CONVENTIONAL ASPHALT MIX DESIGN

Asphaltic Concrete

- Asphaltic concrete is a mixture of
  - Coarse Aggregate
  - Fine aggregate
  - Mineral filler and
  - Bitumen
- Well graded aggregates and mineral filler resulting in maximum density when mixed with optimum quantity of bitumen results in a mix with very high stability

Desirable Properties of AC Mix

- Stability
  - Enough resistance to deformation under sustained or repeated loads
- Durability
  - Resistance to disintegration by weathering or abrasive forces of traffic
- Flexibility
  - Ability of a bituminous mix to bend repeatedly with out cracking and to conform to changes in shape of the base course
- Skid Resistance
  - Offer enough resistance to the skidding of tyres
- Impervious Layer
  - Should be highly impervious to water

Steps Involved in Deriving the Job Mix Formula

- Selection of aggregates
- Selection of aggregate gradation
- Proportioning of aggregates to meet the required gradation
- Selection of bitumen
- Preparation of specimen
- Density – void analysis
- Measurement of stability and flow
- Determination of optimum bitumen content

Selection of Aggregates

- The aggregates should satisfy the specifications laid down for the mix in respect of the following
  - Cleanliness
    - Percent passing 0.075 mm sieve
  - Particle shape
    - Combined flakiness and elongation index
  - Strength
    - Los Angeles abrasion value / Impact value
  - Polishing
    - Polished stone value
  - Durability
    - Soundness test
  - Water absorption
  - Stripping

Selection of Aggregate Gradation

- Densely graded aggregate offers
  - High frictional resistance
  - Greater area of load transfer
- The gradation that results in maximum density would offer high stability to the final mix
- Theoretical gradations could be used as a starting point to arrive at the required gradation by trial and error method

Theoretical Gradation

- Theoretical gradations generally take the following form
  - $P = 100\,(d/D)^x$
  - Where, P = percent passing
  - d = size of sieve opening
  - D = largest size in gradation
- The basic idea of the theory is that the amount of material of a given size should be just sufficient to fill the voids between aggregates of larger size
- Fuller suggested a value of 0.5 for x
- However, a value of 0.45 for x is being used in Superpave gradations

Specified Gradation

- Specified gradations are worked out starting from the theoretical gradations
- Lower and upper limits of gradation for each sieve size are arrived at for allowing window of variation by examining the changes in density and the resulting stability in the final mix
- The specified gradations are also related to the thickness of construction and the nominal size of aggregate used

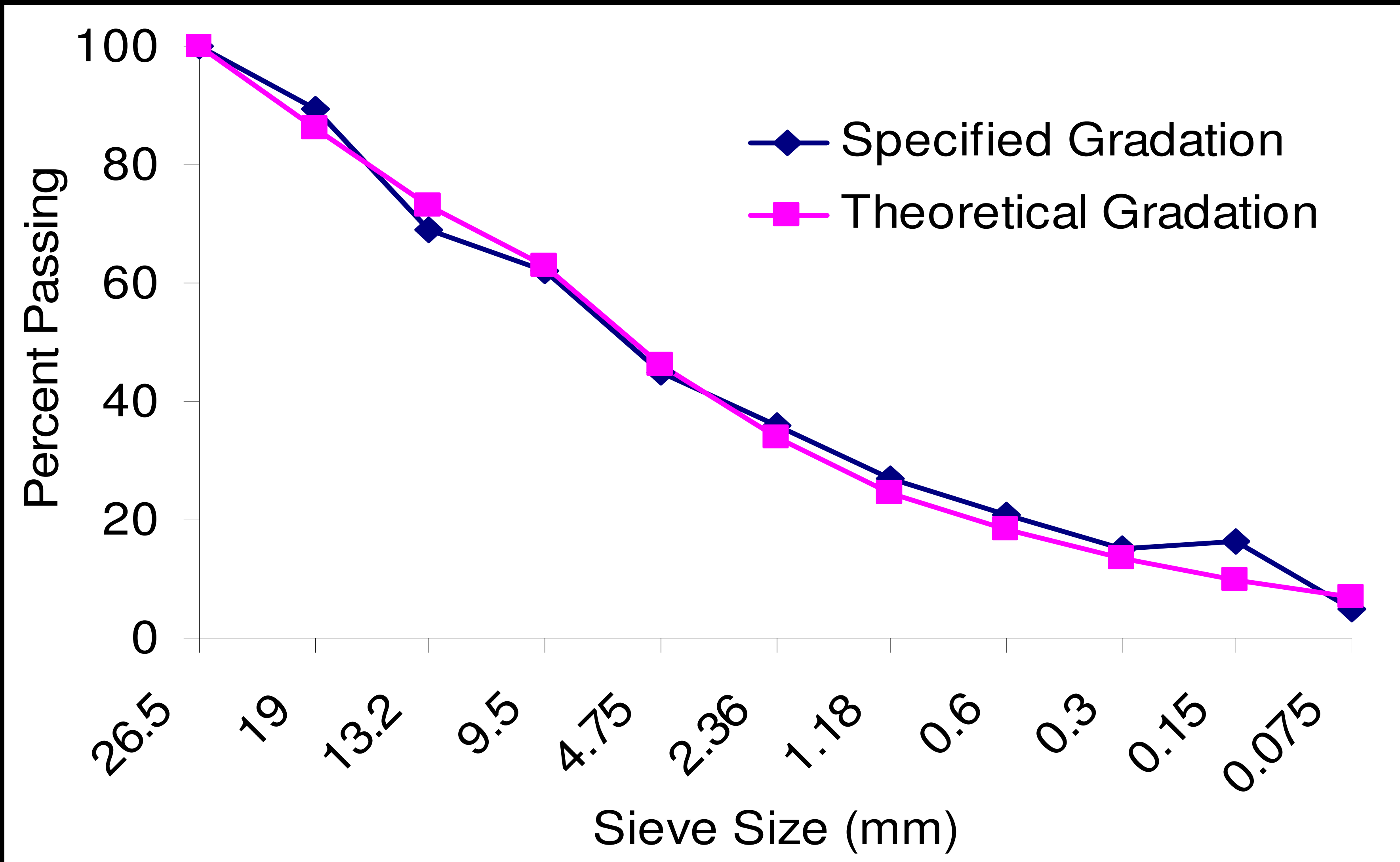
Specified Gradation for BC

Sieve Size mm	Grading I	Grading II
	50-65 mm (19 mm nominal aggregate size)	30-45 mm (13 mm nominal aggregate size)
26.5	100	-
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	42-58
0.60	15-27	26-38
0.30	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10

Specified Vs Theoretical Gradation

- When theoretical Gradations are adopted in actual practice, the smaller particles tend to wedge between the larger ones, increasing the voids that must be filled with the smaller ones
- As a result maximum densities are actually achieved by gradations having an excess of the small sizes compared with the theoretical amounts

Specified Vs Theoretical Gradation



Proportioning of Aggregates

- Normally, the aggregates from the quarry are available in three nominal sizes viz., 19 mm, 9.2 mm and 2.36 mm (Grit and dust)
- Sieve analysis is carried out on each of these aggregates and their individual gradation is determined
- Sieve analysis is also carried out on lime which will be used as filler
- The proportion in which each of these aggregates are to be mixed to get the specified gradation is to be obtained

Typical gradation of Aggregates and Lime

Sieve Size	19 mm Aggregate (A)	9.2 mm Aggregate (B)	Grit + Dust (C)	Lime (D)
26.5	100	100	100	100
19	75.08	100	100	100
13.2	1.48	100	100	100
9.2	0.00	90.00	100	100
4.75	0.00	5.00	100	100
2.36	0.00	0.00	70.50	100
1.18	0.00	0.00	50.55	100
0.6	0.00	0.00	40.50	100
0.3	0.00	0.00	30.00	100
0.15	0.00	0.00	16.54	100
0.075	0.00	0.00	6.00	97.00

Methods of Proportioning

- Graphical Methods
  - Rothfutch's Method
- Trail and Error Method
- Analytical Method
  - For each sieve we write the constraints
    - $a \times F_A + b \times F_B + c \times F_C + d \times F_D <= UL$
    - $a \times F_A + b \times F_B + c \times F_C + d \times F_D >= LL$
    - Where, *a, b, c* and *d* are the proportions of aggregates *A, B, C* and *D* respectively
    - $F_{A,}$ $F_{B,}$ $F_{C,}$ *and* F_D are respectively the percent fines of aggregates *A, B, C* and *D* passing the sieve
  - Solve the above keeping $a+b+c+d = 1$ and d=0.02 (2%)

Worksheet for Proportioning of Aggregates

Selection of Bitumen

- A proper grade should be selected as per specifications
- Bitumen should satisfy all the specifications laid down relating to the following (BIS: 73)
  - Penetration
  - Softening point
  - Ductility
  - Flash point
  - Wax content
  - Loss on heating and retained penetration
  - Solubility
  - Viscosity at 60 ^{O}C and 135 ^{O}C
- If modified bitumen is used then additional tests (elastic recovery, etc) should be performed as specified

Marshall Method of 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 stability of the mix design is defined as a maximum load carried by a compacted specimen at a standard temperature of 60^{o}C.

Preparation of Specimen

- The coarse aggregates, fine aggregates and the filler material should be proportioned and mixed as per the dry mix design
- The required quantity of the dry mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5mm approximately
- Considering the specific gravities of aggregates in this region, approximately 1200gm of aggregates and filler would be required to get a standard specimen

Preparation of Specimen

- The dry mix of aggregates and filler is heated to a temperature of 150 to 170^{o}C
- The compacted mould assembly and rammer are cleaned and kept preheated to a temperature of 100^{o}C to 145^{o}C
- The bitumen is heated to a temperature of 150^{o}C to 165^{o}C and the required quantity of the first trial percentage of bitumen is added to the heated aggregates and thoroughly mixed.
- The mixing temperature of the 60/70 grade is about 165^{o}C.

Preparation of Specimen

- Marshall Mould
  - For preparing specimens of 10.16 cm diameter and 6.35 cm height for Marshall testing.
  - Consists of base plate, forming mold and collar.
  - Interchangeable base plate and collar can be used on either end of compaction mold.

Preparation of Specimen

Compaction of the Specimen

- The mix is placed in the mould and compacted by a rammer with about 75 blows on each side.
- The weight of hammer is 4.54 kg and height of fall is 45.7 cm
- The compacting temperature may be about 135^{o}C for 60/70 grade bitumen.
- The compacted specimen should have a thickness of 63.5 ± 3.0mm.

Preparation of Specimen

Sample Extraction

- The compacted specimens are extracted using a Sample Extractor after the curing time
- Sample extractor is designed for fast extrusion of samples from compaction molds.

Preparation of Specimen

- At least two (preferably three) specimens should be prepared at each trial bitumen content which may be varied at 0.5% increments from 4.5 to 6.5 percent.

Density Void Analysis

- The following quantities are worked out by carrying out density voids analysis
  - Bulk density (γ) / specific gravity (G) of the specimen
  - Average specific gravity of aggregates (G_a)
  - Theoretical maximum specific gravity (G_t)
  - Percent air voids in the final mix (V_V)
  - Percent air voids in mineral aggregates (*VMA*)
  - Percent aggregate voids filled with bitumen (*VFB*)

Bulk Density Determination

- Bulk density of the specimen could be determined by three methods
  - From dimensions: if the specimen is of true size whose dimensions can be accurately determined

    $\gamma = W / V$

    Where, W = weight of the specimen, g

    $V = (\Pi/4)\, d^2 h$, h=height and d = diameter of the specimen in cm
  - *By weighing in air and water: if the specimen has impermeable surface*
    - $G = W / (W - W_w)$
    - *Where, W_w = weight of the specimen in water*
  - *By weighing paraffin coated specimen in air and water : if the specimen has open impermeable surface*

$$G = \frac{W}{W' - W'_w - \dfrac{(W' - W)}{G_P}}$$

- *W' = weight of the paraffin coated specimen in air*
- *W'_w = weight of the paraffin coated specimen in water*

Weights and Volumes in a Compacted Specimen

%Volumes		%Weights	Specifc Gravities
V_v	Voids	0	
V_b	Bitumen	P_b	G_b
V_{ca}	Coarse Aggregate	P_{ca}	G_{ca}
V_{fa}	Fine Aggregate	P_{fa}	G_{fa}
V_{mf}	Mineral Filler	P_{mf}	G_{mf}

Theoretical maximum Specific Gravity

- Average specific gravity (G_a) of the aggregate mix

$$G_a = \frac{P_{ca} + P_{fa} + P_{mf}}{\frac{P_{ca}}{G_{ca}} + \frac{P_{fa}}{G_{fa}} + \frac{P_{mf}}{G_{mf}}}$$

- Theoretical maximum specific gravity (G_t) of the AC mix

$$G_t = \frac{100}{\frac{P_{ca}}{G_{ca}} + \frac{P_{fa}}{G_{fa}} + \frac{P_{mf}}{G_{mf}} + \frac{P_b}{G_b}}$$

V_v, VMA and VFB

- Voids in the final mix

$$V_V = 100\frac{(G_t - G)}{G_t}$$

- Voids in mineral aggregates

$$VMA = 100 - \frac{GP_a}{G_a}$$

$$P_a = P_{ca} + P_{fa} + P_{mf}$$

- Aggregate voids filled with bitumen

$$VFB = 100\frac{(VMA - V_V)}{VAM}$$

Marshall Stability and Flow

- The specimens to be tested are kept immersed in water in a thermostatically controlled water bath at 60 ± 1°C for 30 to 40 minutes.

Marshall Stability and Flow

- Take out the specimen from the water bath and place it in the breaking head

- Place the breaking head in Marshall testing machine

Marshall Stability and Flow

- Load is applied on the breaking head by the loading machine at the rate of 5 cm per minute.

Marshall Stability and Flow

- Stability value is the load taken by the specimen at failure.
- Flow value is the deformation of the specimen at failure
- Record stability either by proving ring or load cell display unit.
- Record the flow by the dial gauge or displacement cell attached to the breaking head
- Apply correction factor to the stability value if the height of specimen is different from 6.35 cm

Marshall Stability and Flow

Correction Factors		
Volume of specimen in cm^3	Approximate Thickness of Specimen in mm	Correction Factors
457-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

Sample No	Bitumen content percent	Stability Value, kg		Flow Value, mm
		Measured	Corrected	
1	4	670	641.56	2.51
2	4	690	634.62	1.82
3	4	650	591.117	2.66
Average			622.43	
1	4.5	770	730.97	2.28
2	4.5	770	700.1225	2.54
3	4.5	550	500.775	2.61
Average			643.95	
1	5	800	756	2.8
2	5	720	651.105	2.77
3	5	910	831.512	2.59
Average			746.20	
1	5.5	890	842.718	2.22
2	5.5	970	880.032	2.58
3	5.5	970	1063.362	5.01
Average			928.70	
1	6	900	900.9	3.53
2	6	880	876.26	3.09
3	6	800	875.5	5.42
Average			884.22	
1	6.5	810	773.55	6.11
2	6.5	850	823.225	4.01
3	6.5	730	744.6	4.34
Average			780.45	

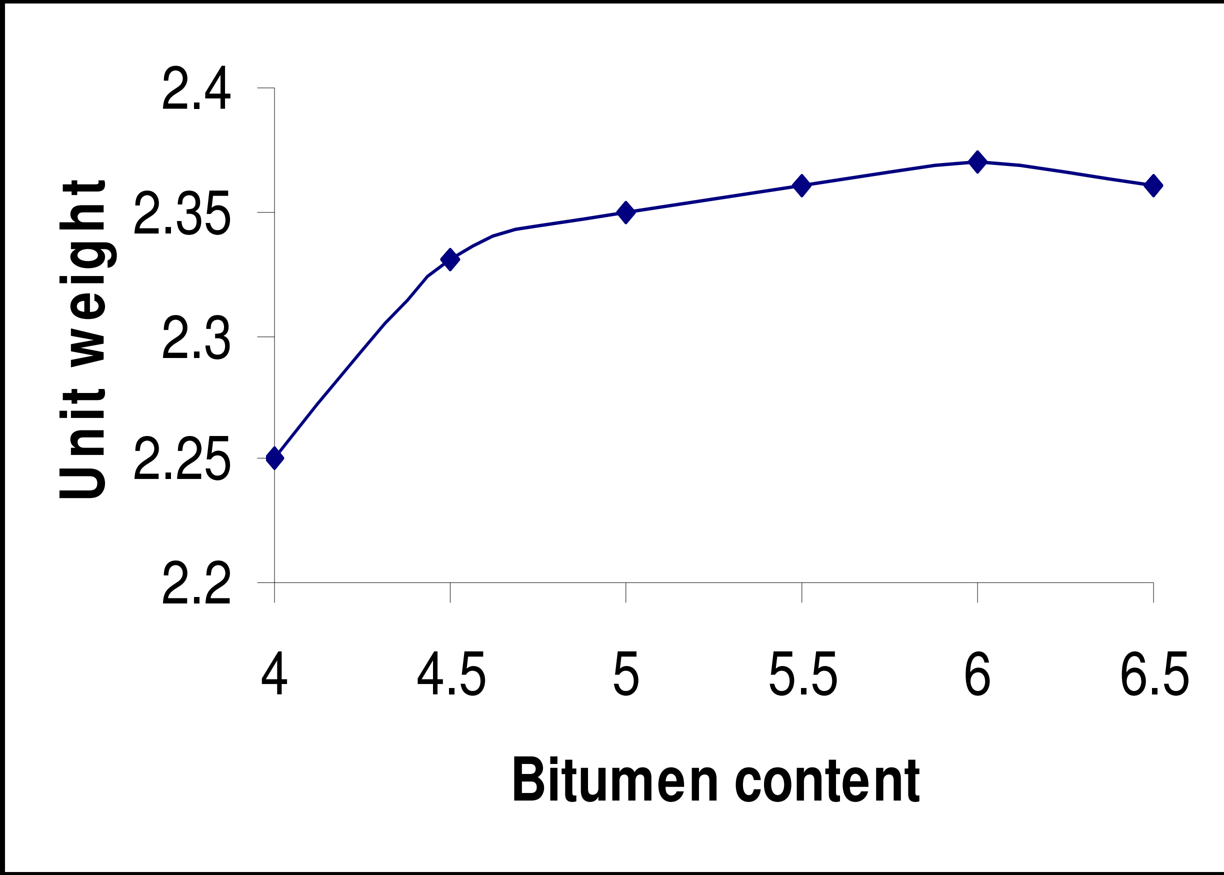
Optimum Content of Bitumen

The following graphs are plotted

- Unit weight vs. bitumen content
- Marshall stability vs. bitumen content
- Percent voids in mix vs. bitumen content
- Percent aggregate voids filled with bitumen vs. bitumen content
- Flow Values vs. bitumen content

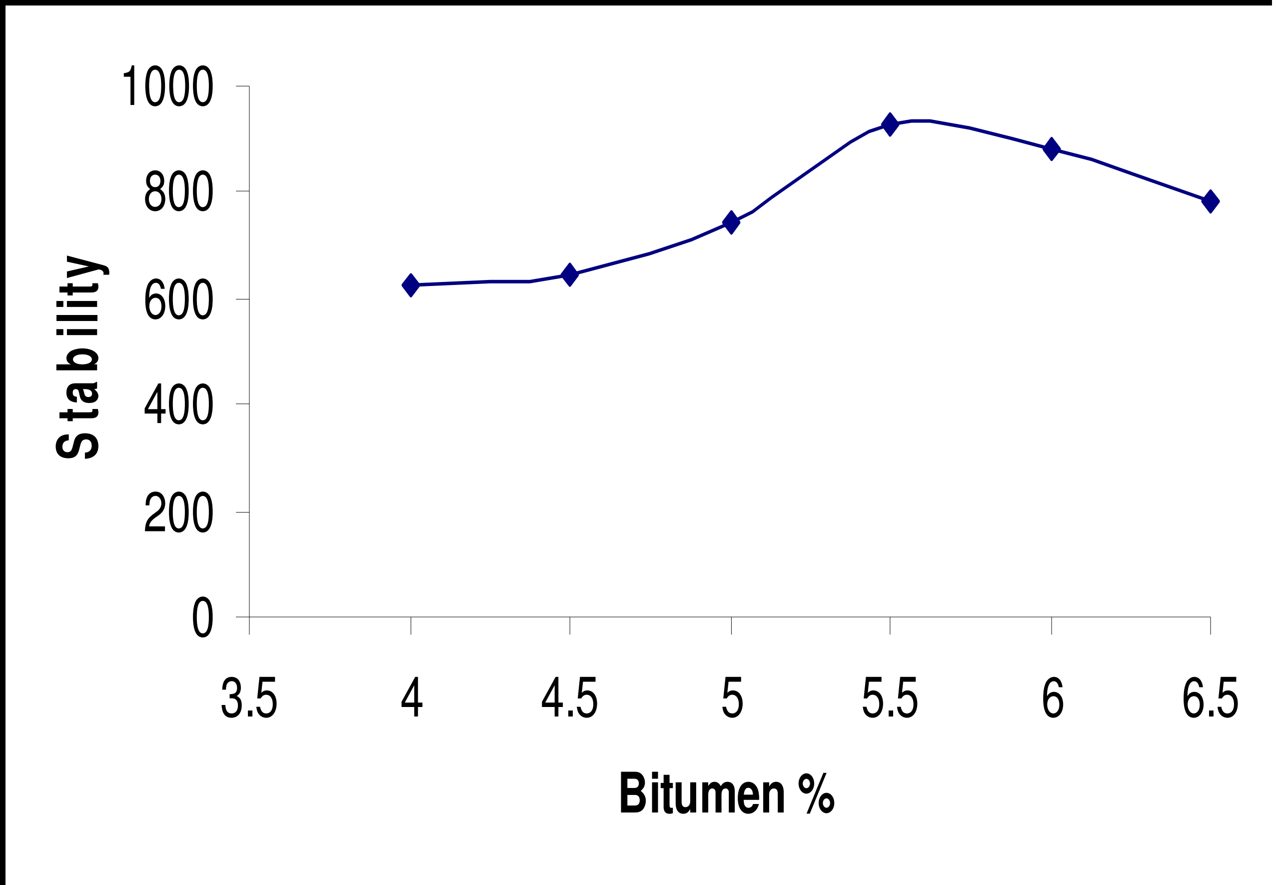
Unit weight vs. Bitumen content

Bitumen content	Unit Weight
4	2.25
4.5	2.33
5	2.35
5.5	2.36
6	2.37
6.5	2.36



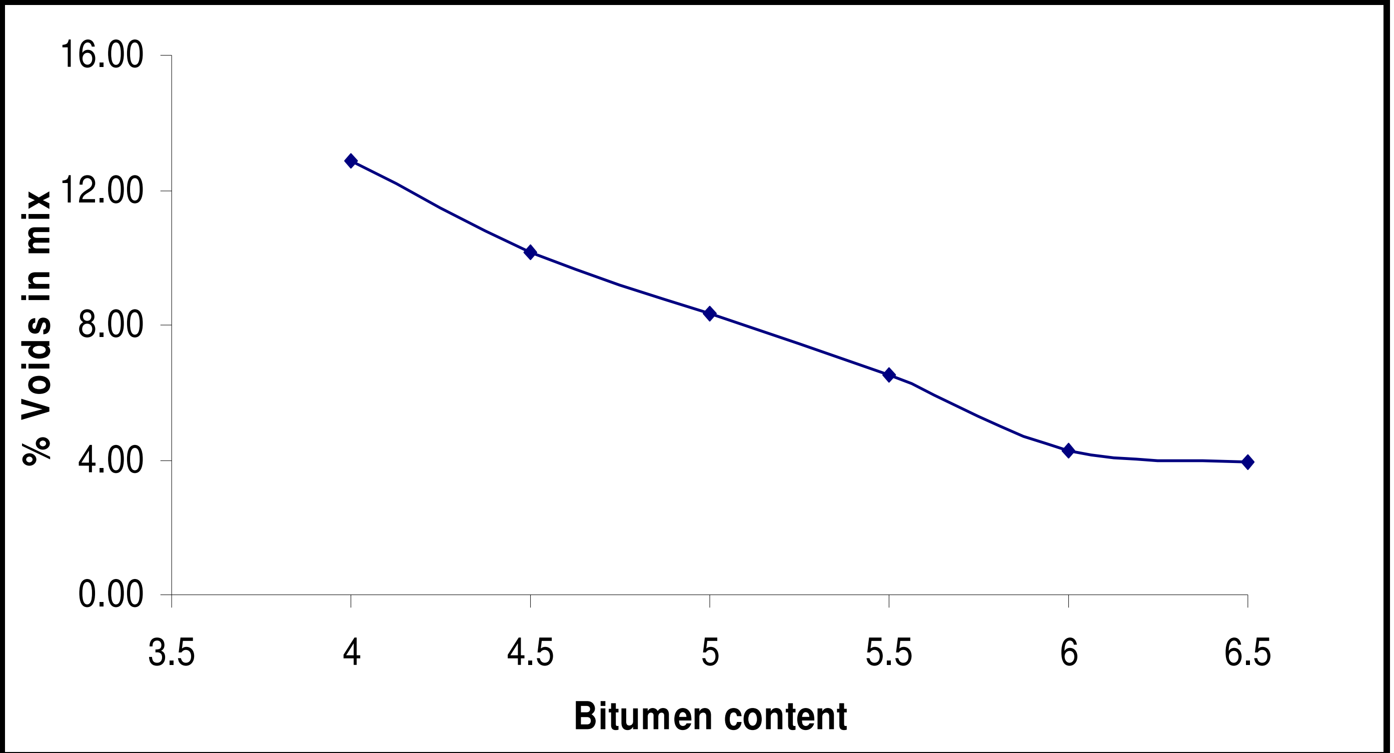
Stability vs. Bitumen Content

Bitumen Content	Stability
4	622.432
4.5	643.955
5	746.205
5.5	928.704
6	884.22
6.5	780.458



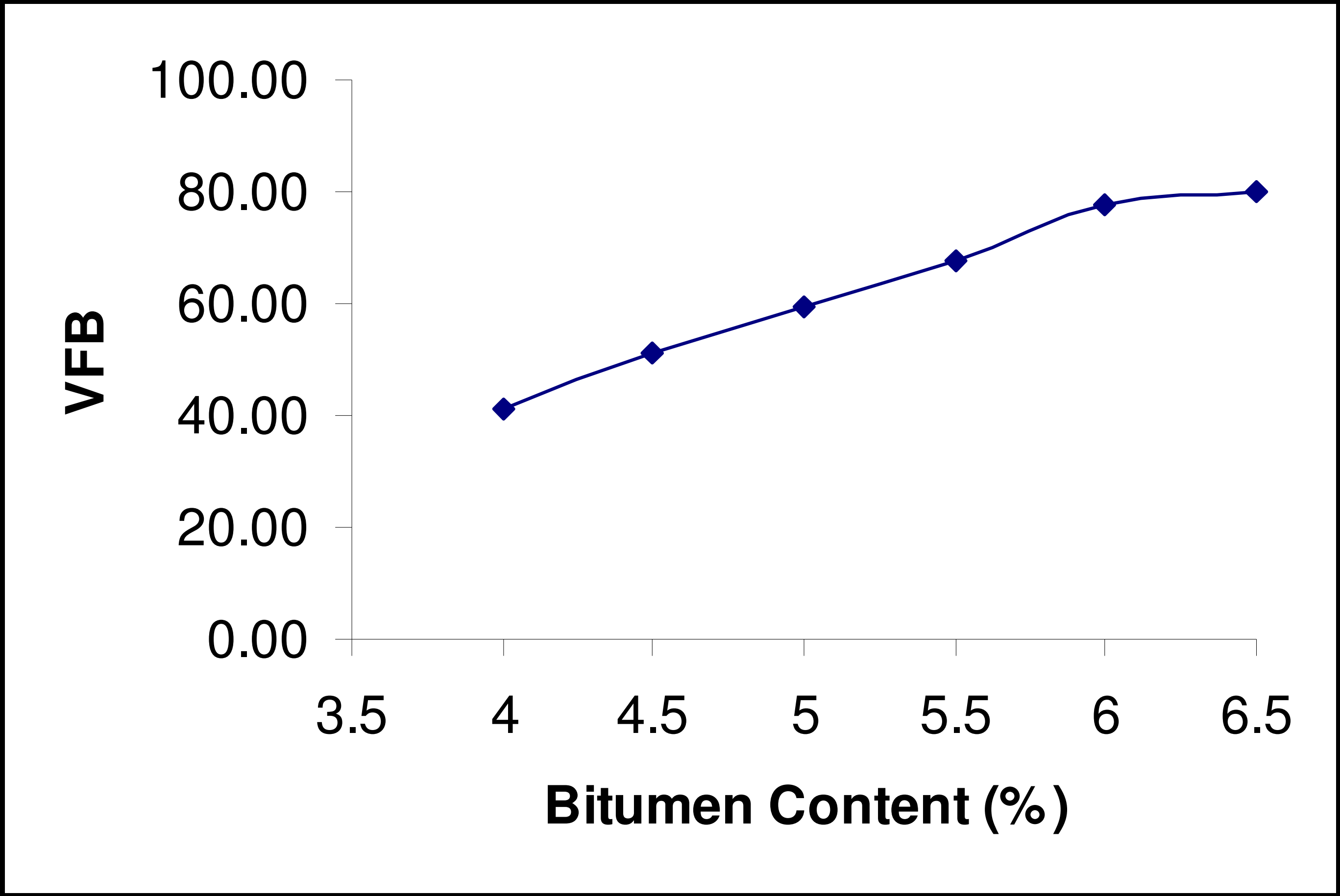
% Voids in Mix vs. Bitumen Content

Bitumen content	v_v
4	12.85
4.5	10.16
5	8.35
5.5	6.51
6	4.26
6.5	3.96



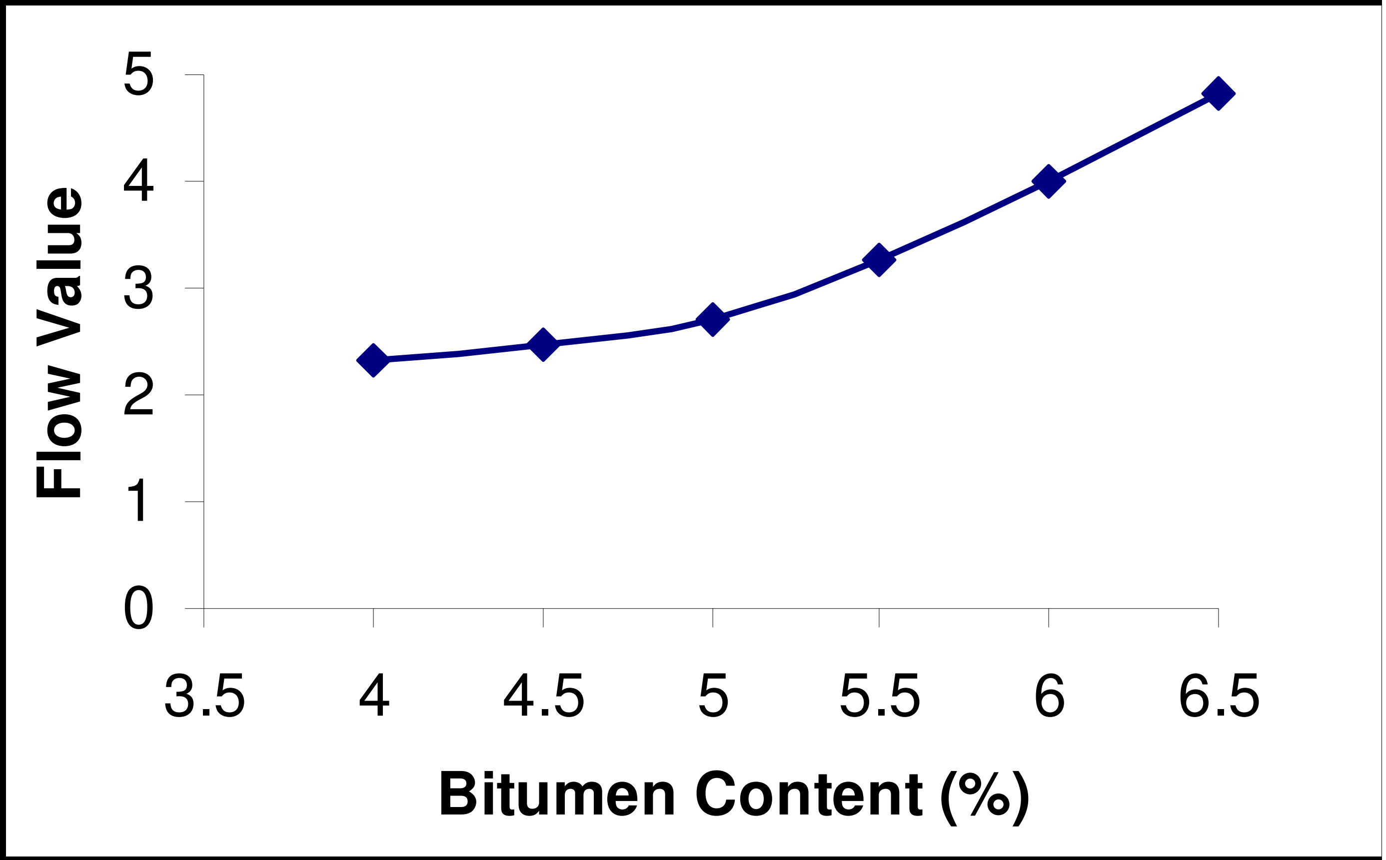
VFB vs, Bitumen Content

Bitumen content	VFB
4	41.43
4.5	51.41
5	59.14
5.5	67.40
6	77.80
6.5	80.26



Flow Value vs. Bitumen Content

Bitumen Content	Flow Value
4	2.33
4.5	2.48
5	2.72
5.5	3.27
6	4.01
6.5	4.82



Optimum Bitumen Content

- Bitumen content corresponding to maximum stability = 5.5 %
- Bitumen content corresponding to maximum bulk density = 6.0%
- Bitumen content corresponding to 4% air voids = 6.34
- Optimum bitumen content of the mix (5.5+6.0+6.34)/3= 5.95%

  Flow Value corresponding to 5.95 % bitumen content = 4 mm
- And VFB at 5.94% = 78%

Brittle Mixes

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