GATE – CIVIL ENGINEERING

TRANSPORTATION ENGINEERING

Online Lecture: 10 (20.06.2020)

Prof.B.Jayarami Reddy
Professor and Head
Department of Civil Engineering
Y.S.R. Engineering College of
Yogi Vemana University,
Proddatur, Y.S.R.(Dt.), A.P-516360.
E.mail : bjrcivilgate@gmail.com

TRANSPORTATION ENGINEERING

Prof. B. Jayarami Reddy

15.3 HIGHWAY MATERIALS

Sub grade soil provide the support to the pavement from beneath.

The desirable properties of soil as a highway material are

a. Stability

b. Incompressibility

c. Permanency of strength

d. Good drainage

e. Ease of compaction

f. Minimum changes in volume and stability under adverse conditions.

Prof. B. Jayarami Reddy

California Bearing Ratio (CBR) Test:

- CBR test was developed by California division of highway.
- It is a method of classifying and evaluating soil sub-grade and base course materials for flexible pavements.
- It is an empirical test- measures the relative strength of the material.
- It is a penetration test- 50 mm diameter plunger is used to penetrate the soil at a standard rate of loading of 1.25 mm per minute.
- In most of the cases, CBR decreases with the increase of penetration.
- CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture condition.
- The test may be conducted in remoulded or undisturbed specimen in laboratory
- It is extremely used for field correlation of flexible pavement thickness requirements.

- Diameter of CBR mould: 150 mm
- The specimen of soil in the mould is soaked in water for four days.
- Load for standard crushed stones:

  At 2.5 mm penetration: 1370 kg (70 kg/cm^2)

  At 5.0 mm penetration: 2055 kg (105 kg/cm^2)
- CBR Value is expressed as a percentage of the actual load causing the penetration of 2.5 mm or 5.0 mm to the standard loads.

$$CBR = \frac{\text{Load carried by the specimen}}{\text{Load carried by standard specimen}} \times 100$$

If $(CBR)_{2.5} > (CBR)_{5.0} \Rightarrow (CBR)_{2.5}$ is considered as CBR

If $(CBR)_{5.0} > (CBR)_{2.5} \Rightarrow$ test is to be repeated for checking

If again $(CBR)_{5.0} > (CBR)_{2.5} \Rightarrow (CBR)_{5.0}$ is reported as CBR

- CBR of the sample is the average of CBR value of three specimens.

Load Vs penetration curve

- If the specimen has surface irregularities, the initial portion of the curve may be concavity upwards.
- A tangent is drawn to the curve at the point of greater slope.
- The tangent is drawn to the curve at the point of greater slope at the initial stage and the convex portion of original curve is to be corrected. The correct curve is with the origin moved to the point where the tangent cuts the *x* axis.

Type of soil	CBR Range	
Clay	2-5	Very poor subgrade
Silt	5-8	Poor subgrade
Sand	8-20	Fair to good subgrade
Gravel	20-30	Excellent subgrade
	30-60	Good subgrade
	60-80	Good base
	80-100	Best base

Prof. B. Jayarami Reddy

eg. Load penetration values from a CBR test are given below:

Penetration, mm	0	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	7.5	10.0	12.5
Load, kg	0	8	29	45	63	80	86	104	119	136	151	164

$$\text{CBR value for 2.5 mm penetration} = \frac{80}{1370} \times 100 = 5.84$$

$$\text{CBR value for 5.0 mm penetration} = \frac{119}{2055} \times 100 = 5.79$$

$$\text{CBR Value} = (CBR)_{2.5} = 5.84$$

Prof. B. Jayarami Reddy

eg. The pressure penetration values from a CBR Test are given below:

Pressure, kg/cm^2	Penetration
5.8	2.0
6.3	2.5
7.0	3.0
8.9	4.5
9.2	5.0
9.5	5.5

The plotted curve of pressure-penetration has concavity upwards and a tangent drawn to the curve meets the *x* axis at 0.5 mm. The value of CBR is …………

As the curve is initially concave upwards, the observations need correction. The tangent to the curve meets at *x* axis at the value of 0.5 mm. The origin needs to be shifted by this amount.

The loads corresponding to 2.5 mm and 5.0 mm penetration are 7.0 kg/cm^2 and 9.5 kg/cm^2 respectively.

$$(\mathrm{CBR})_{2.5} = \frac{7.0}{70} \times 100 = 10\%$$

$$(\mathrm{CBR})_{5.0} = \frac{9.5}{105} \times 100 = 9.05\%$$

$$CBR = (CBR)_{2.5} = 10\%$$

Prof. B. Jayarami Reddy

eg. Pressure at 2.5 mm penetration = 8.0 kg/cm^2

Pressure at 5.0 mm penetration = 12.5 kg/cm^2

$$(CBR)_{2.5} = \frac{8.0}{70} \times 100 = 11.43\%$$

$$(CBR)_{5.0} = \frac{12.5}{105} \times 100 = 11.91\%$$

$$(CBR)_{2.5} < (CBR)_{5.0} \Rightarrow \text{test is to be repeated}$$

Prof. B. Jayarami Reddy

STONE AEEREEATES

Desirable properties of Road aggregates

a. Strength

- Sufficiently strong to withstand the stresses due to traffic wheel load.

b. Hardness

- Sufficiently hard to resist the wear due to abrasive action of traffic.
- Abrasive action increased due to the presence of abrasive material like sand between the tyres of the moving vehicles and the aggregate exposed at the top surface.
- The mutual rubbing of aggregate is called attrition.

c. Toughness

- Resistance to impact.
- The magnitude of impact would increase with roughness of the load surface, speed of the vehicle and other vehicular characteristics.

d. Shape of aggregates

- Rounded, angular, cubical, flaky or elongated shape of particles.
- Flaky and elongated particles have less strength.
- Rounded aggregate may be preferred to cement concrete mix due to low specific surface area and better workability for the same proportion of cement paste and same w/c ratio.
- Rounded particles are not preferred in granular base-course, WBM construction and bituminous construction as the stability due to interlocking of rounded particles is less.

Round Aggregates

Angular Aggregates

Irregular Aggregates

Flaky Aggregates

Prof. B. Jayarami Reddy

e. Durability

- The stone should resist disintegration due to the action of weather.
- Soundness is the property of stones to withstand the adverse action of weather.

f. Adhesion with Bitumen

- Aggregate should have less affinity with water when compared with bituminous materials.
- Bituminous coating on the aggregate will be stripped off in presence of water.

Tests on Road Aggregate

a. Crushing test

- Strength of the course aggregate.
- Aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load.
- Aggregate passing though 12.5mm and retained on 10 mm is used for the test.
- Aggregate crushing value is the percentage of the crushed material passing through 2.36 mm sieve in terms of original weight of the specimen.
- Strong aggregates give low aggregate crushing value.

  Crushing value $\ngtr 45\%$ for base course

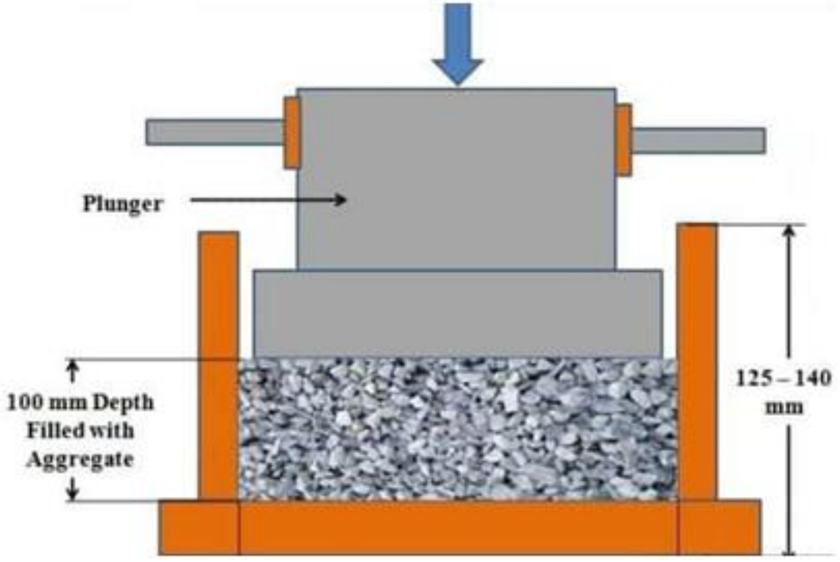
  $\ngtr 30\%$ for surface course

- Aggregate crushing value $= \frac{W_2}{W_1} \times 100$

  W_1: Weight of the total sample

  W_2: Weight of the material passing through 2.36mm

- Aggregate crushing value less than 10% signifies an exceptionally strong aggregate



Prof. B. Jayarami Reddy

b. Abrasion test

- To test the hardness property of stones.
- Abrasion tests on aggregate
    - Los Angeles abrasion test
    - Deval abrasive test
    - Dory abrasive test

Los Angeles abrasion test is preferred as the test results have been correlated with pavement performance i.e. rubbing and pounding action in the test stimulate the field conditions.

Los Angeles abrasion test

- To find the percentage wear due to the relative rubbing action between the aggregate and steel balls used as abrasive change.
- the resistance to wear and impact is evaluated.
- The results is expressed as the percentage wear or percentage passing 1.7 mm sieve expressed in terms of the original weight of the sample
- Abrasion value $\ngtr 30\%$ for good quality aggregate

  $\ngtr 50\%$ for base course

$$\text{Abrasion value} = \frac{W_2}{W_1} \times 100$$

W_1: Weight of the total sample

W_2: Weight of the crushed aggregate passing through 1.7 mm sieve.

Prof. B. Jayarami Reddy

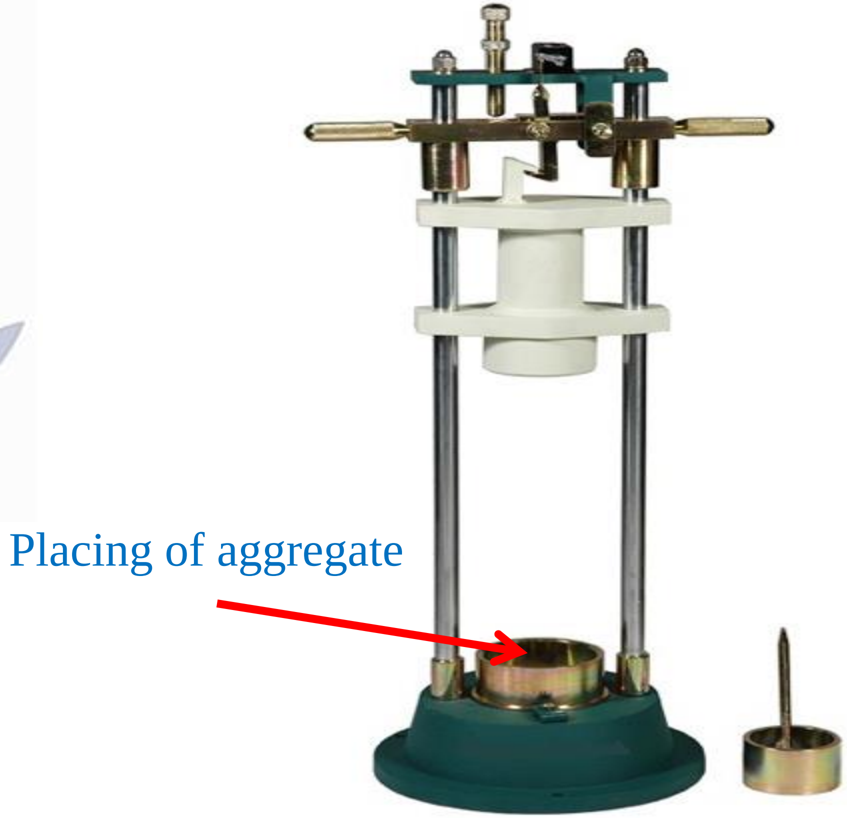
c. Impact Test

- To evaluate the toughness of stones.
- Toughness is the resistance to fracture under repeated impacts.
- The aggregate impact value is expressed as the percentage of the fineness passing through 2.36 mm sieve in terms of the total weight of the sample.
- Aggregate impact value
  - $\ngtr 30\%$ for wearing course.
  - $\ngtr 35\%$ for bituminous macadam base course
  - $\ngtr 40\%$ for water bound macadam base course

$$\text{Aggregate impact value} = \frac{W_2}{W_1} \times 100$$

W_1: Weight of the total sample

W_2: Weight of the crushed aggregate passing through 2.36mm sieve.



Prof. B. Jayarami Reddy

d. Soundness test

- To study the resistance of aggregates to weathering action by conducting accelerated weathering test cycles.
- Sieve analysis is carried out to note the variation in graduation from the original.
- The average loss after 10 cycles $\ngtr$ 12% when tested with sodium sulphate.

  $\ngtr$ 18% when tested with magnesium sulphate.

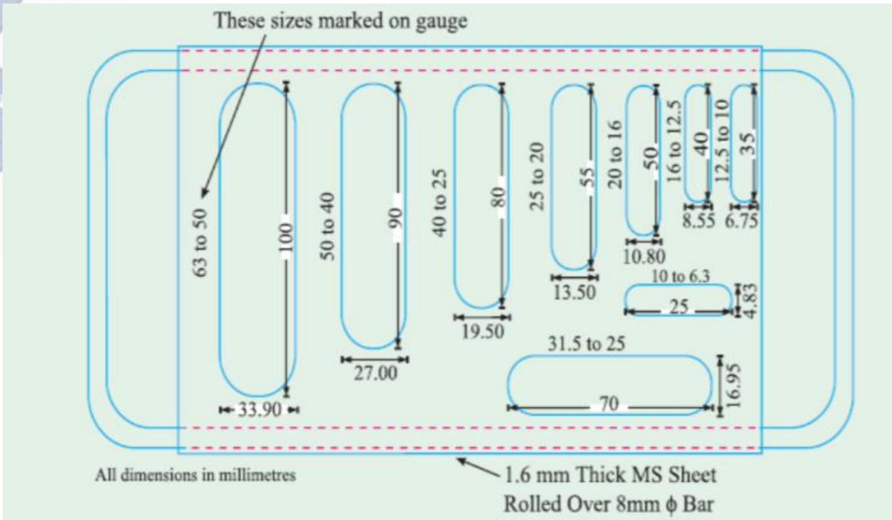
e. Shape tests

- Evaluation of shape of particles – Flakiness index, Elongation index and Angularity number.

Flakiness index of aggregates is the percentage by weight of aggregate particles whose least dimension/ thickness is less than 0.6 times of their mean dimension.

- The test is applicable to sizes larger than 6.3 mm.
- Standard thickness gauge is used to gauge the thickness of the samples.
- Flakiness index is the percentage of flaky materials (width is less than 0.6 of the mean dimension) in terms if the total weight.
- Flakiness index $\ngtr 15\%$ for road construction

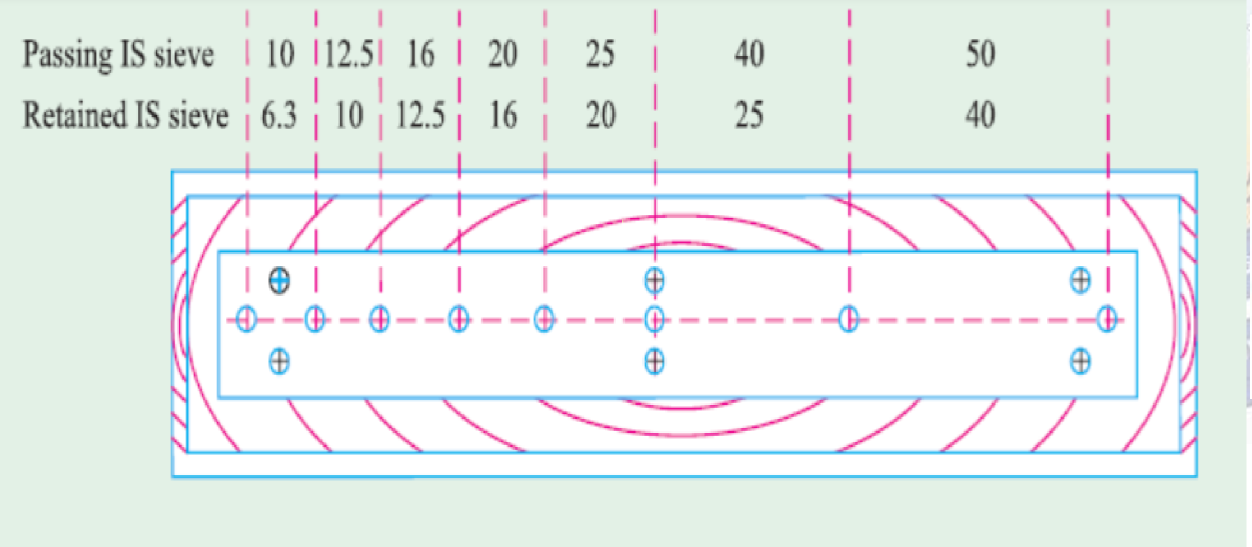
  $\ngtr 25\%$ for other purposes.



Prof. B. Jayarami Reddy

Elongation Index of aggregate is the percentage by weight of aggregate particles whose greatest dimension or length is greater than 1.8 times their mean dimension.

- The test is not applicable for sizes smaller than 6.3 mm.
- Elongation index $\ngtr 15\%$



Prof. B. Jayarami Reddy

eg. 20 mm passing - 16mm retained

$$\text{Thickness} = \frac{20+16}{2} \times 0.6 = 10.8\text{mm}$$

$$\text{Length} = \frac{20+16}{2} \times 1.8 = 32.4\text{mm}$$

Range of particle size: 10.8 mm to 32.4 mm eg. Weight of sample = 1000g

Weight of flakey material = 120 g

Weight of elongated material = 100 g

$$\text{Flakiness index} = \frac{\text{Weight of flakey material}}{\text{Total weight}}$$

$$= \frac{120}{1000} \times 100 = 12\%$$

$$\text{Elongation index} = \frac{\text{Weight of elongated material}}{\text{Total Weight}} \times 100$$

$$= \frac{100}{1000} \times 100 = 10.0\%$$

Prof. B. Jayarami Reddy

Angularity number

- Angularity of the aggregates can be estimated from the properties of voids in a sample of aggregate compacted in a particular manner.
- Angularity number = 67- percent solid volume.
- The angularity number measures the voids in excess of 33 percent.
- The higher the number, more angular in the aggregate.
- Range of angularity number for aggregates used in construction is 0 to11.
- 67 represents the volume of solids in % for rounded gravel in a well compacted state which has 33% voids.
- Angularity number $= 67 - \dfrac{100W}{C.G}$

W: weight of aggregate in the cylinder

C: weight of water filling the cylinder

G: specific gravity of aggregate

Prof. B. Jayarami Reddy

S.No	Property of aggregate	Type of test
1	Crushing strength	Crushing test
2	Hardness	Los Angeles abrasion test
3	Toughness	Aggregate impact test
4	Durability	Soundness test/Durability test
5	Shape factor	Shape tests
6	Specific gravity	Specific gravity test
7	Porosity	Water absorption test
8	Adhesion to bitumen	Stripping value of aggregate

Bituminous materials:

- **Native asphalts** are those which occur in a pure state in nature.
- **Rock asphalts** are those native asphalts which are associated with large proportion of mineral matter.
- **Cutback** is a bitumen with low viscosity.
- **Emulsion** is a bitumen suspended in a finely divided condition in an aqueous medium and stabilized with an emulsifier.
- **Tar** is the viscous liquid obtained when natural organic materials such as wood and coal are carbonized or destructively distilled in the absence of air.
- Tar is soluble only in toluene.

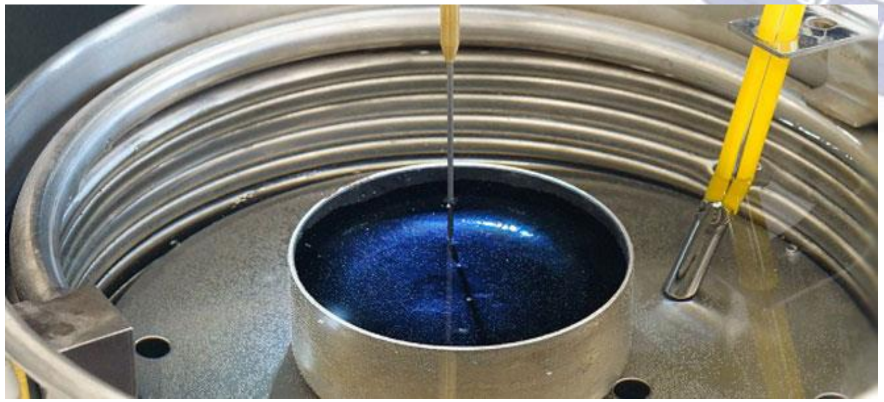
Asphalt

Prof. B. Jayarami Reddy

Tests on bitumen:

Penetration test:

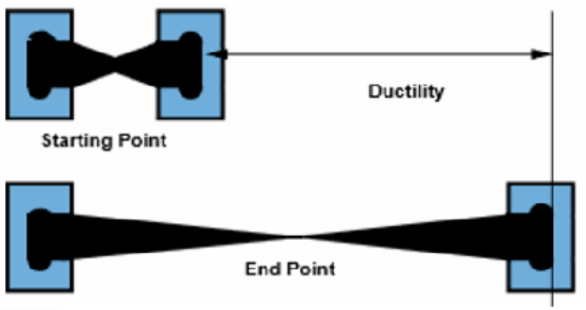
- To determine the hardness or softness of bitumen.
- The depth measured in tenths of a mm to which a standard loaded needle will penetrate vertically in 5 sec.
- The bitumen grade is specified in terms of penetration value.
- 80/100 grade bitumen means that the penetration value of the bitumen is in the range of 80 to 100 at standard test conditions.
- Penetration test cannot be used for soft materials like tars, cutbacks and emulsions.
- In hot climates, lower penetration grade bitumen like 30/40 bitumen is preferred.



Prof. B. Jayarami Reddy

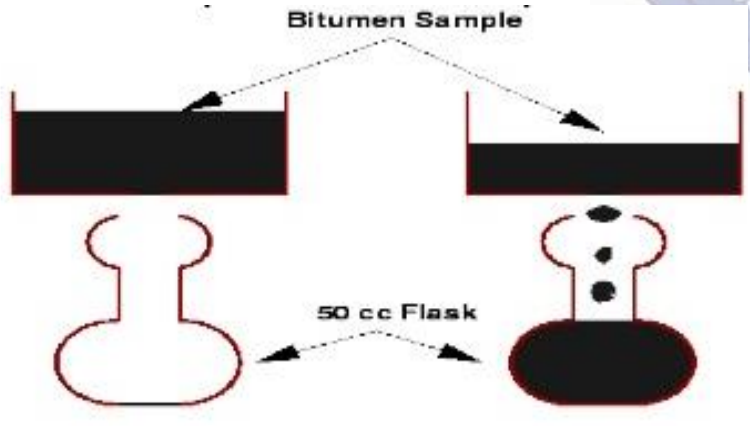
Ductility test:

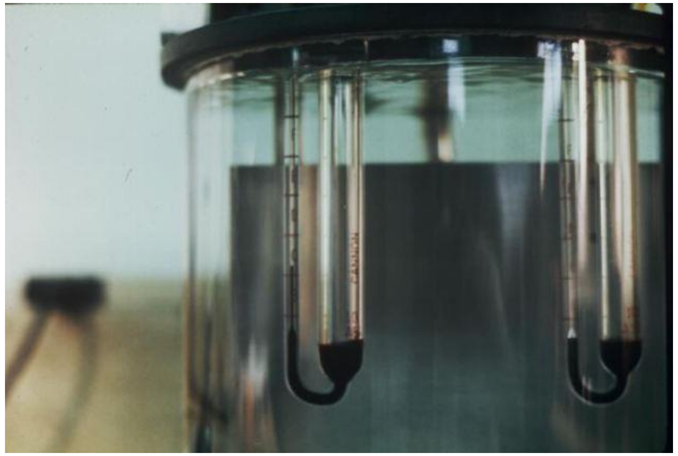
- To measure the adhesive property of bitumen and its ability to stretch.
- Minimum ductility value as per BIS is 75 cm.



Viscosity test:

- Viscosity is defined as inverse of fluidity.
- Viscosity is a measure of resistance to flow.
- At low viscosity, the bituminous binder lubricates the aggregate particles instead of providing a uniform film for binding action.
- High viscosity bitumen resists the compactive effort and the resulting mix is heterogeneous in character exhibiting low stability values.

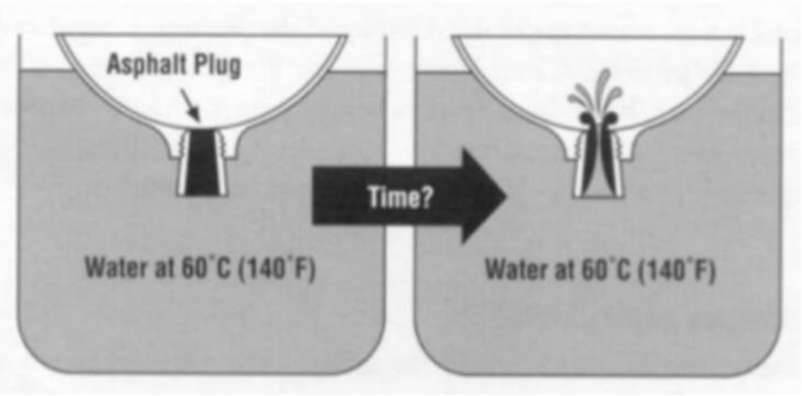




Prof. B. Jayarami Reddy

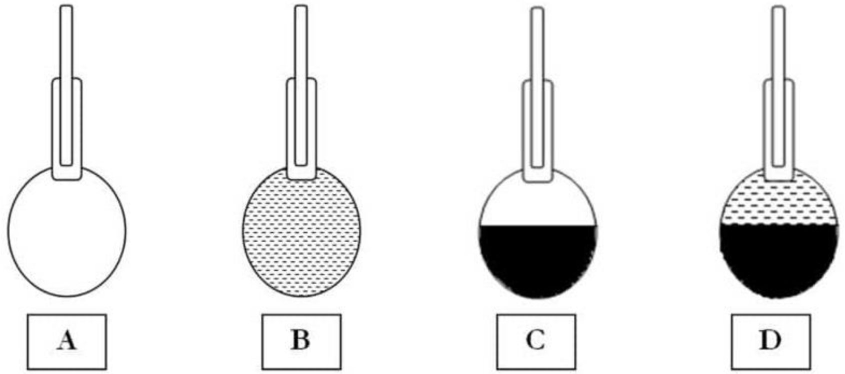
Float test:

- To determine the consistency of the bituminous materials for which neither viscosity test nor penetration test could be used.
- The higher the float test value, the stiffer is the material.



Specific gravity test:

- Specific gravity of pure bitumen: 0.97 to 1.02.
- Specific gravity of tar: 1.10 to 1.25.
- Specific gravity calculation of bitumen:

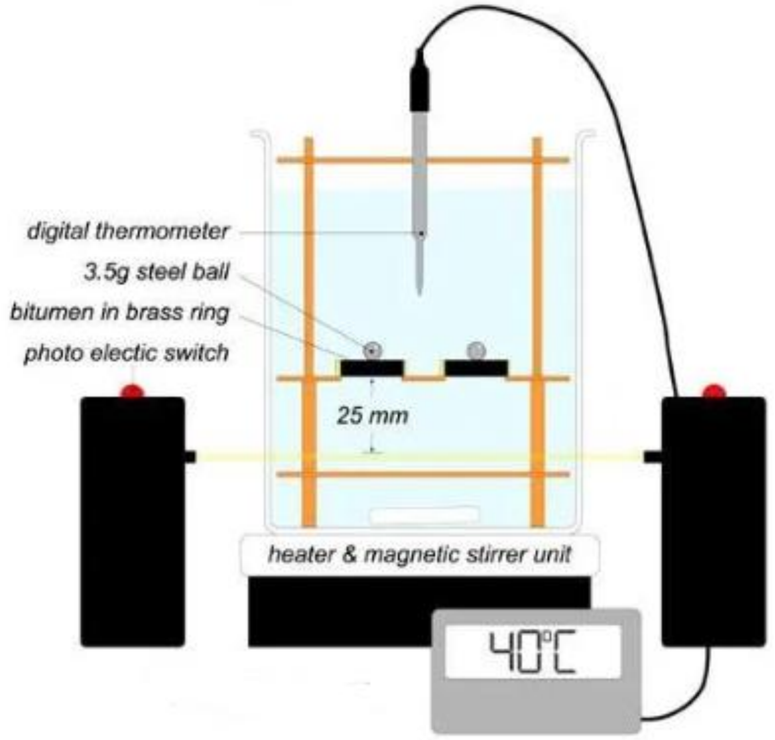


Group	Weights				Specific gravity =(C-A)/[(B-A)-(D-C)]
	Pycnometer, (A)	Pycnometer + Water, (B)	Pycnometer + Asphalt, (C)	Pycnometer + Water + Asphalt, (D)	
	(gm)	(gm)	(gm)	(gm)	
1	22.277	74.151	55.445	74.628	1.015

Prof. B. Jayarami Reddy

Softening point test:

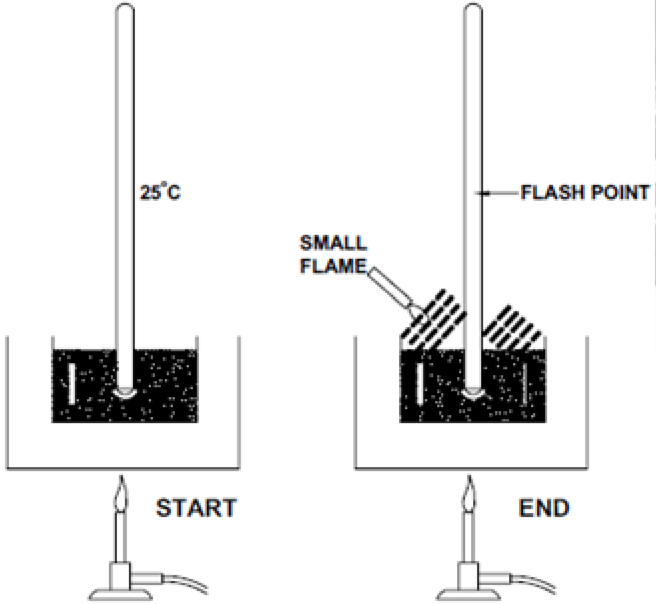
- Softening point is the temperature at which the substance attains a particular degree of the softening under specified condition of test.
- Softening point is determined by ring and ball test.
- Hard grade bitumen possess higher softening point than soft grade bitumen.
- Softening point of bitumen grades: 35 to 70°C.



Prof. B. Jayarami Reddy

Flash and Fire point test:

- The flash point of a material is the lowest temperature at which the vapour of a substance momentarily takes fire in the form of a flash under specified conditions of test.
- The fire point is the lowest temperature at which the material gets ignited and burns under specified conditions of test.
- The minimum specified flash point of bitumen used in pavement construction is 175°C.



Prof. B. Jayarami Reddy

Solubility test:

- Pure bitumen is completely soluble in solvents like carbon disulphide and carbon tetrachloride.
- The minimum proportion of bitumen soluble in carbon disulphide is specified as 99%.

Spot test:

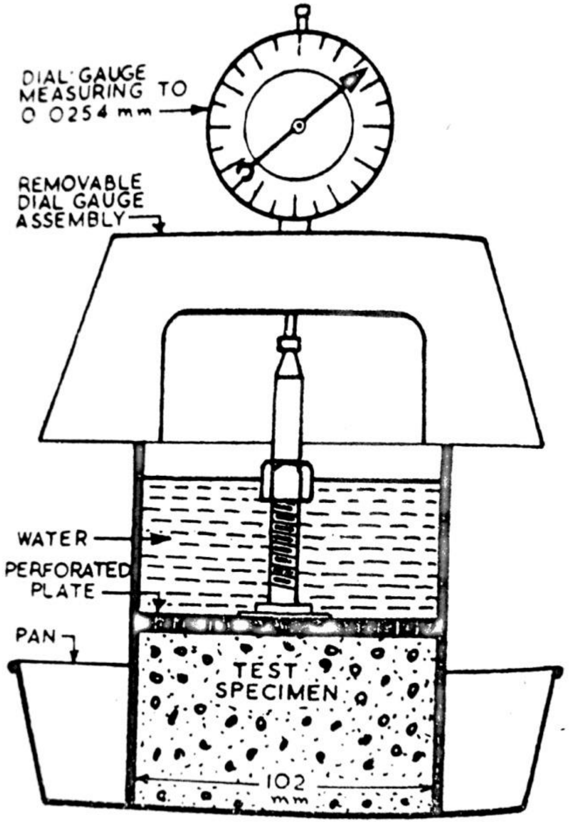
- Used for detecting over heated or cracked bitumen.

Loss on heat test:

- When bitumen is heated, it loses the volatiles and gets hardened.

Water content test:

- It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated above the boiling point of water.
- The water content in bitumen should not exceed 0.2% by weight.



Prof. B. Jayarami Reddy

Apparent specific gravity:

- It is computed based on the net volume of aggregate ie. volume excluding water permeable voids.

$$G_{app} = \frac{W_d / V_N}{\gamma_w}$$

W_d : Dry weight of aggregate

V_N: Net volume of aggregate excluding the volume of the absorbed matter

γ_w: Unit weight of water

Bulk specific gravity (G_{bulk})

- It is computed based on the total volume of aggregate including water permeable voids.

$$G_{app} = \frac{W_d / V_B}{\gamma_w}$$

V_B: Total volume of aggregate including the volume of absorbed water.

Prof. B. Jayarami Reddy

Different layers in a pavement:

1. **Bituminous base course**: Consist of mineral aggregate such as stone, gravel, or sand bonded together by a bituminous material and used as a foundation upon which to place a binder or surface course.

2. **Bituminous binder course:** A bituminous-aggregate mixture used as an intermediate course between the base and surface courses or as the first bituminous layer in a two-layer bituminous resurfacing. It is sometimes called a levelling course.

3. **Asphaltic/Bituminous concrete:** Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, typically less than 25 mm, through fine filler that is smaller than 0.075 min. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and clastic properties.

Selection of Appropriate Grade of Bitumen

Guidelines for selection of bitumen grade in India are given below:

Type of Bitumen	Use
Penetration Grade 30/40	Hot mix work in areas where the difference between maximum and minimum temperature is less than 25°C and on roads with high volume of traffic
Penetration Grade 60/70	Hot mix work for bituminous macadam's and bituminous concrete for superior type of roads with high traffic and in normal summer temperatures. • For surface dressing • For premix works in high altitudes • For premix works in roads with less traffic intensity.
Cutback Bitumen	• Surface dressing in cold weather • Premix in cold weather • Medium Curing (MC) and Slow Curing (SC) cut backs are used for priming
Emulsion	• Used for surface dressing in cold weather, wet conditions and maintenance works • Used for premix works in wet weather • Priming.

Cutback Bitumen

The viscosity of bitumen is reduced by a volatile diluents.

Cutback bitumens are available in three types.

1. Rapid Curing (RC)   2. Medium Curing (MC)   3. Slow Curing (SC)

- The cutbacks are designated by numerals representing progressively thicker or viscous cutback. For example RC-2 is more thick than RC-1 but RC-2, MC-2 and SC-2 have same viscosity.
- RC-0 and SC-0 may have 45% solvent and 55% bitumen whereas RC-5 and MC 5 may contain 15% solvent and 85% bitumen.
- RC-Cutback: They have penetration value of 80 to 120 eg., Petroleum products such as naptha or gasoline
- MC-Cutback: They have good wetting properties, eg., kerosene and light diesel oil.
- SC-cutback: These can be obtained by blending bitumen with high boiling point gas oil or by controlling the rate of flow and temperature of crude during the first cycle of refining.

Bituminous Emulsion

- Emulsion is a two phase system consisting of two immiscible liquids.
- The bitumen/tar content in emulsion range from 40 to 60% and the remaining portion is water.
- The average diameter of globules of bitumen portion is about 2 mm.
- Emulsion are used especially in maintenance and patch repair works
- The main advantage of emulsion is that it can be used in wet weather even when it is raining
- Emulsions can be used for soil stabilization in deserts.

Tar

Tar can be produced in 3 stages

i. Carbonization of coal to produce crude tar.

ii. Refining or distillation of crude tar.

iii. Blending of distillation residue with distillate oil fraction to give desired road tar.

- RT-1 is lowest viscosity used for surface painting where as RT-4 may be used for premix in macadam.
- RT-5 is used for grouting which has highest viscosity.

Comparison between Tar and Bitumen:

Bitumen	Tar
Bitumen is manufactured by fractional distillation of petroleum in presence of air	Tar is manufactured by destructive distillation of coal or wood in absence of air
Bitumen is soluble in carbon disulphide (CS_2) and carbon tetra chloride (CC_4)	Tar is soluble in only toluene
More resistant to water	Less resistance to water
Less temperature susceptibility	More susceptible to temperature resulting in great variation in viscosity with temperature
Free carbon content is less	Free carbon content is more

Requirement of Bituminous mixes:

Stability:

- Stability is defined as the resistance of the paving mix to deformation under traffic load.
- Two examples of failure are
  - showing a transverse rigid deformation which occurs at areas subject to severe acceleration
  - grooming - longitudinal ridging due to channelization of traffic.
- Stability depend on the inter-particle friction, primarily of the aggregates and the cohesion offered by the bitumen.
- Sufficient binder must be available to coat all the particles, at the same time should offer enough liquid friction
- The stability decreases when the binder content is high and when the particles are kept apart

Durability:

- Durability is defined as the resistance of the mix against weathering and abrasive actions.
- Weathering causes hardening due to loss of volatile in the bitumen.
- Abrasion is due to wheel loads which causes tensile strains.
- Typical examples of failure are
  - Pot-holes: deterioration of pavements locally
  - Stripping: loss of binder from the aggregates and aggregates are exposed
- Disintegration is minimized by high binder content since they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening

Flexibility:

- Flexibility is a measure of the level of bending strength needed to counteract traffic load and prevent cracking of surface.
- Fracture is the cracks formed on the surface
  - hair-line-cracks, alligator cracks occur due to shrinkage and brittleness of the binder.
- Shrinkage cracks are due to volume change in the binder due to aging.
- Brittleness is due to repeated bending of the surface due to traffic loads.
- Higher bitumen content will give better flexibility and less fracture.

Skid Resistance:

- It is resistance of the finished pavement against skidding which depends on the surface texture and bitumen content.
- It is an important factor in high speed traffic.
- Normally, an open graded coarse surface texture is desirable.

Prof. B. Jayarami Reddy

Workability:

- Workability is the ease with which the mix can be laid and compacted, and formed to the required condition and shape.
- It depends on the gradation of aggregates, their shape and texture, bitumen-content and its type.
- Angular, flaky, and elongated aggregates reduces workability. Rounded aggregates improve workability

Desirable properties of a bituminous mix:

The desirable properties of a bituminous mix are as follows:

- Stability to meet traffic demand
- Bitumen content to ensure proper binding and water proofing.
- Voids to accommodate compaction due to traffic.
- Flexibility to meet traffic loads particularly in cold season
- Sufficient workability for construction
- Economical mix

MIX DESIGN METHODS

The popular methods of mix design are:

1. Marshall method
2. Hubbard-Field method
3. Hveem method
4. Smith traxial method

- Each of the above methods is associated with a set of design criteria for the properties of the mix.
- The Marshall method is the most popular in India.

Marshall Stability:

- Applicable to hot mix paving mixture design using penetration grade bitumen and containing aggregate with maximum size of 25mm.
- Specimen: 100mm diameter, 63mm height
- Load at failure is known as Marshall stability value and deformation at failure is known as Marshall flow value.
- As Marshall stability value increases, the strength increases.
- As Marshall flow value increases, deformation increases and stiffness decreases.
- Each of the above methods is associated with a set of design criteria for the properties of the mix.
- The Marshall method is the most popular in India.

Objectives of mix design

The objective of the mix design is to produce a bituminous mix by proportioning various components so as to have

1. sufficient bitumen to ensure a durable pavement
2. sufficient strength to resist shear deformation under traffic at higher temperature
3. sufficient air voids in the compacted bitumen to allow for additional compaction by traffic
4. sufficient workability to print easy placement without segregation
5. sufficient flexibility to avoid premature cracking due to repeated bending by traffic
6. sufficient flexibility at low temperature to prevent shrinkage cracks.

Prof. B. Jayarami Reddy

Constituents of a mix

1. **Coarse aggregates:** Offer compressive and shear strength and shows good interlocking properties. eg. Granite
2. **Fine aggregates**: Fills the voids in the coarse aggregate and stiffens the binder. eg. Sand, Rock dust
3. **Filler:** Fills the voids, stiffens the binder and offers permeability, eg. Rock dust, cement, lime
4. **Binder:** Fills the voids, cause particle adhesion and gluing and offers impermeability. eg. Bitumen, Asphalt, Tar

Prof. B. Jayarami Reddy

Types of mix

1. **Well-graded mix:** Dense mix, bituminous concrete has good proportion of all constituents and are called dense bituminous macadam, offers good compressive strength and some tensile strength
2. **Gap-graded mix:** Some large coarse aggregates are missing and has good fatigue and tensile strength.
3. **Open-graded mix**: Fine aggregate and filler are missing, it is porous and offers good friction, low strength and for high speed.
4. **Unbounded:** Binder is absent and behaves under loads as if its components were not linked together, though good interlocking exists. Very low tensile strength and needs kerb protection.

Prof. B. Jayarami Reddy

Determination of optimum bitumen content

Determine the optimum binder content for the mix design by taking average value of the following three bitumen contents found from the graphs.

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

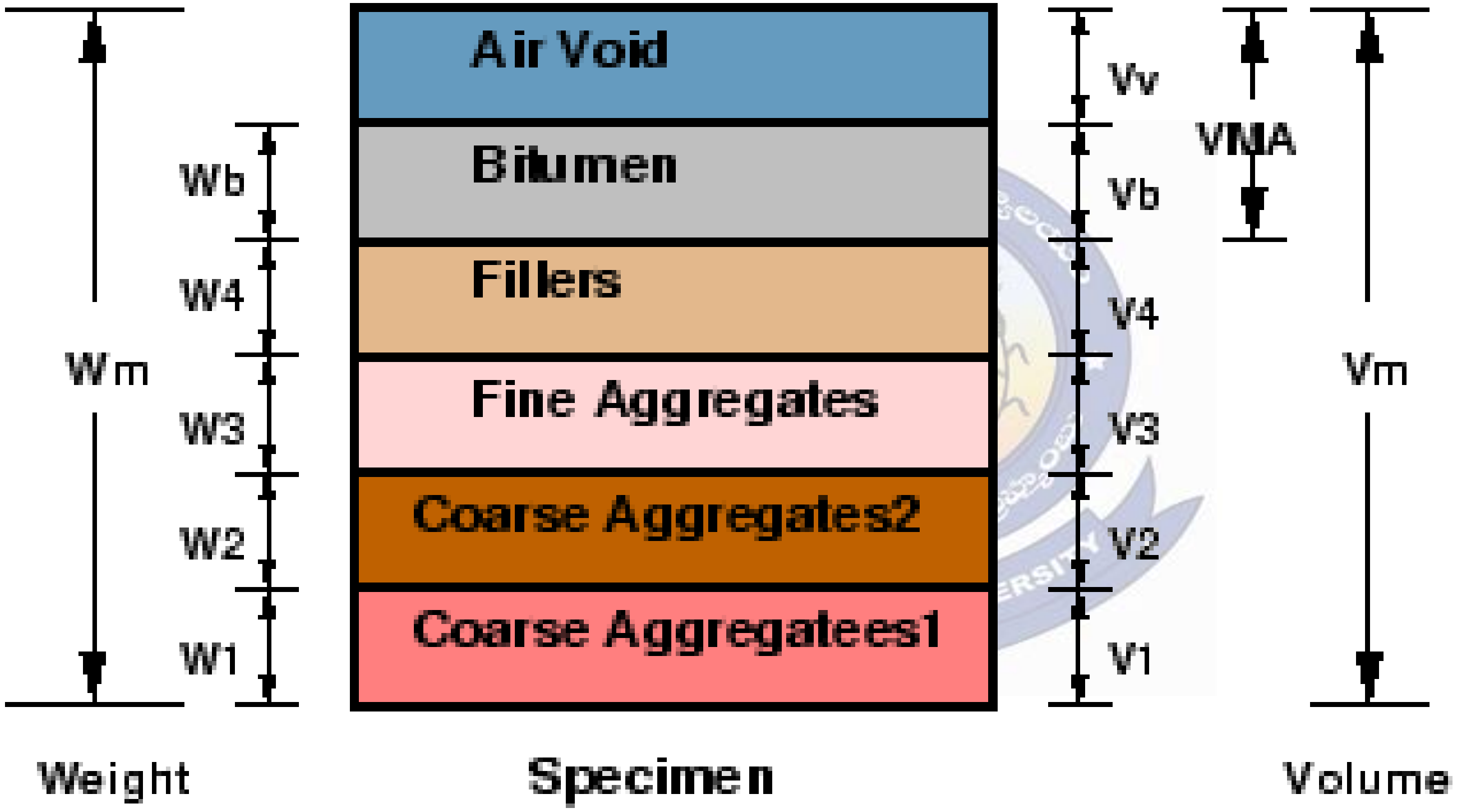
- The stability value, flow value and VFB are checked with Marshall mix design specification chart.
- Mixes with very high stability value and low flow value are not desirable as the pavements constructed with such mixes are likely to develop cracks due to heavy moving loads.

Prof. B. Jayarami Reddy

Marshall Mix design specification:

Test Property	Specified Value
Marshall Stability, kg	340 (minimum)
Flow Value, 0.25 mm units	8-16
Percentage air voids in the mix, V_v %	3-5
Voids filled with bitumen, VFB%	75-85

Marshall mix design



Bituminous mix:

Theoretical maximum specific gravity of the mix is given by $G_t = \dfrac{100}{\dfrac{W_a}{G_a} + \dfrac{W_b}{G_b}}$.

W_a : Percent by weight of aggregate.

W_b : Percent by weight of bitumen.

G_a : Specific gravity of aggregate.

G_b : Specific gravity of bitumen.

Percent air voids:

$$V_v = 100 - \gamma_t \;\; ; \qquad \gamma_t = \frac{100\ G}{G_t} \qquad V_v = \frac{G_t - G_m}{G_t} \times 100$$

G_m: Bulk or mass specific gravity of specimen.

G_t : Theoretical specific gravity of mixture. $G_t = \dfrac{100}{\dfrac{W_1}{G} + \dfrac{W_2}{G_2} + \dfrac{W_3}{G_3} + \dfrac{W_4}{G_4}}$

W_1, W_2, W_3 and W_4 : Percent by weight of coarse aggregate, fine aggregate, filler and bitumen in total mix respectively.

G_1, G_2, G_3 and G_4 : Specific gravity of coarse aggregate, fine aggregate, filler and bitumen respectively.

Percent voids in mineral aggregate (VMA):

$$VMA = V_v + V_b = 100 - \frac{G}{W_a}$$

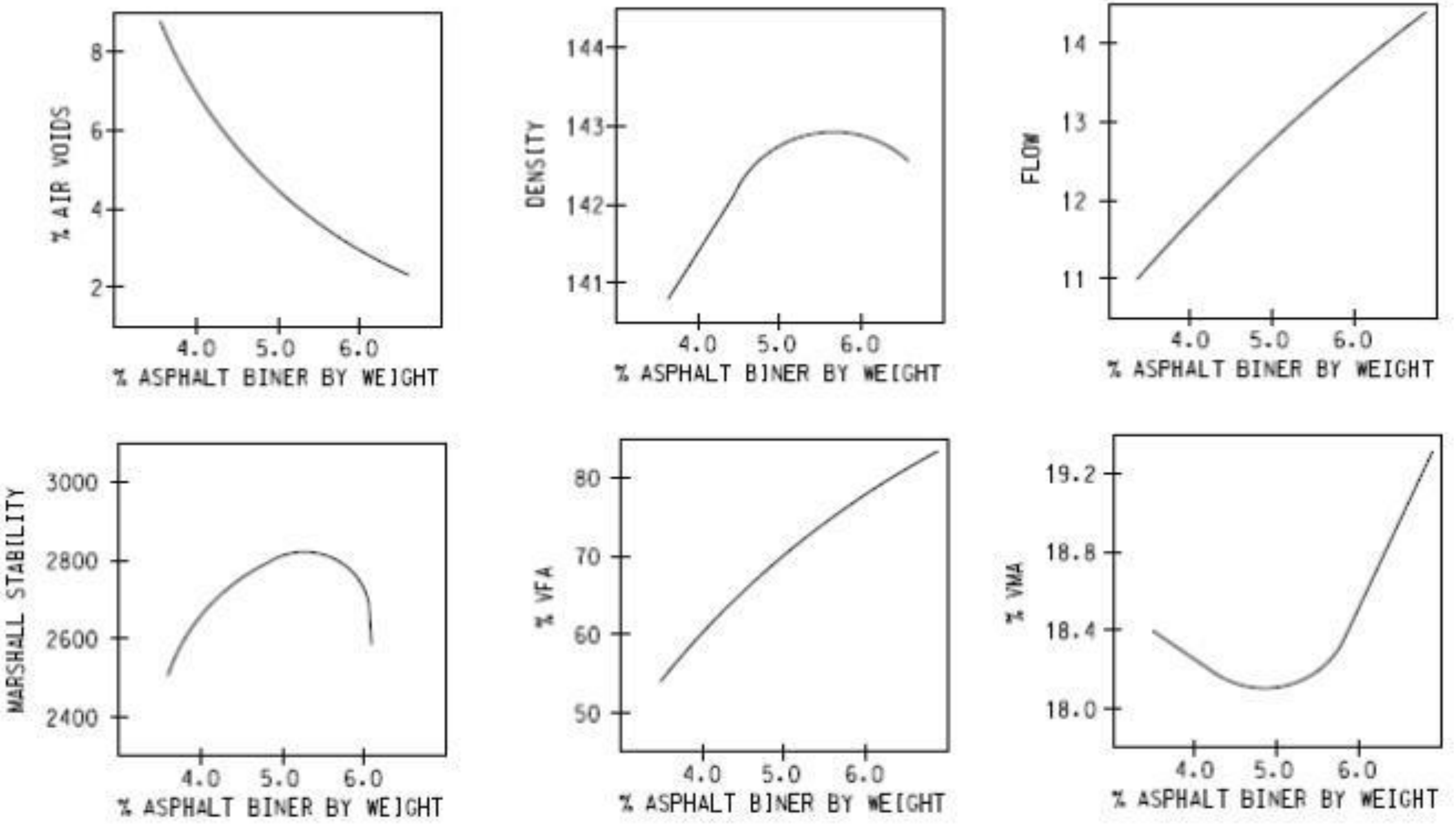
V_v : Volume of air voids, %.

V_b : Volume of bitumen. % = $G_m . \frac{W_4}{G_4}$

Percent voids filled with bitumen (VFB): $VFB = \frac{100 V_b}{VMA}$

Prof. B. Jayarami Reddy

Design graphs for Marshall mix design



Prof. B. Jayarami Reddy