NEPAL ENGINEERING COUNCIL LICENSURE EXAMINATION

ER. SAURAV SHRESTHA
MSC. IN TRANSPORTATION ENGINEERING
PULCHOWK CAMPUS

TRANSPORTATION ENGINEERING SYLLABUS OF NEC LICENSE EXAM

9. Transportation **(ACiE09)**

9.1 Highway planning and survey: Modes of transport, history of road development in Nepal; classification of roads; road survey; highway alignment and controlling factors; evaluating alternate alignments; Road Standards of Nepal. (ACiE0901)

9.2 Geometric design of highway: basic design control and criteria; elements of highway cross-section; highway curves; super elevation; average and ruling gradients; stopping sight distance; design considerations for horizontal and vertical alignments, extra widening, and set back distance; design of road drainage structures; design considerations for hill roads. (ACiE0902)

9.3 Highway materials: types of aggregates and tests on their gradation, strength, durability; binding materials and their tests; design of asphalt mixes; evaluation of subgrade soil. (ACiE0903)

9.4 Traffic engineering and safety: impact of human and vehicular characteristics on traffic planning; traffic operations and regulations; traffic control devices; traffic studies (volume, speed, O&D, traffic capacity, traffic flow characteristics, parking, accident, flow); road intersections (types, configurations, design); traffic lights; factors influencing night visibility, road safety measures. (ACiE0904)

9.5 Road pavement: different types of pavement; design methods for flexible and rigid pavements (DOR Guidelines); loads and other factors controlling pavement design; stress due to load, temperature. (ACiE0905)

9.6 Road construction & maintenance: activities, techniques, tools, equipment and plants used in road construction; preparation of road subgrade; field compaction control and soil stabilization; construction of asphalt concrete layers; construction procedure for penetration macadam, bituminous bound macadam and plain cement concrete pavements; road maintenance, repair and rehabilitation. (ACiE0906)

ROAD AGGREGATES

- **Road aggregate**, or simply "**aggregate**", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic **aggregates**

DESIRABLE PROPERTIES OF AGGREGATES

1) Strength (Resistance to crushing)
2) Hardness (Resistance to abrasion)
3) Toughness (Resistance to impact)
4) Durability (Resistance to weathering)
5) Water absorption
6) Shape of Aggregate
7) Adhesion with Bitumen
8) Surface texture

ADHESION WITH BITUMEN

- The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on the aggregate will be stripped off in presence of water.

FREEDOM FROM DELETERIOUS PARTICLES

- Specifications for aggregates used in bituminous mixes usually require the aggregates to be clean, tough and durable in nature and free from excess amount of flat or elongated pieces, dust, clay balls and other objectionable material.
- Aggregates must be free from impurities and deterious substances which are likely to interfere with the process of hydration, prevention of effective bonds between the aggregates and mixes

GOOD TEXTURE

- Surface texture is the property which defines whether a particular surface is polished or dull, smooth or rough.

WATER ABSORPTION OR MOISTURE CONTENT

- water absorption may be defined as the difference between the weight of very dry aggregates and weight of saturated aggregates with dry surface conditions. Water absorption of aggregates affect on its w/c ratio and durability. For coarse aggregates, it is about **0.5 to 1%** by weight of aggregates.

TEST FOR ROAD AGGREGATE

A. Descriptive Test
B. Destructive Test
C. Non Destructive quality Test
D. Sp. Gravity Test

- Particle Shape
- Surface Texture

DESCRIPTIVE TEST

- These tests are intended to define the visual examination of an aggregate that enables it to describe in terms of both the shape and the surface texture of the particles.
- The particle shape may be described as rounded, irregular, flaky, angular, elongated, and both flaky and elongated.
- Surface texture may be defined as glassy, smooth, granular, rough, crystalline, honeycombed and porous.

SIGNIFICANCE OF TESTS:

- Descriptive test is very valuable guides relative to the internal friction properties of aggregates.
- which resists the movements of aggregates pass each other. Road aggregates with high internal friction have good interlocking qualities

B. DESTRUCTIVE TEST

- Crushing test
- Abrasion test
- Impact test
- Soundness test
- Bitumen Adhesion Test

- **Crushing test** Surface coarse ≤ 30% Base course ≤ 45%
- **Abrasion test**

For cement concrete ≤ 16%

Bituminous surface coarse ≤ 30%

Bituminous base course ≤ 50%

- **Impact test**

20% - 30% = satisfactory for road surface

> 35% = weak for road surface

- **Soundness test**

≤ 12% loss for sodium sulfide, ≤ 18% loss for Mg

- **Bitumen adhesion test** ≤ 25%

AGGREGATE CRUSHING TEST

- is a measure of the resistance of an aggregate to crushing under gradually applied compressive load.
- Aggregates used in road construction should be strong enough to resist crushing under traffic load.
- The test is normally carried out on material passing the 12.5 mm and retained on the 10 mm IS sieve.

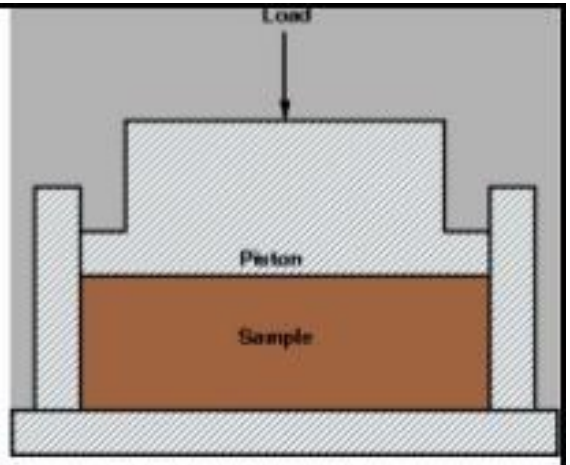
Aim : To determine crushing strength of a given aggregate

Apparatus:

(1)A steel cylinder of internal diameter 15.2cm (Steel cylinder with open ends)

(2)A square base plate, plunger having a piston diameter of 15cm. (3)A cylindrical measure of internal diameter of 11.5 and height 18cm (4)Steel tamping rod having diameter of 1.6cm length 45 to 60cm. (5)Balance of capacity 3kg with accuracy up to 1gm.

(6) Compression testing machine capable of applying load of 40 tonnes at a loading rate of 4tonnes per minute


Load
Piston
Sample

PROCEDURE

- Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve.
- The aggregate to be tested is dried in oven for a period of not less than 4 hours.
- Take weight of this material (WA)
- The cylindrical steel cup is filled with 3 equal layers of aggregate and each

  layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
- The surface is leveled and the plunger is inserted so that it rests horizontally

  on the surface. The whole assembly is then placed between the platens of testing machine and loaded at a uniform rate so as to reach a load of 40 tones in 10 minutes.

- The load is released and all aggregate is removed from the cup and sieved on 2.36 mm until no further significant amount passes in one minute.
- The fraction passing the sieve is weighed to an accuracy of 0.1 g (WB)
- The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.
- Aggregate crushing Value =(WB/WA) × 100

Surface coarse ≤ 30% Base course ≤ 45%

ABRASION TEST

- Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works.
- Los Angeles abrasion test is a preferred one for carrying out the hardness property.

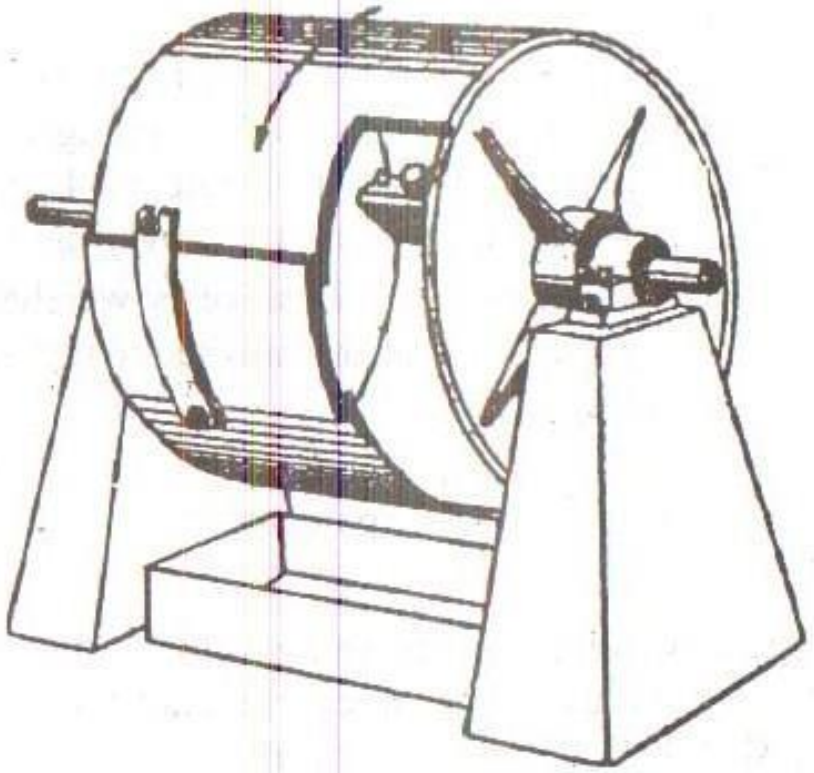
LOS ANGELES ABRASION TEST

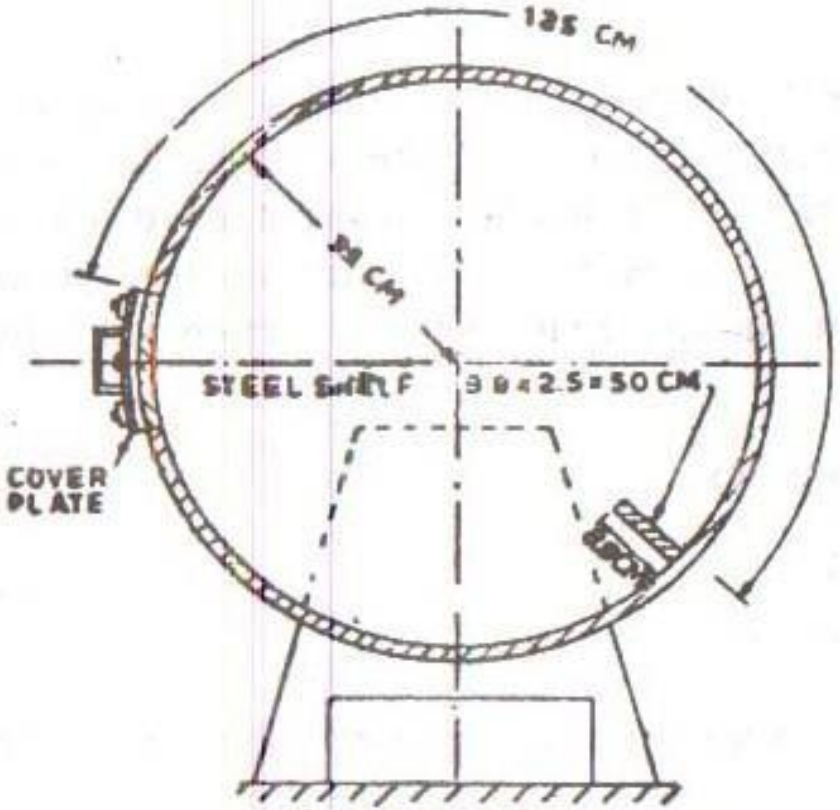
The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge in drum for specific number of revolutions.

- Objective:- To determine the Los Angeles Abrasion Value

APPARATUS

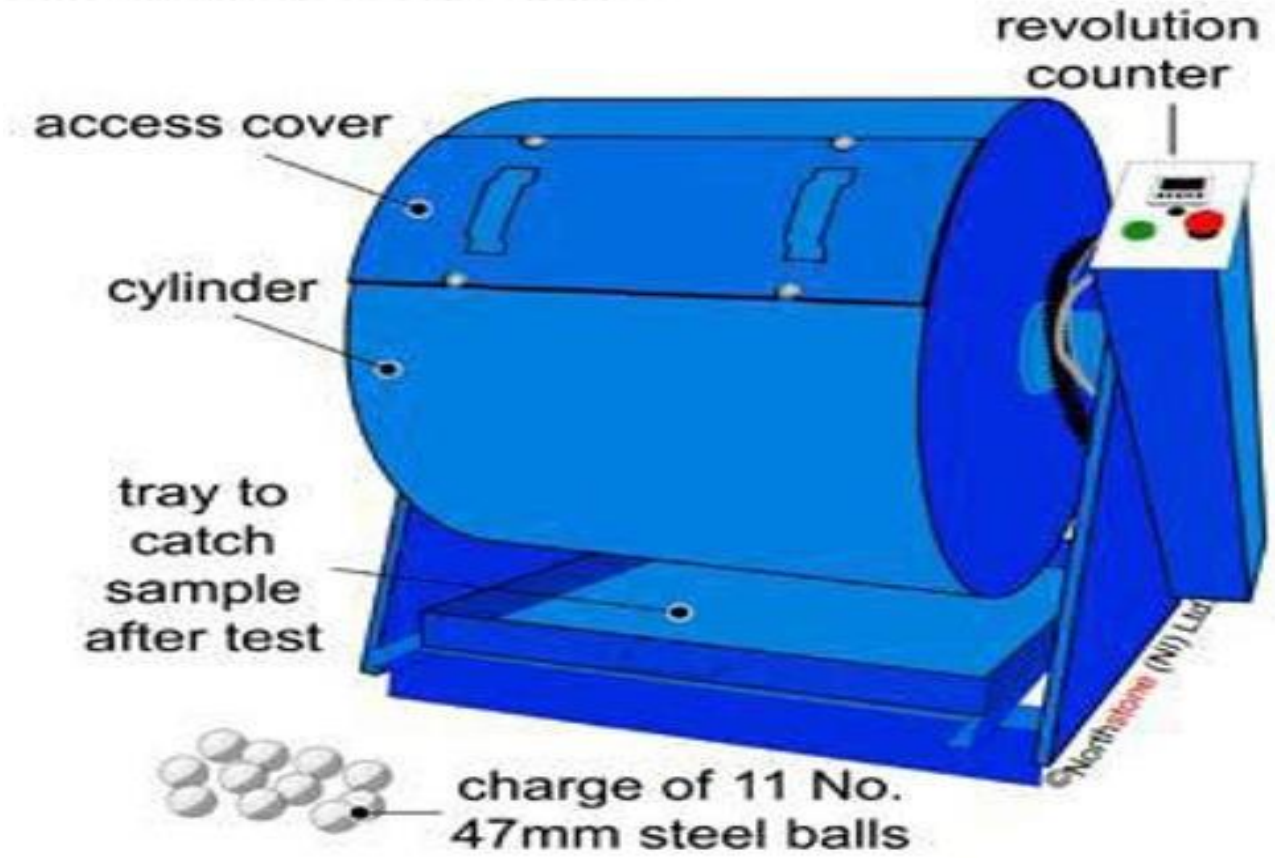
- Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated.
- An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates.
- The number of the abrasive spheres varies according to the grading of the sample.





CROSS SECTION

Los Angeles machine



- Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Figure).
- An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates.
- The number of the abrasive spheres varies according to the grading of the sample.
- The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg (W1).
- The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

STANDARD GRADING GROUP FOR LA TEST

Grading	Weight in grams of each test sample in the size range, mm (Passing and retained on square mesh)										Number of spheres
	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
B	-	-	-	-	-	2500	2500	-	-	-	11
C	-	-	-	-	-	-	-	2500	2500	-	8
D	-	-	-	-	-	-	-	-	-	5000	6
E	2500	2500	5000	-	-	-	-	-	-	-	12
F	-	-	5000	5000	-	-	-	-	-	-	12
G	-	-	-	5000	5000	-	-	-	-	-	12

- After specified revolutions, the material is sieved through 1.7 mm sieve and take weight of aggregate retained on 1.7mm sieve (W2).

$$\frac{W1 - W2}{W1} X100$$

- This value is called Los Angeles abrasion value.
- A maximum value of 40 percent is allowed for WBM base course. For bituminous concrete, a maximum value of 35 is specified.

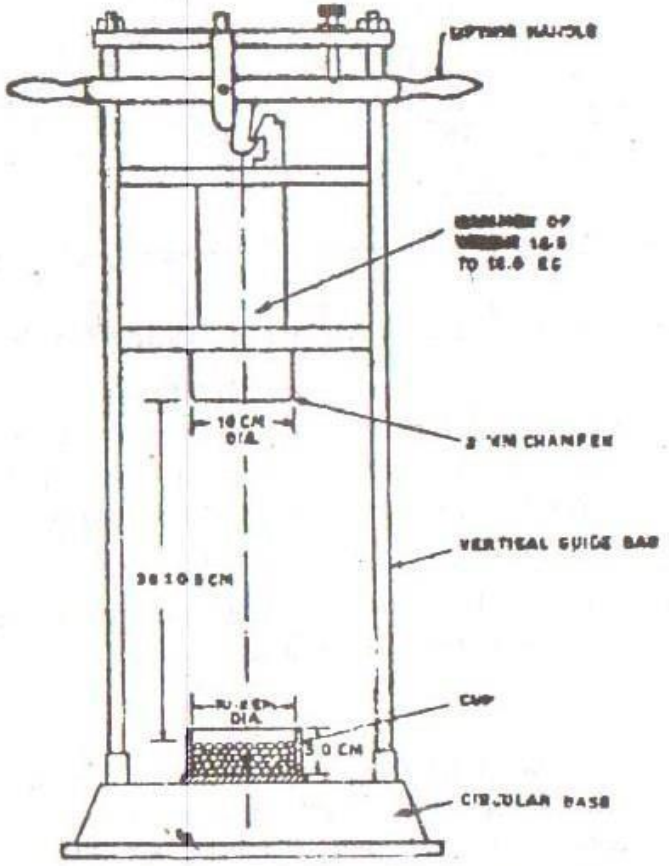
IMPACT TEST

- The aggregate impact test is carried out to evaluate the resistance to impact of aggregates.
- Aim:-

To determine the impact value of road aggregate

APPARATUS

- Testing machine
- Metal base with 30 cm diameter
- Cylindrical steel cup
- Internal diameter 102 mm, Depth 50 mm
- Minimum thickness 6.3 mm
- Metal hammer
- Weighing 13.5 to 14.0 kg
- Free fall of hammer should be within 380±5 mm.
- Tamping rod
- A balance


10 CM
DIA.
VERTICAL GUIDE BAR
CLIP
5.0 CM
CIRCULAR BASE

PROCEDURE

- Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia. 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine.
- The material is filled in 3 layers where each layer is tamped for 25 number of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 number of blows.
- The crushed aggregate is allowed to pass through 2.36 mm IS sieve.

- After 15 impacts the material passing the 2.36 mm sieve is expressed as a percentage of the total weight of original sample and termed as the aggregate impact value.
- Total weight of the oven dry aggregate sample = W1
- Weight of the crushed material passing 2.36 mm IS sieve after test = W2
- Aggregate Impact Value (AIV) = W2/ W1 X 100 %

- For wearing course, AIV<30 %
- For bituminous macadam < 35%
- For Water bound macadam base < 40%

SOUNDNESS TEST

- Study of resistance of aggregates to disintegrate due to alternate cycle of dry and wet condition conducting accelerated weathering test cycle Procedure

SOUNDNESS TEST

- Weight and count the dry and clean aggregate of specific size.
- Immersed in the saturated solution of sodium sulphate or magnesium sulphate for 16 to 18 hours.
- Oven dry the specimen at 105-110°C thus making one cycle of immersion and drying.
- The average loss in weight of aggregates to be used in pavement construction after 10 cycles should not exceed 12 percent when tested with sodium sulphate and 18 percent when tested with magnesium sulphate.

BITUMEN ADHESION TEST

- The static immersion test is very commonly used as it is quite easy and simple.
- Aggregate fully coated with binder is immersed in water, maintained at specified temperature and is estimated the degree of stripping.
- The result is reported as the percentage of stone surface that is stripped off after the specified time period.
- Stripping value should < 25% for road surface construction .(when 40ºC for 24 hours)

NON-DESTRUCTIVE QUALITY TESTS

- These non-destructive tests are carried out on the aggregate to determine its suitability for a specific use.
- The results obtained are normally compared with aggregate specifications to see whether they comply with the desired properties and characteristics.

➢water absorption and

➢shape test

➢Gradation

WATER ABSORPTION TEST:

- The procedure consist of soaking the aggregate sample in distilled water for 24 hours, surface drying and weighted and then oven drying and weighted again. Then the water absorption is given by
- $W_A = W_1 - W_2 / W_2 * 100$

W_A=Water absorption

W_1=wt. of surface dried aggregate W_2=wt. of oven dried aggregate

- Significance of tests:
- The porosity of the aggregate affects the amount of binder required and additional binder material may have to be incorporated in the mixture to satisfy the absorption by the aggregate after the ingredients have been mixed.
- The water absorption values allowed for road aggregates normally range from less than 0.1 percent to about 2 percent for materials used in road surfacing, while values of up to 4 percent may be accepted in road bases.

SHAPE TEST:

- Flakiness Index (F.I)
- Elongation Index (E.I)
- Angularity Number (A.N.)

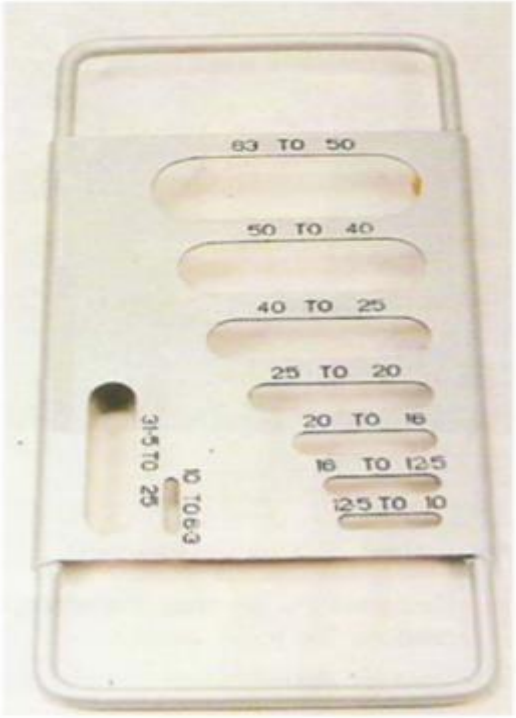


Figure 7.3 Standard Thickness Gauge

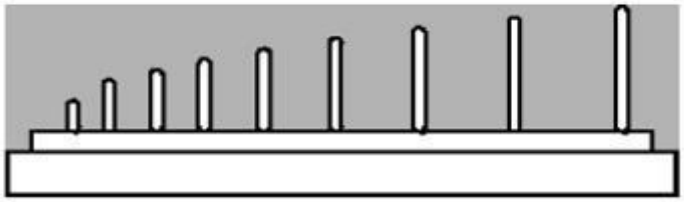


Figure 5: Elongation gauge

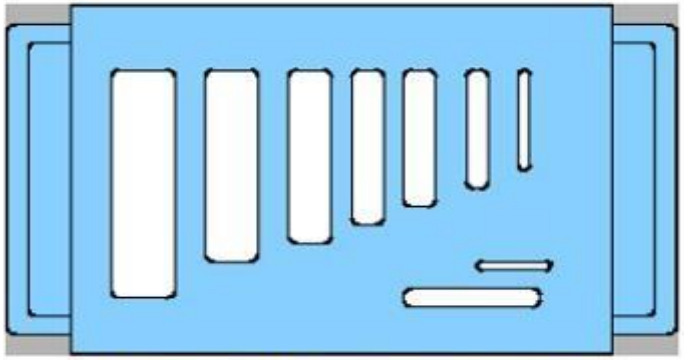


Figure 4: Flakiness gauge

1. The fine aggregate are the natural or crushed stone that more than 50%

a. retained in sieve size 4.75 mm

b. passes through sieve size 4.75 mm but retained in 2.36 mm

c. passes through sieve size 4.75 mm but retained in 0.075 mm

d. passes through sieve size 2.36 mm but retained in 0.075mm

1. The binding materials used for rigid pavement is

a. Stone dust

b. Cement

c. Bitumen

d. Clay

1. The binding materials used for AC pavement is

a. Stone dust

b. Cement

1. The method used for gradation test of aggregate is

a. Abrasion test

b. Flakiness index

c. Sieve analysis

d. Soundness

The aggregate sample used for crushing test is
•Passes through 2.36 mm
•Passes through 4.75 mm and retained on 2.36 mm
•Passes through 7.5 mm and retained on 4.75 mm
•Passes through 12.5 mm and retained on 10 mm

1. The cylindrical drum used in Los Angles Abrasion test is rotated at the speed of

a. 10-15 revolutions per minutes

b. 20-22 revolutions per minutes

c. 30-33 revolutions per minutes

d. 60-80 revolutions per minutes

The test carried out for toughness of stone or resistance to fracture under repeated load is
•Abrasion test
•Crushing test
•Impact test
•Soundness test

•For soundness test of aggregate with magnesium sulphate, the average loss in weight should not exceed
•5%

•**Crushing test** Surface coarse ≤ 30% Base course ≤ 45%

•**Abrasion test**

For cement concrete ≤ 16%

Bituminous surface coarse ≤ 30%

Bituminous base course ≤ 50%

• **Impact test**

20% - 30% = satisfactory for road surface

> 35% = weak for road surface

• **Soundness test**

≤ 12% loss for sodium sulfide, ≤ 18% loss for Mg

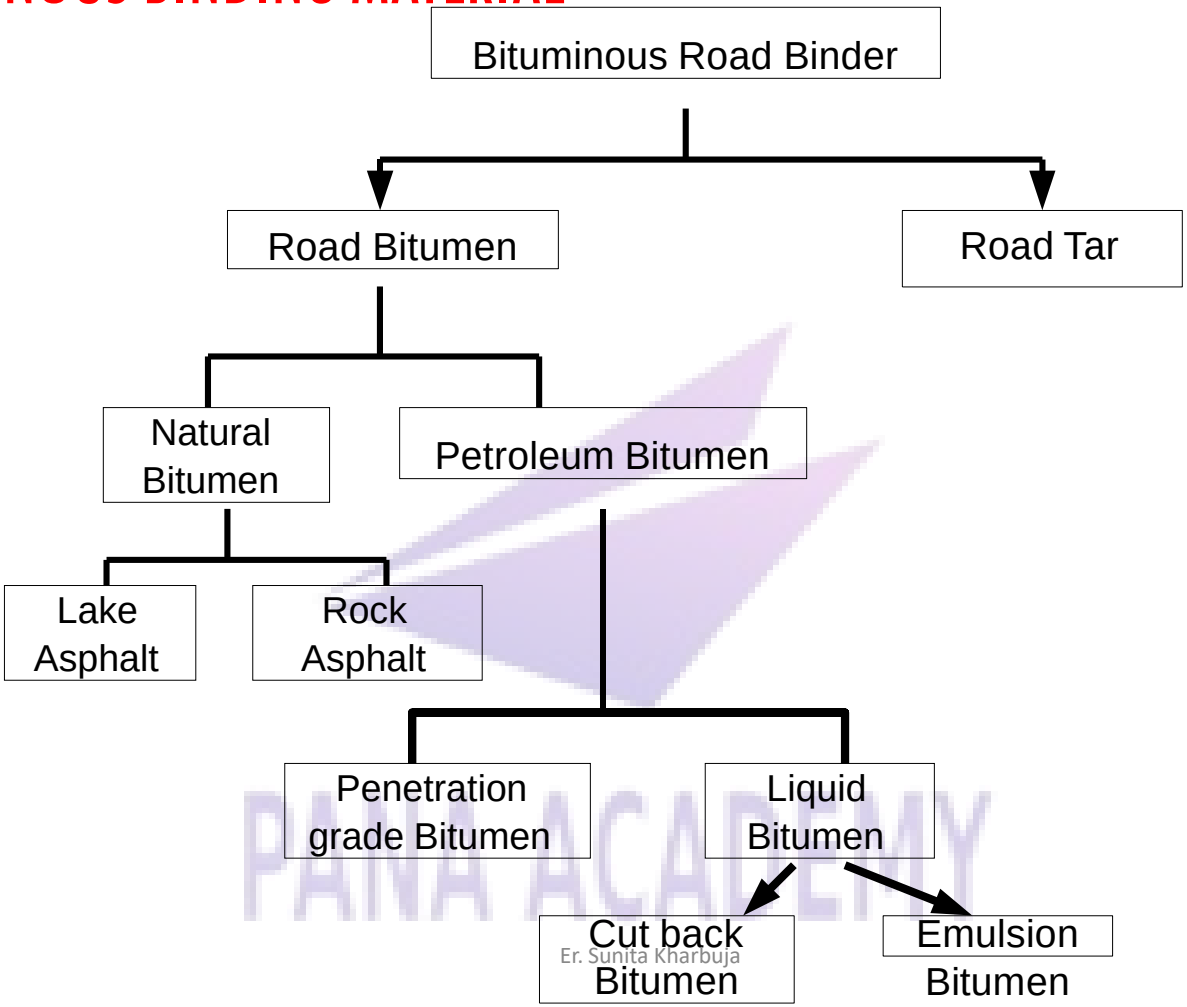
• **Bitumen adhesion test** ≤ 25%

BITUMEN

- Bitumen is a sticky, black, and highly viscous liquid or semi-solid form of petroleum product produced by removing the lighter liquid, petroleum gas, petrol and crude oil during the refining process. possesses adhesion and water proofing properties,.

•It may be found in natural deposits
refined product and

BITUMINOUS BINDING MATERIAL



DESIRABLE PROPERTIES OF BITUMEN

- Adhesion
- Resistance to Water
- Hardness
- Viscosity and Flow
- Softening Point
- Ductility
- Specific Gravity
- Versatility
- Strength

CUTBACK BITUMEN

Normal practice is to heat bitumen to reduce its viscosity. In some situations preference is given to use liquid binders such as cutback bitumen. In cutback bitumen suitable solvent is used to lower the viscosity of the bitumen. From the environmental point of view also cutback bitumen is preferred. The solvent from the bituminous material will evaporate and the bitumen will bind the aggregate.

BASED ON THE RATE OF CURING CUTBACK BITUMEN IS CLASSIFIED INTO THREE TYPES:

- **Slow curing (SC):** solvent is low volatile (diesel) and non volatile oils and used for premix with appreciable quantity of fine aggregates.
- **Medium curing (MC):** if the fluidity is increased by adding medium volatile (kerosene) and recommended for premix with less quantity of fine aggregates
- **Rapid curing (RC):** mixing the bitumen with highly volatile (petrol) agent and recommended for surface dressing and patchwork.

BITUMEN EMULSION

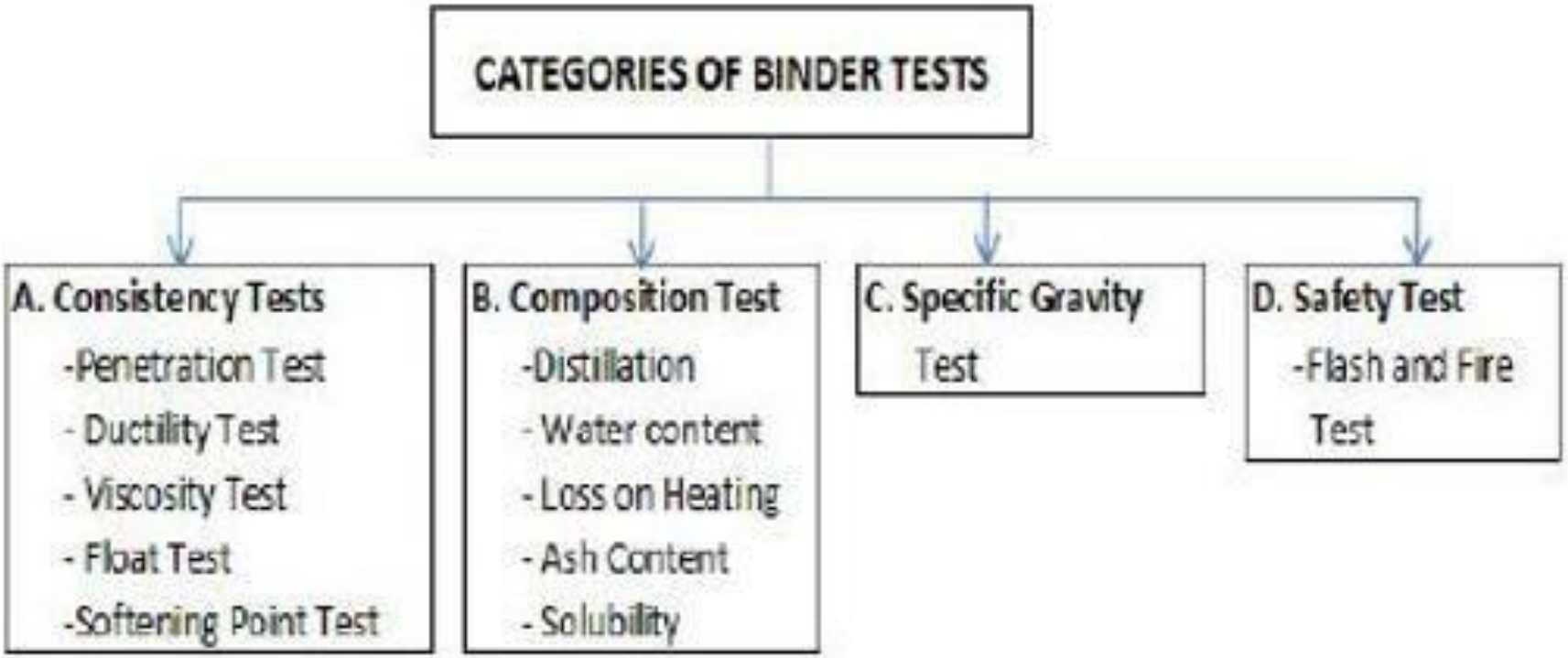
Bitumen emulsion is obtained by dissolving very finely divided bitumen in aqueous medium. Suitable stabilizing agents are added to this solution.

- Bituminous emulsions may be
- **Rapid setting (RS),**
- **Medium setting (MS),**
- **Slow setting (SS).**

RS emulsions are used for surface dressing work.

MS emulsions are preferred for premix jobs and patch repairs work. SS emulsions are preferred in rainy season

TESTS ON BITUMINOUS BINDER AND THEIR SIGNIFICANCE



A. PENETRATION TEST:

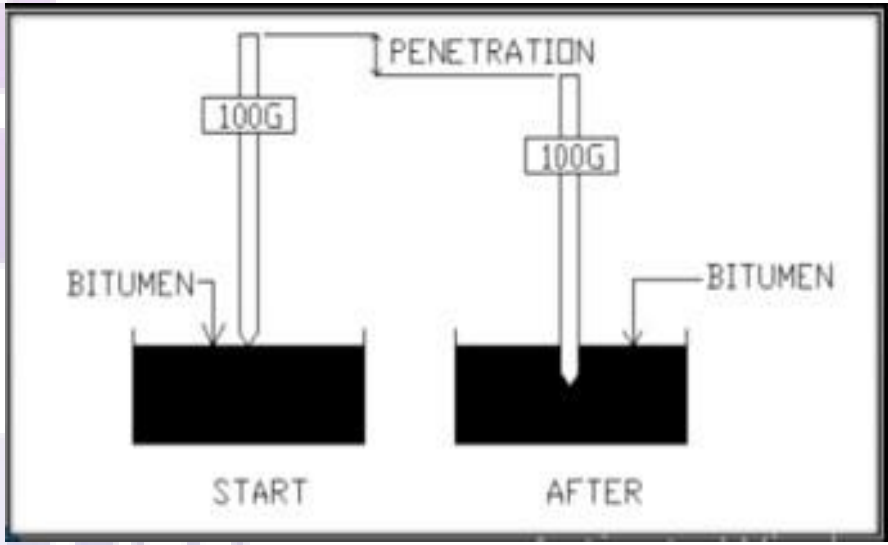
- Measurement of hardness of bitumen under specified temperature.
- The test consists of determining how far a standard steel needle will penetrate vertically into binder under standard condition of temperature. Temperature is 25°C, weight is 100 gm, and time is 5 sec.

Apparatus:

•The penetrometer consists of a needle assembly with a total of 100 gm and device for releasing and locking in any position. There is a graduated dial to read penetration values to 1/10th of a millimeter.

PROCEDURE:

- The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration.
- The sample container is placed in a temperature controlled water bath at a temperature of 25°C for one hour.
- The sample container is taken out and the needle is arranged to make contact with the surface of the sample.
- The dial is set to zero or the initial reading is taken and the needle is released for 5 seconds. The final reading is taken on dial gauge.
- Three penetration tests are made on this sample by testing at distances of at least 10 mm apart.

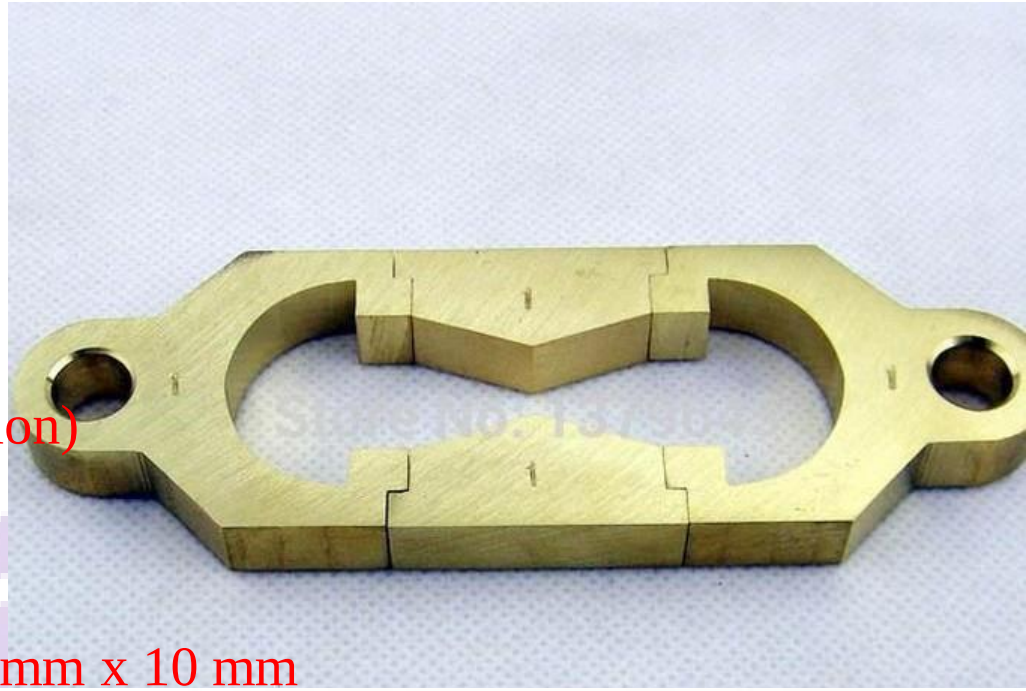


B. DUCTILITY TEST

The ductility of the bituminous binder is expressed as the distance in centimeters that a standard briquette will elongate before breaking.

- The binders which do not possess sufficient ductility would crack under repeated traffic loads.
- The test measures the adhesiveness and elasticity of bitumen

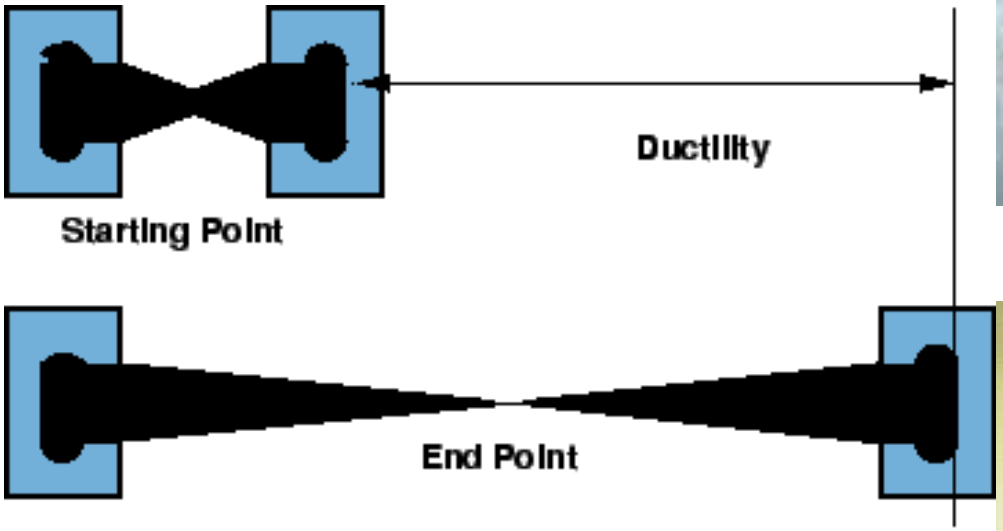
APPARATUS:

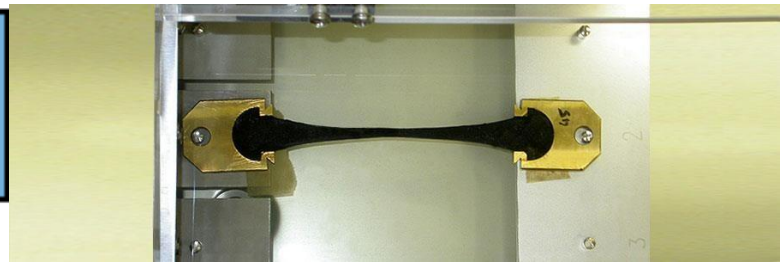


- standard ductility test apparatus.
- Mould – (8 shaped standard dimension)
- Temperature - 27°C •
- Pull rate - 50 mm/min
- Starting minimum width (neck) - 10 mm x 10 mm

PROCEDURE

- The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in the water bath at 27 C temperature.
- The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with the assembly containing sample is kept in the water bath of the ductility machine for about 90 minutes.
- The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of the breaking of thread is the ductility value which is reported in cm.
- The ductility value gets affected by factors such as pouring temperature, test temperature, the rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Figure 0.1 shows ductility moulds to be filled with bitumen.


Ductility
Starting Point
End Point



C. VISCOSITY TEST

- Defined as the inverse of fluidity and indicates fluid property of bituminous material.
- This property greatly influences on the ability of bituminous material to spread, penetrate into voids and also coat the aggregates.
- Highly viscous binder may not fill up the voids completely resulting in poor density whereas lower viscous binder does not hold the aggregates together but just acts as lubricant.
- Generally it is carried out for cutback, emulsion and road tar.

Specified Conditions of Test:

- Apparatus - Orifice type Viscometer
- Diameter - 4 and 10 mm
- Temperature- 250C & 400C
- Quantity of Binder - 50 cc
- Time taken to flow - Sec – Viscosity

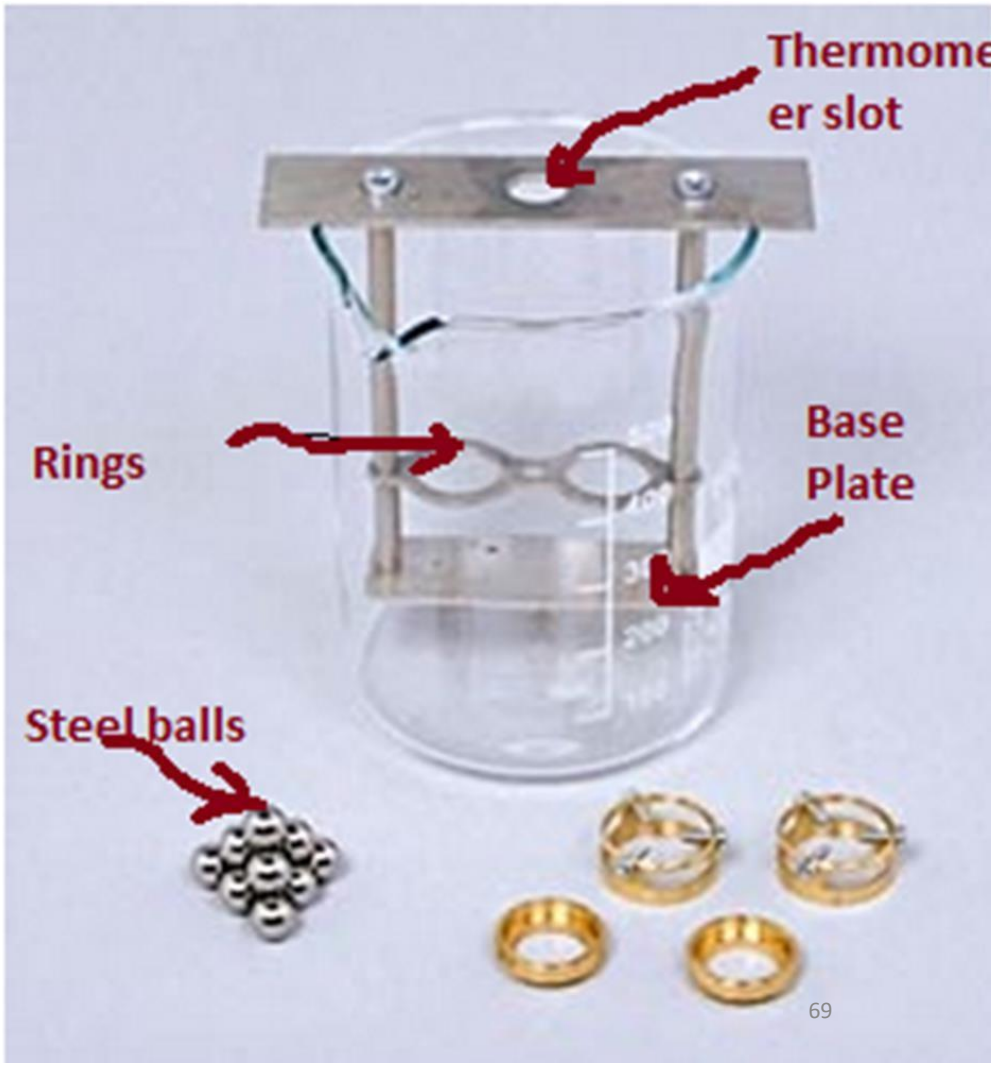
E. SOFTENING POINT

- Temperature at which the bitumen attains a particular degree of softening under specified conditions of test.
- It is carried out in Ring & ball test apparatus. It consists of brass Ring and Steel ball.
- Ring is plugged with the sample of bitumen & then heated of 50C per minute till the bitumen softens and touches the bottom of metal plate placed at specified distance below the ring.
- This temperature is the softening point of bitumen.

- Apparatus

Ring and Ball apparatus Water bath with stirrer Thermometer

Glycerin, and Steel balls each of 9.5mm and weight of 2.5±0.08gm.



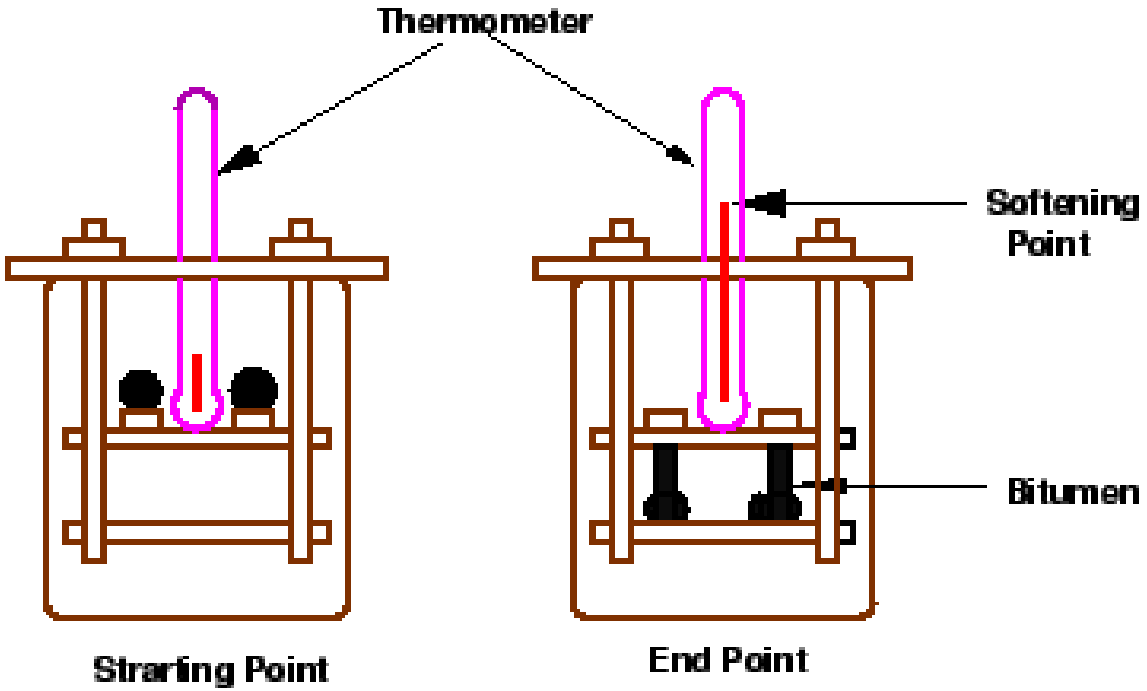
PROCEDUR E

A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature.

- A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5 C per minute.
- Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

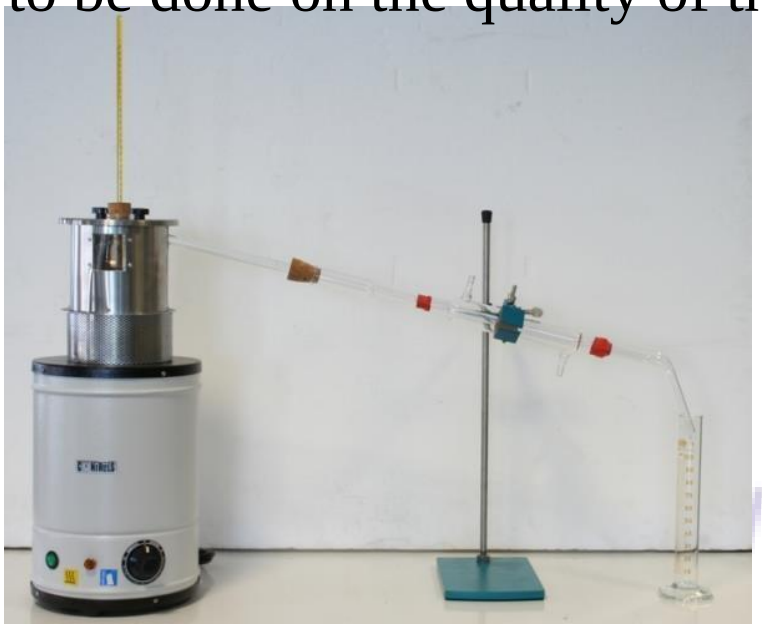
PROCEDURE

- Sample material is heated to a temperature between 75° and 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on the 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.
- At this time the temperature of distilled water is kept at 5°C. This temperature is maintained for 15 minutes after which the balls are placed in position.
- Then the temperature of water is raised at uniform rate of 5°C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls.


Thermometer
Softening Point
Bitumen
Strarting Point
End Point

SIGNIFICANCE OF TESTS:

- To identify the type of volatiles in the binder and on the rate at which these volatiles will be lost under field conditions, enable to close check to be done on the quality of the binders on the road projects.



C. LOSS ON HEATING TEST:

- In this test a 50 gm. of bitumen sample is placed in a small container and left for 5 hours, in a revolving aluminum shelf oven, the temperature of which is maintained at 165°C.
- At the end of heating period, the sample is cooled to room temperature and weighed.
- Loss in weight of the sample is then expressed as a percentage of the original weight.

4. SAFETY TEST

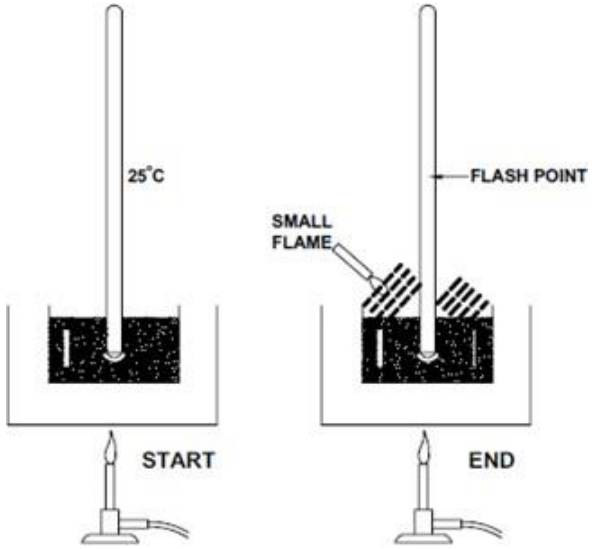
Flash and fire point test

•The flash and fire point test are the two tests under safety test.

Significance:

•The flash point of most penetration grade bitumen lies in the range of 245 to 335°C. The minimum specified flash point of bitumen used in pavement construction is 175°C

- Bitumen materials leave out volatiles at temperatures depending upon their grade. These volatiles catch fire causing a flash.
- This condition is very hazardous and it is therefore essential to qualify this temperature for each bitumen grade.



Flash point:

the flash point as the temperature at which the vapor of bitumen momentarily catches fire in the form of flash under specified test conditions.

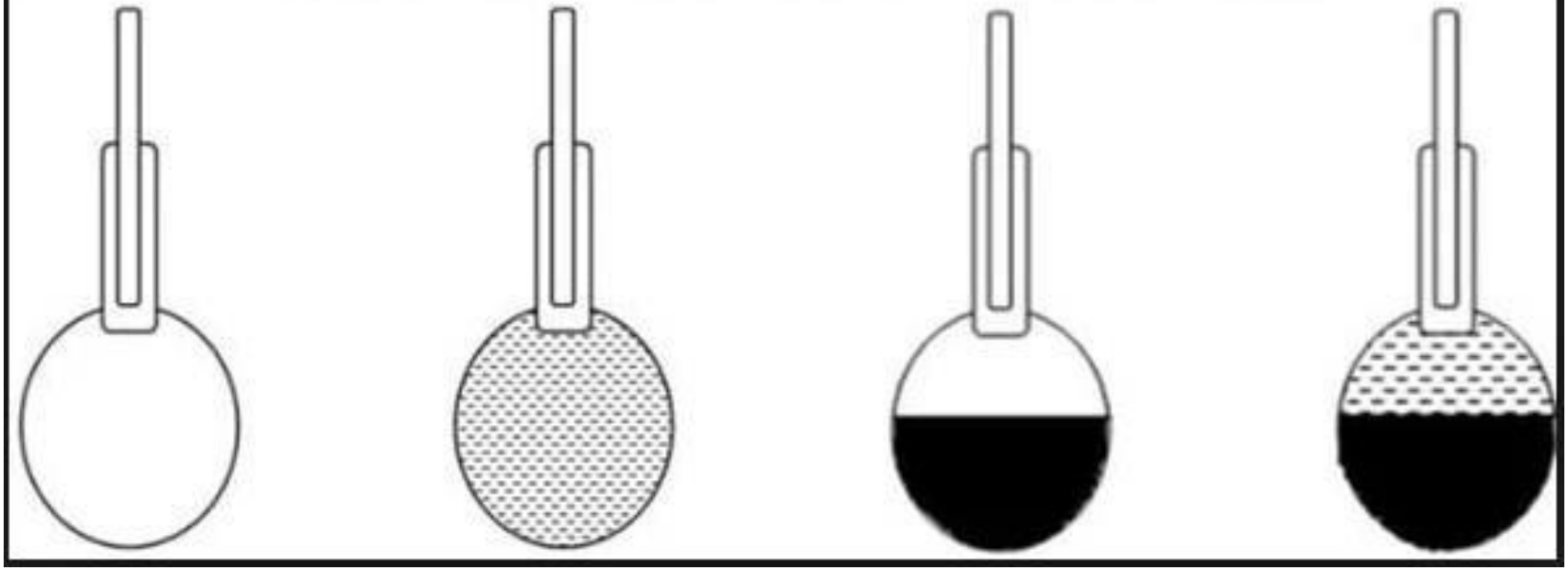
Fire point:

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

A. PYCNOMETER METHOD:

- Specific gravity = (w3-w1) / (w2-w1)-(w4-w3)
- w1 = weight of the specific gravity bottle 7
- w2 = weight of the specific gravity bottle filled with distilled water
- w3 = weight of the specific gravity bottle about half filled with bitumen
- w4 = weight of the specific gravity bottle, about half filled with bitumen and rest with distilled water.

Specific Gravity Computation of Bituminous Material



B. BALANCE METHOD:

- Specific gravity = w1/ (w1-w2)
- Where, w1 = weight of the dry specimen
- w2= weight of the specimen immersed in distilled water

- Specific gravity of bitumen varies from 0.97 to 1.02.
- Specific gravity of tar varies from 1.16 to 1.28.

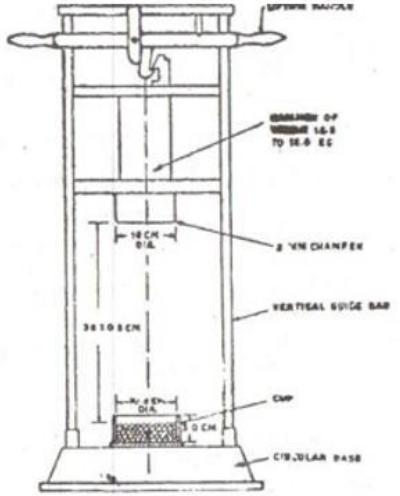
9. The flakiness index of an aggregate is defined as the percentage by weight of particles whose
   a. Least dimension is less than 0.6 times mean size
   b. Least dimension is less than 1.8 times mean size
   c. Greatest dimension is more than 0.6 times mean size
   d. Greatest dimension is more than 1.8 times mean size

10. Impact value is used to measure
   a. Hardness
   b. Toughness
   c. Wheel load
   d. Strength

11. . If the aggregates are exceptionally strong then they are having impact value which is
   a. Less than 10
   b. Less than 15
   c. Less than 30
   d. Greater than 30

Aggregate impact value<= 10%, that is exceptionally strong
Aggregate impact value 10%-20%, that is strong
Aggregate impact value 20%-30%, that is satisfactory for road surface
Aggregate impact value > 35%, that is weak for road surfacing

- After 15 impacts the material passing the 2.36 mm sieve is expressed as a percentage of the total weight of original sample and termed as the aggregate impact value.
- Total weight of the oven dry aggregate sample = W1
- Weight of the crushed material passing 2.36 mm IS sieve after test = W2
- Aggregate Impact Value (AIV) = W2/ W1 X 100 %



12. Weight of proportion retained in the sieve size 2.36mm is 180gm for the total dry aggregat as 300 gm. So, the impact value is
    a. 40%
    b. 60%
    c. 70%
    d. 65%

13. The fine aggregates are having a size less than
    a. 5mm
    b. 4.75mm
    c. 2.36 mm
    d. 75 microns

14. For testing loss in heating, the bitumen sample is heated at the temperature of
    a. 127°C
    b. 150°C
    c. 163°C
    d. 200°C

15. The minimum specified flash point of bitumen used in pavement construction is ___°C
    A. 127°C
    B. 175 °C
    C. 163°C
    D. 200°C

16. The test used for detecting over heated or cracked bitumen is
    a. Ductility test
    b. LAA test
    c. Flash and fire point test
    d. Softening point test

17. The apparatus used for viscosity test, an orifice viscometer of size
    a. 2.5 mm
    b. 20 mm
    c. 15 mm
    d. 4-10 mm

DETERMINATION OF OPTIMUM BINDER CONTENT (OBC)

- It is done to ensure maximum stability. Stability is defined as resistance of paving mix to deformation under load.

1.Surface Area Concept

2.Void Concept Method

MARSHALL MIX DESIGN

- The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army.
- The Marshall method is very popular because of its relative simplicity, economical equipment and proven record.

MARSHALL TEST AND DESIGN PROCEDURE

Used in designing and evaluation of bituminous paving mixes.

Major features of the Marshall method of designing mixes are to determine the two important properties of strength and flexibility.

In this test, an attempt is made to obtain optimum binder content for the type of aggregate mix used and the expected traffic intensity.

- Strength is measured in term of the ‘Marshall’s Stability’ of the mix which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60°c . This temperature represents the weakest condition for a bituminous pavement in use.
- Flexibility is measured in term of the “flow value” which is measured by the change in diameter of the sample in the direction of load application between the start of loading and the time of maximum load.

- **APPARATUS**
  - Mold Assembly: cylindrical moulds of 10.16 cm diameter and 6.35 cm height consisting of a base plate and collar extension
  - Sample Extractor: for extruding the compacted specimen from the mould (Figure 11.2)
  - Compaction pedestal and hammer.
  - Breaking head.
  - Loading machine (Figure 11.1)
  - Flow meter , water bath, thermometers

- In the Marshall test method of mix design three compacted samples are prepared for each binder content.
- At least fourbinder contents are to be tested to get the optimum binder content.
- All the compacted specimens are subject to the following tests:
  - Bulk density determination.
  - Stability and flow test.
  - Density and voids analysis.

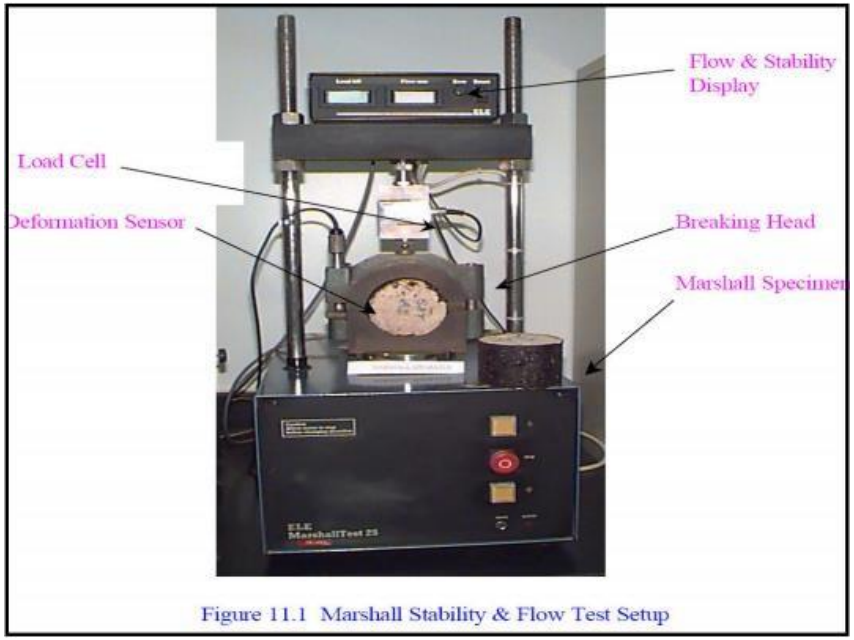


Figure 11.1 Marshall Stability & Flow Test Setup

Figure 11.2 Marshall Specimen Extractor

PROCEDURE

- **Preparation of Test specimen**
  - Measure 1200gm of aggregates and heat upto 175^{o}C to 190^{o}C
  - Heat bitumen to a temperature of 121 − 125^{o}C with the first trial percentage of bitumen (say 3.5 or 4% by weight of the mineral aggregates).
  - Mixed thoroughly the heated aggregates and bitumen at a temperature of 154 − 160^{o}C.
  - Placed the mix in a preheated mould and compact by a rammer with 50 blows on either side at temperature of 138^{o}C to 149^{o}C.
  - After compaction extract the sample by pushing it out the extraction
  - Allow the sample to stand for a few hours to cool
  - Obtain the sample's mass in air and submerged to measure density of specimen, so as to allow calculation of voids properties
  - Vary the bitumen content in the next trial by 0.5% and repeat the above procedure.

- **Testing of Sample**
  - Specimens are heated to $60^{o} \pm 1^{o}$ in a water bath for 30 to 40 min
  - Remove the specimens from the water bath and place in the lower segment of the breaking head. Then place the upper segment of the breaking head on the specimen and place the complete assembly in position on the testing machine
  - Place the flow meter over one of the post and adjust it to read zero
  - Apply load at a rate of 50mm/min until the maximum load reading is obtained
  - Record the maximum load reading in N. at the same instant obtain the flow meter in units of mm.

+

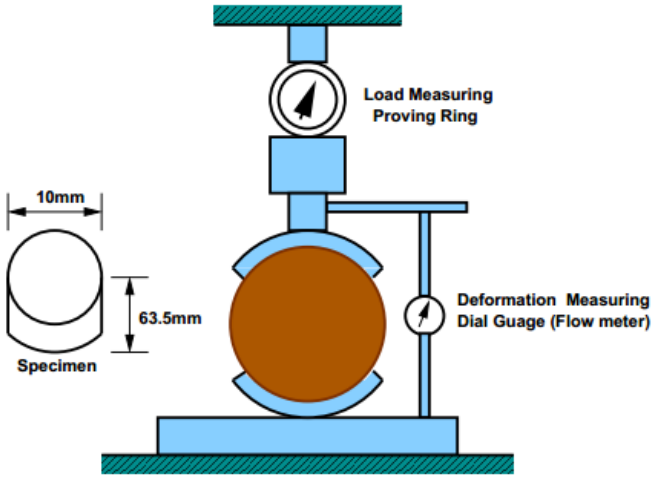
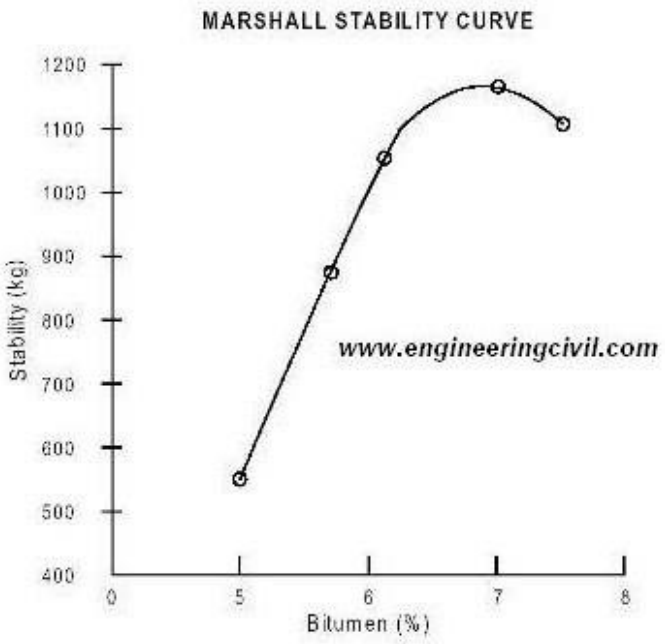
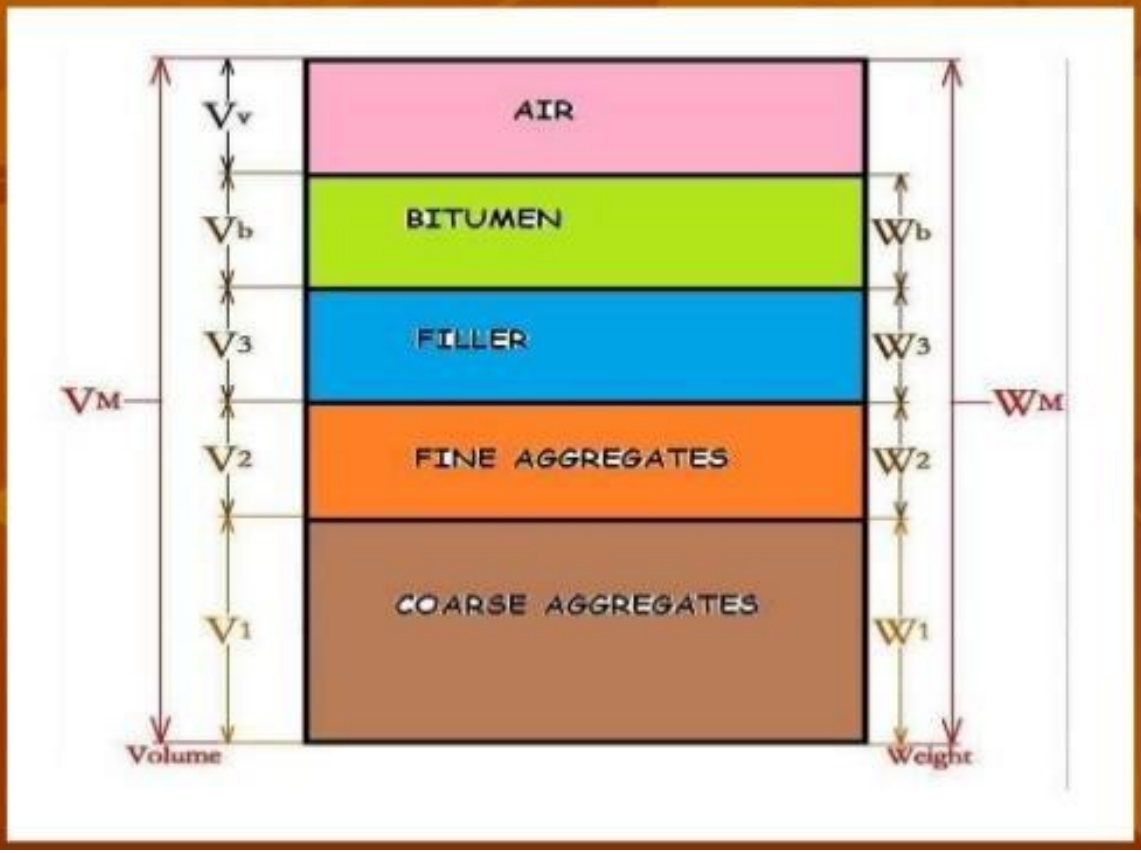


Figure 26:1: Marshall test setup



SPECIMEN PHASE DIAGRAM



26.4.1 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:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}} \tag{26.1}$$

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,

26.4.2 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:

$$G_m = \frac{W_m}{W_m - W_w} \tag{26.2}$$

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.

26.4.3 Air voids percent V_v

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

$$V_v = \frac{(G_t - G_m)100}{G_t} \tag{26.3}$$

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.

26.4.4 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:

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}} \tag{26.4}$$

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.

26.4.5 Voids in mineral aggregateVMA

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

$$VMA = V_v + V_b \tag{26.5}$$

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. (26.4).

26.4.6 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:

$$VFB = \frac{V_b \times 100}{VMA} \tag{26.6}$$

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.

- The average value of each of the above properties are found for each mix with the different bitumen content.
- Graphs are plotted with the bitumen content on the X-axis and the following values on the Y-axis:
  - Marshal stability value
  - Flow value
  - Unit weight
  - Percent voids in total mix (VTM)
  - Percent voids filled with bitumen (VFB)

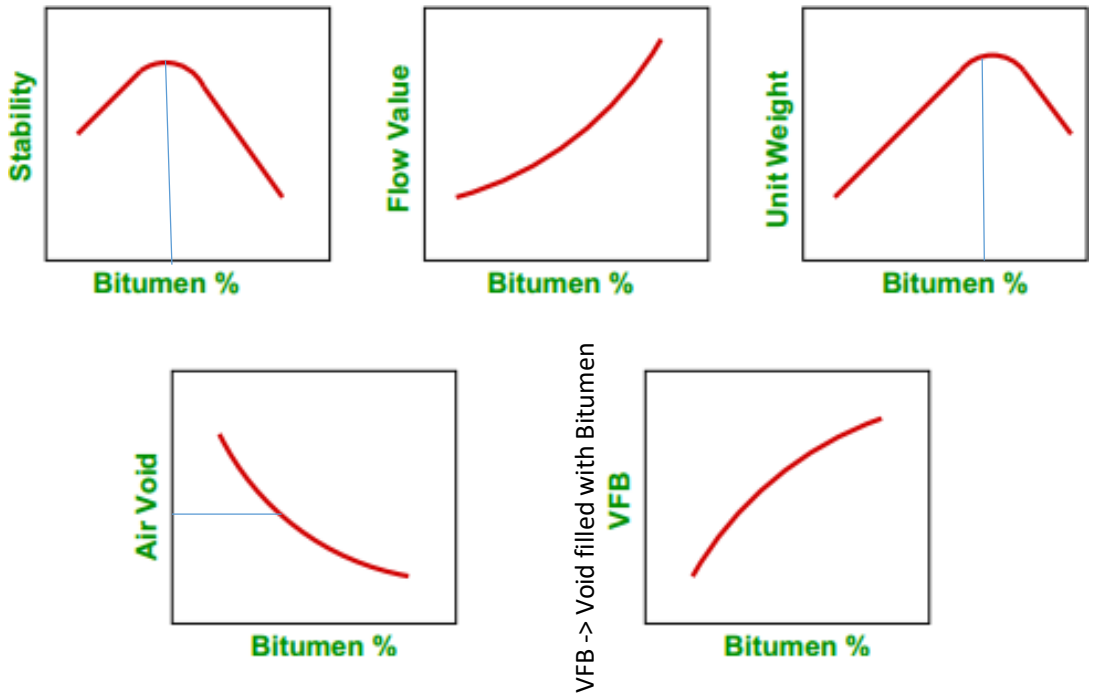
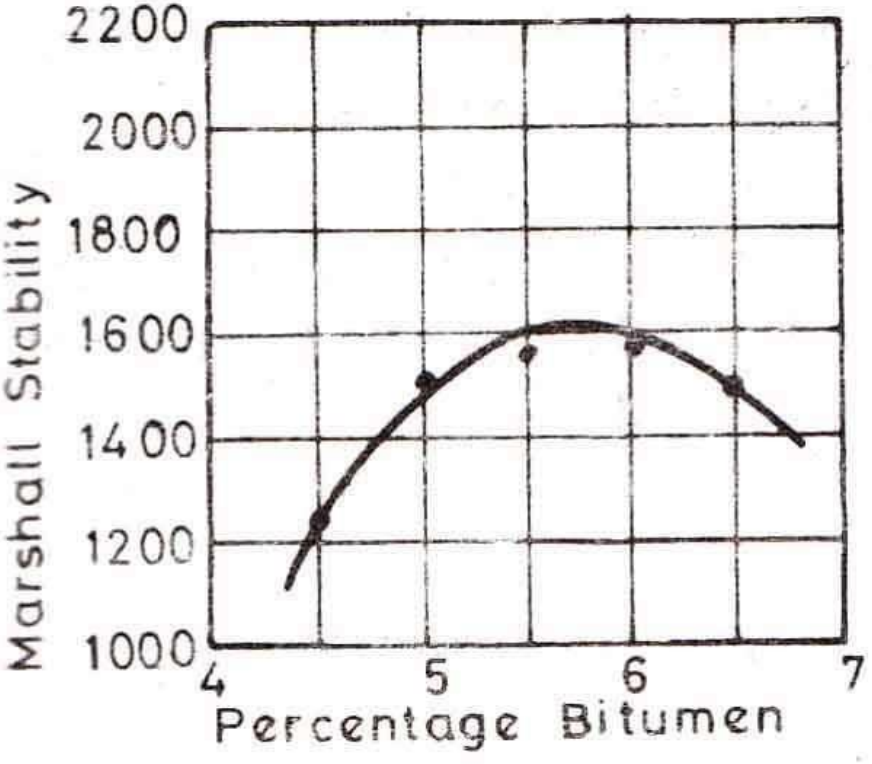


Figure 26:3: Marshal graphical plots

- 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 value** is measured as the deformation in units of 0.25mm between no load and maximum load carried by the specimen during stability test.


2200
2000
1800
1600
1400
1200
1000
Marshall Stability
4
5
6
7
Percentage Bitumen

- The optimum bitumen content for the mix design is found by taking the average value of the following three bitumen contents found from the graphs:

1. Bitumen content corresponding to maximum stability
2. Bitumen content corresponding to maximum unit weight
3. Bitumen content corresponding to the median of percent air voids in total mix.

- The Marshal stability value, flow value and percent voids filled with bitumen at the average value of bitumen content are checked with the Marshal mix design criteria given in table:

Test property	Specified value
Marshal stability , Kg	340 (minimum)
Flow value, 0.25mm units	8 to 16
Air voids in total mix, Vv %	3 to 5
Voids filled with bitumen, VFB%	75 to 85