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Laboratory Simulation of Compaction of Bituminous Concrete Mix for Refusal Density Criteria

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ABSTRACT

The use of bituminous wearing courses, design using the Marshall method, under sever loading condition is often not appropriate. The density and particle orientation obtained during the Marshall test does not represent the ultimate condition and density in the road pavement after compaction by slow moving heavy vehicles.

Many developing countries including our country have limited facilities for bituminous mix design. Hence we need an improved method of design, which requires only commonly available or inexpensive equipments to produce mechanically more stable mix again making it more resistance to deformation at high temperatures and heavy loadings.

One such technique may be design of mixes using refusal density concept. The refusal density of bituminous mixes needs to be determining accurately to predict the life of pavements subjected to heavy traffic while maintaining 3% voids in the mix.

Key words: Marshall Method, Refusal Density, Wearing Courses,

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INTRODUCTION

The growth of economy of a country depends largely upon efficient transport system. Road transport has acquired dominant position amongst the various modes of transportation system due to its flexibility, door-to-door service, reliability and speed. Bituminous pavements represents major share among the pavement structure all over the world due to their low initial investments costs. It is imperative to provide proper and appropriate mix in order to provide serviceable good pavements from the points of view of structural and functional conditions. Bitumen has been used in the construction of asphalt pavements for more than a century. As a viscoelastic material, bituminous mix plays a prominent role in determining many aspects of road performance. For example, a bituminous mixture needs to be flexible enough at low service temperature to prevent pavement cracking and to be stiff enough at high service temperature to prevent rutting.

Due to rapid urbanization and mass industrial development, there has been a tremendous increase in traffic intensity and due to the overloaded trucks increased axle loads. In India, majority of the pavements are bituminous since they consume lesser initial cost when compared with rigid pavements i.e. cement concrete pavements. Increasing numbers of new roads in developing countries are being built with thick bituminous concrete surfacing to accommodate increasing traffic volume. However, due to heavy wheel loads on roads, secondary compaction has led to premature plastic deformation in bituminous mix.

Currently Marshal Method of mix design is used in most of countries for bituminous mix design. In the Marshal] procedure the laboratory compaction is intended to simulate the in-place density after the mix has endured several years of traffic. In this method the resistance to plastic deformation of cylindrical test specimen of bituminous mixture is measured when the same is loaded at the periphery at a rate of 5cm per minute. There are two major features of this method namely -

I. Stability - flow test
II. Density - voids analysis.

Table 1.The number of blows of Marshal hammer required for compaction of specimen at varying traffic as per roadnote 19[12] is given below –

Category and design traffic	**No. of blows of Marshall hammer**
Heavy (1-5) million ESA	75
Medium (0.4-1) million ESA	50
Light (< 0.4) million ESA	35

The use of bituminous wearing courses, design using the Marshall method, under sever loading condition is often not appropriate. The density and particle orientation obtained during the Marshall test does not represent the ultimate condition and density in the road pavement after compaction by slow moving heavy vehicles.

Under sever loading conditions conventional bitumen behaves in viscous manner, allowing Considerable secondary compaction of the mix under traffic. Sever conditions cannot be precisely defined but will consist of a combination of two or more of the following:

- High maximum temperature
- Very heavy axle loads
- Very channelized loads
- Stopping or slow moving traffic

The subsequent reduction in air voids can cause the matrix of fine aggregate and bitumen to reduce the mechanical interlock between coarse aggregates, which eventually results in structural instability leading to severe plastic deformation.

The voids in the mix (VIM) are an important parameter as for as heavy traffic is concerned. The failure of bituminous mixes due to plastic deformation owing to the reduction of VIM to less than desired level has become a common problem.

Studies in several countries have shown that failure by plastic deformation in continuously graded mixes can occur very rapidly once the voids in the mix (VIM) are below 3%. To be sure that in situ VIM never drops below 3% we need an additional test procedure in which samples are compacted to refusal condition that is until they refuse to become any dense.

Many developing countries including our country have limited facilities for bituminous mix design. Hence we need an improved method of design, which requires only commonly available or inexpensive equipments to produce mechanically more stable mix again making it more resistance to deformation at high temperatures and heavy loadings.

One such technique may be design of mixes using refusal density concept. The refusal density of bituminous mixes needs to be determining accurately to predict the life of pavements subjected to heavy traffic while maintaining 3% voids in the mix.

PROBLEM FORMULATION

In this study an attempt has been made to come up with a laboratory testing procedure, simulating the secondary compaction due to traffic loading by extended Marshall Compaction. To take into account lower speed, bituminous mix design has also been done for climbing lanes and junctions for secondary compaction. Refusal density of bituminous mixes corresponds to 3% voids in the mix has been determined and concept of refusal density is incorporated in the design of mixes.

OBJECTIVES OF THE STUDY

Following were the objectives of present study:

a. To simulate the secondary compaction due to heavy traffic loading in the laboratory by extended Marshall Compaction.
b. To study the refusal density of the mix for various types of binders.
c. To study the effect of degree of compaction on gradation of aggregates in the mix.
d. To modify the mix design including the concept of refusal density and to study the properties of modified mix.

METHODOLOGY

Following methodology was adopted for study-:-

a. Testing of materials: Aggregates, various types of bitumen, filler etc. were tested in laboratory for various laboratory tests.

b. Bituminous mix samples were prepared and tested as per normal Marshall Design procedure for 2 types of binders (i.e. grade 60/70 and 80/100).

c. Additional test samples were prepared and compacted to increasing number of blows 100, 150, 200, 250, 300 with Marshall Hammer and refusal density of mixes have been determined.

d. By plotting graphs of VIM against number of blows, optimum number of blows at VIM of 3% has been determined.

e. Mix design has been done with binder content corresponds design VIM of 3%.

LABORATORY TESTS AND DATA ANALYSIS

Table2. Observed Aggregate Properties

Impact Value (%)	**Specific Gravity**	**Water Absorption (%)**	**Shape Test (FI+EI) (%)**
17.27	C.A – 2.82 F.A – 2.73 Filler -2.52	1.57	20.82

Table3. Observed Bitumen (60/70) Properties

Penetration	**Ductility(cm)**	**Softening Point**	**Specific Gravity**
67	91	51^{o}C	1.00

Table4. Observed Bitumen (80/100) Properties

Penetration	**Ductility(cm)**	**Softening Point**	**Specific Gravity**
94	97	43.5^{o}C	0.995

Table5. Gradation Adopted for Bituminous con concrete

Sieve Size (mm)	**Mass retained**	**% Retained**	**Cumulative % Retained**	**Cumulative% Passing**	**Desired Cumulative % Passing (As per MORT&H 2001)**
19	0.00	0.00	0.00	100.00	100
13.2	8.90	8.90	8.90	90.40	79-100
9.5	14.40	14.40	23.30	76.70	70-88
4.75	22.90	22.90	46.20	53.80	53-71
2.36	10.40	10.40	56.60	43.40	42-58
1.18	7.50	7.50	64.10	35.90	34-48
600	9.00	9.00	73.10	26.90	26-38
300	7.50	7.50	80.60	19.40	18-28
150	6.10	6.10	86.70	13.30	13-20
75	8.50	8.50	95.20	4.80	4-10

Table6. Average Physical Properties of Bituminous Concrete Mixes

Properties	60/70 (%)				80/100 (%)			
	4.50	**5.00**	**5.50**	**6.00**	**4.50**	**5.00**	**5.50**	**6.00**
Bulk Density (gm / cc)	2.41	2.43	2.44	2.42	2.42	2.44	2.44	2.41
Air Voids (%)	6.28	4.83	3.83	4.03	5.72	4.50	3.87	4.10
VMA (%)	16.66	16.40	16.55	17.72	16.21	16.17	16.63	17.82
VFB (%)	62.27	70.57	76.88	77.27	64.72	72.14	76.74	77.01
Stability (kg)	1053.0	1264.0	1314.0	1131.0	1009.0	1175.0	1112.0	979.0
Flow (mm)	2.80	3.10	3.50	3.80	2.70	3.00	3.70	4.00

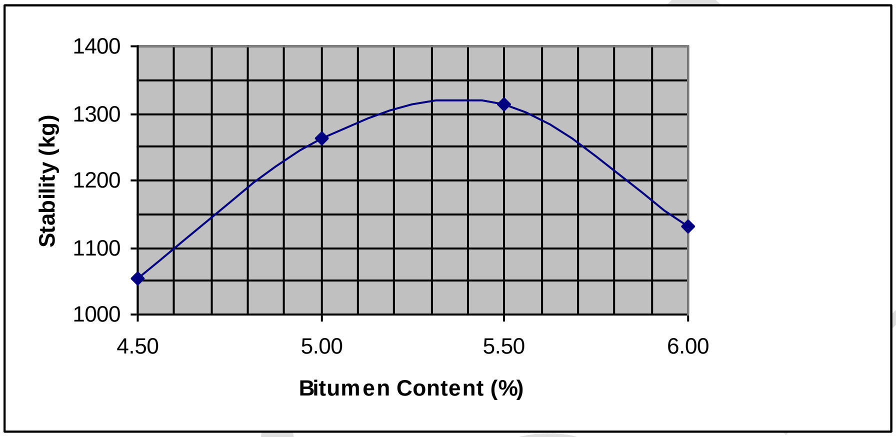

Fig 1 Stability vs bitumen content (60/70)

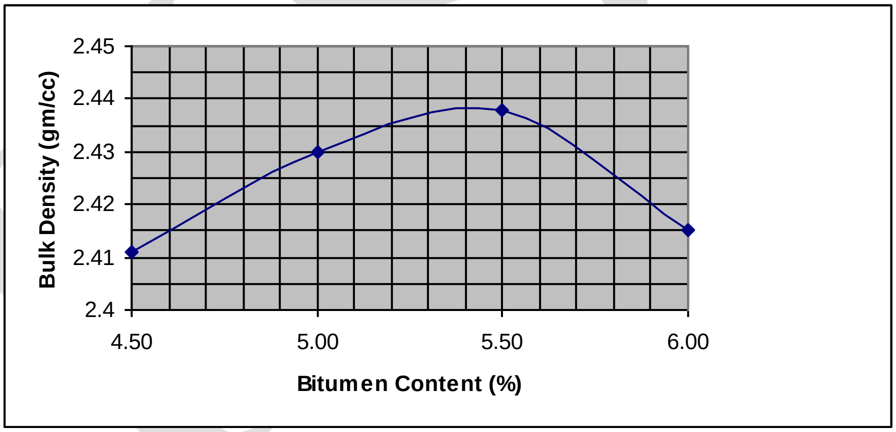

Fig 2 Bulk Density vs bitumen content (60/70)

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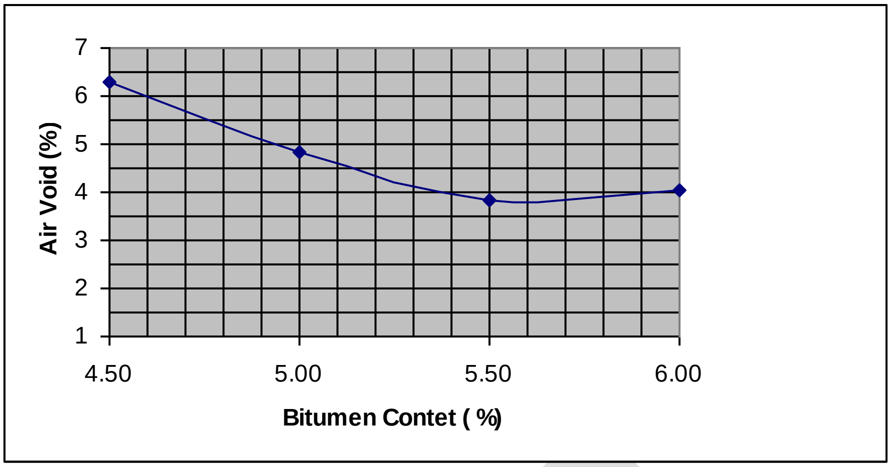

Fig 3 Air Void vs bitumen content (60/70)

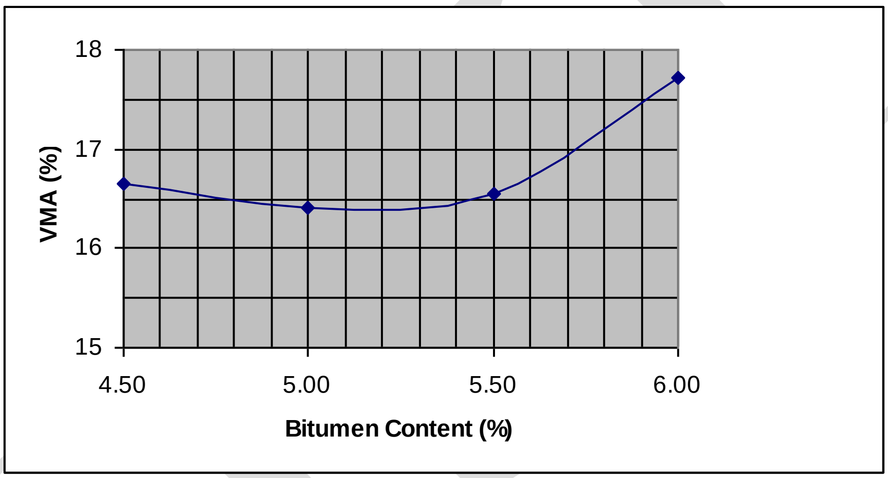

Fig 4 VMA vs bitumen content (60/70)

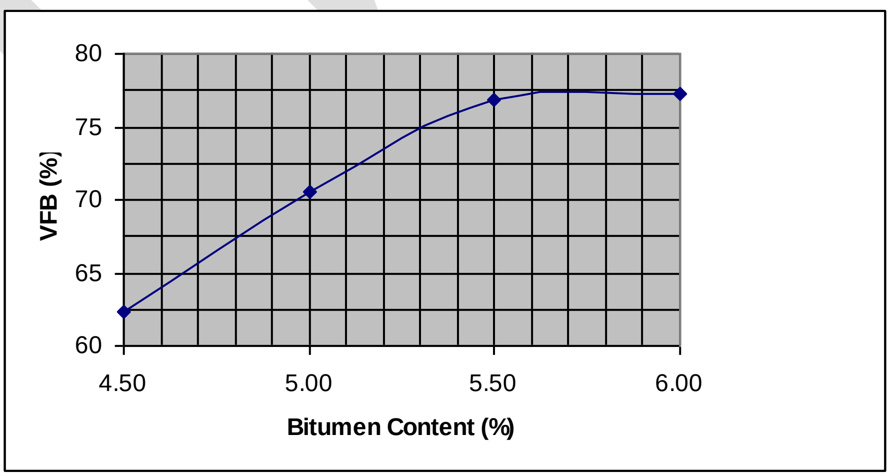

Fig 5 VFB vs bitumen content (60/70)

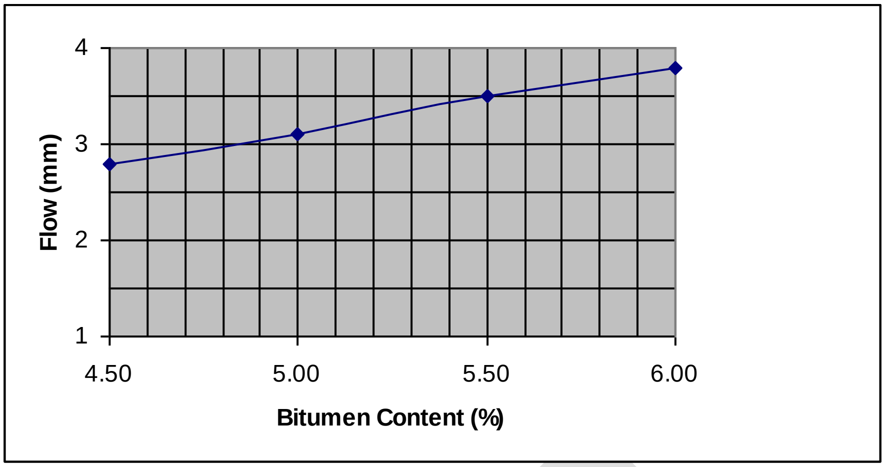

Fig 6 Flow vs bitumen content (60/70)

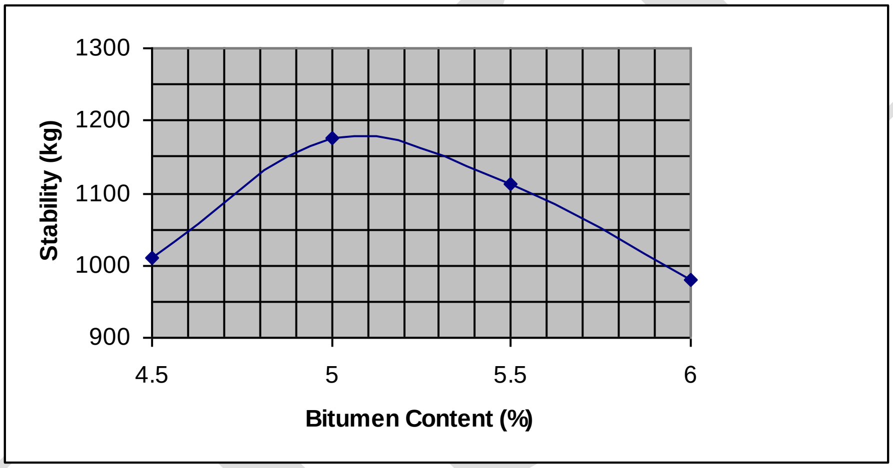

Fig 7 Stability vs bitumen content (80/100)

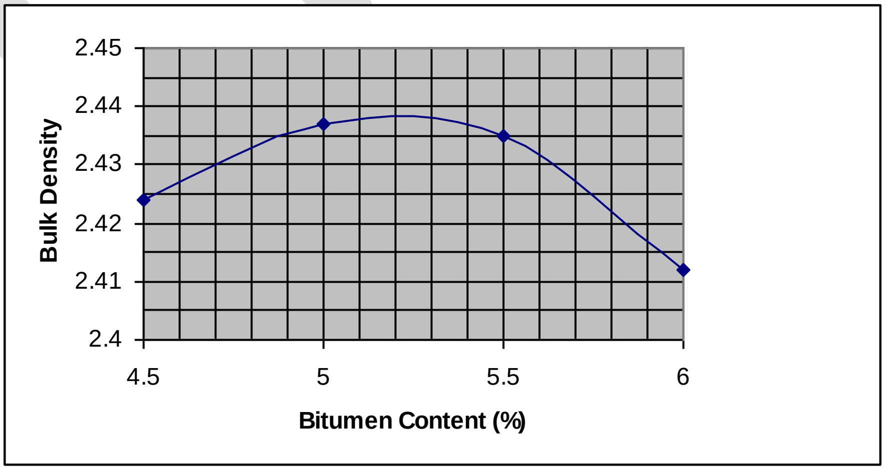

Fig 8 Bulk Density vs bitumen content (80/100)

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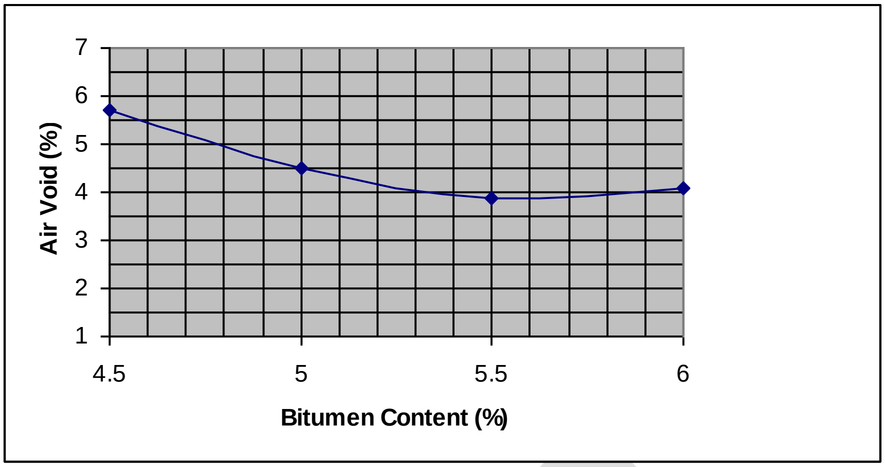

Fig 9 Air Void vs bitumen content (80/100)

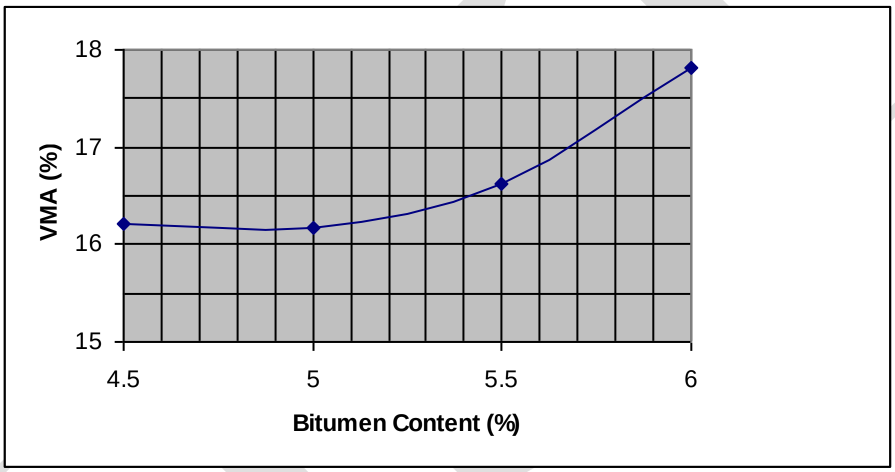

Fig 10 VMA vs bitumen content (80/100)

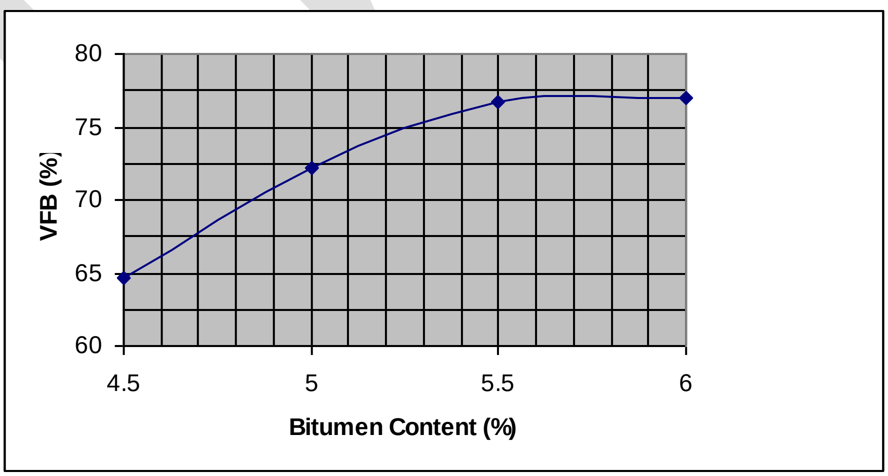

Fig 11 VFB vs bitumen content (80/100)

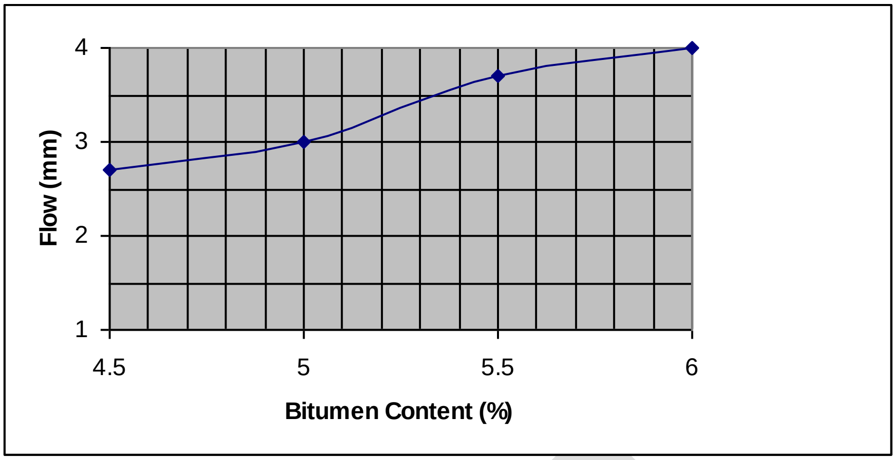

Fig 12 Flow vs bitumen content (80/100)

Table7. Bituminous Concrete Mix Properties at OBC

PROPERTIES	60/70	80/100	MORT&H SPECIFICATIONS
OBC (%)	5.3	5.1	5 to 7
Bulk Density (gm / cc)	2.435	2.438	——
Air Voids (%)	4.25	4.35	3 to 6
VMA (%)	16.4	16.2	Min 14
VFB (%)	74.8	73.5	65 to 75
Stability (kg)	1300	1180	Min 900
Flow (mm)	3.4	3.1	2 to 4

DISCUSSIONS AND CONCLUSIONS

Bituminous mixes design by Marshall method in accordance with the guideline of MS-2 and MoRT&H specifications have been performing to early under heavy traffic conditions. 75 blow Marshall compaction is inadequate to represent the in place density attend by the field mixes under heavy axle load. The mixes fail for one or more of the following reasons-

1. Inadequate initial compaction, making the mix vulnerable to high secondary compaction under heavy traffic.

2. Relatively high bitumen content that allows the reduction of air voids to lower than 3% under secondary compaction there by leading to rutting when pavement temperature rises in summer.

3. Low bitumen content and high air voids, leading to top-down cracking, raveling and stripping, thereby making the mix less durable.

The propensity of a bituminous mix for rutting under secondary compaction due to heavy traffic was judged by studying the air voids levels under increased Marshall compaction up to refusal density.

From the present study it can be concluded that 250 blows of extended Marshall compaction can be considered as the refusal density for the gradation and type of aggregate selected in the study as 3 percent air voids was retained in the mix. The study can be extended for different types of aggregates and varying gradation. It can be concluded that the bituminous concrete mix design with refusal density as additional parameter helps in deciding the compaction level in the field.

From the study it is also concluded that binder content can be reduced after applying the concept of refusal density. Hence it can be concluded that the refusal density is a tool for arriving at the optimum and economical binder content. The reduction in binder content resulted in reduced film thickness, but satisfied the required range of 6-8um, minimum film thickness. But the reduced binder resulted in the Marshall stability and flow values within the Specification limits.

As per Road Note 19, the Refusal Density Mix Design has to be adopted for sites affected by severe traffic, and in India most of the National Highway or State Highway sections is subjected to heavy traffic movement, hence, refusal density mix design may be adopted. Although performance testing of design mixes is ultimate goal, the proposed methodology may help to prevent premature rutting and bleeding of the mix.

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