HIGHWAY ENGINEERING LAB MANUAL








INDEX

1. AGGREGATE CRUSHING VALUE TEST (IS: 2386 (Part IV))

AIM: To determine mechanical properties of road stone required are:

1. Satisfactory resistance to crushing under the roller during construction and
2. Adequate resistance to surface abrasion under traffic.

THEORY:.

The crushing strength of road aggregates is an essential requirement in India as they need to resist surface stress under rigid tire rims of heavily loaded animal drawn vehicles which is in considerable amounts.

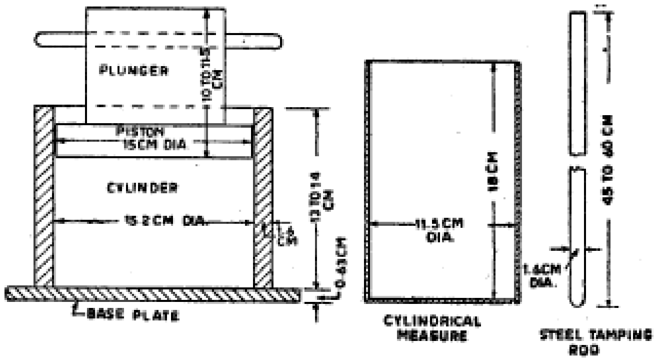
Crushing strength of road stones may be determined either on aggregate or on cylindrical specimens cut of rocks. The two tests are quite different in not only the approach but also in the expression of the results.

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 structures is likely to be adversely affected. The strength of coarse aggregates is assessed by aggregate 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 1) consists of the following:

1. Steel cylinder with open end internal diameter 25.2cm, square base plate plunger having a piston of diameter 15cm, 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.
2. Cylindrical measure having internal diameter of 11.5cm and a height 18cm.
3. Steel temping rod with one rounded end, having a diameter of 1.6cm and length 45 to 60cm.
4. Balance of capacity 3kg with accuracy up to 1kg.
5. Compression of testing machine capable of applying load of 40 tones, at a uniform rate of loading of 4 tones per minute.



PROCEDURE:

The aggregates passing through 12.5mm sieve and retained on 10mm IS sieve is selected for standard test. The aggregates should be in surface dry condition before testing. The aggregate may be dried by heating at a temperature of 100^0C to 110^0C 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 are leveled off by using the tamping rod as a straight edge. About 6.5kg of aggregate is required for preparing two tests samples. The test samples thus taken are 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 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 10cm. 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 plunger in position is placed on compression testing machine. Load is then applied through the plunger at a uniform rate of 4 tones per minute until the total load is 40 tones, and the load is released. Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36mm 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 average value.

CALCULATIONS:

Total weight of dry sample taken = W_1g.

Weight of the portion of crushed material passing 2.36mm is sieve = W_2g.

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

Aggregate crushing value = $\left(\frac{W_2}{W_1} * 100\right)$

OBSERVATION SHEET:

SIZE OF THE AGGREGATE :

RATE OF APPLICATION OF LOAD :

TOTAL LOAD APPLIED :

S. No	Details	Trail Number 1	2	Average
1	Weight of aggregate sample in the cylindrical measure, W_1gm (excluding empty weight of cylindrical measure)			
2	Weight of crushed aggregates after passing through 2.36 mm sieve, W_2 g			
3	Aggregate Crushing Value $(W_1/W_2)*100$			

RESULTS:

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

DISCUSSION:

In general, large size of aggregates is 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 1.1.

TABLE 1.1 DETAILS FOR AGGREGATE CRUSHING TEST WITH NON-STANDARD SIZES OF AGGREGATE:

Aggregate size		Diameter of cylinder to be used, cm	Quality of material and preparation of test sample	Loading	Size of IS sieve for separating fines
Passing sieve size mm	Retained on sieve size, mm				
25	20	15*(standard cylinder)	*Standard method loading, standard loading 3.35 mm		+Standard 4.75 mm
20	12.5	15	Standard method Metal measure 5cm dia & 9cm height tamping	Rate of loading one ton per min. Up to a total	1.70mm

			rod 8mm dia 30cm long	load of 10 tons	
10	6.3	7.5	Depth of material in 7.5cm cylinder after tamping 5cm		
6.3	4.75	7.5	As above	As above	1.18mm
4.75	3.35	7.5	As above	As above	850 microns
3.35	2.36	7.5	As above	As above	600 microns

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 quantity of test sample to be taken is specified by weight, 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 cylindricalspecimen 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/cm^2• 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.

APPLICATIONS 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 cans 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 tires 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 IS) 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.

2. AGGREGATE IMPACT VALUE TEST (IS: 2386 (Part IV))

AIM:

To determine aggregate impact value of given aggregate.

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 standardized by the British standards institution and the Indian Standards Institution.

The aggregate impact value indicates a relative measure of the resistance of an aggregate to a sudden shock or 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 sieves, 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 10cm and depth of 5cm is rigidly fastened centrally to the base plate. A metal hammer of weight between 13.5 and 14.0kg having the lower end cylindrical in shape, 10cm in diameter and 5 cm long, with 2 mm chamber at the lower edge is capable of sliding freely between vertical guide 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 up to 0.5cm. A key is provided for supporting the hammer while fastening or removing the cup. Refer Figure 2.1.

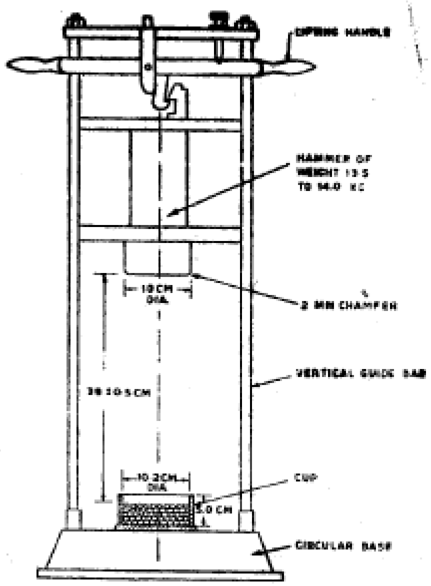
(b) Measure: A cylindrical metal measure having internal diameter 7.5 cm and depth 5cm for measuring at one end.

(c) Tamping rod: A straight metal tamping rod of circular cross section, 1cm in diameter and 23cm long, rounded at one end.

(d) Sieve: IS sieve of sizes 12.5mm,10 mm and 2.36 mm for sieving the aggregates.

(e) Balance: A balance of capacity not less than 500 g to weigh accurate up to 0.1 gm.

(f) Oven: A thermostatically controlled drying oven capable of maintaining constant temperature between 100°C and 110°C.



PROCEDURE:

The test sample consists of aggregates passing 12.5mm sieve and retained on 10 mm sieve and dried in an oven for four hours at a temperature 100°C to ll0ºC and cooled. Test aggregates are filled up to about one-third full in the cylindrical measure and 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 fiat 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 2.30 mm sieve until no further significant amount passes. The fraction passing the sieve is weighed accurate to 0.1g. 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 original weight of the specimen by more than one gram, if 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 be W_1 g and the weight of fraction passing 2.36 mm IS sieve be W_2g.

Aggregate impact value = $(W_2/W_1)*100$

This is recorded correct to the first decimal place.

TABLE 2.1: Maximum Allowable Impact Value Of Aggregate In Different Types Of Pavement Material/ Layers:

S. No	Types of pavement material/ layer	Aggregate impact value %(max)
1	Water bound macadam(WBM), Sub-base course	50
2	Cement concrete, base course (as per ISI)	45
3	a. WBM, base course with bitumen surfacing b. Built up-Spray grout, base course	40
4	Bituminous macadam, base course	35
5	a. WBM, surfacing course b. Built up spray grout, surfacing course c. Bituminous penetration macadam d. Bituminous macadam, binder course e. Bituminous surface dressing f. Bituminous/ asphaltic concrete g. Bituminous carpet h. Cement concrete, surface course	30

TABLE 2.2

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

OBSERVATION TABLE FOR AGGREGATE IMPACT VALUE TEST:

S. No	**Details**	**Trail Number**		**Average**
		1	**2**	
1	Weight of aggregate sample in the cylindrical measure, W_1 g (excluding empty weight of cylindrical measure)			
2	Weight of crushed aggregates after passing through 2.36 mm sieve W_2 g			
3	Aggregate Impact Value: $(W_1/W_2)*100$			

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 values

< 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 hammer on the specimens will be equal. On the other hand, if equal weight of different aggregate samples is 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. 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 finely grained highly siliceous aggregate which are less resistant 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 values for the different types of pavements, those recommended by the Indian Roads congress are given in Table2.1.

3.FLAKINESS INDEX TEST (IS: 2386 part-I)

AIM:

To determine flakiness index of a given aggregates sample.

DEFINITION:

The flakiness index of aggregate is the percentage dry 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 5.1, IS sieves of the sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3 mm and a balance to weight the samples.

PROCEDURE:

The sample is sieved with the sieves mentioned in the table 5.1 A minimum of 200 pieces of each fraction to be tested are taken and weighed =W1g. in order to separate flaky materials, each friction is then gauged for thickness on a thickness gauge shown in fig 5.1 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 5.1 for the appropriate size of the material. The amount of flaky material passing the gauge is weighed to accuracy of at least 0.1 percent of the test sample.

TABLE 3.1: DIMENSIONS OF THICHNESS 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	Retaining on IS sieve mm		
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

CALCULATIONS AND RESULT:

In order to calculate the flakiness index of the entire sample of aggregates first the weight of each fraction of aggregates passing and retained on the specified set of sieves is noted. As an example let 200 pieces of the aggregates passing 50 mm sieve and retained on 40 mm sieve be= W1g. Each of the particles from this fraction of the thickness gauge in this example the width of the appropriate gauge of the thickness gauge is

$$\frac{(50+40)}{2} * 0.6 = 27mm$$

Let the weight of the flaky material passing this gauge be W1g. similarly the weights of the fractions passing and retained the specified sieves. W1, W2, W3 etc weighted and the total weight W1+W2+W3=W g is found also the weights of material passing each of the specified thickness gauges are found= w1, w2, w3…..And the total weight of the material passing the different thickness gauges= w1+w2+w3+…..and the total weight of the flakiness index is the total weight of the sample gauged.

$$\text{Flakiness index}= \frac{(w1 + w2 + w3 + \square) * 100}{(w1 + w2 + w3 + \square)}$$

BSERVATION TABLE:-

Size of Aggregates		Weight of the fraction consisting of 200 pieces, kg	Thickness Gauge (0.6 times the mean sieve), mm	Weight of aggregates in each fraction passing through thickness gauge, kg
Passing through IS sieve, mm	**Retained on IS sieve, mm**			
TOTAL		**W =**		**w =**

RESULT:- Flakiness index of the given aggregate **(w/ W)× 100=**

4.ELONGATION INDEX

AIM: To determine elongation index of given aggregate sample.

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 (1.8 times) of their mean dimension. The elongation test is not applicable to sizes smaller than 6.3 mm.

APPARATUS: The apparatus length gauge consists of the Standard length gauge. IS sieve of size 50, 40, 25, 20, 16, 12.5, 10 and 6.3 mm .A balance to weigh the samples.

PROCEDURE: The sample is sieved through the specified set of IS sieves. 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. The gauge individually for length gauge. 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 separatelyto find the total weight of aggregate retained by the length gauge are weighed to an accuracy of at least 0.1 percent of the weight of the test sample.

CALCULATION AND RESULT:

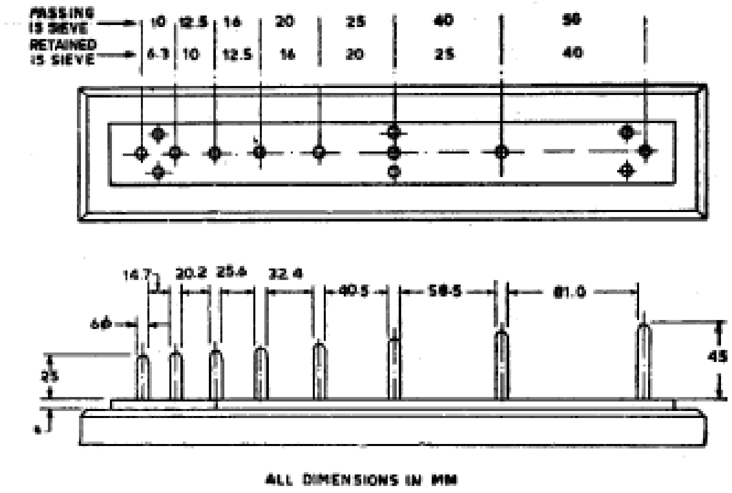
In order to calculate the elongation index of the entire sample of aggregates, the weight of aggregates which is retained on the specified gauge length from each fraction is noted. As an example, let 200 pieces of the aggregate passing 40 mm sieve and retained 25 mm sieve weight W1g. Each piece of these are tried to be passed through the specified gauge length of length gauge, which in this example is

$$= \frac{(45+25)}{2} * 1.8 = 59.5 mm$$

With its longest side and those elongated pieces which do not pass the gauge are separated and the total weight determined=W1g. similarly the weight of each fraction of aggregate passing and retained on specified sieves sizes are found, W1, W2, W3……… and the total weight of sample determined = W1+W2+W3+………=W g. Also the weight of material from each fraction retained determined on the specified gauge length are found =X1, X2, X3……… and the total weight retained determined =X1+X2+X3…. =X g.

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

$$\text{Elongation index} = \frac{(X1 + X2 + X3 + \ldots)}{W1 + W2 + W3 + \ldots..} * 100$$



OBSERVATION SHEET:-

Size of aggregate		Wt of aggregate in each fraction retained on length gauge grams.	Length gauge (1.8 times the mean sieve) mm.	Wt of the aggregate consisting of at least 200 pieces grams.
Passing through IS sieve mm.	Retained on IS sieve mm.			
1	2	3	4	5

RESULT: Elongation index of the given aggregates sample is = ………

RESULT: The Shape test value of the aggregate is the sum of the flakiness index value and the elongation index value and it is found out to be ……

5.ATTRITION TEST

AIM: To determine the Deval attrition value.

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

(i) Deval machine: The Deval abrasion testing machine shall consist of one or more hollow cast iron cylinders closed at one end and furnished with a tightly fitting iron cover at the other. The inside diameter of the cylinders shall be 20 cm and depth 34 cm. The cylinders shall be mounted on a shaft at an angle of 30 degrees with the axis of rotation of the shaft.

(ii) Sieve: 1.70, 4.75,10,12.5,20,25,40 mm IS Sieves.

(iii)Balance of capacity 5kg or 10kg

(iv)Drying oven

(v) Miscellaneous like tray

PROCEDURE:

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

i. Select the grading to be used in the test such that it conforms to the grading to be used in construction, to the maximum extent possible.
ii. Place the aggregates on the cylinders and fix the cover.
iii. Rotate the machine at a speed of 30 – 33 revolutions per minute. The number of revolutions is 10000. The machine should be balanced and driven such that there is uniform peripheral speed.
iv. The machine is stopped after the desired number of revolutions and material is discharged to a tray.
v. The entire stone dust is sieved on 1.70 mm IS sieve.
vi. The material coarser than 1.7mm size is weighed correct to one gram.

Table 6.1

Grading	Passing IS Sieve (mm)	Retained on IS sieve (mm)	Percentage of Sample
A	20	12.5	25
	25	20	25
	40	25	25
	50	40	25
B	20	12.5	25
	25	20	25
	40	25	50
C	20	12.5	50
	25	20	50
D	12.5	4.75	50
	20	12.5	50
E	10	4.75	50
	12.5	10	50

The weight of the test sample shall depend upon its average specific gravity and shall be as follows:

Range in specific Gravity	Weight of Sample (g)
Over 2.8	5500
2.4 to 2.8	5000
2.2 to 2.39	4500
Less than 2.2	4000

OBSERVATIONS:

Original weight of aggregate sample (W_1) =

Weight of aggregate sample retained (W_2) =

Weight passing 1.7mm IS sieve ($W_1 - W_2$) =

Attrition value = $\frac{(W_1 - W_2) * 100}{W_1}$

RESULT: Attrition value of the given aggregate sample is

6.AGGREGATE ABRASION VALUE TEST

INTRODUCTION:

Due to the 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 aggregates, 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 types move on the road, the soil particles present between the wheel and road surface causes abrasion on the road stone. Steel tires 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 abrasion 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:

a) Los Angeles abrasion test
b) Deval's abrasion test
c) Dorry's 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 "Polishing 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.

Los Angeles Abrasion Test (IS : 2386 (Part 4))

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 relative rubbing action between aggregates and steel balls used as abrasive charge. The pounding action of these balls also exits 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 is 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 70cm and an inside length of 50cm, 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 on the 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 3.1. 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 3.1. IS sieve with l.70 mm 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 anyone of the grading A, to G, as per Table 3.l. is used for the test. The grading or gradations 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 3.1 depending on the grading of the aggregate 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 revolutions for gradations A. B, C and D, for gradations 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 1.7mm size is washed and dried in an oven at 105 to ll0°C to constant weight and weighed correct to one gram.

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 7.1 Los Angeles Abrasion grading table

Grading	Weight in grams of each test sample in the size range, mm (Passing and retained on square holes)										Abrasive charge (number of spheres)	Weight of charges, g
	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		
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

*Tolerance of ±2 percent is permitted.

Let the original weight of aggregate =W_1 gm

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

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

Los Angeles abrasive value, %= Percentage wear $=\frac{(W1-W2)}{W1}*100$

DISCUSSION:

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

Different specification limits may be required for gradations 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 is highly reproducible.

Applications 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 3.2.

TABLE 7.2 Maximum Allowable Los Angeles Abrasion Values of Aggregates in Different Types of Pavement Layers

Serial no.	Type of pavement layer	Los Angeles abrasion value, maximum %
1.	Water Bound Macadam (WBM), sub-base course	60
2.	(i) WBM base course with bituminous surfacing (ii) Bituminous Macadam base course (iii) Built-up spray grout base course	50 50 50
3.	(i) WBM surfacing course (ii) Bituminous Macadam binder course (iii) Bituminous penetration Macadam (iv) Built-up spray grout binder course	40 40 40 40
4.	(i) Bituminous carpet surface course (ii) Bituminous surface dressing, single or two coats (iii) Bituminous surface dressing using precoated aggregates (iv) Cement concrete surface course (as per IRC)	35 35 35 35
5.	(i) Bituminous/ Asphaltic concrete surface course (ii) Cement concrete pavement surface course (as per IRC)	30 30

OBSERVATION SHEET:

Grade of the material =

Number of spheres used =

Weight of charge =

Size of the aggregate =

Number of revolutions =

Speed of rotation =

Table 7.3: Calculations

Sample No.			
Total weight of dry sample (W_1) gms			
Weight of aggregate retained on 1.7mm IS sieve after the test (W_2) gms			
Loss in weight due to wear ($W_1 - W_2$)gms			
Los Angeles abrasion value: $\frac{W_1 - W_2}{W1} * 100$			

RESULT:

The abrasion value of given aggregate sample is _____________

7. SPECIFIC GRAVITY AND WATER ABSORPTION TESTS OF AGGREGATES (IS : 2386 (Part 3))

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregates having low specific gravity are generally weaker than those with high specific gravity. This property helps in a general identification of aggregates.

Water absorption also gives an idea on the internal structure of aggregate. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, unless found to be acceptable based on strength, impact and hardness tests.

AIM:

To determine the specific gravity and water absorption of the given aggregate.

Apparatus:

The apparatus required for these tests are:

1. A balance of at least 3 kg capacity, with a accuracy to 0.5 g.
2. An oven to maintain a temperature range of 100 to 110^0 C.
3. A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
4. A container for filling water and suspending the wire basket in it.
5. An airtight container of capacity similar to that of basket, a shallow tray and two dry absorbent clothes.

Procedure for aggregate coarser than 6.3 mm:

1. About 2 kg of aggregate sample is taken, washed to remove fines and then placed in the wire basket. The wire basket is then immersed in water, which is at a temperature of 22^0 C to 32^0 C.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket 25 mm above the base of the tank and allowing it to drop, 25 times at a rate of about one drop per second.
3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 22^0 C to 32^0 C.

5. The basket and aggregates are removed from water and dried with dry absorbent cloth.
6. The empty basket is suspended back in water tank and weighed.
7. The surface dried aggregates are also weighed.
8. The aggregate is placed in a shallow tray and heated to about 110 ^{0}C in the oven for 24 hours. Later, it is cooled in an airtight container and weighed.

Observations and Calculations:

Table 7.1 Observation table for Specific gravity and water absorption

S.No	Details	Observed Values
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 aggregates in air: W_3 g	
4	Weight of oven dry aggregates in air: W_4 g	
5	Apparent Specific Gravity: $W_4 / [W_4 – (W_1 - W_2)]$	
6	Bulk Specific Gravity: $W_4 / [W_3 – (W_1 - W_2)]$	
7	Water Absorption: $[(W_3 – W_4) \times 100]/ W_4$	

Results:

Bulk Specific Gravity =

Apparent Specific Gravity =

Water Absorption = %

1. Aggregate of size finer than 6.3 mm

Results:

Apparent Specific Gravity

Specifications:

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. Water absorption value ranges from 0.1 to about percent for aggregates normally use in road surfacing.

Applications:

Specific gravity of aggregates is considered as an indication of strength. Material having higher specific gravity is generally considered as having higher strength. Water absorption of aggregate is a measure of porosity. This value is considered as a measure of resistance to frost action, and as a measure of sustaining weathering action.

8.PENETRATION TEST (IS: 1203-1978)

AIM: To determine grade of given bitumen

THEORY: The consistency of bituminous materials vary depending upon several factors such as constituents, temperatures etc. At temperature ranges between 25 and 50 degrees centigrade most of the paving bitumen grades remain in semisolid or in plastic states and their viscosity of most of the tars and cut backs are sufficiently low at this temperature range. To permit these bituminous materials to be in a liquid state, enabling some of the grades are mixed with aggregates even without heating.

Determination of absolute viscosity of bituminous materials is not so simple. Therefore the consistency of bitumen is determined by penetration test which is a very simple test, the viscosity of tars and cutback bitumen is determined indirectly using an orifice viscometer in terms of time required for a specified quantity of bituminous materials, wherein the materials is too soft for penetration test, but the viscosity is so high that the material cannot 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 this materials for the purpose of grading them, my 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 penetration test is the measurement of the penetration (in units of $1/10^{th}$ of mm) of standard needle in a bitumen sample maintained at 25^0C during 5 seconds. The total weight of the needle assembly being 100g, the softer the bitumen the greater will be the penetration.

The penetration test is widely used world over for classifying the bitumen in to different grades. The ISI as standardized the penetration test equipment and the test procedure in figure7.1. Even though it is recognized that the empirical test like penetration, softening point etc. cannot only fully qualify the paving binder for its temperature susceptibility characteristics the simplicity and quickness of operation of this test cannot be ignored for common use.

APPARATUS:

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

Container:-A flat bottomed cylindrical metallic container 55 mm in diameter 35 mm or 57 mm in height.

Needle: A straight highly polished cylindrical hard steel needle with conical end having the shape and dimensions as given in figure 7.2.

Water bath: A water bath is maintained at 25 $\pm$ 1^0C containing not less than 10 liters of water. The simple is immersed to depth not less than 100mm from the top and supported on a perforated shelf not less than 50mm from the bottom of the bath.

Penetrometer: It is an apparatus which allows the needle assembly of gross weight 100g to penetrate without appreciable friction for the desire duration of time. The dial is accurately calibrated to give penetration value in units one tenth of mm.

Electrically operated automatic penetrometers are also available. Typically sketch of penetrometer as shown in fig 7.3.

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 75^0C and 100^0C 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 in to 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 13^0C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25^0C for a period of one hour.

The sample container is placed in the transfer way 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 100g. 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 initial reading is taken before releasing the needle. The needle is released exactly for a period of 5.0 seconds by pressing the knob and the final reading is taken on the dial. At least three measurements are made on this simple by testing at distance of less than 100 mm apart. The sample container is also transferred in the water bath before next testing done so as to maintain a constant temperature of 25^0C. The test is repeated with sample in the other container.

RESULTS:

The difference between the initial and final penetration reading 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
Above225	7 percent

DISCUSSION:

It may be noted that the penetration value is influenced by any inaccuracy as regards:

- Pouring temperature.
- Size of needle.
- Weight placed on the needle.
- Test temperature.
- 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. A higher test temperature gives considerably higher penetration values. The duration of releasing the penetration needle can be exactly 5.0 sec`s. 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 10 mm from the side of the dish.

APPLICATION OF PENETRATION TEST:

Penetration test is the most commonly adopted test on bitumen to grade the material in terms of it hardness.

Depending up on 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 value of various types of bitumen used in pavement construction in this country range between 20 and 225. For bitumen macadam and penetration macadam Indian roads congress suggest 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 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 A35) are from Assam petroleum and those designated ‘S’(such as S35) are from other sources.

Table 9.1: various types of bitumen and their penetration values

Bitumen grade	A25	A35&S35	A45&S45	A65&S65	A90&S90	A200&S200
Penetration value	20 to30	30 to 40	40 to 50	60 to 70	80 to 100	175 to 225

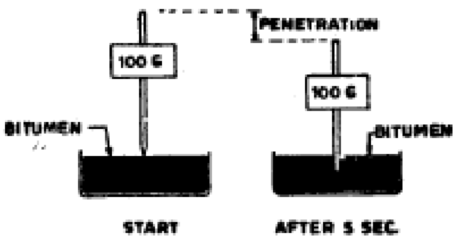


Fig 7.1 Penetration Test Concept

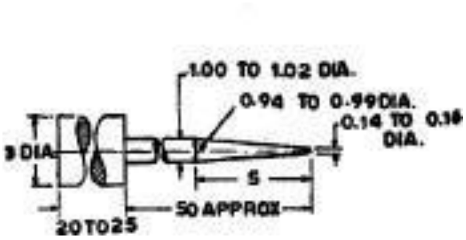


Fig 7.2 Penetration Needle

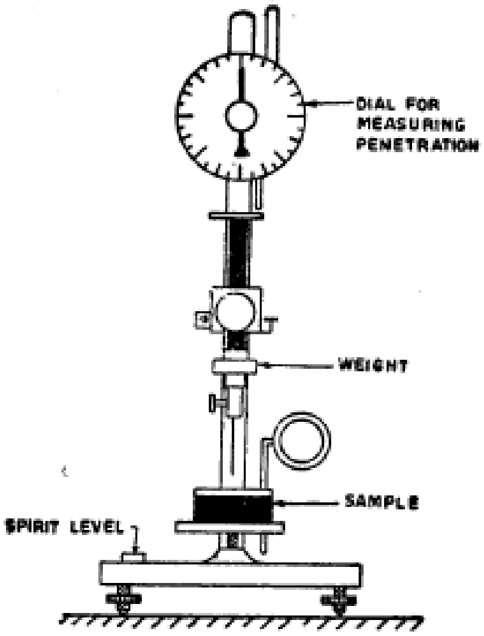


Fig 7.3 Penetrometer

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	**Test1**	**Test2**	**Test3**
Initial			
Final			

RESULT: The penetration value of given bitumen sample is…………..

9.SOFTENING POINT TEST (IS: 1205-1978)

AIM: To determine softening point of a given bitumen sample.

THEORY: Bitumen does not suddenly change from solid to liquid state ,but as the temperature increases it gradually becomes softer until it flows readily .A 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 liquefy 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 usually determined by Ring and Ball test. Brass ring test containing the test sample of bitumen is suspended in liquid like water or glycerin 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 obvious but harder grade bitumen posses higher softening point than softer grade bitumen. The concept of determining the softening point by Ring and Ball apparatus is shown fig8.1

APPARATUS:

- It consists of Ring and Ball apparatus
- Steel Balls they are two in number. Each as a diameter of 9.5mm and weight 2.5 to 5g.
- 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 fig 8.1
- Support the metallic support is used for placing pair of rings.
- The upper surface of the rings is adjusted to be 50mm below the surface of the water or liquid contained in the bath. A distance the bottom of the rings on top surface of the bottom plate of support is provided it has a housing for a suitable thermometer.
- Bath and Stirrer: A heat resistance glass container of 85mm dia and 120mm materials having softening point above 80 degree C and glycerin for materials having softening point above 80 degree C. Mechanical stirrer is used for ensuring uniform distribution all times throughout the bath.

PROCEDURE:

Sample material is heated to a temperature between 75 and 100^{0}C above the approximate softening point until it is 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 glycerin and dextrin .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 above .At this time the temperature of distilled water is kept at 5^0C. 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 5^0C per minute with a controlled heating unit 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 80^0C, glycerin is used as a heating medium and the starting temperature is 35^0 C, instead of 5^0 C.

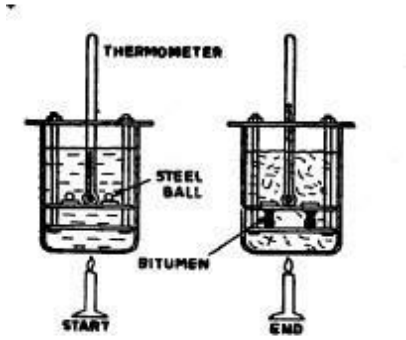


Fig 11.1 Softening Point Test Concept

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 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 to 80°C	1°C	2°C
Above 80°C	2°C	4°C

DISCUSSION:

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

1) Quality and type of liquid
2) Weight of balls
3) Distance between bottom of ring and bottom base plate
4) Rate of heating

Impurity in water or glycerine has been observed to effect the result considerably. It is logical to observe lower softening point if there weight of ball is excessive on the other hand increased distance between bottom of ring and bottom of 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 equi-viscous temperature.

The softening point found by the ring and ball apparatus is approximately 20^{0}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 the warmer place.

The ranges of softening point specified by the Indian standards Institute for various grades of bitumen are given below.

Table 10.1: Ranges of Softening Point Specified by The Indian Standards Institution for Various Grades of Bitumen

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 ATMOSHERE :

PERIOD OF COOLING IN WATER BATH :

ROOM TEMPERATURE :

RATE OF HEATING :

TEST TEMPERATURE :

LIQUID USED IN WATER BATH :

RATE OF HEATING :

TIME IN MINTUES	TEMPERATURE IN °C

RESULT: The softening point of given bitumen sample is

10. FLASH AND FIRE POINT OF BITUMINOUS MATERIAL (IS: 1209-1978)

AIM:

To determine the flash and fire point of the bitumen.

THEORY:

Bitumen materials leave out volatiles at high temperatures depending upon their grades. These volatile vapours catch fire causing flash. This condition is very hazardous and it is therefore essential to qualify the temperature for each bitumen grade so that the paving engineers may restrict the mixing or application temperature well within the limit. The flash point is the lowest temperature at which the ignition of the volatile vapors occurs when small flame is brought in contact with the vapors of a bituminous product. When the bituminous materials are further heated to a higher temperature, burning of material takes place. This is called fire point. Flash point is always less than fire point of bitumen.

Flash point "The flash point is the lowest temperature at which the vapors of substance momentarily takes fire in the term of a under specified point test.

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

APPARATUS:

1) Pensky martens closed tester consists of cup device cover shutter exposure device etc.

2) Pensky marten open tester as above with the modification, that the cover of the cup replaced by a clip which encircles the upper rim of the cup and carries the thermometer and test flame.

PROCEDURE:

1) All parts of the cup are cleaned and dried thoroughly the test is started. The material is filled in the cup up to a filling mark. The lid is placed to close the cup in a closed system.

2) All accessories including thermometer of 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 rate of 5 degrees to 6 degrees per minute the string 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 at least 17°Cbelow the actual flash point and then at every 1°C to 3°C.

OBSERVATION SHEET:

TYPE OF CUP:

RATE OF HEATING:

TIME IN MINUTES	TEMPARATURE IN ^{0}C.

FLASH POINT :

FIRE POINT :

RESULTS:

The flash point of the bitumen is ___________________

The fire point of the bitumen is___________________

The flash point is taken as the temperature used on the on thermometer at the of the flame application that causes a bright flash in the interior of the cap in closed system. For open cap it is the instance when flash appears best any point on the surface of the material. Flash heat continued until the volatile ignites and the material continuous 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 result should not differ from the mean by more than 3^0 C. For materials flashing above 104^0C and not than 1^0 C from the mean flashing below 104^0 C. sometimes bluish hallow that surrounds the test flame confused with true flash. For open cup system, it is specified that ISI that the mean value should not differ from the individual values by more than 3^0 C. for flash point, and by 6^0 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 cutback 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 ISI 175 for all the grades of bitumen.

10.DUCTILITY TEST (IS: 1208-1978)

AIM: To determine 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 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 the type of bitumen depends on crude source of the bitumen, 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 and 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 $27^{0} \pm 0.5^{0}C$ and a rate of pull of 50 ± 2.5mm per minute .The test has been standardized by the ISI .The ductility test concept is show in fig 10.1.

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 fig10.2. Both ends called clips possess circular holes to grip the fixed and movable ends of the testing machine. Side pieces when placed together from the briquette of the following dimensions:

Length-- 75mm

Distance between clips -------------------- 30mm

Width at mouth of clips-------------------- 20mm

Cross section at minimum width --------- 10mm x10mm

(b) Ductility machine: It is an equipment which functions as constant temperature water bath and a pulling device at a pre-calibrated 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 clips are thus pulled apart horizontally at a uniform speed of 50 ± 2.5mm 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 75^0C to 100^0C 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 along with the sample is placed in water bath maintained at 27^0C for 30 minutes .The sample and mould assembly are removed from water bath excess bitumen is cut if by to level the surface using hot knife .After trimming the specimen, the mould assembly containing sample is replaced in water both maintained at27^0C 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 min. The distance at which the bitumen thread of each specimen breaks, is recorded (in cm) to report as ductility value.

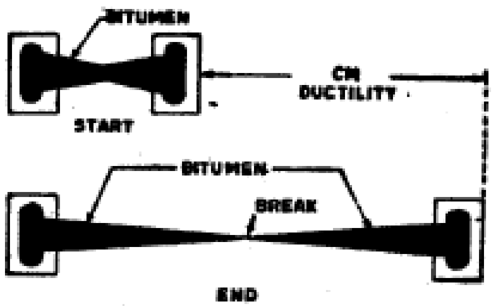


Fig. 8.1 Ductility Test Concept

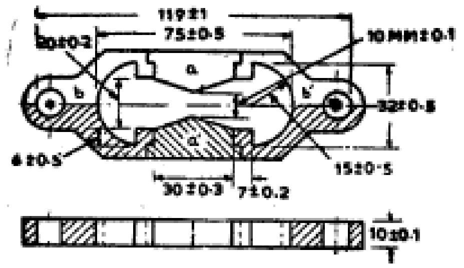


Fig. 8.2 Briquette Mould

RESULTS:

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

Repeatability: 5percent Reproducibility: 10 percent

DISCUSSION:

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

(1)Pouring temperature
(2) Dimensions of briquette
(3) Improper level of briquette placement
(4)Rate of pulling

Increase in minimum cross section of 10sq.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 bitumen nixes 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 value of 50cm is specified for bituminous construction.

Table 9.2: The Minimum Ductility values specified By the Indian Standards Institution for Various Grades of Bitumen Available in India

Source of paving bitumen and penetration grade	**Minimum ductility value, cm.**
Assam petroleum A 25	5
A 35	10
A 45	12
A 65, A90& A 200	15
Bituminous from sources other than Assam	
petroleum S 35	50
S45, S65,S90	75

OBSERVATION SHEET:

POURING TEMPERATURE :

PERIOD OF COOLING IN ATMOSPHERE :

PEROID OF COOLING IN WATER BATH BEFORE TRIMMING :

PEROID OF COOLING IN WATER ABTH AFTER TRIMMING :

ROOM TEMPERATURE :

DIMENSIONS OF BRIQUETTE:

- LENGTH
- DISTANCE BETWEEN THE CLIPS
- WIDTH AT MOUTH OF CLIPS
- CROSS SECTION AT MINIMUM WIDTH

BRIQUETE NUMBER	**1**	**2**	**3**
INITIAL: **FINAL:** **MEANDUCTILITY VALUE:**			

RESULT:

The ductility value of given bitumen sample is___________

12. MARSHALL STABILITY TEST

Aim: :

1) To find out optimum bitumen content of given mix.

2) To determine the strength (Marshall's Stability Value) and flexibility (Flow Value) for the given bituminous mixture.

THEORY:

Bruce Marshall, formerly bituminous engineer with Mississippi state highway department, USA formulated Marshall's method for designing bituminous mixes. Marshall's test procedure was later modified and improved upon by U.S.corps of engineers through their extensive research and correlation studies .ASTM and other agencies have standardized the test procedure. Generally, this stability test is applicable to hot-mix design using bitumen and aggregates with maximum size of 25mm. Strength is measured in terms of the 'Marshall Stability' of the mix which is defined as the

maximum load carried by a compacted specimen at a standard test temperature of 60ºC. This temperature represents the weakest condition for a bituminous pavement in use. The flexibility is measured in terms of the 'flow value' which is measured by the change in diameter of the sample in the direction of load application between the start of loading and the time of maximum load. In this test an attempt is made to obtain optimum binder content for the aggregate mix type and trafficintensity.

APPARATUS:

1) Mould assembly: Cylindrical moulds of 10cm diameter and 7.5cm height are required. It further consists of a base plate and collar extension. They are designed to be interchangeable with either end of cylindrical mould.

2) Sample Extractor: For extruding the compacted specimen from the mould, an extractor suitably fitted with a jack or compression machine.

3) Compaction pedestal and hammer: It consist of a wooden block capped with M.S. plate to hold the mould assembly in position during compaction. The compaction hammer consists of a flat circular tamping face 8.8 cm diameter and equipped with a 4.5 kg. Weight constructed to provide a free fall of 47.5cm. Mould holder is provided consisting of spring tension device designed to hold compaction mould in place on the compaction pedestal.

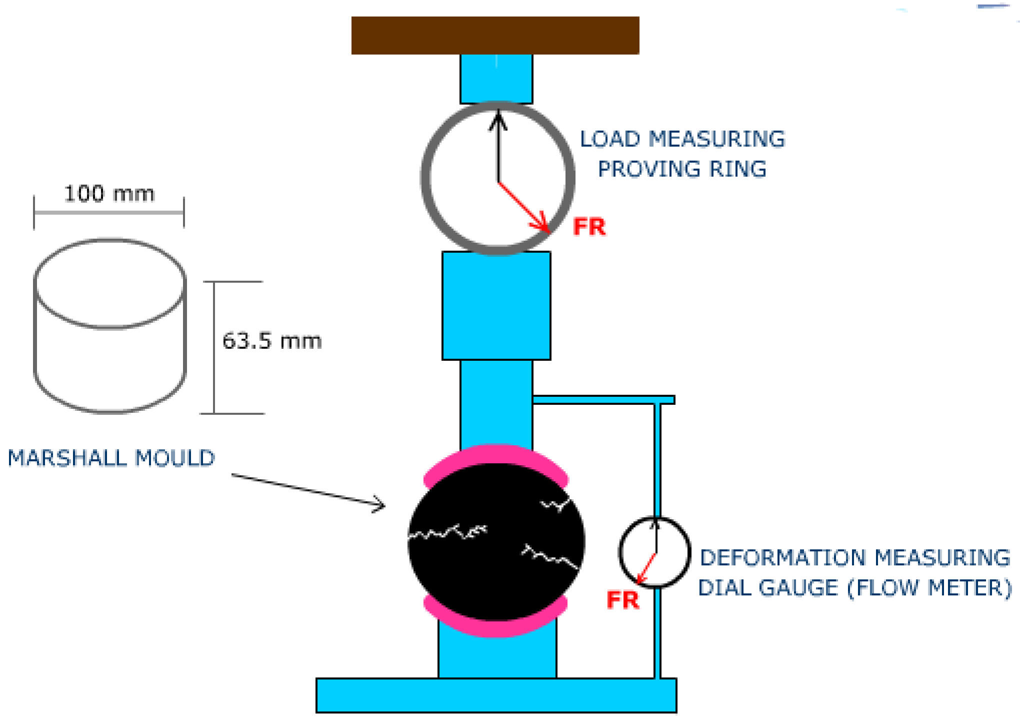
4**) Breaking head**: It consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 5cm. The lower segment is mounted on a base having two vertical guide rods which facilitate insertion in the holes of upper test head.

5)Loading machine:The loading machine is provided with a gear system to lift the base in upward direction. On the upper end of the machine, a pre-calibrated proving ring of 5 tonne capacity is fixed. In between the base and the proving ring, the specimen contained in test head is placed. The loading machine produces a movement at the rate of 5cm per minute. Machine is capable of reversing its movement downward also. This facilitates adequate space for placing test head system after one specimen has been tested.

6) Flow Meter: One dial gauge fixed to the guide rods of a testing machine can serve the purpose. Least count of 0.025 mm is adequate. The flow value refers to the total vertical upward movement from the initial position at zero load to a value at maximum load. The dial gauge or the flow meter should be able to measure accurately the total vertical movement upward. Besides the above equipment, the following are also required: a) Ovens on hot plate b) Mixing apparatus c) Water bath, thermometers of range up to 200^0 C with sensitivity of 2.5^0 C

PROCEDURE:

Specimen preparation: Approximately 1200gm of aggregates and filler is heated to a temperature of 175−190°C. Bitumen is heated to a temperature of 121 − 125°C with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of 154 − 160°C. The mix is placed in a preheated mould and compacted by a rammer with 75 blows on either side at temperature of 138°C to 149°C. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by +0.5% and repeat the above procedure. Number of trials are predetermined.



Marshall Mould

1.The specific gravity values of different aggregates, filler and bitumen used are determined first. The theoretical specific gravity of the mix is determined.

2. Soon after the compacted bituminous mix specimens have cooled to room temperature, the weight, average thickness and diameter of the specimen are noted. The specimens are weighted in air and then in water.

3. The bulk density value of the specimen if calculated from weight and volume. 8. Then the specimen to be tested is kept immersed under water in a thermostatically controlled water bath maintained at 60° ±1°C for 30 to 40 minutes.

4. The specimens are taken out one, placed in the marshal test and the marshal stability value and flow are noted.

10. The corrected Marshall Stability value of each specimen is determined by applying the appropriate correction factor, if the average height of the specimen is not exactly 63.5mm.
11. Five graphs are plotted with values of bitumen content against the values of density, Marshall Stability, voids in total mix, flow value, voids filled by bitumen.
12. Let the bitumen contents corresponding to maximum density be B1, corresponding to maximum stability be B2 and that corresponding to the specified voids content (at 4.0%) be B3. Then the optimum bitumen content for mix design is given by: Bo = (B1+B2+B3)/3

OBERSVATION AND CALCULATIONS:

Theoretical specific gravity of the mix (Gt):
Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of fine aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, G1 is the apparent specific gravity of coarse aggregate, G2 is the apparent specific gravity of fine aggregate, G3 is the apparent specific gravity of filler and Gb is the apparent specific gravity of bitumen.

Bulk specific gravity of mix (Gm)
The bulk specific gravity or the actual specific gravity of the mix Gm is the specific gravity considering air voids and is found out by:

$$G_m = \frac{W_m}{W_m - W_w}$$

where, Wm is the weight of mix in air, Ww is the weight of mix in water, Note that Wm-Ww gives the volume of the mix. Sometimes to get accurate bulk specific gravity, the specimen is coated with thin film of paraffin wax, when weight is taken in the water. This, however requires to consider the weight and volume of wax in the calculations.

Air voids percent Vv
Air voids Vv is the percent of air voids by volume in the specimen and is given by:

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

Percent volume of bitumen Vb

The volume of bitumen Vb is the percent of volume of bitumen to the total volume and given by:

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}}$$

where, W1 is the weight of coarse aggregate in the total mix, W2 is the weight of fine aggregate in the total mix, W3 is the weight of filler in the total mix, Wb is the weight of bitumen in the total mix, Gb is the apparent specific gravity of bitumen, and Gm is the bulk specific gravity of mix.

Voids in mineral aggregate(VMA)

Voids in mineral aggregate V MA is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, and is calculated from

$$VMA = V_v + V_b$$

where, Vv is the percent air voids in the mix, given by equation 26.3. and Vb is percent bitumen content in the mix,

Voids filled with bitumen (V FB)

Voids filled with bitumen V FB is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as:

$$VFB = \frac{V_b \times 100}{VMA}$$

where, Vb is percent bitumen content in the mix, given by equation 26.4. and V MA is the percent voids in the mineral aggregate.

Observation table for Marshall Stability and flow value

Sample No	Bitumen content percent	Stability Value		Flow dial reading	Flow value 0.25mm units
		Measured	Corrected		
1					
2					
3					
Average					
1					
2					
3					
Average					
1					
2					
3					
Average					
1					
2					
3					
Average					

Prepare graphical plots The average value of the above properties are determined for each mix with different bitumen content and the following graphical plots are prepared:

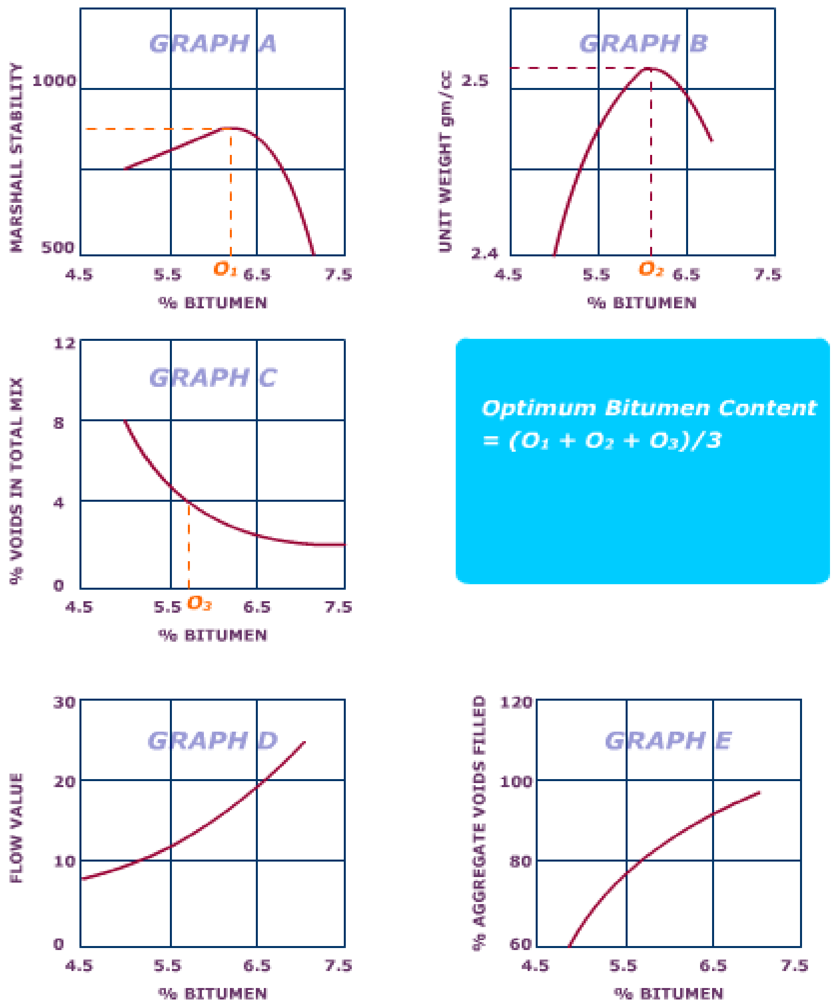
1. Binder content versus corrected Marshall stability
2. Binder content versus Marshall flow
3. Binder content versus percentage of void (Vv) in the total mix
4. Binder content versus voids filled with bitumen (V FB)
5. Binder content versus unit weight or bulk specific gravity (Gm)

Determine optimum bitumen content:

Determine the optimum binder content for the mix design by taking average value of the following three bitumen contents found form the graphs obtained in the previous step. 1. Binder content corresponding to maximum stability

2. Binder content corresponding to maximum bulk specific gravity (Gm)

3. Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e. 4%)



RESULT: optimum Bitumen content is ___________________