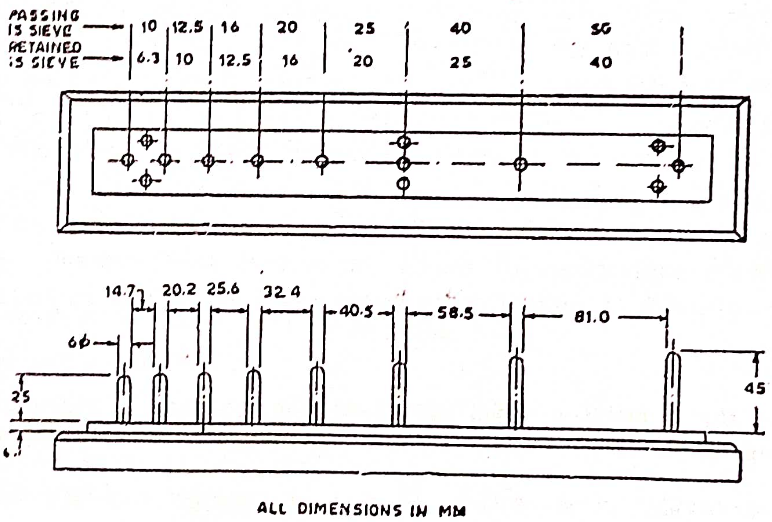


Figure 15.2 Length Gauge

Calculation and Result

In order to calculate the elongation index of the entire sample of aggregates, the weight of aggrega which is retained on the specified gauge length from each fraction is noted. As an example, let 200 piec of the aggregate passing 40 mm sieve and retained 25 mm sieve weight W_1 g. Each piece of these are tri to be passed through the specified gauge length of the length gauge, which in this example is

$$= \frac{(40 + 25)}{2} \times 1.8 = 58.5 \text{ mm}$$

with its longest side and those elongated pieces which do not pass the gauge are separated and the total weig determined = w_1 g. Similarly the weight of each fraction of aggregate passing and retained on specifi sieves sizes are found, W_1, W_2, W_3 ...and the total weight of sample determined = $W_1 + W_2 + W_3$ ... = Wg. Also the weight of material from each fraction retained on the specified gauge length found = x_1, x_2, x_3 ... and the total weight retained determined = $x_1 + x_2 + x_3 + ... = X$ g.

longation index is the total weight of the material retained on the various length gauges, expressed ntage of the total weight of the sample gauged.

$$\text{Elongation Index} = \frac{(x_1+x_2+x_3...)\ 100}{W_1+W_2+W_3+...} = 100\ \frac{X}{W}\ \text{percent}$$

RITY NUMBER

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

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

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

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

A metal tamping rod of circular cross section, 16 mm in diameter and 60 cm in length, rounded d

A metal scoop of about one liter heaped capacity of size 20×10×5 cm, and

A balance of capacity 10 kg to weigh up to 1.0 g

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

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

se aggregate larger than 20 mm sieve is used for the test, the volume of the cylinder should be an 3 litres, but when aggregates smaller than 4.75 mm 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 e[illegible] given by : (weight of the tamping rod × height of fall × number of blows) should be proportional to volume of the cylinder.

The samples of single-size aggregate retained between the specified pair of sieves is dried in an ove[illegible] a temperature 100° to 110°C for 24 hours and cooled in an air tight container prior to testing. The scoo[illegible] filled and heaped to overflowing with the aggregate, which is placed in the cylinder by allowing it to s[illegible] gently off the scoop from the lowest possible height. The aggregates in the cylinder are subjected to blows of the tamping rod at a rate of about 2 blows per second. Each blow is applied by holding the vertically with its rounded end 5 cm above the surface of the aggregate and releasing it so that it [illegible] vertically and no force is applied to the rod The 100 blows should be distributed evenly over the sur[illegible] to the aggregates.

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

Individual pieces of aggregate are then added and rolled in to the surface by rolling the tamping across the upper edge of the cylinder, and this finishing process is continued as long as the aggregate do lift the rod off the edge of the cylinder on either side, during rolling. The aggregate should not pushed in or forced down and no downward pressure should be applied to the tamping rod, which 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. Three separate determinations made and the mean weight of the aggregate in the cylinder is calculated. If the result of any one of determination differs from the mean by more than 25 g, three additional determinations are immedia[illegible] 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 shapes of the aggregates. Particular care ha[illegible] be taken while carrying out the test for angularity number.

Application of Shape Tests

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

Indian Roads Congress has recommended the maximum allowable limits of flakiness index values various types of construction, as given in Table 15.2.

4. Explain Flakiness Index. How is it found ?
5. What is Elongation Index ? How is it determined in the laboratory ?
6. Discuss the advantages and limitations of rounded and angular aggregates in different type pavements.
7. Explain Angularity Number. How is it found ?
8. What are the applications of shape tests ?

OBSERVATION SHEET — FLAKINESS INDEX AND ELONGATION INDEX

General description of the aggregate :

Size of aggregate: Passing through IS sieve, mm	Size of aggregate: Retained on IS sieve, mm	Weight of the fraction consisting of atleast 200 pieces, g	Thickness gauge size, mm	Weight of aggregate in each fraction passing thickness gauge, g	Length gauge size, mm	Weigh aggrega each fra retained length ga
1	2	3	4	5	6	7
63	50	W_1 =	23.90	w_1 =	—	—
50	40	W_2 =	27.00	w_2 =	81.0	x_1 =
40	25	W_3 =	19 50	w_3 =	58.0	x_2 =
31.5	25	W_4 =	16.95	w_4 =	—	—
25	20	W_5 =	13.50	w_5 =	40.5	x_3 =
20	16	W_6 =	10.80	w_6 =	32.4	x_4 =
16	12.5	W_7 =	8.55	w_7 =	25.5	x_5 =
12.5	10.0	W_8 =	6.75	w_8 =	20.2	x_6 =
10.0	6.3	W_9 =	4.89	w_9 =	14.7	x_7 =
Total		W =	—	w =	—	x =

$$\text{Flakiness Index} = \frac{(w_1+w_2+w_3+\ldots)}{(W_1+W_2+W_3+\ldots)} 100 \text{ percent} = \frac{100\,w}{W} \text{ percent} =$$

$$\text{Elongation Index} = \frac{(x_1+x_2+x_3+\ldots)}{(W_1+W_2+W_3+\ldots)} 100 \text{ percent} = \frac{100\,x}{W} \text{ percent} =$$

ANGULARITY NUMBER

Weight of water filling the cylinder = C g =

Specific gravity of the aggregate = G =

Particulars	Trial number 1	2	3	Mean	4	5	6
Weight of aggregate filling the cylinder to the nearest five grams, g							

Mean weight of aggregate filling the cylinder, W_g =

$$\text{Angularity Number} = 67 - \frac{100\,W}{CG}$$

Remarks :

4. Experiment: To conduct the Los Angeles Abrasion test.

Apparatus:

(1)Los Angeles abrasion testing machine

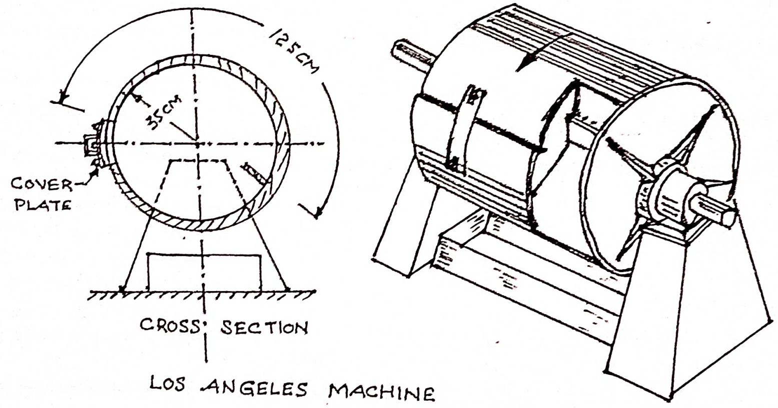
(2)Abrasive charge , consisting of cast iron spheres approximately 4.8 cm in diameter &390 to 445 gm in weight.

(3)IS sieve 1.70 mm in opening.

Theory:

Due to movement 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 aggregate ,especially when used in wearing course. Thus road stones should be hard enough to resist the abrasion due to traffic. When fast moving traffic fitted with pneumatic tyres move on the road, the soil particles present between the wheel & road surface causes abrasion on the road surface. Steel tyres of animal drawn vehicles which rub against the stones can cause considerable abrasion of stones on the road surface.

Diagram:



LOS ANGELES MACHINE

Procedure:

Clean aggregates dried in an oven at 105-110 C to constant weight ,conforming to any one of the grading A to G is used for the test . Aggregates weighing 5 Kg for grading A to D & 10 Kg for E to G may be taken as test specimen & placed in the cylinder. The abrasive charge is also chosen depending upon the grading of the aggregates & is placed in the cylinder of the machine. The cover is then fixed dust-tight. The machine then rotated for 500 revolutions for grading A to D & 1000 revolutions for grading E to G.

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

Table 2.11

Grading	*Weight in grams of each test sample in the size range, mm (Passing and retained on square holes.)*										*Abrasive charge*	
	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
B	–	–	–	–	–	–	–	25000	2500	–	8	3330±20
D	–	–	–	–	–	–	–	–	–	5000	6	2500±15
E	2500*	2500*	5000*	–	–	–	–	–	–	–	12	500±25
F	–	–	5000*	5000*	–	–	–	–	–	–	12	5000±25
G	–	–	–	5000*	5000*	–	–	–	–	–	12	5000±25

* Tolerence of ± 2 percent is permitted.

4. Procedure

(a) Clean aggregate dried in an oven at 105° - 110°C to constant weight, confirming to any one of the grading A to G, as per table 2.11, is used for the test.

(b) Aggregates weighting 50 N (5 kg) for grading A,B,C or D and 100 N (10 kg) for grading E, F or G may be taken and is placed in the cylinder.

(c) The abrasive charge is also chosen from Table 2.11 and is placed in the cylinder.

(d) The cover is fixed dirt-tight and the machine is rotated at a speed of 30 to 33 r.p.m.

(e) The machine is rotated for 500 revolutions for grading A,B, C and D and 1000 revolutions for E,F, and G.

(f) Material is discharged from the machine taking care to take out entire stone dust.

(g) Using a sieve of size-larger than 1.70 mm IS Sieve, the material is first separated into two parts and the finer portion is taken out and sieved further on a 1.7 mm IS Sieve.

(h) The portion of material coarser than 1.7 mm size is washed and dried in an over at 105 to 110°C to constant weight and weighed correct to one gram.

5. Observations and Calculations

Number of revolutions provided =

Original weight of aggregates = W_1(g) =

Weight of aggregates retained on 1.7 mm I.S. Sieve after the test = W_2 (g) =

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

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

6. Results

Percentage wear of Aggregate is = ---------------%

7. Precautions

(a) To minimize wear of 1.7 mm Sieve use a higher grade sieve first.

(b) No spillage of aggregates should be there while putting the sample in the machine or while taking it out.

(c) All the weighting should be done accurately.

OBSERVATIONS & CALCULATIONS:

(1)Type of aggregate	=
(2)Grading	=
(3)No. of spheres used	=
(4)Wt. of charge	=
(5)No. of revolutions	=
Let the original wt. of aggregate	= W1 gm.
Wt. of aggregate retained on 1.70 mm IS sieve after the test	= W2 gm.
Loss in wt. due to wear	= (W1-W2) gm.
Los Angeles abrasion value (%)	= (W1-W2) /W1*100

QUESTIONS:

(1) How is Los Angeles abrasion value expressed ?

(2) The abrasion value found from Los Angeles test for aggregates A & B are 35 & 15 respectively . Which aggregate is harder ? Why ? For what type of constructions are these suitable?

(3) Briefly explain the Los Angeles abrasion test procedure.

(4) What are the desirable limits of Los Angeles abrasion values specified for different types of pavement surfacing?

5.TO DETERMINE THE SPECIFIC GRAVITY AND WATER ABSORPTION OF AGGREGATES.

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. tones having low specific gravity are generally weaker than those with higher specific gravity values. The pecific gravity test helps in the 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 'c' above)

(f) A shallow tray and two dry absorbent clothes, each not less than 75 × 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 with a cover of least 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 wighing, they should be jolted 25 times as described above in the new tank to remove air before weighing. This 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_2 g.

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 a single layer, covered and allowed to dry for at least 10 minutes unit the aggregates are completely surface dry. 10 to 60 minutes drying may be needed. The aggregate should not be exposed to the atsmosphere, 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 = W_3 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 = W_4 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 = $(W_1-W_2) = W_s$ g

Weight of saturated surface dry aggregate in air = W_3 g

Weight of water equal to the volume of the aggregate = (W_3-W_s) g

(1) Specific gravity

$$= \frac{\text{dry weight of aggregate}}{\text{weight of equal volume of water}}$$

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

(2) Apparen' specific gravity

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

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

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

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

Discussion

The size of the aggregates and whether is has been artificially heated should be indicated. The 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.

Applications of Specific Gravity and Water Absorption Tests

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.

SPECIFIC GRAVITY AND WATER ABSORPTION TESTS

Water absorption value ranges from 0.1 to about 2.0 percent for aggregates normally used in road urfacings. Stones with water absorption upon 4.0 percent have been used in base courses. Generally a alue of less than 0.6 percent is considered desirable for surface course. though slightly higher values are llowed in bituminous constructions. Indian Roads Congress has specified the maximum water absorption alue as 1 0 percent for aggregates used in bituminous surface dressing and built-up spray grout.

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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 = $\frac{W_4}{W_3 - (W_1 - W_2)}$			
6. Apparent specific gravity = $\frac{W_4}{W_4 - (W_1 - W_2)}$			
7. Water absorption = $\frac{(W_3 - W_4)\,100}{W_4}$ 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 :

6.TO DETERMINE THE C. B. R. VALUE OF A GIVEN SOIL SAMPLE.

7.TO DETERMINE THE C. B. R. VALUE OF GIVEN SOIL AGGREGATES MIX.

INTRODUCTION

The California Bearing Ratio (CBR) test was developed by the California Division of Highway as a method of classifying and evaluating soil-subgrade and base course materials for flexible pavements. Just after World War II, the U.S. Corps of Engineers adopted the CBR test for use in designing base course for airfield pavements. The test is empirical and results can not be related accurately with any fundamental property of the material. The method of test has been standardised by the ISI also.

The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimens in the laboratory. U.S. Corps of Engineers have also recommended a test procedure for in-situ test. Many methods exist today which utilise mainly CBR test values for designing pavement structure. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement.

Briefly, the test consists of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The loads, for 2.5 mm and 5 mm are recorded. This load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The standard load values were obtained from the average of a large number of tests on different crushed stones and are given in Table 6 1.

Table 6.1 Standard Load Values on Crushed Stones for Different Penetration Values

Penetration, mm	Standard Load, kg.	Unit standard load, kg/cm²
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

LABORATORY C.B.R. TEST

Apparatus

(a) *Loading Machine :* Any compression machine which can operate at a constant rate of 1.25 per minute can be used for this purpose. If such machine is not available then a calibrated hydra press with proving ring to measure load can be used. See Figure 6.1. A metal penetration pistor plunger of diameter 50 mm is attached to the loading machine.

(b) *Cylinderical Moulds :* Moulds of 150 mm diameter and 175 mm height provided with a coll about 50 mm length and detachable perforated base are used for this purpose. A spacer disc of 148

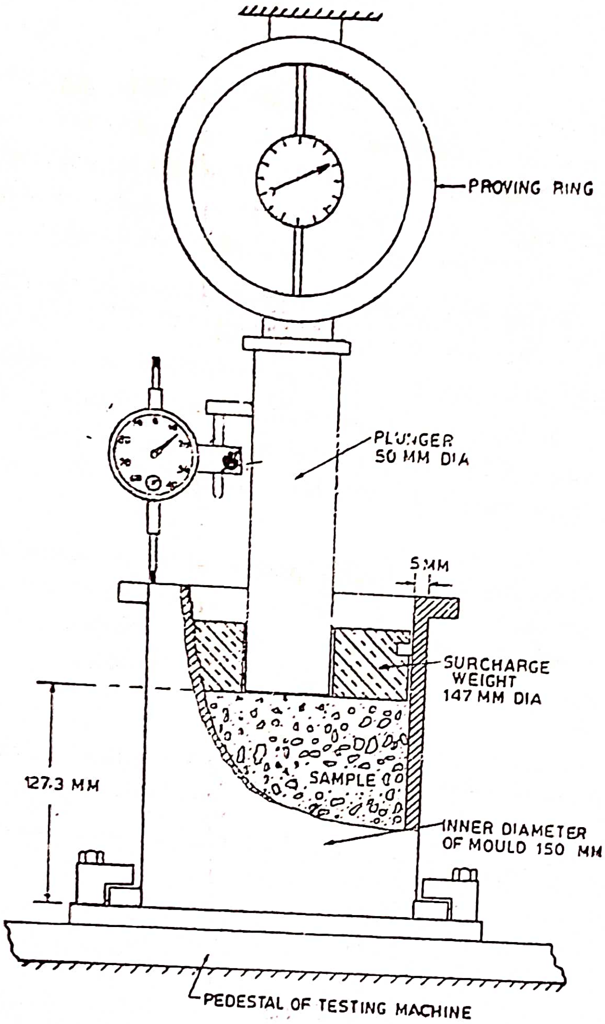

Figure 6.1 C.B.R. Test Apparatus

eter and 47.7 mm thickness is used to obtain a specimen of excactly 127.3 mm height.

(c) *Compaction Rammer :* The material is usually compacted as specified for the work, either by mic compaction or by static compaction. The details for dynamic compaction suggested by the ISI iven in Table 6.2.

Table 6.2 Specifications for Dynamic Compaction

of compaction	Number of layers	Magnitude of blows Weigh of hammer, kg	Fall, cm	Number of blows
Compaction	3	2.6	31	56
y Compaction	5	4.89	45	56

(d) *Adjustable stem, perforated plate, tripod and dial gauge :* The standard procedure requires that the ample before testing should be soaked in water to measure swelling. For this purpose the above listed sories are required. See the arrangement in Figure 6.2.

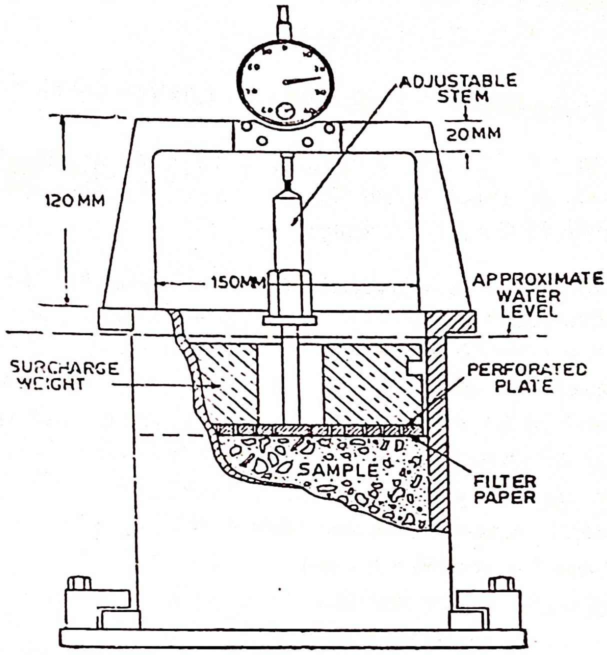

Figure 6.2 C.B.R. Mould with Swell Measuring Device

(*e*) *Annular weight :* In order to simulate the effect of the overlying pavement weight, annular weights each of 2.5 kg weight and 147 mm diameter are placed on the top of the specimen, both at the time of soaking and testing the samples, as surcharge.

Besides above equipment, coarse filter paper, sieves, oven, balance, etc. are required.

Procedure

As per the ISI, the CBR test may be performed either on undisturbed soil specimens obtained by fitting a cutting edge to the mould or on remoulded specimens. Remoulded soil specimens may eb compacted either by static compaction or by dynamic compaction. When static compaction is adopted, the batch of soil is mixed with water to give the required moisture content; the correct weight of moist soil to obtain the desired density is placed in the mould and compaction is attained by pressing in the spacer disc using a compaction machine or jack. The preparation of soil specimens by dynamic compaction or ramming is more commonly adopted and is explained below.

About 45 kg of material is dried and sieved through 20 mm sieve. If there is note worthly proportion of materials retained on 20 mm sieve. allowance for larger size materials is made by replacing it by an equal weight of material passing 20 mm sieve and retained on 4.75 mm sieve. The optimum moisture content and maximum dry density of the soil are determined by adopting either IS light compaction (Proctor compaction) or IS heavy compaction (modified Proctor or modified AASHO compaction) as per the requirement.

Each batch of soil (of atleast 5.5 kg weight for granular soils and 4.5 to 5.0 kg weight for fine grained soils) is mixed with water upto the optimum moisture content or the field moisture content if specified so. The spacer disc is placed at the bottom of the mould over the base plate and a coarse filter paper is placed over the spacer disc. The moist soil sample is to be compacted over this in the mould by adopting either the IS light compaction or the IS heavy compaction.

CALIFORNIA BEARING RATIO TEST

i) For IS light compaction or Proctor compaction, the soil to be compacted is divided into three parts; the soil is compacted in three equal layers, each of compacted thickness about 44 mm by ing 56 evenly distributed blows of the 2.6 kg rammer.

ii) For IS heavy compaction or the modified Proctor compaction, the soil is divided into five equal the soil is compacted in five equal layers, each of compacted thickness about 26.5 mm by applying nly distributed blows of the 4.89 kg rammer. After compacting the last layer, the collar is removed e excess soil above the top of the mould is evenly trimmed off by means of the straight edge. It is tant to see if the excess soil to be trimmed off while preparing each specimen is of thickness about m; if not the weight of soil taken for compacting each specimen is suitably adjusted for the repeat so that the thickness of the excess layer to be trimmed off is about 5.0 mm. Any hole that develops surface due to the removal of coarse particles during trimming, may be patched with smaller size al. Three such compacted specimens are prepared for the CBR test. About 100 g of soil samples are ed from each mould for moisture content determination. from the trimmed off portion

he clamps are removed and the mould with the compacted soil is lifted leaving below the perforated plate and the spacer disc which is removed. The mould with the compacted soil is weighed. A paper is placed on the perforated base plate, the mould with compacted soil is inverted and placed sition over the base plate (such that the top of the soil sample is now placed over the base plate) he clamps of the base plate are tightened. Another filter paper is placed on the top surface of the and the perforated plate with adjustable stem is placed over it. Surcharge weights of 2.5 or 5.0 kg are placed over the perforated plate and the whole mould with the weights is placed in a water tank king such that water can enter the specimen both from the top and bottom. The swell measuring consisting of the tripod and the dial gauge are placed on the top edge of the mould and the spindle dial gauge is placed touching the top of the adjustable stem of the perforated plate, (See Fig. 6.2). itial dial gauge reading is recorded and the test set up is kept undisturbed in the water tank to allow g of the soil specimen for four full days or 96 hours. The final dial gauge reading is noted to measure pansion or swelling of the soil specimen due to soaking.

he swell measuring assembly is removed, the mould is taken out of the water tank and the sample wed to drain in a vertical position for 15 minutes. The surcharge weights, the perforated plate em and the filter paper are removed. The mould with the soil sample is removed from the base nd is weighed again to determine the weight of water absorbed.

e mould with the specimen is clamped over the base plate and the same surcharge weights are on the specimen centrally such that the penetration test could be conducted. The mould with late is placed under the penetration plunger of the loading machine. The penetration plunger is at the centre of the specimen and is brought in contact with the top surface of the soil sample by g a seating load of 4.0 kg. The dial gauge for measuring the penetration values of the plunger d in position. The dial gauge of the proving ring (for load readings) and the penetration dial gauge to zero. The load is applied through the penetration plunger at a uniform rate of 1.25 mm/min. d readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 5 mm. In case the load readings start decreasing before 12.5 mm penetration, the maximum load and the corresponding penetration value are recorded. After the final reading, the load is released e mould is removed from the loading machine. The proving ring calibration factor is noted so e load dial values can be converted into load in kg. About 50 g of soil is collected from the e cm depth of the soil sample for the determination of moisture content.

CALIFORNIA BEARING RATIO TEST

Calculation

The swelling or expansion ratio is calculated from the observations during the swelling test using the formula :

$$\text{Expansion ratio} = \frac{100\,(d_f - d_i)}{h}$$

where d_f = final dial gauge reading after soaking, mm

d_i = initial dial gauge reading before soaking, mm

h = initial height of the specimen, mm.

The load values noted for each penetration level are divided by the area of the loading plunger (19.635 cm^2) to obtain the pressure or unit load values on the loading plunger. The load - penetration curve is then plotted in natural scale for each specimen as shown in Fig. 6.3. If the curve is uniformly convex upwards as shown for specimen no. 1, no correction is needed. In case there is a reverse curve or the initial portion of the curve is concave upwards as shown for specimen no. 2, necessity of a correction is indicated. A tangent is drawn from the steepest point on the curve (point X in Fig. 6.3) to intersect the base at point Y which is the corrected origin corresponding to zero peneration. The unit load values corresponding to 2.5 and 5.0 mm penetration values (either from the original origin for curve without correction or from the corrected origin for the curve with correction, as the case may be) are found from the graph. The CBR value is calculated from the formula :

$$\text{CBR, percent} = \left[\frac{\text{Unit load carried by soil sample at defined penetration level}}{\text{Unit load carried by standard crushed stones at above penetration level}}\right] \times 100$$

The unit load values on standard stones are given in Table 6.1.

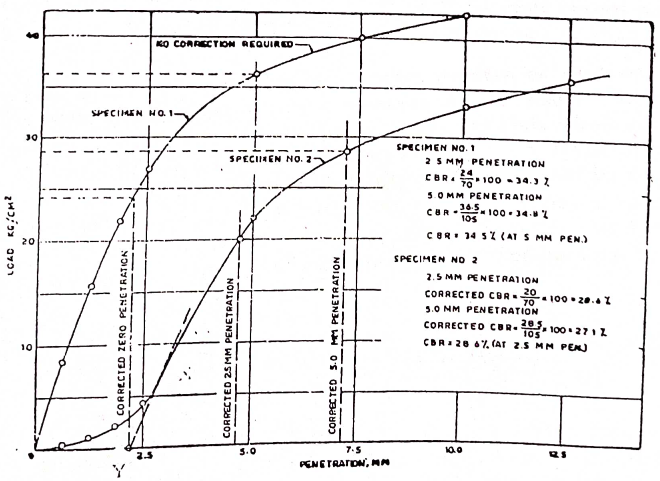

Figure 6.3 C.B.R. Test Load-Penetration Curve

lts

The expansion ratio of soil due to soaking and the other details of the test may be reported as given e observation sheet.

The CBR values at 2.5 mm and 5.0 mm penetrations are calculated for each specimen from the sponding graphs. Generally the CBR value at 2.5 mm penetration is higher and this value is ted. However if higher CBR value is obtained at 5.0 mm penetration, the test is to be repeated to y the results; if the value at 5.0 mm is again higher, this is adopted as the CBR value of the soil sample. average CBR value of three specimens is reported to the first decimal place.

According to the Indian Roads Congress, if the maximum variation in laboratory in CBR values een the three specimens exceeds the values given below for the different ranges, the CBR tests should be ated on additional three specimens and the average value of six specimens is adopted.

Maximum permissible variation in CBR values, %	Range of CBR values, %
3.0	upto 10
5.0	10 to 30
10.0	30 to 60
Not significant	above 60

ssion

Undisturbed soil samples may be used for the CBR test by taking out samples from the field in the d by attaching a core cutter. Due to high degree of disturbance in sample, this method is generally dopted.

The CBR test is essentially an arbitrary strength test and hence can not be used to evaluate the mental soil properties. Unless the test procedure is strictly followed, dependable results cannot be ned. The compaction specifications such as total height of compacted specimen (before trimming off), quality of thickness of the five compacted layers and the uniformity of distribution the blows of the er in each layer (in the case of dynamic compaction) affect the test results. The initial upward vity of the load-penetration curve calling for the correction may be due to (i) piston surface not being in contact with top of the specimen or (ii) the top-layer of soaked soil being too soft. The test is t only for soil and granular base course materials and hence may not be suitable for semi-rigid ials like soil-cement.

FIELD C.B.R. TEST

atus

reaction load like a truck, tractor or truss is required for applying the load by means of a mechanical jack. The other equipment needed are 5 cm diameter loading plunger, extension rods, jacks, ng ring assembly, dial gauge, datum frame, annual surcharge plate 25 cm in diameter and 5 kg in t, with a central hole and slot width 5.3 cm and two circular slotted weighis of 10 kg and diameter 25 cm with central hole and slot width of 5.3 cm.

CALIFORNIA BEARING RATIO TEST

Procedure

A circular area of about 30 cm in diameter is trimmed and levelled. Particular care should be taken at the centre where the plunger is to be seated. The surcharge load of 15 kg is placed on this surface and the plunger is seated properly. The dial gauge to measure the penetration is attached to the plunger from an independent datum frame. A seating load of 4 kg is applied and the load and penetration dials are set to zero.

The load is applied to the plunger by means of the jack such that the rate of penetration is approximately 1.25 mm/minute. The load readings are noted for at penetrations 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0. 7.5, 10.0 and 12.5 mm. The load is released and moisture content specimen is taken from underneath the plunger.

Calculation

The load-penetration curve is plotted, and the C.B.R. value is calculated as in the case of laboratory C.B.R. The correction is applied where necessary i.e., in the case of load-penetration curves which are concave initially upwards.

Three in-place CBR tests shall be performed at each elevation to be tested and the average value is adopted. However if the three tests in any group do not show reasonable agreement within the maximum specified variation for the range of CBR values, (tolerance of 3 for conducted CBR values upto 10%, 5 for values 10 to 30%, 10 for 30 to 60% and 25 for values greater than 60%) three additional tests shall be made in the average of six tests be adopted for design.

Discussion

The field-CBR value is found at the existing moisture content. It is not easy to obtain the field CBR value under soaked condition, unless the test site is subjected to soaking by flooding prior to the test. It is not possible to satisfactorily simulate the critical conditions of dry density and moisture content in the field. As the CBR value of a soil largely depends on the density and moisture content of the soil, the test conditions should be selected with due care.

Applications of CBR test

Based on extensive CBR test data collected, empirical design charts were developed by the California

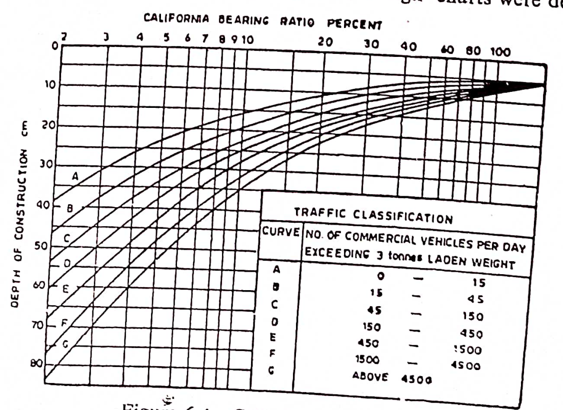

Figure 6.4 CBR Design Chart

OBSERVATION SHEET

CALIFORNIA BEARING RATIO TEST

Compacting moisture content =

Dry Density =

Condition of test specimen :—soaked/unsoaked

Moisture content (a) At top 3 cm layer after soaking =

(b) Average after soaking =

Proving ring calibration factor =

Surcharge weight = Period of soaking = Expansion ratio =

Sample Number (1)	Penetration mm (2)	Proving ring dial reading (3)	Load on Plunger, kg (4)	Corrected load, kg (5)	Unit/load kg/cm^2 (6)
	0.00				
	0.5				
	1.0				
	1.5				
	2.0				
	2.5				
	3.0				
	4.0				
	5.0				
	7.5				
	10.0				
	12.5				

CBR at 2.5 CBR at 5.0 mm

1	2	3	4	5	6

CBR at 2.5 mm ....CBR at 5.0 mm...................

1	2	3	4	5	6

CBR at 2.5 mm................CBR at 5.0 mm...................

Average CBR value at penetration mm = %

Remarks

8. TO CONDUCT THE GRAIN SIZE ANALYSIS OF COARSE AGGREGATE & FINE AGGREGATES.

OBJECT:- To determine the fineness modulus and particle size distribution of coarse, fine and all-in aggregates.

THEORY:- The aggregates are classified as fine and coarse according as they pass through or are retained on 4.75 mm IS sieve. The fineness modulus is an index number which indicated the average sixe of the particles in the aggregates. The coarser the aggregate, the larger is the fineness modulus and vice versa. The aggregate is sieved through a set of sieves and the weight of aggregate retained on each sieve is determined. The sum of the cumulative percentages retained on all the sie divided by 100 gives the fineness modulus. The values of fine ness modulus vary between 2.0 to 3.5 for fine aggregate, 6.0 to 8.0 for coarse aggregate and 3.5 to 6.5 for all-in-aggrega The sieves used in the sieve analysis are:- 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns and 15 microns conformind to IS-460 specifications.

The purpose of determining fineness modulus is to grade the aggregate for most economical mix having required strength an workability using theleast quantity of cement.

APPARATUS:- Weighing balance(accuracy 0.1% of sample weight), Sieves of sizes 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns and 150 microns conforming to IS-460-197 vice plates, trays, sieve shaker drying oven.

PROCEDURE:-(I) COARSE AGGREGATE:

1. Select a sample of 50 kg. 15 kg., 2 kg. or 1 kg. accord ng a maximum size the particles present in substantial proportion 63 mm, 40mm, 20mm, or 10mm. from 5times bigger sample. by quartering or select a sample of 10 kg. The sample should air-dry.
2. Shake the sieves by hand in order of 80mm, 40mm, 20mm, 10mm, 4.75mm, over a clean-dry tray for at lease 2 minutes, shake the sieves with different motions: left to right, backwords forwards, clockwise and anticlockwise with frequent jarring that the material is in motion over the sieve-surface in con nuously changing directions.

3. Find the weight of aggregate retained on each sieve taken in order.

(II) FINE AGGREGATE:-

4. Select a sample of 1kg. from a 10 times bigger sample by quarter ing. The sample should be in air-dry condition.

5. Arrange the sieves in order: 4.75mm, 2.36mm, 1.18mm, 600 microns, 300 microns & 150 microns from top to bottom. Put a pan at the bottom and a cover at the top and fix in the sieve shaker.

6. Put the sample in 4.75mm sieve, replace the cover and carry out sieving for 10 minutes. Determine the weight retainedon each sieve.

(III) ALL-IN-AGGREGATE:-

7. Take a sample of 10kg. ~~xxxxxx~~ from a sample of 50 kg. by quart ing. The aggregate should be in air-dry condition.

8. Separate the coarse and fine aggregates by sieving by hand and determine their weights.

9. Sieve the coarse aggregate and fine aggregate as given above and determine the weight retained on each sieve.

10. Draw the curve between percentage passing and sieve size for co fineand all-in-aggregates.

OBSERVATIONS AND CALCULATIONS:-

(I) COARSE AGGREGATE:

Weight of aggregate taken = Kg.

IS sieves Size	Weight retained (g)	Percentage retained	Percentage passing	Cumulative percentage retained (c)	Remarks.
80mm					
40mm					
20mm					
10mm					
4.75mm					
Pan					

Σc

Fineness modulus of coarse aggregate = $\frac{\Sigma c + 500}{100}$

Fineness modulus of all-in-aggregate $= \frac{M}{100}$

PRECAUTIONS:-

1. All the sieves should be cleaned properly.
2. The sieves should be shaken in all directions for at least 2 minutes in hand sieving.
3. Care should be taken to avoid any spillage of aggregate durir shaking or weighing.
4. All the weighings should be recorded carefully.
5. The aggregate particles should be air-dry and should not be forced through the sieve sieve-mesh during sieving.

DISCUSSIONS:- Plot the curves between percentage passing and sieve size for coarse, fine and all-in-aggregate. Comment on these curves. Also comment on the values of the fineness modulus obtained and discuss the suitability of the aggregate for construction purposes.

VIVA QUESTIONS:-

1. What do you understand by the fineness modulus of aggregate ?
2. What is the significance of fineness modulus ?
3. How will you do the quartering of an aggregate ?.
4. Why the grading of aggregate is done ?
5. What do you understand by diameter of opening of a sieve ?
6. What is the effect of size of aggregate on fine-ness modulu
7. What are normal limits of fineness modulus of coarse, fine an all-in-aggregate ?
8. What do you understand from the particle size dist-ribution curve ?
9. What precautions will you take while performing this experime
10. What is the time required for shaking the sieves on a sieve shaker ?
11. What is the use of aggregate in concrete ?
12. How are the aggregates stored in the field ?

....

9.TO PERFORM PENETRATION TEST ON BITUMEN SAMPLE.

INTRODUCTION

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, where-in 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 assembly being 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 standardised the penetration test equipment and the test procedure, Figure 17.1. Even though it is recognised that the empirical tests like penetration, softening point etc. can not fully qualify the paving binder for its temperature susceptibility chararacteristics, 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 17.2. 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 containing not less than 10 litres of water, the sample is immersed to depth not les 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 17.3.

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

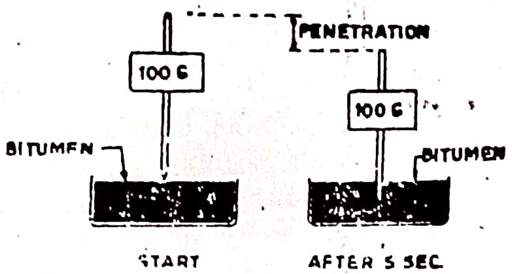

Fig. 17.1 Penetration Test Concept

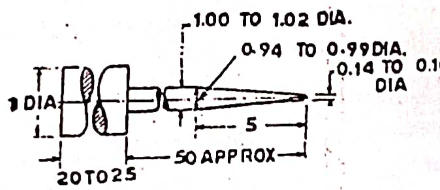

Fig 17.2 Penetration Needle

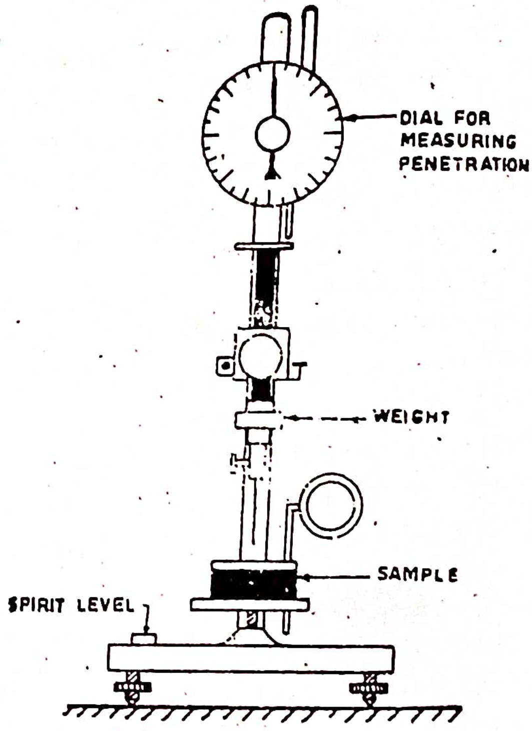

Fig. 17.3 Penetrometer

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 secs 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 100 mm 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 is 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) povring 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 temperatures give 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 consistant results. The penetration needle should not be placed closer than 10 mm 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, bitumens 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 intented 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	A 25	A 35 & S 35	A 45 & S 45	A 65 & S 65	A 90 & S 90	A 200 & S 200
Penetration value	20 to 30	30 to 40	40 to 50	60 to 70	80 to 100	175 to 225

PENETRATION TEST

REFERENCES

1. Indian Standard Methods for Testing Tar and Bitumen, Determination of Penetration, IS : 1203, *Indian Standards Institution.*
2. Bituminous Road Construction, *Burmah Shell*
3. Asphalts, *ESSO*
4. Bituminous Materials in Road Construction, *D.S.I.R.*, H.M.S.O., London
5. Recommennded Practice for Bituminous Penetration Macadam, (Full Grout), *Indian Roads Congress.*
6. Indian Standard Specification for Paving Bitumen, IS : 73-1961, *Indian Standards Institution.*

PROBLEMS

1. How is penetration value of bitumen expressed ?
2. What are the standard load, time and temperature specified for penetration test.
3. Briefly outline the penetration test procedure.
4. What do you understand by 80/100 bitumen ?
5. What are the effects of : (i) higher test temperature (ii) higher pouring temperature (iii) exposed bitumen, on penetration test results.

OBSERVATION SHEET — PENETRATION TEST

(i) Pouring Temperature, °C =

(ii) Period of cooling in atmosphere, minutes =

(iii) Room temperature, °C =

(iv) Period of cooling in water bath, minutes =

(v) Actual test temperature, °C =

Readings	Sample No.				Sample No.			
	Test 1	Test 2	Test 3	Mean value	Test 1	Test 2	Test 3	Mean value
Penetrometer dial reading (i) initial								
(ii) final								
Penetration value								
Repeatability, percent								

Mean Penetration value =

Remarks :

10.TO DETERMINE THE SOFTENING POINT OF BITUMEN SAMPLE:

INTRODUCTION

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 rate. The temperature at which the softened bitumen touches the metal plate placed 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 bitumens possess higher softening point than softer grade bitumens. The concept of determining the softening point by ring and ball apparatus is shown in Figure 19.1.

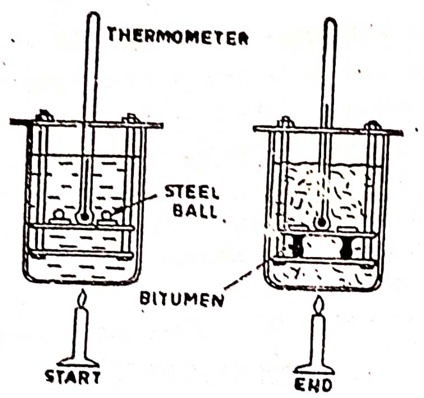

Fig. 19.1 Softening Point Test Concept

Apparatus

It consists of Ring and Ball apparatus.

(a) *Steel Balls :* They are two in number. Each has a diameter of 9.5 mm 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	15.9 mm	Outside diameter	20.6 mm

Brass rings are also placed with ball guides as shown in Figure 19.2.

(c) *Support :* The metallic support is used for placing pair of rings.

SOFTENING POINT TEST

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 25 mm 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.

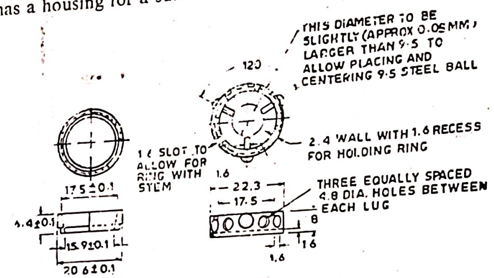

Fig. 19.2 Ring and Ball Guides

(d) *Bath and stirrer :* A heat resistant glass container of 85 mm diameter and 120 mm 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 is trimmed 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 of 5°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°C to 80°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 bitumens 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'.

REFERENCES

Indian Standards Methods of Testing Tar and Bitumen : Determination of Softening Point, IS : 1205, *Indian Standards Institution.*

2. Bituminous Road Construction, *Burmah Shell.*
3. Bituminous Road Construction, *D.S.I.R.*, H.M.S.O., London.
4. Indian Standard Specification for Paving Bitumen, IS : 73, 1961, *Indian Standards Institution.*

PROBLEMS

1. What is softening point ?
2. What does softening point of bituminous materials indicate ?
3. What are the applications of ring and ball test results ?
4. What are the factors which affect the ring and ball test results ?

OBSERVATION SHEET

SOFTENING POINT TEST

(i) Bitumen grade =

(ii) Approximate softening point =

(iii) Liquid used in the bath = water/glycerine

(iv) Period of air cooling, minutes =

(v) Period of cooling in water bath, minutes =

Rate of heating :

Time, minutes	Temperature, °C	Time minutes	Temperature °C
0		11	
1		12	
2		13	
3		14	
4		15	
5		16	
6		17	
7		18	
8		19	
9		20	
10			

Observation :

Test Property	Sample no. 1		Sample no. 2		Mean value, Softening point
	Ball no. (i)	Ball no. (ii)	Ball no. (i)	Ball no. (ii)	
Temperature (°C) at which sample touches bottom plate					
Repeatability					
Reproducibility					

Remarks :

11. TO DETERMINE THE DUCTILITY VALUE OF A BITUMENOUS MATERIAL.

INTRODUCTION

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 pervious 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 bitumens, 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 Figure 18.1.

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 18.2. Both ends called clips possess circular holes to grip the fixed and movable ends of the testing machine. Side pieces when placed together form the briquette of the following dimensions :

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

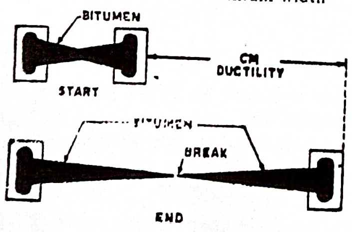

Fig. 18.1 Ductility Test Concept

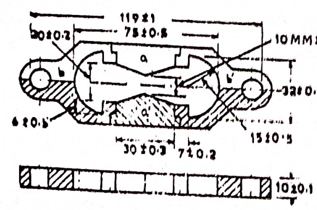

Fig. 18.2 Briquette Mould

(b) ~tility machine : It is an equipment which functions as constant temperature water bath and a pulling device at a precalibrated rate. The central rod of the machine is threaded and through a gear system provides movement to one end where the clip is fixed during initial placement. The other clip end is hooked at the fixed end of the machine. Two clips are thus pulled apart horizontally at a uniform speed of 50 ± 2.5 mm per minute. The machine may have provision to 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 glycerine and dextrine 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 material is cut off by levelling the surface using hot knife. After trimming the specimen, the mould assembly containing sample 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 reeorded (in cm) to report as ductility value.

Results

The distance stretched by the moving end of the specimen upto the point of breaking of thread measured in centimeters is 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) test temperature
(v) 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 varicus grades of bitumen available in India are given below :

DUCTILITY TEST

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

REFERENCES

1. Indian Standard Method for Tar and Bitumen: Determination of Ductility, IS : 1203, *ISI*
2. Bituminous Road Construction, *Burmah Shell.*
3. Bituminous Materials in Road Construction, *D.S.I.R.*, H.M.S.O., London.
4. Indian Standard Specification for Paving Bitumen, IS : 73—1961, *Indian Standards Institution.*

PROBLEMS

1. Explain ductility of Bitumen and its significance.
2. How is ductility value expressed ?
3. Outline the ductility test procedure.
4. What is the minimum area of cross section of the ductility specimen ?
5. What are the precautions to be taken while finding the ductility value ?
6. What are the factors affecting the ductility test results ?

OBSERVATION SHEET — DUCTILITY TEST

(i) Grade of bitumen : =

(ii) Pouring temperature, °C =

(iii) Test temperature, °C =

(iv) Periods of cooling, minutes, (a) in air =

(b) in water bath before trimming =

(c) in water bath after trimming =

Test Property	Briquette Number (i)	(ii)	(iii)	Mean value
1. Ductility value (cm)				
2. Repeatability percent				
3. Reproducibility percent				

Remarks :