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1. AGGREGATE CRUSHING VALUE TEST

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^{0}C to 110^{0}C for a period of 4 hours and is tested after being cooled to room temperature.

The cylindrical measure is filled by the test sample of aggregate in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod. After the third layer is tamped, the aggregates at the top of the cylindrical measure 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: $\left(\frac{W_2}{W_1} * 100\right)$			

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 method		+Standard 4.75 mm
20	12.5	15		Rate of	1.70mm

10	6.3	7.5	Metal measure 5cm dia & 9cm height tamping rod 8mm dia 30cm long Depth of material in 7.5cm cylinder after tamping 5cm As above	loading one ton per min. Up to a total load of 10 tons	
6.3	4.75	7.5	As above	As above	1.18mm
4.75	3.35	7.5		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 cylindrical specimen prepared out of rock sample by drilling, sawing and grinding. The specimen may be subjected to a slowly increasing compressive load until failure to find the crushing strength in kg/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.

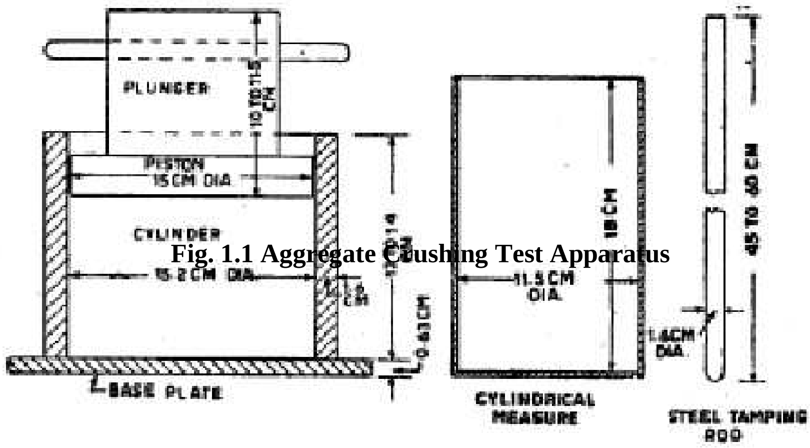

Fig. 1.1 Aggregate Crushing Test Apparatus

2. AGGREGATE IMPACT TEST

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 froma 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 ll0 $_{o}$C 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.

Fig. 2.1 Aggregate Impact testing Machine

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.

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

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 1	Trail Number 2	Average
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: $\left(\frac{W_2}{W_1} * 100\right)$			

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 Table 2.1.

For deciding the suitability of soft aggregates in base course construction, this test has been commonly used. A modified impact test is also often carried out in the case of soft aggregates to find the wet impact value after soaking the test sample. The recommendations given in Table 2.2 based on work reported by different agencies; have been made to assess the suitability of soft aggregates for road construction.

3. DEVAL ATTRITIONTEST

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.

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Table 3.1

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:Deval attrition value =

4. 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

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 4.1 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 = *100

RESULT:

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

DISCUSSION:

It may seldom happen that the aggregates desired for a certain construction project has the same grading as 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 4.2Maximum 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	50
	(ii) Bituminous Macadam base course	50
	(iii) Built-up spray grout base course	50

3.	(i) WBM surfacing course	40
	(ii) Bituminous Macadam binder course	40
	(iii) Bituminous penetration Macadam	40
	(iv) Built-up spray grout binder course	40
4.	(i) Bituminous carpet surface course	35
	(ii) Bituminous surface dressing, single or two coats	35
	(iii) Bituminous surface dressing using precoated aggregates	35
	(iv) Cement concrete surface course (as per IRC)	35
5.	(i) Bituminous/ Asphaltic concrete surface course	30
	(ii) Cement concrete pavement surface course (as per IRC)	30

OBSERVATION SHEET:

Grade of the material =

Number of spheres used =

Weight of charge =

Size of the aggregate =

Number of revolutions =

Speed of rotation =

Sample No.			
Total weight of dry sample (W_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: $\left(\frac{W_1 - W_2}{W_1}\right) * 100$			

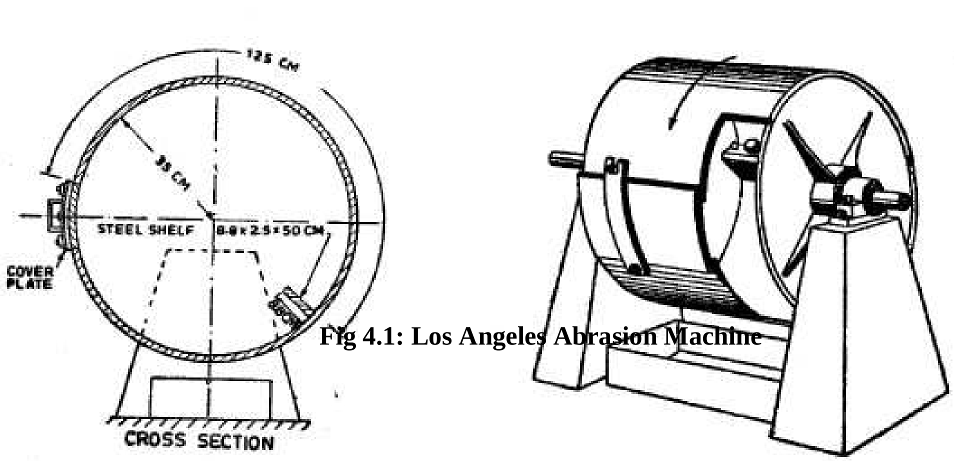

Fig 4.1: Los Angeles Abrasion Machine

RESULT:

The abrasion value of given aggregate sample is

5. SHAPE TEST

INTRODUCTION:

The particle shape of aggregate is determined by the percentage of flaky and elongated particles contained in it. In 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 is 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 voids content in an aggregate of any specified size increases and hence the grain size distribution of a grade 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 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, particularity with reference to flakiness, elongation and angularity is necessary.

A. FLAKINESS INDEX TEST

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.

Fig. 5.1 Thickness Gauge

TABLE 5.1: 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

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

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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.

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

OBSERVATION TABLE:-

Size of Aggregates				
Passing through IS sieve, mm	**Retained on IS sieve, mm**	**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**
Total		**W=**		**w=**

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

B. 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 separately to 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.

Fig. 5.2 Length Gauge

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

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

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.

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

OBSERVATION SHEET:-

Size of aggregate		Wt of aggregate in each fraction retained on length gauge grams.	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**

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

QUESTIONS:-

1) What Is The Significance Of The Shape Tests?
2) Why Flaky Or Elongated Particles Are Avoided In Pavement Construction?
3) What Are The Applications Of Shape Tests?
4) Define Flakiness Index?
5) Define Elongation Index?

6. SPECIFIC GRAVITY AND WATER ABSORPTION TESTS OF AGGREGATES

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.
6. Pycnometer of 100ml for aggregates finer than 6.3 mm and Specific gravity bottle

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.

Procedure for specific gravity determination of aggregate finer than 6.3 mm :

1. A clean, dry pycnometer is taken and its empty weight is determined.
2. About 1000g of clean sample is taken into the pycnometer, and it is weighed.
3. Water at 27 ^{0}C is filled up in the pycnometer with aggregate sample, to just immerse sample.
4. Immediately after immersion the entrapped air is removed from the sample by shaking pycnometer, placing a finger on the hole at the top of the sealed pycnometer.
5. Now the pycnometer is completely filled up with water till the hole at the top, and after confirming that there is no more entrapped air in it, it is weighed.
6. The contents of the pycnometer are discharged, and it is cleaned.
7. Water is filled up to the top of the pycnometer, without any entrapped air. It is then weighed.

For mineral filler, specific gravity bottle is used and the material is filled upto one-third of the capacity of bottle. The rest of the process of determining specific gravity is similar to the one described for aggregate finer than 6.3 mm.

Observations and Calculations:

1. Aggregate coarser than 6.3 mm

Table 6.1 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 = %

2.Aggregate of size finer than 6.3 mm

Table 6.2 Observation table for Specific gravity test (finer than 6.3 mm)

S.No	Details	Observed Values
1	Weight of Pycnometer in air: W_1 g	
2	Weight of aggregates and Pycnometer: W_2 g	
3	Weight of aggregates, Pycnometer and water: W_3 g	
4	Weight of water and Pycnometer in air: W_4 g	
5	Apparent Specific Gravity: $(W_2 – W_1) / [(W_4 – W_1) - (W_3 - W_2)]$	

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 2.0 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.

7. PENETRATION TEST

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 baks 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. The needle is provide with a shank approximately 3.0 mm in diameter in to which it is immovably fixed.

Water bath: A water bath is maintained at 25 + 1$_0$C 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$_0$C and 100$_0$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 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 $_0$C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25 $_0$C 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 $_0$C. 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

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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.

Table7.1: 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…………..

8. DUCTILITY TEST

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 $27^0 + 0.5^0$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 ^{0}C to 100^{0}C above the approximate softening point until it is fluid .It is strained through IS sieve 30, poured in the mould assembly and placed on a brass plate ,after a solution of glycerin and dextrin is applied at all surfaces of the mould exposed to bitumen .Thirty to forty minutes after the sample is poured into the moulds the plate assembly along with the sample is placed in water bath maintained at 27^{0}C 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 ^{0}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 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.

Table8.1: The Minimum Ductility values specified By The Indian Standards Institution For Various Grades Of Bitumen Available In India

Source of paving bitumen and penetration Minimum ductility value, cm.
grade
Assam petroleum A 255
A 3510
A 4512
A 65, A90& A 20015
Bituminous from sources other than Assam
petroleum S 3550
S45, S65,S9075

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:			
MEAN DUCTILITY VALUE:			

RESULT:

The ductility value of given bitumen sample is

9. FLASH AND FIRE TEST

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 plac.Tthis 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.

RESULTS:

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 pointthisis 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.

OBSERVATION SHEET:

TYPE OF CUP:

RATE OF HEATING:

TIME IN MINUTES	TEMPARATURE IN ^{0}C.

FLASH POINT :

FIRE POINT :

10. MARSHALL STABILITY TEST

AIM:

To find out optimum bitumen content of given mix.

Theory:

Bruce Marshall, formerly bituminous engineer with Mississippi state highway department, USA formulated Marshall'smethod 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.

In this method, the resistance to plastic deformations of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at 5 cm per minute. This test procedure is used in designing and evaluating bituminous paving mixes. The test procedure is extensively used in routine test program for the paving jobs. There are two major features of the Marshall method of designing mixes namely, (i) Density-voids analysis, (ii) stability-flow tests. The Marshall stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature at 60^{0}C. The flow value is a deformation the Marshall test specimen undergoes during the loading up to the maximum load in 0.25 mm units. In this test an attempt is made to obtain optimum binder content for the type of aggregate mix and traffic intensity. The proposed designed steps for the design of bituminous mix are given below.

- Select grading to be used.
- Select aggregates to be employed in the mix.
- Determine the proportion of each aggregate required to produce design grading.
- Determine the specific gravity of the aggregate combination and of the asphalt cement.
  Make up trail specimens with varying asphalt contents.
  Determine the specific gravity of each component specimen.
- Make stability tests on the specimens.
- Calculate the percentage of voids, VMA and the percent voids filled with
- bitumen each specimen.
- Select the optimum bitumen content with design requirements. The design may be required if necessary after altering the gradation so as to fulfill the design requirements.

APPARATUS:

1. Mould assembly: Cylindrical moulds of 10cm diameter and 7.5cm height are required. It further consist 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 consist 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: See fig. 14.1. 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.

Fig. 10.1 Marshall Stability Testing Machine

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.,

- Ovens on hot plate,
- Mixing apparatus,
- Water bath,thermometers of range up to 200^{0}C with sensitivity of 2.5^{0}C.

PROCEDURE:

In the Marshall method each compacted test in specimen is subjected to the following tests and analysis in the order listed below:

- Bulk density determination,
- Stability and flow test,
- Density and voids analysis,

At least three samples are prepared for each binder content.

PREPARATION OF TEST SPECIMENS:

The coarse aggregates, fine aggregates and the filter material should be proportioned and mixed in such a way that final mix after blending has the gradation within the specified range.The specified gradation of mineral aggregates and the bitumen binder as perIRC: 29-1968 are given in table 14.1

The aggregates and filter are mixed together in the desired proportion as per the design requirements are fulfilling the specified gradation. The required quantity of mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5mm approximately.

Approximately 1200g of aggregates and filter are taken and heated to a temperature of 175 to 190^{0}C. The compaction mould assembly and rammer are cleaned and kept pre heated to a temperature of 100 to 145^{0}C. The bitumen is heated to temperature of 121 to 138^{0}C and the required quantity of first trail percentage of bitumen (say 3.5% by weight of mineral aggregates) is added to the heated aggregate and thoroughly mixed using a mechanical mixer or by hand mixing with trowel. The mixing temperature for 80/100 grade bitumen may be around 154^{0}C and that for 60/70 grade about 160^{0}C. The mix is placed in a mould and compacted by rammer, with 75 blows on either side. The compacting temperatures may be about 138^{0}C for 80/100 grade bitumen and 149^{0}C for 60/70 grade. The compacted specimen should have a thickness of 63.5 mm. The weight of the aggregate taken may be suitably altered to obtain a thickness of 63.5 + 3.0 mm. At least two specimens, but preferably three or four specimens should be prepared at each trail bitumen content which may be varied at 0.5 percent increments up to about 6.0 or 6.5 percent. The compacted specimens are allowed to cool to room temperature, the sample height and weight is determined, theoretical density is calculated. The specimen is then weighed in air and then in water for determining volume and later bulk density. The specimens are then transferred into a water bath, kept at 60^{0} C for 30 to 40 minutes. They are then removed, dried and placed in Marshall test head. Their Stability and flow values are noted. They are corrected for variation from average height.

TESTS:

Specific gravity of compacted specimens:

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

$$G_t = \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}} =$$

Where W1= percent of weight of coarse aggregates,

W2= percent of weight of fine aggregates,

W3= percent of weight of filler,

W4= percent by weight of bitumen in total mix,

G1, G2, and G3 are apparent specific gravity values of the coarse aggregates, fine aggregates and filler respectively and G4 is the specific gravity of bitumen.

Density and void analysis:

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 to be weight in air and then in water. The bulk density value Gb of the specimen if calculated from the weight and volume. The voids analysis is made as given below:

V_v = Air voids in the mix = $\frac{100(G_t - G_b)}{G_t}$ = %

V_b = Volume of bitumen,% = $G_b * \frac{W_4}{G_4}$ =

VMA = Void in Mineral Aggregates = $V_v + V_b$ = %

VFB = Voids Filled with Bitumen,% = $\frac{100 * V_b}{VMA}$ =

Marshall Stability and flow values:

The specimens to be tested are kept immersed under water in a thermostatically controlled water bath maintained at 60^0C for 30 to 40 minutes. The specimens are taken one by one, placed in the marshall test head and the Marshall stability value (maximum head carried in kg. before failure load in o.25mm units) are noted. The corrected Marshall stability value of each specimen is determined by applying the approximate correction factor, if the average height of the specimen is not exactly 63.5mm the correction factors are given in table 14.2.

DETERMINATION OF OPTIMUM BITUMEN CONTENT

Five graphs are plotted with values of bitumen content against the value of:

- Density G_b. g/cm^3,
- Marshall stability S, kg,
- Voids in total mix Vv %,
- Flow value ,F (0.25mm units)
- Voids filled with bitumen , VFB %,

Let the bitumen content corresponding to maximum density be B_1, corresponding to maximum stability be B_2 and that corresponding to the specified voids content Vv (4.0% in the case of dense AC mix) to B_3. Then the optimum bitumen content for deign mix is given by

$$B_0 = (B_1+B_2+B_3)/3.$$

The value of flow and VFB are found from the graphs, corresponding to the bitumen content B_0. All the design values of Marshall Stability, flow, voids and VFB are checked at the optimum bitumen content B_0, with the specified design requirements of the mix.

DESIGN REQUIREMENTS OF THE MIX:

As per IRC: 29-1968, when the specimens are compacted with 50 blows on either face of the designed AC mix should fulfill the following requirements.

- Marshall stability value Kg(minimum)=340
- Marshall flow value , 0.25mm units= 8 to 16
- Voids in total mix, Vv%=3 to 5
  Voids in mineral aggregates filled With bitumen,VFB %=75 to 85

The highest possible Marshall Stability values in the mix should be aimed at consistent with the other three requirements mentioned above. In case the mix designed does not fulfill any one or more of the designed requirements, the gradation of the aggregates or filter content or bitumen content or combination of these are altered and the design tests are repeated till all the requirements are simultaneously fulfilled.

JOB MIX FORMULA:

The proportions in which the different aggregates, filter and bitumen are to be mixed specified by weight or by volume for implementation during construction.

CALCULATIONS:

The following values are either measured or computed:

1) Bulk density,
2) Stability,
3) Flow,
4) Percentage air voids,
5) Percent voids filled with bitumen or tar,
6) Percent voids in mineral aggregates,
   Values 1, 2, 3 are measured where values listed in 4, 5, 6 are computed in following:

The theoretical specific gravity of the mix is given as:

$$G_t = \frac{100}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4}} =$$

Where W1= percent of weight of coarse aggregates,

W2= percent of weight of fine aggregates,

W3= percent of weight of filler,

W4= percent by weight of bitumen in total mix,

G1, G2, and G3 are apparent specific gravity values of the coarse aggregates, fine aggregates and filler respectively and G4 is the specific gravity of bitumen.

G_b = Bulk density

V_v = Air voids in the mix = $\frac{100(G_t - G_b)}{G_t}$

V_b = Volume of bitumen,% = $G_b * \frac{W_4}{G_4}$

VMA = Void in Mineral Aggregates = $V_v + V_b$

VFB = Voids Filled with Bitumen = $\frac{100 * V_b}{VMA}$

RESULTS:
Above values obtained for four or five binder contents with a constant aggregate gradation are plotted on the graph for determining optimum binder content. From these plots, bitumen contents are determined corresponding to the following:

- Maximum stability,
- Maximum bulk density,
- Percent air voids apparent between 3 to 5 (depending up on the type of mix and the traffic intensity, usually taken at 4%)

Fig. 14.2 Bituminous mix Design by Marshall Test

The optimum bitumen content of the mix is the numerical average of the three values for the bitumen contents are determined above.

DISCUSSION:
The Marshall stability test method is very simple and rapid method for designing bituminous mixes scientifically. The stability values obtained in the test produce indirectly represent the strength of a paving mix at a zero vertical stress less which is critical.

Mixes with very high Marshall stability values and very flow values are not desirable as the pavements of such mixes may be brittle and are likely to crack under heavy traffic.

Table 10.1: specified grading of aggregate for bituminous concrete

Sieve size	Percentage passing by weight grade 1	Percentage passing by weight grade 1
20mm	-	100
12.5mm	100	80-100
10mm	80-100	70-90
4.75mm	55-75	50-70
2.36mm	35-50	35-50
600µ	18-29	18-29
300 µ	13-23	13-23
150 µ	8-16	8-16
75 µ	4-10	4-10
Binder content percent by weight of mix	5-7.5	5-7.5

Table 10.2: Correction Factors

Volume of specimen in cubic centimeter	Approximate thickness of specimen in mm	Correction factors
457-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

Notes:

1. The measured stability of a specimen multiplied by the ratio for the thickness of specimen is equal to the corrected stability for a 63.5 mm specimen.

2. Volume thickness relationship is based on a specimen diameter of 10 cm.

OBSERVATION SHEET:

Stability and flow value determination

Type of grading of aggregate :

Mixing temperature :

Number of blows on either side :

Grade of bitumen :

Compaction temperature :

Providing ring calibration factor :

Flow value dial, 1 division :

Table 10.3 Observation table for density and voids

Sample No	**Bitumen content,%**	**Height of sample, mm**	**Weight (g) in air**	**Weight (g) in water**	**Bulk Density G_b**	**G_t**	**V_v**	**V_b**	**VMA**	**VFB**
1										
2										
3										
Average										
1										
2										
3										
Average										
1										
2										
3										
Average										
1										
2										
3										
Average										

Table 10.4 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					

1. Optimum bitumen content determination:

   B_1 = Bitumen content corresponding to maximum density =

   B_2 = Bitumen content corresponding to maximum Stability =

   B_3 = Bitumen content corresponding to 4% voids content =

   B_o = Optimum bitumen content = ($B_1 + B_2 + B_3$) / 3 =

In addition to these, graphs are plotted between, with bitumen content on x axis, and:

1. Bulk density, G_b
2. Marshall Stability, M
3. % voids in total mix, V_v
4. Flow value, f
5. % voids filled with bitumen, VFB

RESULTS

Optimum bitumen content = %

Marshall Stability at optimum bitumen content = kg

Marshall flow value at optimum bitumen content, 0.25 mm units = mm

Voids in total mix at optimum bitumen content, V_v = %

Voids in mineral aggregate filled with bitumen, VFB = %

11. SOFTENING POINT TEST

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 9.5 mm and weight 2.5 to 5 g.
- Brass Rings there are two rings of the following dimensions.

  Depth6.4 mm
  Inside diameter at top17.5 mm
  Inside diameter at bottom15.9 mm
  Outside diameter20.6 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 through out 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 for15 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 11.1: 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

12. VISCOSITY TEST

AIM : To determine the viscosity value of the given bitumen sample .

INTRODUCTION:

Viscosity is defined as the inverse of fluidity. Viscosity thus defines the fluid property of bituminous material. The degree of fluidity at the temperature greatly influences the ability of bituminous materials to spread, penetrate into the voids and also coat the aggregates hence effects the strength characteristics of the resulting paving mixes. High or low fluidity at mixing and compaction have been observed to result in lower stability values. There is an optimum value of fluidity or viscosity for mixing and compacting for each aggregate gradation of the mix and bitumen grade. At high fluidity or low viscosity, the bitumen binder simply “lubricants” the aggregate particles instead of providing uniform film thickness for binding action. Similarly, low fluidity or high viscosity does not enable the bitumen to coat the entire surface of aggregates in the mix easily and also resists the competitive effort and the resulting mix is heterogeneous in character exhibiting low stability values. The ISI specifies a test procedure for liquid binders like cutback bitumen, emulsion and liquid tar. One of the methods by which viscosity is measured is by determining the time taken by 50 CC of the material to flow from a cup through specified orifice at given temperature. This is illustrated in Fig 21.11 In the range of consistency of bituminous materials when neither orifice viscometer test nor penetration test could be conducted; float test may be carried out. Equipment like sliding plate micro-viscometer and Brookfield viscometer are however in use for defining the viscous characteristics of the bitumen of all grades irrespective of testing temperature. The viscosity of bitumen of all grades irrespective of temperature. The viscosity of bitumen can also be measured by capillary tube viscometer.

APPARATUS:

Ten millimeter orifice viscometer is specified for testing road tar and is called tar viscometer 4.0 mm orifice is used to test cutback grades 0 and 1 and 10 mm orifice to test all other grades. The apparatus consists of main parts like cup, valve, water bath, sleevs, stirrer, receiver and thermometers, etc.

PROCEDURE:

The tar cup is properly levelled and water in the bath is heated to the temperature specified for the test and maintained throughout the test. Stirring is also continued. The sample material heated at the temperature 20$_0$C above the specified test temperature, and the material is allowed to cool. During this the material is continuously, stirred. When material reaches slightly above test temperature, the same is poured in tar cup, until the levelling peg on the valve rod is just immersed. In the graduate receiver (cylinder), 20ml of mineral oil or one percent by weight solution of soft soap is poured. The receiver is placed under the orifice. When the sample material reaches the specified temperature within + 0.1$_0$C and is maintained for 5 min, the valve is opened. The stop watch is started when cylinder records 25ml. The time is recorded for flow up to a mark of 75ml.

The viscosity test on road tar is carried out using 10mm orifice and the standard test temperature for road tar grades RT1, RT2, RT3 and RT4 are 35, 40, 45, and 55 ^{0}C respectively. In case the viscosity test is being carried out to classify a given sample of road tar or to find its grade, then the test should be first conducted at the lowest temperature of testing road tar is 35^{0}C, if the time taken for 50ml of the tar sample to flow through the 10mm orifice is more than 55s or if the Sample does not flow freely test may be repeated at the highest temperature till the viscosity value falls in the specified range.

Fig 12.1: viscosity test.

RESULT:

The time in seconds for 50ml of the test sample to flow through the orifice is defined as the viscosity at a given test temperature. Therefore the temperature at which the test was conducted and the diameter of the orifice used should also be mentioned. The viscosity values of repeat tests should not vary by more than 4.0 percent from the mean value.

DISUSSION:

The results of the viscosity test will get affected greatly if the test temperature of the sample is not correctly maintained throughout the test. Erratic results are obtained due to clogging of the orifice and due to the presence of lumps in the sample of bituminous material.

APPLICATION OF VISCOSITY TEST:

Orifice viscosity test gives an indirect measure of viscosity of tars and cutbacks in seconds, higher the duration, more viscous is the material.

The determination of viscosity by orifice viscometer in seconds is an indirect measure of viscosity. The absolute unit of viscosity dyne-second per cm^2 or poise.

TABLE12.1. Test Temperature and Viscosity Values of Road Tars

Road Tar Grades	RT1	RT2	RT3	RT4	RT5
Test Temperature, ^{0}C	35	40	45	55	-
Viscosity Range, Secs.	30 to 55	30 to 55	35 to 60	40 to 60	-

OBSERVATION SHEET:

i) Material =
ii) Grade=
iii) Specified test temperature, ^{0}C =

iv) Size of orifice, mm =

v) Actual test temperature, ^{0}C =

Test property	Test run 1	2	3	Mean value
Viscosity in seconds				
Repeatability,percent				

RESULT:

The viscosity value of given bitumen sample is

13. STRIPPING VALUE OF AGGREGATES

AIM: To determine the stripping value of aggregates by static immersion method.

THEORY: Bitumen and tar adhere well to all normal types of aggregates provided they are dry and are not exceptionally dusty. Largely the viscosity of the binder controls the process of binding. When the viscosity of the binder is high, coating of aggregates by the binder is slower. In the absence of water there is practically no adhesion problem in bituminous road construction. Two problems are observed due to presence of water. First, if aggregate is wet and cool it is normally not possible to coat with a bituminous binder. This problem can be dealt with by removing the water film on aggregate by drying, and by increasing the mixing temperature. Second problem is stripping of coated binder from the aggregate due to presence of water. This problem of stripping is experienced only with bituminous mixtures, which are permissible to water.

APPARATUS: Thermostatically controlled water bath , beaker.

PROCEDURE:

1. This method covers the procedure for determining the stripping value of aggregates by static immersion method, when bitumen and tar binder are used. 200gm of dry and clean aggregates passing 20mm IS sieve and retained on 12.5mm sieve are heated up to 150^{0}C
2. When these are to be mixed with bitumen, the aggregates are heated up to 100^{0}C.
3. The aggregates and binder are mixed thoroughly till they are completely coated and the mixer is transferred to 500ml beaker and allowed to cool at room temperature for about 2 hours.
4. Distilled water is then added to immerse the coated aggregates. The beaker is covered and kept in water bath maintained at 40^{0}C, taking care that level of water bath is at least half the height of the beaker.
5. After 24 hours the beaker is taken out, cooled at room temperature and the extent of stripping is estimated visually while the specimen is still under water.
6. The stripping value is the ratio of the uncovered area observed visually to the total area of aggregates in each test, expressed as a percentage.

LIMITS: The maximum stripping value is 5 %.(i.e., minimum retained coating is 95%)

14. TRAFFIC STUDIES---INTERSECTION

Channelizing islands: Channelizing islands should be provided at the entrance and exit of the rotary to prevent undesirable weaving, and turning and to reduce area of conflict. Further these channelizing islands help in forcing the vehicle to reduce their speed to the design speed of the rotary and to serve as convenient place for erecting traffic signs and as pedestrian refuge. The shape and size of channelizing island is governed by the radius of rotary and the radii of the entrance and exit curves and the angles and layout of the radial road and rotary. The channelizing islands are generally provided with kerbs 15 to 21 cm high.

Camber and super elevation: A vehicle passing along a rotary traverses a reverse curve while changing from one-way path of roadway to the exit of radial road. Hence the cross slope of the rotary roadway at the point of change in direction should be minimum. The inward slope of the cross slope or camber serves as super elevation for the traffic going around the central island, though design of curve has been made assuming no super elevation. The outer slope of the camber helps the vehicles turning left towards the exit curve to the radiating road.

Sight distance, grade: The sight distance in the rotary should be as large as possible and in no case less than the safe stopping distance for the design speed. The minimum sight distance should be 45 and 30 m for design speeds of 40 and 30 kmph respectively. It is preferable to locate a rotary on level ground. It may also be located on the area which is on a single plane, with the slope not exceeding 1 in 50 with the horizontal.

Lighting: The minimum lighting required is one each on the edge of central island facing each radiating road. Additional lights 'B' may be provided when the central island is larger than 60 m diameter. Light 'C' may also be provided near the entrance curve if the pedestrians are large in number.

Traffic signs: The standard traffic (warning) signs indicate the presence of rotary intersection should be installed at all approaching roads to give advance information to traffic. At night a red reflector or red light is placed about one meter above the road level on the nose of each directional island and on the kerb of the central island facing on the approaching roads. Vertical black and white strips of width 25 to 30 cm painted on kerb of central island and channelizing islands improve visibility.

Provision for cyclists and pedestrians: One of the main use of traffic rotary of non-stop and consistent journey is lost, if pedestrians are allowed to enter the rotary intersection or if pedestrian crossings are provided and vehicles are controlled by stop signals. Also the rotary would become a constant problem for traffic control and enforcement. Hence as far as possible pedestrians and even cyclists should be isolated from the general traffic utilizing the rotary. In India the problem is very typical as rotaries are needed in urban areas where the number of pedestrians and cyclist are also high, making problem complex. If the number of cyclists is less than 50 per hour, a separate cycle track to segregate cyclist will be desirable. If there are large number of pedestrians, separate foot path with guard rails should be provided around the rotary on the outer side to prohibit them from entering the rotary. However, if they are allowed to cross along pedestrian crossing near the channelizing islands, there would be problems of stopping the stream of fast vehicles entering and leaving the rotary. Provision of crossing facilities to pedestrian by *subway* or *over bridge* is possible solution, but the proposal would however be costly.

Conditions when traffic rotary is justified

Construction of traffic rotary needs large area which may be available in rural areas at reasonable cost. But in India generally the volume of fast moving traffic is very low in rural areas. There are various other points to be considered before the construction of a traffic rotary can be justified.

The American Association of State Highway Officials, now AASHTO have suggested that the lowest limit of traffic volume when a traffic rotary is justified is about 500 vehicles per hour on all intersecting roads put together and maximum limit beyond which rotary may not efficiently function is about 5000 vehicles per hour. However, if a large proportion of traffic is turning traffic, provision of rotary even outside these limits is justified.

However the IRC suggests that the maximum volume of traffic that a rotary can efficiently handle is 3000 vehicles per hour entering from all the legs of intersection.

Keeping in view the mixed traffic conditions, it is recommended by the Indian Road Congress that traffic rotaries may be provided where the intersecting motor traffic is about 50 percent or more of the total traffic on all intersecting roads or where the fast traffic turning right is as least as 30 percent of the total traffic.

Advantages and limitations of traffic rotary

Various advantages of Rotary

i. Crossing man oeuvre is converted into weaving or merging and diverging operations. Hence there is no necessity of any of the vehicles, even those which have to go in cross direction, to stop and proceed within a traffic rotary. Thus the journey is more consistent and comfortable when compared with any other intersection at grade.
ii. All traffic including those turning right or going straight across the rotary have equal opportunity as those turning left.
iii. The variable cost of operation of automobile is less at a traffic rotary than at a traffic rotary than at a signalized intersection where the vehicles have to stop and proceed. Though the distance to be traversed by vehicles which are to turn to the right or proceed straight across is higher, still the fuel consumed in the process of crossing the rotary intersection is likely to be less. This is because one stop-proceed operation at a signal is likely to consume fuel required for travelling about 275 metre at a uniform speed without stopping.
iv. There is no necessity of traffic police or signal to control the traffic as the traffic rotary could function by itself as a traffic controlled intersection and is the simplest of all controls. The maintenance cost is hence almost nil.
v. The possible number of accidents and the severity of accidents are quite low because of low relative speed. Further weaving, merging and diverging man oeuvres are easier and less dangerous operation than crossing. Check on speed of vehicles is automatically enforced by proper design.
vi. Rotaries can be constructed with advantage when the number of intersecting roads is between four and seven.

The capacity of the rotary intersection is the highest of all other intersections at grade. The rotary can accommodate a total traffic up to 3000 vehicles per hour and enable radial streets to carry traffic almost to their full capacity.

Various limitations of Rotary:

i. Rotary requires comparatively a large area of land and so where space is limited and costly as in built up areas; the total cost may be very high.
ii. Where pedestrian traffic is large as in urban areas the rotary by itself cannot control the traffic and hence has to be supplemented by traffic police. If the

vehicular traffic has to stop to allow pedestrian to cross, the main purpose of rotary is defeated.

iii. In places where there is mixed traffic and large number of cyclists and pedestrians, the design of rotary become too elaborate and operation and control of traffic also become complex.

iv. Where the angle of intersection of two roads is too acute or when there are more than seven intersecting roads, rotaries are unsuitable.

v. When the distance between intersections on an important highway is less, rotaries become troublesome.

vi. Where there are a large number of cycle and animal drawn vehicles, the extra length to be traversed by crossing and right turn traffic is considered troublesome and there is a tendency to violate the traffic regulation of clock wise movement around the central island.

vii. When the traffic volume is very low as in most of the rural areas of India, construction of a rotary cannot be justified.

15 TRAFFIC STUDIES---ROTARY INTERSECTION

ROTARY INTERSECTION:

A rotary intersection or traffic rotary is an enlarged road intersection where all converging vehicles are forced to move round a large central island in one direction (clock wise) before they can weave out of traffic flow into their respective directions radiating from Central Island. The main objectives of providing a rotary are to eliminate the necessity of stopping even for crossing streams of vehicles and to reduce the area of conflict. The crossing of vehicles is avoided by allowing all vehicles to merge into streams around the rotary and then to diverge out to the desired radiating road. Thus the crossing conflict is eliminated and converted into weaving manoeuvre or a merging operation from the right and a diverging operation to the left.

DESIGN FACTORS OF ROTARY:

Various design factors to be considered in a traffic rotary are speed, shape of central island, radius of rotary roadway, weaving angle, weaving distance, width of rotary roadway, radius of entrance and exit curves, channelizing islands, camber and super elevation, grade, lighting and signs.

These are briefly explained here

(1) ***Design speed:***

Vehicles approaching as intersection at grade have to considerably slow down their speed when compared to the design speed standard of the highway under consideration. Though there is no need for vehicles in traffic rotary to come to a dead stop before allowing cross traffic to cross, still there has to be considerable reduction in speed. With these in view the design speed for traffic rotaries in India is taken as 40 kmph for rotaries in rural area when one or more of converging roads is/are important. In all other cases and for rotaries in urban areas, a speed 30 kmph is adopted for design.

(2) ***Shape of central island:***

It depends on the number and layout of intersecting roads. The outline of the island consists of a number of curves of large radii, without corners. The various shapes considered to suit different conditions are circular elliptical, turbine and tangent shapes each having its own advantages and limitations. When two equally important roads cross at roughly right angles, a circular shape is suitable. The island may be often elongated to accommodate in the layout four or more intersecting roads; and to allow a greater traffic flow along the direction of elongation. Two much elongation and tangent shape are also not desirable as there is a tendency of traffic to move faster in this direction. Turbine shape forces reduction in speeds of vehicles entering the rotary and enables speeding up of vehicles going out; however at night, the head light glare is a limitation of the design.

(3) ***Radius of rotary roadway:***

The one-way round the central island has different radii at different points depending upon the shape of island.

Adequate super elevation cannot be provided at the rotary roads and hence it is safer to neglect the super elevation and to take friction into consideration

The values of the design coefficient of friction 'f' are taken as 0.43 and 0.47 for the speeds 40 and 30 kmph respectively, after allowing a factor of safety of 1.5. The IRC has suggested the radius of entry curve to be 20 to 35 m and 15 to 25 m for rotary design speeds of 40 and 30 kmph. The recommended minimum radii of central island are 1.33 times the radius of entry curves. Though these radii are for the rotary roadway, in practice it is convenient to design the central island to conform to the above radii.

Weaving angle and weaving distance:

The angle between the path of a vehicle entering the rotary and that of another vehicle leaving the rotary at adjacent road, thus crossing the path of the former is termed as the weaving angle. Vehicles entering the rotary from a road and leaving towards another radiating road have to first merge into the one-way traffic flow in the rotary road way around the central island and then weave out to diverge from this flow to the required road outlet. The weaving operation including merging and diverging can take place between the two channelizing islands of the adjacent intersecting legs, and this length of the rotary roadway is known as *weaving length.*

For smooth flow of the traffic the weaving angle should be small but not less than 15° as the diameter of the central island required will be too large. For any design speed the freedom of movement on a rotary depends on the size of the weaving area. The weaving length should be at least four times the width of weaving section. The recommended value of the weaving length are45 to 90 m for 40 kmph and 30 to 60 m for 30 kmph design speeds.

Width of the carriageway at entry and exit:

The carriageway width at the entrance and exit of a rotary is governed by the amount of traffic entering the rotary from the road or that leaving the rotary to the road. The minimum width of the carriageway at the entrance and exit should be 5.0 m and the entry width e_1 may be increased to 6.5, 7.0, and 8.0 m when the carriageway width of approach road is 7.0, 10.5 and 14.0 m respectively and the radius at entry is 25 to 35 m.

Width of rotary roadway:

All the traffic entering the rotary have to go round the one-way rotary roadway for atleast a short distance. As the outer kerb lines follow the entrance and exit-sides of the roads, the actual width of the rotary roadway varies from section to section. The minimum width of the roadway between edge of the central island and adjoining kerb is the effective width of the rotary roadway or of the weaving section and this by and large determines the capacity of the rotary.

The width of the non-weaving section e_2 of the rotary should be equal to the widest single entry to the rotary and should generally be less then the width of weaving section. The width of the weaving section W of the rotary should be one traffic lane wider than the mean width of the entry and non-weaving section i.e.,

m

Entrance and exit curves:

The curve traced by the inner rear wheel of vehicles determines the radius and shapes to which the kerb line is to be set. A vehicle entering a rotary has to slow down to the design speed of the rotary and therefore the radius of the entrance curve should be the same as the minimum recommended radius of the central island. For the design speed of 40 kmph the suggested radius at entry curves is 20 to 35 kmph, 15 to25 m. It has been that the buses and trucks can take right angled turn easily at these curves at the design speeds. Where practicable three centered entry curves may be provided instead of simple circular curve.

Vehicles leaving the rotary would accelerate to the speed of the radiating roads and hence the exit curves should be of a larger radius than entry curves; one and a half to two times radius of entry is considered reasonable.

The normal pavement width at entrance and exit should be equivalent to two lanes in order to prevent clustering of mixed traffic at the approaches. Extra widening has to be provided at the entrance and exit curve.

The pavement width at entrance curve will be higher than at exit curve as the radius of the former is less than the latter.

Capacity of the rotary:

The practical capacity of the rotary is dependent on the minimum capacity of the individual weaving section. The capacity is calculated from the formula:

Where Q_P =practical capacity of the weaving section of a rotary in pcu per hour.

W = width of the weaving section (6to18 m)

e= average width of the entry e_1 and width of the non-weaving section e_2 for the range e/W = 0.4 to 1.0

L = length of the weaving section between the ends of channelizing islands in meter for the range of W/L = 0.12 to 0.4

p = proportion of the weaving traffic given by

p= in the range 0.4 to 1.0

a = left turning traffic moving along left extreme lane

d = right turning traffic moving along right extreme lane

b = crossing/weaving traffic turning towards right while entering the rotary

c = crossing/weaving traffic turning towards left while entering the rotary

Some corrections have been suggested in the calculated capacity values depending on the entry, exit and internal angles and the pedestrian traffic in the rotary intersection. The IRC has recommended the following PCU values for finding the capacity of the rotary:

Cars, light commercial vehicles and three wheelers = 1.0

Buses, medium and heavy commercial vehicles = 2.8

Motor cycles, scooters = 0.75

Pedal cycles = 0.50

Animal drawn vehicles = 4 to 6