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ASPHALT MIX DESIGN

THEORY:

The mix design (wet mix) determines the optimum bitumen content. This is preceded by the dry mix design discussed in the previous chapter. There are many methods available for mix design which vary in the size of the test specimen, compaction, and other test specifications. Marshall method of mix design is the most popular one and is discussed below.

Marshall mix design

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designated as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to the loading. The flow value is recorded in 0.25 mm (0.01 inch) increments at the same time when the maximum load is recorded. The important steps involved in marshal mix design are summarized next.

Specimen preparation

Approximately 1200gm of aggregates and filler is heated to a temperature of $175-190°C$. Bitumen is heated to a temperature of $121-125°C$ with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates). The heated aggregates and bitumen are thoroughly mixed at a temperature of $154-160°C$. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of $138°C$ to $149°C$. The weight of mixed aggregates taken for the preparation of the specimen may be suitably altered to obtain a compacted thickness of 63.5+/-3 mm. Vary the bitumen content in the next trial by $+0.5\%$ and repeat the above procedure. Number of trials are predetermined. The prepared mould is loaded in the Marshall test setup as shown in the figure 1.

Marshall Mould

Properties of the mix

The properties that are of interest include the theoretical specific gravity G_t, the bulk specific gravity of the mix G_m, percent air voids V_v, percent volume of bitumen V_b, percent void in mixed aggregate VMA and percent voids filled with bitumen VFB. These calculations are discussed next. To understand these calculation a phase diagram is given in Figure 2.

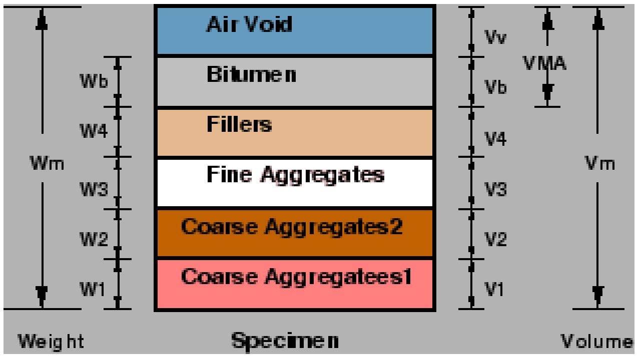


Figure 2: Phase diagram of a bituminous mix

Theoretical specific gravity of the mix G_t

Theoretical specific gravity G_t is the specific gravity without considering air voids, and is given by:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}} \quad (1)$$

where, W_1 is the weight of coarse aggregate in the total mix, W_2 is the weight of fine aggregate in the total mix, W_3 is the weight of filler in the total mix, W_b is the weight of bitumen in the total mix, G_1 is the apparent specific gravity of coarse aggregate, G_2 is the apparent specific gravity of fine aggregate, G_3 is the apparent specific gravity of filler and G_b is the apparent specific gravity of bitumen,

Bulk specific gravity of mix G_m

The bulk specific gravity or the actual specific gravity of the mix G_m is the specific gravity considering air voids and is found out by:

$$G_m = \frac{W_m}{W_m - W_w} \tag{2}$$

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

Air voids percent V_v

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

$$V_v = \frac{(G_t - G_m)100}{G_t} \tag{3}$$

where G_t is the theoretical specific gravity of the mix, given by equation 26.1. and G_m is the bulk or actual specific gravity of the mix given by equation 26.2.

Percent volume of bitumen V_b

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

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}} \quad (4)$$

where, W_1 is the weight of coarse aggregate in the total mix, W_2 is the weight of fine aggregate in the total mix, W_3 is the weight of filler in the total mix, W_b is the weight of bitumen in the total mix, G_b is the apparent specific gravity of bitumen, and G_m is the bulk specific gravity of mix given by equation 26.2.

Voids in mineral aggregate VMA

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

$$VMA = V_v + V_b \quad (5)$$

where, V_v is the percent air voids in the mix, given by equation 26.3. and V_b is percent bitumen content in the mix, given by equation 26.4. (4).

Voids filled with bitumen VFB

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

$$VFB = \frac{V_b \times 100}{VMA} \quad (6)$$

where, V_b is percent bitumen content in the mix, given by equation 26.4.
and VMA is the percent voids in the mineral aggregate, given by equation 26.5.

Determine Marshall stability and flow

Marshall stability of a test specimen is the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain (5 cm per minute). While the stability test is in progress dial gauge is used to measure the vertical deformation of the specimen. The deformation at the failure point expressed in units of 0.25 mm is called the Marshall flow value of the specimen.

Apply stability correction

It is possible while making the specimen the thickness slightly vary from the standard specification of 63.5 mm. Therefore, measured stability values need to be corrected to those which would have been obtained if the specimens had been exactly 63.5 mm. This is done by multiplying each measured stability value by an appropriated correlation factors as given in Table below.

Table 1: Correction factors for Marshall stability values

Volume of specimen (cm^3)	Thickness of specimen (mm)	Correction Factor
457 - 470	57.1	1.19
471 - 482	68.7	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

Prepare graphical plots

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

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

Determine optimum bitumen content

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

1. Binder content corresponding to maximum stability
2. Binder content corresponding to maximum bulk specific gravity (G_m)
3. Binder content corresponding to the median of designed limits of percent air voids (V_v) in the total mix (i.e. 4%)

The stability value, flow value, and VFB are checked with Marshall mix design specification chart given in Table below. Mixes with very high stability value and low flow value are not desirable as the pavements constructed with such mixes are likely to develop cracks due to heavy moving loads.

Table 2: Marshall mix design specification

Test Property	Specified Value
Marshall stability, kg	340 (minimum)
Flow value, 0.25 mm units	8 - 17
Percent air voids in the mix V_v %	3 - 5
Voids filled with bitumen VFB%	75 - 85

CRUSHING VALUE OF AGGREGATE TEST

THEORY:

Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load.

Coarse aggregate crushing value is the percentage by weight of the crushed material obtained when test aggregates are subjected to a specified load under standardized conditions.

Aggregate crushing value is a numerical index of the strength of the aggregate and it is used in construction of roads and pavements.

Crushing value of aggregates indicates its strength. Lower crushing value is recommended for roads and pavements as it indicates a lower crushed fraction under load and would give a longer service life and a more economical performance.

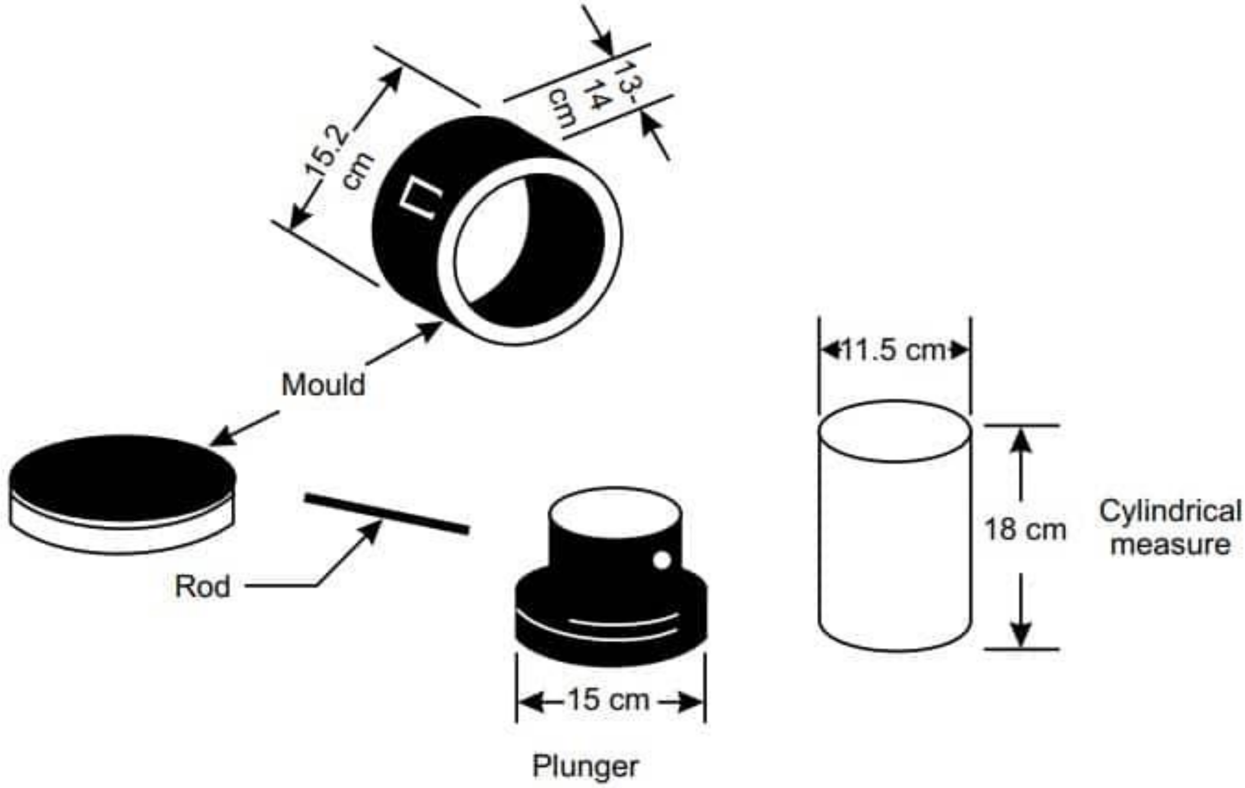
The aggregates used in roads and pavement construction must be strong enough to withstand crushing under roller and traffic. If the aggregate crushing value is 30 or higher' the result may be anomalous and in such cases the ten percent fines value should be determined instead.

OBJECTIVES:

1. Determine the aggregate crushing value of coarse aggregate
2. Assess suitability of coarse aggregates for use in different types of road

APPARATUS REQUIRED:

1. A steel cylinder 15 cm diameter with plunger and base plate.
2. A straight metal tamping rod 16mm diameter and 45 to 60cm long rounded at one end.
3. A balance of capacity 3 kg readable and accurate to one gram.
4. IS sieves of sizes 12.5mm, 10mm and 2.36mm
5. A compression testing machine.
6. Cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of 11.5cm diameter and 18cm height.
7. Dial gauge



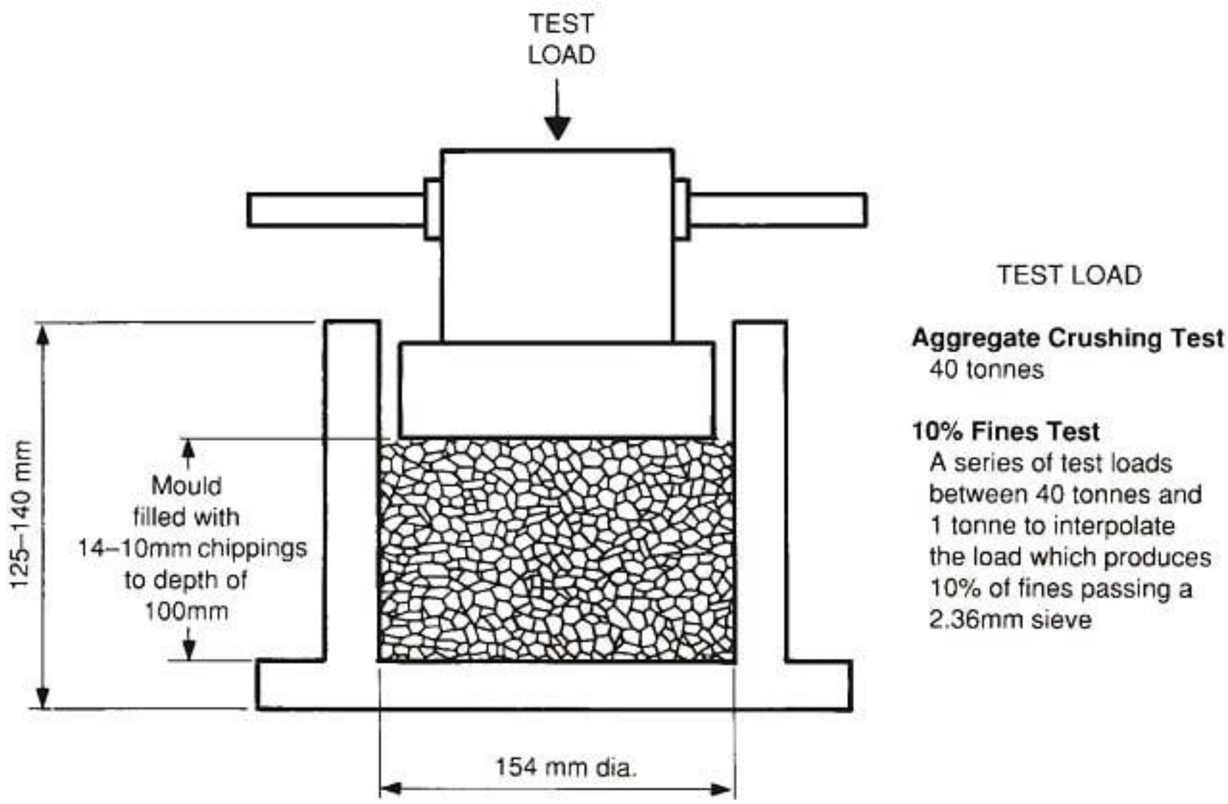
SAMPLING OF AGGREGATES:

Coarse aggregate passing 12.5mm IS sieve and retained on a10mm IS sieve are selected and heated at 100 to 110°C for 4 hours and cooled to room temperature.

The quantity of aggregate shall be such that the depth of material in the cylinder , after tamping as described below shall be 10 cm. The appropriate quantity may be found conveniently by filling the cylinder.

Measure in three layers of approximately equal depth, each layer being tamped 25 times with the tamping rod and finally leveled off using the tamping rod as straight edge.

Care being taken in the case of weaker materials not to break the particles. The weight of the material comprising the test sample shall be determined (weight A) and the same weight of sample shall be taken for the repeat test.



PROCEDURE:

1. Put the cylinder in position on the base plate and weigh it **(W)**.
2. Put the sample in 3 layers, each layer being subjected to 25 strokes using the tamping rod. Care being taken in the case of weak materials not to break the particles and weigh it **(W1)**.
3. Level the surface of aggregate carefully and insert the plunger so that it rests horizontally on the surface. Care being taken to ensure that the plunger does not jam in the cylinder.
4. Place the cylinder with plunger on the loading platform of the compression testing machine.
5. Apply load at a uniform rate so that a total load of 40T is applied in 10 minutes.
6. Release the load and remove the material from the cylinder.
7. Sieve the material with 2.36mm IS sieve, care being taken to avoid loss of fines.
8. Weigh the fraction passing through the IS sieve **(W2)**.

OBSERVATION AND CALCULATION:

The ratio of weight of fines formed to the weight of total sample in each test shall be expressed as a percentage, the result being recorded to the first decimal place.

Aggregate crushing value = (W2 x 100) / (W1-W)

W2 =Weight of fraction passing through the appropriate sieve

W1-W =Weight of surface dry sample.

The mean of two result to nearest whole number is the aggregate crushing value.

Here, W2=2.11 kg

W1-W=2.5 kg

So,Aggregate Crushing Strength= 84.4

RESULT:

The aggregate crushing value of the given sample=84.4

DISCUSSION AND CONCLUSION:

The table below shows limits of aggregate crushing value for different types of road construction:

Types of Roads / Pavements	**Aggregate Crushing Value Limit**
Flexible Pavements	
Soling	50
Water bound macadam	40
Bituminous macadam	40
Bituminous surface dressing or thin premix carpet	30
Dense mix carpet	30
Rigid Pavements	
Other than wearing course	45
Surface or Wearing course	30

So, the aggregates having crushing value of 84.4 can be used for all the purposes mentioned above in the table

DUCTILITY OF BITUMEN

THEORY:

Ductility of bitumen is its property to elongate under traffic load without getting cracked in road construction works. Ductility test on bitumen measures the distance in centimeters to which it elongates before breaking.

Apparatus required, theory, procedure, precautions, observations, reporting and recommended values of bitumen ductility is discussed in this article.

The ductility test gives a measure of adhesive property of bitumen and its ability to stretch. In flexible pavement design, it is necessary that binder should form a thin ductile film around aggregates so that physical interlocking of the aggregates is improved.

Binder material having insufficient ductility gets cracked when subjected to repeated traffic loads and it provides pervious pavement surface.

Ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when two ends of standard briquette specimen of material are pulled apart at a specified speed and specified temperature.

OBJECTIVES:

1. To measure the ductility of a given sample of bitumen
2. To determine the suitability of bitumen for its use in road construction

APPARATUS REQUIRED:

The apparatus as per IS: 1208-1978 consists of:

(i) Briquette mould: It is made of brass. Circular holes are provided at ends called clips to grip the fixed and movable ends of the testing machine. The mould when properly assembled form a briquette specimen of following dimensions:

- Total length 75.0 ± 0.5 mm
- Distance between clips 30.0 ± 0.3mm
- Width at mount of slip 20.0 ± 0.2mm
- Width at minimum cross-section (half way between clips) 10.0 ± 0.1mm
- Thickness throughout 10.0 ± 0.1mm

(ii) Water bath: A bath maintained within 27.0° ±0.1 °C of the specified test temperature containing not less than 10 litres of water, the specimen being submerged to a depth of not less than 10 cms and supported on a perforated shell and less than 5 cms from the bottom of the bath.

(iii) Testing machine: For pulling the briquette of bituminous material apart, any apparatus may be used which is so constructed that the specimen will be continuously submerged in water while the two clips are being pulled apart horizontally at a uniform speed of 50 ± 2.5 mm per minute.

(iv) Thermometer: Range 0-44°C and readable up to 0.2°C

PROCEDURES:

1. Melt the bituminous test material completely at a temperature of 75°C to 100° C above the approximate softening point until it becomes thoroughly fluid.
2. Strain the fluid through IS sieve 30.
3. After stirring the fluid, pour it in the mould assembly and place it on a brass plate. In order to prevent the material under test from sticking, coat the surface of the plate and interior surfaces of the sides of the mould with mercury or by a mixture of equal parts of glycerine and dextrine.
4. After about 30-40 minutes, keep the plate assembly along with the sample in a water bath. Maintain the temperature of the water bath at 27° C for half an hour.
5. Remove the sample and mould assembly from the water bath and trim the specimen by levelling the surface using a hot knife.
6. Replace the mould assembly in water bath for 80 to 90 minutes.
7. Remove the sides of the mould.
8. Hook the clips carefully on the machine without causing any initial strain.
9. Adjust the pointer to read zero.
10. Start the machine and pull clips horizontally at a speed of 50 mm per minute.
11. Note the distance at which the bitumen thread of specimen breaks.

Mean of two observations rounded to nearest whole number is ductility value.

Note: Machine may have a provision to fix two or more moulds so as to test three specimens simultaneously.

Precautions for the Test

1. The plate assembly upon which the mould is placed shall be perfectly flat and level so that the bottom surface of the mould touches it throughout.
2. In filling the mould, care should be taken not to distort the briquette and to see that no air pocket is within the molded sample.

OBSERVATIONS AND CALCULATIONS:

1. Bitumen Grade =
2. Pouring Temperature =
3. Test Temperature =
4. Period of cooling in minutes

- In air =
- In water bath before trimming =
- In water bath after trimming =

RESULT:

Ductility value =56 cm

DISCUSSION AND CONCLUSIONS:

Suitability of bitumen is judged depending on its type and proposed use. Bitumen with low ductility value may get cracked especially in cold weather. Minimum values of ductility specified by ISI for various grades are as follows.

Source of paving bitumen and penetration grade	Min ductility value (cms)
Assam Petroleum A25	5
A35	10
A45	12
A65, A90 and A200	15
Bitumen from sources other than Assam Petroleum S35	50
S45, S65 and S90	75

LOS ANGELES ABRASION TEST

THEORY:

Los Angeles abrasion test on aggregates is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. This test is carried out by AASHTO T 96 or ASTM C 131: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

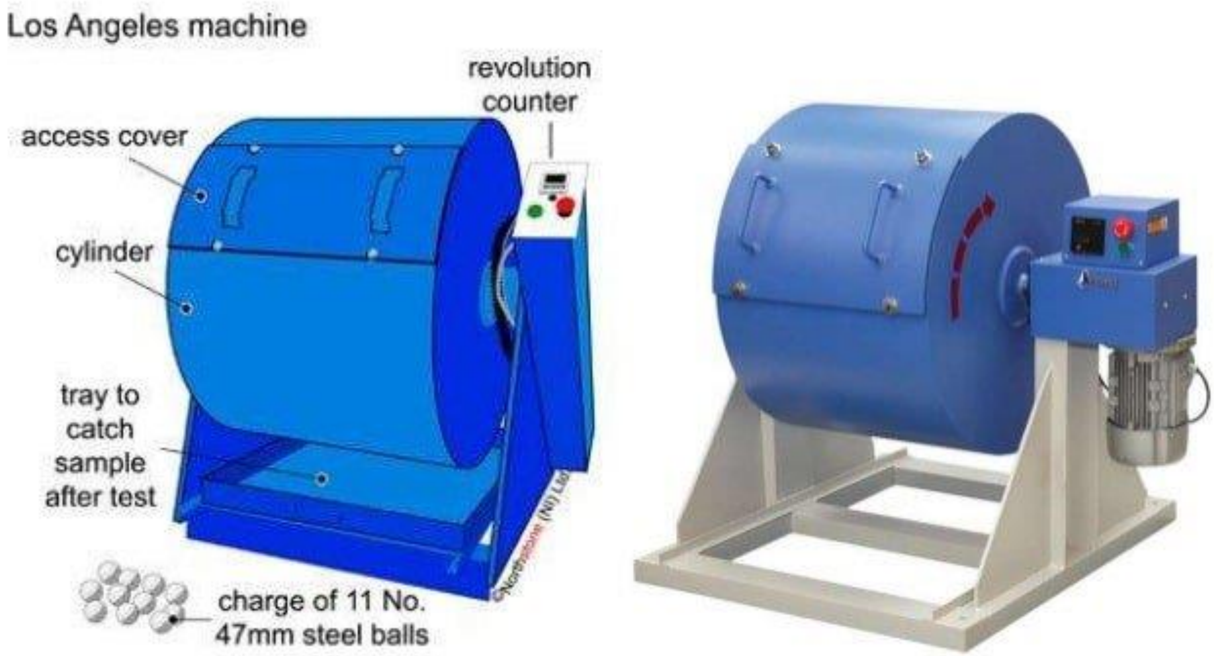
The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic.

When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. The steel rimmed wheels of animal driven vehicles also cause considerable abrasion of the road surface.

Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.

The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates.

The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value.



Los Angeles abrasion test setup

OBJECTIVES:

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

APPARATUS REQUIRED:

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

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

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.

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

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

Sieve size (square hole)	Weight of test sample in gm							
Passing (mm)	**Retained on (mm)**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
80	63					2500*		
63	50					2500*		
50	40					5000*	5000*	
40	25	1250					5000*	5000*
25	20	1250						5000*
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

Table 2: Selection of Abrasive Charge

Grading	**No of Steel balls**	**Weight of charge in gm.**
A	12	5000 ± 25
B	11	4584 ±25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

OBSERVATION AND CALCULATIONS:

Original weight of aggregate sample = 5000 g
Weight of aggregate sample retained = 4179 g
Weight passing 1.7mm IS sieve = 5000 g-4179 g = 821g
Abrasion Value = ((821 g) / (5000 g)) X 100%
=16.42%

RESULTS:

Los Angeles Abrasion Value = 16.42%

CONCLUSION AND RECOMMENDATION:

Los Angeles test is commonly used to evaluate the hardness of aggregates. The test has more acceptability because the resistance to abrasion and impact is determined simultaneously.

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

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

So, the bitumen can be used for every one of the construction works above.

MARSHALL STABILITY TEST OF BITUMEN

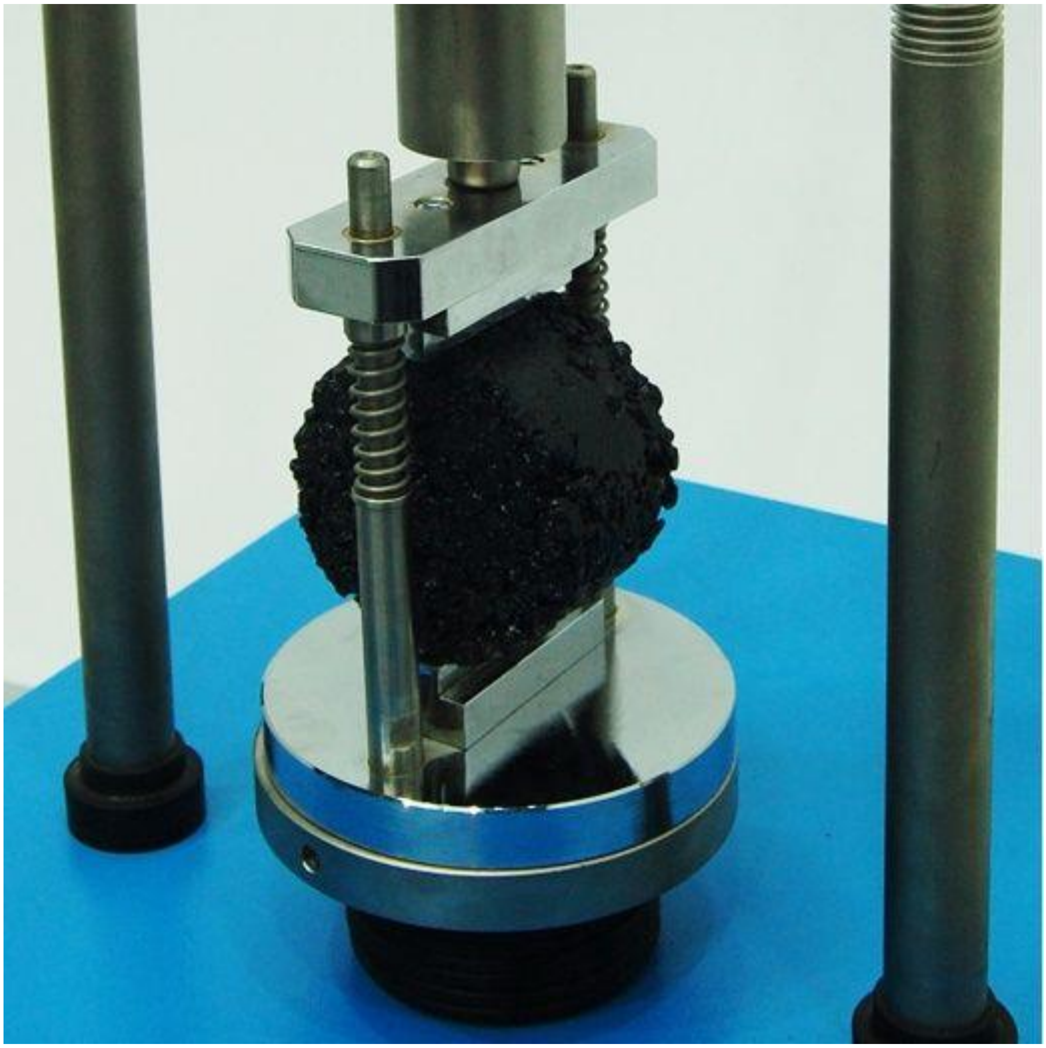
THEORY

Mississippi State Highway Department formulated Marshall stability test – flow test on bitumen and is applicable to hot mix design of bitumen and aggregates of maximum size 2.5 cm.

Bituminous concrete mix is commonly designed by Marshall Method. This test is extensively used in routine test programmes for the paving jobs.

The stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature of 60^0C. The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test (flow value may also be measured by deformation units of 0.1 mm).

This test attempts to get the optimum binder content for the aggregate mix type and traffic intensity. This is the test which helps us to draw Marshall Stability vs. % bitumen.



OBJECTIVES:

1.To determine the Marshall stability of bitumen as per ASTM D 1559

2. To select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values (White, 1985).

APPARATUS REQUIRED:

The apparatus for the Marshall Stability test consists of the following:

1. Specimen mould assembly comprising mould cylinders 10.16cm diameter by 6.35cm height, base plate and extension collars.

2. Specimen extractor for extracting the compacted specimen from the mould. A suitable bar is required to transfer load from the extension collar to the upper proving ring attachment while extracting the specimen.

3. Compaction hammer having a flat circular tamping face 4.5kg sliding weight constructed to provide a free fall of 45 cm.

4. Compaction pedestal consisting of a 20×20×45 cm wooden block capped with 30×30×2.5 cm MS plate to hold the mould assembly in position during compaction. Mould holder is provided consisting of spring tension device designed to hold compaction mould in place on compaction pedestal.

5. Breaking head: this consists of upper and lower cylindrical segments or test heads having a inside radius curvature of 5 cm. the longer segment is mounted on a base having two perpendicular guide rods which facilitate insertion in the holes of upper test segment.

6. Loading Machine: It is provided with a gear system to lift the upward direction. Pre-calibrated proving ring of 5 tonnes capacity is fixed on the upper end of the machine, specimen contained in the test head is placed in between the base and the proving ring.

The load jack produces a uniform vertical moment of 5 cm per minute. Machine is capable of reversing its moment downward also. This facilitates adequate space for placing test head system after one specimen has been tested.

7. Flow meter consist of guide, sieve and gauge. The activating pin of the gauge slides inside the guide sleeve with a slight amount of frictional resistance. 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 value at maximum load. The dial gauge of the flow meter should be able to measure accurately the total vertical moment upward.

In addition to above the following general equipment are also required:

1. Oven or hot plate
2. Water bath
3. Thermometers of range up to 200^{o}C with sensitivity of 2.5^{o}C and
4. Miscellaneous equipment like containers, mixing and handling tools etc.

PROCEDURE:

Preparation of Test Specimen

1. 1200 grams of aggregates blended in the desired proportions is measured and heated in the oven to the mixing temperature.

2. Bitumen is added at the mixing temperature to produce viscosity of 170 ± centi-stokes at various percentages.

3. The materials are mixed in a heated pan with heated mixing tools.

4. The mixture is returned to the oven and reheated to the compacting temperature (to produce viscosity of 280±30 centi-stokes).

5. The mixture is then placed in a heated Marshall mould with a collar and base and the mixture is spaded around the sides of the mould. A filter paper is placed under the sample and on top of the sample.

6. The mould is placed in the Marshall compaction pedestal.

7. The material is compacted with 50 blows of the hammer (or as specified), and the sample is inverted and compacted in the the other face with same number of blows.

8. After compaction, the mould is inverted. With collar on the bottom, the base is removed and the sample is extracted by pushing it out the extractor.

9. The sample is allowed to stand for the few hours to cool.

10. The mass of the sample in air and when submerged is used to measure the density of specimen, so as to allow, calculation of the void properties.

Sample no	**Weight in air(g)**	**Weight in water(g)**	**Specific gravity**
1			
2			
3			

Sample	Softening point(^{0}C)
1	
2	

Test Procedure

1. Specimens are heated to 60 ±1^{o}C either in a water bath for 30-40 minutes or in an oven for minimum of 2 hours.

2. The specimens are removed from the water bath or oven and place in lower segment of the breaking head. The upper segment of the breaking head of the specimen is placed in position and the complete assembly is placed in position on the testing machine.
3. The flow meter is placed over one of the post and is adjusted to read zero.
4. Load is applied at a rate of 50 mm per minute until the maximum load reading is obtained.
5. The maximum load reading in Newton is observed. At the same instant the flow as recorded on the flow meter in units of mm was also noted.

DISCUSSIONS AND CONCLUSIONS:

The optimum asphalt binder content is finally selected based on the combined results of Marshall stability and flow, density analysis and void analysis. Optimum asphalt binder content can be arrived at in the following procedure (Roberts et al., 1996):

1. Plot the following graphs:
   - Asphalt binder content vs. density. Density will generally increase with increasing asphalt content, reach a maximum, then decrease. Peak density usually occurs at a higher asphalt binder content than peak stability.
   - Asphalt binder content vs. Marshall stability. This should follow one of two trends:
   - * Stability increases with increasing asphalt binder content, reaches a peak, then decreases.
   - * Stability decreases with increasing asphalt binder content and does not show a peak. This curve is common for some recycled HMA mixtures.
   - Asphalt binder content vs. flow.
   - Asphalt binder content vs. air voids. Percent air voids should decrease with increasing asphalt binder content.
   - Asphalt binder content vs. VMA. Percent VMA should decrease with increasing asphalt binder content, reach a minimum, then increase.
   - Asphalt binder content vs. VFA. Percent VFA increases with increasing asphalt binder content.

2. Determine the asphalt binder content that corresponds to the specifications median air void content (typically this is 4 percent). This is the optimum asphalt binder content.

3. Determine properties at this optimum asphalt binder content by referring to the plots. Compare each of these values against specification values and if all are within specification, then the preceding optimum asphalt binder content is satisfactory. Otherwise, if any of these properties is outside the specification range the mixture should be redesigned.

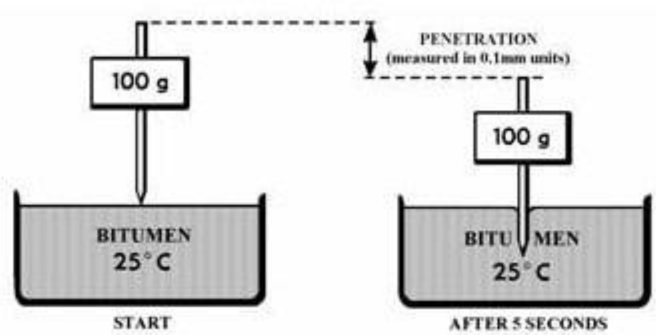
PENETRATION TEST OF BITUMEN:

THEORY:

Penetration value test on bitumen is a measure of hardness or consistency of bituminous material. A 80/100 grade bitumen indicates that its penetration value lies between 80 & 100.

Penetration value is the vertical distance traversed or penetrated by the point of a standard needle into the bituminous material under specific conditions of load, time and temperature. This distance is measured in one tenths of a millimeter.

Penetration test is used for evaluating consistency of bitumen. It is not regarded as suitable for use in connection with the testing of road tar because of the high surface tension exhibited by these materials.



OBJECTIVES:

To determine:

1. Consistency of bituminous material

2. Suitability of bitumen for use under different climatic conditions and various types of construction.

APPARATUS REQUIRED:

Container

A flat bottomed cylindrical metallic dish 55 mm in diameter and 35 mm in depth is required. If the penetration is of the order of 225 or more, dish of 70mm diameter and 45mm depth is required.

Needle

A straight, highly polished, cylindrical hard steel rod.

Water bath

Water bath maintained at 25° ± 0.1 °C, containing not less than 10 litres of water, the sample being immersed to a depth not less than 100mm from top and supported on perforated shelf not less than 50mm from bottom of the bath.

Transfer dish or tray

Should provide support to the container & should not rock it. It should be of such capacity as to completely immerse container during test.

Penetration apparatus

Should be such that it allows needle to penetrate without much friction& is accurately calibrated to give results in one tenth of a millimeter.

Thermometer

Range 0- 44 °C and in readable upto 0.20 C.

Time measuring device

With an accuracy of l second.

PROCEDURE:

(i) **Preparation of test specimen:** Soften the material to a pouring consistency at a temperature not more than 60°C for tars and 90°C for bitumen above the approximate softening point and stir it thoroughly until it is homogeneous and is free from air bubbles and water.

Pour the melt into the container to a depth at least 10mm in excess of the expected penetration. Protect the sample from dust and allow it to cool in an atmosphere at a temperature between 15° to 30° C for one hour. Then place it along with the transfer dish in the water bath at 25° ± 0.1 °C, unless otherwise stated.

(ii) Fill the transfer dish with water from the water bath to depth sufficient to cover the container completely, place the sample in it and put it upon the stand of the penetration apparatus.

(iii) Clean the needle with benzene, dry it and load with the weight. The total moving load required is 100 ± 0.25 gms, including the weight of the needle, carrier and super-imposed weights.

(iv) Adjust the needle to make contact with the surface of the sample. This may be done by placing the needlepoint in contact with its image reflected by the surface of the bituminous material.

(i) Make the pointer of the dial to read zero or note the initial dial reading.

(ii) Release the needle for exactly five seconds.

(vi) Adjust the penetration machine to measure the distance penetrated.

(vii)Make at least 3 readings at points on the surface of the sample not less than 10 mm apart and not less than l0mm from the side of the dish. After each test return the sample and transfer dish to the water bath and wash the needle clean with benzene and dry it.

In case of material of penetration greater than 225, three determinations on each of the two identical test specimens using a separate needle for each determination should be made, leaving the needle in the sample on completion of each determination to avoid disturbance of the specimen.

Precautions during Penetration Test

1. There should be no movement of the container while needle penetrates into sample.
2. The sample should be free from any extraneous matter.
3. The needle should be cleaned with benzene and dried before penetration.

OBSERVATIONS:

Actual test temperature = 27 °C

Reading	First set	Second set	Third set
Initial	93	146	0
Final	146	196	55
Difference	53	50	55

RESULT:

Penetration value was found to be 52.67

DISCUSSIONS AND CONCLUSIONS:

Penetration test is a commonly adopted test on bitumen to grade the material in terms of its hardness. A 80/100 grade bitumen indicates that its penetration value lies between 80 & 100.

Grading of bitumen helps to assess its suitability in different climatic conditions and types of construction. For bituminous macadam and penetration macadam, IRC suggests bitumen grades 30/40, 60/70, 80/100.

In warmer regions, lower penetration grades are preferred to avoid softening whereas higher penetration grades like 180/200 are used in colder regions to prevent the occurrence of excessive brittleness. High penetration grade is used in spray application works.

SOFTENING POINT OF BITUMEN:

THEORY:

Ring and ball test is used to determine the softening point of bitumen, asphalt and coal tar. This test consists of two brass ring and two steel ball, using which the softening point of various bituminous materials are determined.

The softening point of bitumen or tar is the temperature at which the substance attains particular degree of softening. As per IS: 334-1982, ASTM E28-67 or ASTM D36 or ASTM D6493 – 11, it is the temperature in ºC at which a standard ball passes through a sample of bitumen in a mould and falls through a height of 2.5 cm, when heated under water or glycerin at specified conditions of test. The binder should have sufficient fluidity before its applications in road uses.

The determination of softening point helps to know the temperature up to which a bituminous binder should be heated for various road use applications. Softening point is determined by ring and ball apparatus.

OBJECTIVE:

1.To find the temperature up to which bitumen binder should be heated for different purposes

APPARATUS REQUIRED:

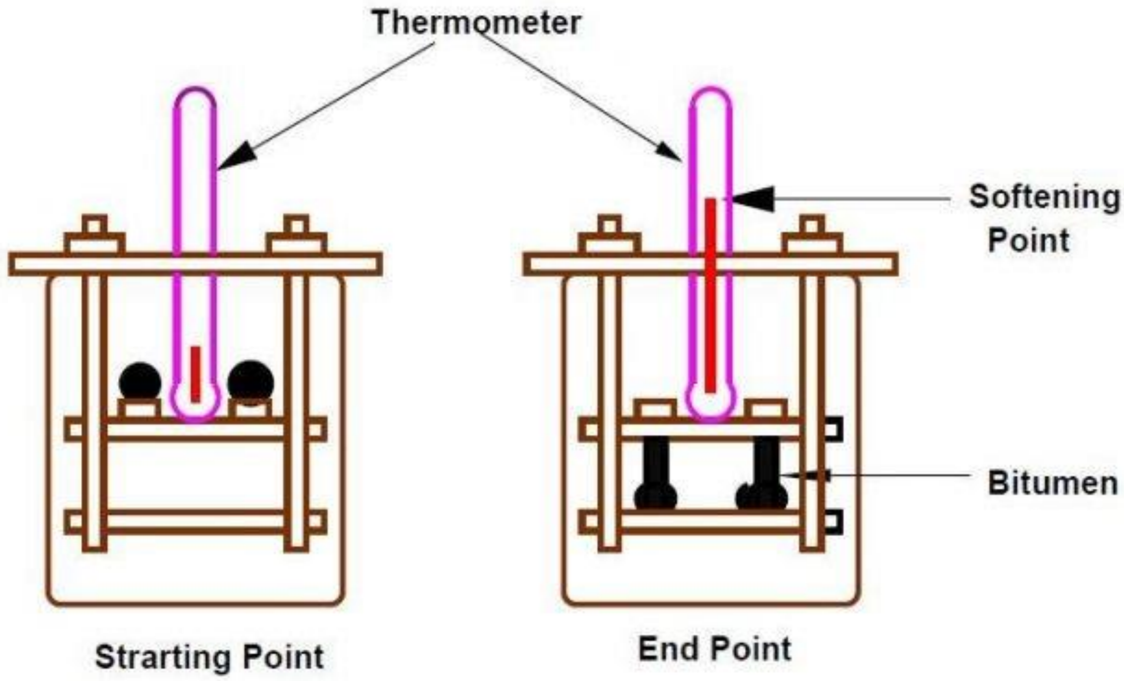
1. The ring and ball apparatus consisting of:

1. Steel balls-two numbers each of 9.5 mm diameter weighing 3.5 ± 0.05 g.
2. Brass rings-two numbers each having depth of 6.4 mm. The inside diameter at bottom and top is 15.9mm and 17.5 mm respectively.
3. Ball guides to guide the movement of steel balls centrally.
4. Support -that can hold rings in position and also allows for suspension of a thermometer. The distance between the bottom of the rings and the top surface of the bottom plate of the support is 25mm.

2. Thermometer that can read up to 100° C with an accuracy of 0.2° C.

3. Bath–heat resistant glass beaker not less than 85 mm in diameter &1220mm deep.

4. Stirrer



PROCEDURE:

1. Preparation of test sample

Heat the material to a temperature between 75-100° C above its softening point; stir until, it is completely fluid and free from air bubbles and water. If necessary, filter it through IS sieve 30.

Place the rings previously heated to a temperature approximating to that of the molten material, on a metal plate which has been coated with a mixture of equal parts of glycerin and dextrin.

After cooling for 30 minutes in air, level the material in the ring by removing the excess material with a warmed, sharp knife.

2. Assemble the apparatus with the rings; thermometer and ball guides in position

3. Fill the bath with distilled water to a height of 50mm above the upper surface of the rings. The starting temperature should be 5° C.

Note: Use glycerin in place of water if the softening point is expected to be above 80° C; the starting temperature may be kept 35° C.

4. Apply heat to the bath and stir the liquid so that the temperature rises at a uniform rate of 5 ± 0.5 °C per minute.

5. As the temperature increases the bituminous material softens and the balls sink through the rings carrying a portion of the material with it.

6. Note the temperature when any of the steel balls with bituminous coating touches the bottom plate.

7. Record the temperature when the second ball touches the bottom plate. The average of the two readings to the nearest 0.5°C is reported as softening point.

Precautions During Softening Point Test

1. Distilled water should be used as the heating medium.
2. During the conduct of test the apparatus should not be subjected to vibrations. (iii)The bulb of the thermometer should be at about the same level as the rings.

OBSERVATIONS AND CALCULATIONS:

Temperature when the ball touches bottom (first)=52.5'C

Temperature when the ball touches bottom (second)=53.8'C

Average temperature when ball touches bottom=53.15'C

RESULTS:

Softening point of bitumen= 53.15°C

CONCLUSIONS AND DISCUSSIONS:

Softening point indicates the temperature at which binders possess the same viscosity. Bituminous materials do not have a melting point. Rather, the change of state from solid to liquid is gradual over a wide range of temperature.

Softening point has particular significance for materials to be used as joint and crack fillers. Higher softening point ensures that they will not flow during service. Higher the softening point, lesser the temperature susceptibility. Bitumen with higher softening point is preferred in warmer places. The average value of this test should be obtained between 35 to 70 degree Celsius, so our test seems justified.

VISOCITY OF CUTBACK BITUMEN:

THEORY:

Viscosity is the inverse of fluidity. The degree of fluidity at the application temperature greatly influences the ability of bituminous material to spread, penetrate into voids and also coat the aggregate and hence affect the strength and characteristics of resulting paving mixes. At high fluidity or low viscosity, bitumen binder simply lubricates the aggregate particles instead of providing an uniform film thickness for binding action. Low fluidity or high viscosity does not enable the bitumen to coat the entire surface of aggregate in the mix easily and also resists the compactive effort and resulting mix is heterogeneous in character.

OBJECTIVE:

To determine the viscosity of bitumen using tar viscometer

APPARATUS REQUIRED:

Tar viscometer, cup, valve, receiver, thermometer etc.

PROCEDURE:

The tar cup is properly levelled and water in the bath is heated to the test temperature. Stirring is also continued. Material is heated to 20°C above the test temperature and material is allowed to cool. During this material is continuously stirred. When temperature reaches 40°C, it is poured into cup of the tar viscometer until levelling peg on valve rod is just immersed. Receiver is placed under the orifice. Valve is opened after applying kerosene in the receiver. Stop watch is started when cylinder records 50 ml. Time is recorded for flow upto a mark of 100ml.

DISCUSSIONS AND CONCLUSIONS:

The recommended values are shown below,it should be checked

Cutback bitumen SC,MC,RC of grades	0	1	2	3	4	5
Orifice size (mm)	4.0	4.0	10.0	10.0	10.0	10.0
Test Temperatures(°C)	25	25	25	25	40	40
Viscosity Ranges	25-75	30-250	10-20	25-75	14-45	60-140

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