OPTIMUM BITUMEN CONTENT BY MARSHALL MIX DESIGN FOR DBM

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ABSTRACT : *In India use of bitumen content since many year ago. Although these first mixture proved as a successful as a pavement material, they were not design any proper mix design method. As a knowledge regarding paving material expanded , need for more economical, functional and safer design criteria should require to find out optimum bitumen content in semi dense bitumen macadam. To satisfy the mix design specification, number of method have been developed. The present paper aims to highlight this variability involved in the asphalt mix design process and develop a procedure to find out optimum bitumen content by Marshall mix design method which attain maximum stability. This study is based on Indian specifications, where mix design, like in many other countries, is performed in accordance with Marshall Method.*

KEYWORDS: Optimum Bitumen content, dense bitumen macadam, Marshal Mix design.

1. INTRODUCTION

Most of the Indian Highways are of covered surface by bitumen. A Bituminous concrete as well as Dense Bitumen Macadam are commonly used asphalt courses. Mix designs for DBM and BC are based on guideline given by MoRTH . In mix design method improvements should finally aim to achieve long-lasting perpetual pavements. In a flexible pavement bituminous mixes serve the following three important functions:

Provide structural strength, Facilitate subsurface drainage and Provide surface friction especially when pavement in wet condition.

The bituminous mix design aims to determine the proportion of bitumen, Filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The requirements of the mix design and the two major stages of the mix design, i.e. dry mix design and wet mix design. Mix design objectives are to provide sufficient workability to permit easy placement without segregation, sufficient flexibility to avoid premature cracking due to repeated bending by traffic, sufficient air voids in the compacted bitumen to allow for additional compaction by traffic, sufficient strength to resist shear deformation under traffic at higher temperature, sufficient bitumen to ensure a durable pavement and sufficient flexibility at low temperature to prevent shrinkage cracks.

2 WHY DID THE ASPHALTIC CONCRETE FAIL?

Main reason of failure that the mix was too stiff for the high levels of strain that it experienced.However,that simple answer hides many mis-conceptions and we need to look at these if we are not to be in danger of repeating our mistakes.

Causes of cracks in road pavement

Cracks are caused by tensile stresses or strains. These can result from Traffic or the Environment.

Traffic: Standard structural theory says that the largest tensile strains occur at the bottom of the asphalt, directly under the vehicle wheel. Smaller, but significant, tensile strains also occur at the top of the asphalt, before and after the wheel. However, there are also strains all around the contact area between the tire and the road, caused by localized deformation of the surface, and immediately below the wheel, caused by traction, braking and steering forces. All these strains occur predominantly at the upper surface of the asphalt.

Environment: Changes in temperature, from day to night and from hot to cold seasons, produce tensile strains in the asphalt, especially at the upper surface.

Where cracks start

At the surface of the road the bitumen looses its lighter oils, by evaporation, and is progressively oxidized. These changes lead to it becoming hard and brittle. The penetration can drop to between 10 and 20 at the top while it may be 50 or above in the body of the layer. Classical pavement design theory assumed that cracks would start at these bottom of the asphalt because that is where the tensile strains, caused by flexure of the pavement, are largest. However, cores taken from cracked roads have shown that most cracks start at the top of the asphalt. Apparently, the embrittlement makes the tensile strains at the top of the layer more damaging than those at the bottom.

Design to prevent premature failure by cracking

Well-designed mixes will. have a higher strain tolerance than bad ones but all will eventually fail. Even a good mix may fail prematurely if the road is too weak and the strains too high for the number of vehicles that must be carried. Hence, prevention of premature cracking involves both:

* mix design and
* pavement design.

In such mixes is possible that Binder Film Thickness will be useful to ensure there is "enough" bitumen to make the mix durable. Mixes that fall into this class include coarse DBM mixes as well as SMA open graded asphalts. The grading curves for all these mixes lie well below the Fuller Curve. In mixes that have a continuous sand asphalt matrix with discontinuous stone particles, it is the sand asphalt that is exposed to the atmosphere. Because this is a continuum, the concept of individual articles, each coated by a finite thickness of binder, is not relevant. For such mixes, which include continuous (AC) and gap) graded mixes, the percentage Voids Filled with Bitumen (VFB) is likely to be a better criterion for durability than BFT.

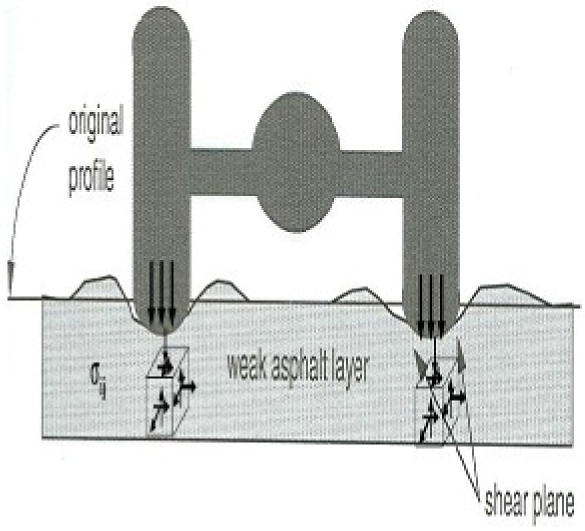

Fig. 1 Permanent Deformation in Asphalt Mixtures

3 MIX DESIGN METHODS

This section provides an overview of the mixture design methods that have been or being used by the asphalt industry. Generally, most of the mix design methods rely on experience and performance of mixes of known composition. Almost all mixture design methods include specimen fabrication and compaction in the mix design process to determine the mixture composition and volumetric properties.

Hubbard – field method

This method might be considered as the first formal design method for asphalt mixtures. It was originally developed to design sand-asphalt mixtures and later modified for aggregates (Roberts Freddy L, 2002). The method included the compaction of 50.8 mm in diameter by 25.4 mm high specimens at a range of asphalt contents. Each specimen is heated to 60^0C in a water bath and placed in a testing mold which is in turn placed in the 60^0C water bath and a compressive load is applied at a rate of 6.0 cm/min. The specimen is forced through a restricted orifice 44.5 mm in diameter. The maximum load sustained, in Kg, is the Hubbard Field stability. After testing all of the prepared specimens, the average stability at each asphalt content is calculated and plotted to determine the optimum asphalt content. One of the problems reported in this method was the size of the test specimens which limit the use of large size aggregates greater than 12.7 mm since that would violate the ratio of 4:1 of mold diameter to maximum aggregate size (Roberts Freddy L, 2002).

Hveem mix design method

This is one of the oldest mix design methods that dates back to 1927 when a California engineer, Francis Hveem began an extensive work to develop a mixture design method that can be reliably used by asphalt engineers and that does not solely depends on experience to reach to the optimum asphalt content (Asphalt Institute MS-2). Hveem used the aggregate surface area concept to develop a methodology for predicting the amount of asphalt needed for what used to be called oil mix (Hveem, 1942). The basis of this method is that the proper amount of binder in a mix of different size particles depends on the surface area of the gradation and that finer mixtures require higher binder content. A design chart was developed that relates the surface area to what is called asphalt index. Multiplication of surface area by the asphalt index gives the so called the oil ratio which is simply the Kilogram of oil (binder) per Kilogram of aggregates. A series of standard test specimens of 64.0 mm height and 102 mm diameter compacted using a special mechanical kneading compactor, with binder contents that vary around an estimated optimum value are subjected to several tests in order to arrive at the actual optimum value. The tests Hveem used to judge the fitness of the compacted mixtures were the stabilometer, cohesion meter and the swell test. The stabilometer is a predecessor of the triaxial test that utilizes a special triaxial-type testing cell and used to determine the stability of a mixture by measuring the radial expansion due to an axially applied load. Naturally, an over-filled mixture would show relatively large deformations and thus be judged unstable. The results from this test are expressed in a relative stabilometer value, where a true liquid was considered to have zero relative stability (lateral pressure equal to vertical pressure) while a non-deforming solid was the end of the range (radial deformation of zero). To account for the influence of height versus diameter ratio's, Hveem established correction curves for specimens with non-standard heights. The second test Hveem used, the cohesiometer test, was basically a force controlled bending test. By dropping a controlled quantity of a material with a known weight per time unit in a container, the applied load steadily increased. The force necessary to arrive at a standard displacement of the loading arm is recorded as the cohesiometer value. Hveem stability characterization of asphalt concrete has been used by the road industry and is specified in ASTM D1561 and AASHTO T246.

Marshall mix design method

Marshall test is used for the asphalt mix design as per Indian recommendation. The various mix specifications are available in the MoRT&H specifications for road and bridge works and other in IRC specifications. Two things are of primary concern in a asphalt mix, namely the aggregate gradation and the mix design requirements. Various mixes have various gradation. The acceptable volumetric parameters and Marshall Stability requirements are different for different mixes (See tables 2.1 and 2.4). Thus for various individual mixes a separate Marshall mix design needs to be carried out to find out the OBC value.

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

4 DESIGN CALCULATION

For the design of dense bitumen criteria with the help of MORTH ,IS 2316 (part I,II, and V) , IS 1202, IS 1203,IS 1208,IS 2386 and IS 1205.All the observation and analysis are as below.

Table 1 Physical characteristics of aggregates used in the mix :

Sr no	test	Test method	Size	Result	Spec. limit
1	Aggregate impact Value	IS : 2386 - Pt-4	20 mm	11.50%	Max. 27 %
2	Flakiness &	IS : 2386 - Pt-1	20 mm	13.36 + 13.96 =27.32%	Max. 30 %
	Elongation		10 mm		
3	Soundness	IS 2386 - Pt -5	20 mm	1.58%	Max. 12 %
	(I) Loss with sodium	5 Cycles	10 mm	2.00%	
	Sulphate		6 mm	2.43%	
4	Stripping Value	IS : 6241	20 mm	< 5	Min. 5.0 %
			10 mm		

Above table shows the physical characteristic of z0mm and 10 mm used aggregate in bitumen mix design.


Fig 2 sieving of aggregate


Fig 3 Penetration setup

Fig 3 Mixing of aggregate and bitumen

Table 2 Summary of DBM Mix Design

Bitumen Grade	**60 - 70**	**Required Limit As per MORTH**
Proportion (20 mm : 10 mm : 6 mm : stone Dust)	35:20:20:30	-
Bitumen % By wt. of Agg.	4.900	-
Bitumen % By wt. of Mix.	4.700	-
No of blow on Each side of SPN	75	75
Stability (KN)	17.626	9.0
Flow (mm)	3.78	2 -- 4
Voids in Mix (VIM)	5.150	3 -- 6
Voids in Minaral Agg (VMA)	16.242	Table 500 - 12
Voids Field by Bitumen (VFB)	68.29	65 - 75
Density (gm / cc)	2.452	-
Sp. Gr. Of Bitumen	1.03	-
Sp. Gr. Of Mix	2.585	-

Table 2 shows criteria for bitumen as per MORTH section 500 .The gradation of course aggregate as per guide line given in MORTH .

Table 3 Test results of bitumen

Sr. No.	Description	Test Method	Test Results	Spec. Limits as per MOST
1	Specific Gravity	IS : 1202	1.03	0.99 Min.
2	Penetration	IS : 1203	63.50	60- 70
3	Ductility	IS : 1208	90 cm	--
4	Softening Point	IS : 1205	52.5^0 C	--

Table 4 Aggregate result

Sr. No.	Aggregate / Material	Sp. Gr.	Apparent Sp.Gr.	Water absorption
1	20 mm	2.86	2.92	0.67
2	10 mm	2.84	2.91	0.85
3	6mm down	2.78	2.87	1.08
4	Stone Dust	2.66	2.74	1.12

Table 5 Analysis of result

Trail Mix	% of Bitumen by wt. of Agg.	% of Bitumen by wt. of Mix.	Bulk Sp. Gr. (**Gsb**)	App. Sp. Gr. (**Gsa**)
1	4.0	3.846	2.795	2.815
2	4.5	4.306	2.795	2.815
3	5.0	4.762	2.795	2.815
4	5.5	5.213	2.795	2.815
5	6.0	5.660	2.795	2.815

Table 6 Analysis of result

Trail Mix	% of Bitumen by wt. of Agg.	Effective Sp. Gr. (Gse)	Max.Sp. Gr. Of Mix (Gmm)	Sp. Gr. Of Mix (Gmb)	Va %
1	4.0	2.795	2.614	2.389	8.633

2	4.5	2.795	2.593	2.422	6.610
3	5.0	2.795	2.573	2.435	5.363
4	5.5	2.795	2.553	2.434	4.664
5	6.0	2.795	2.533	2.433	3.931

Table 5 and 6 shows mix design calculation .

Table 7 Marshal Stability calculation

% of Bitumen	VMA	VIM	VFB
4.30	17.514	7.478	57.30
4.48	16.659	6.071	63.56
4.66	16.242	5.150	68.29
4.84	16.589	5.095	69.29
5.02	17.096	5.227	69.43

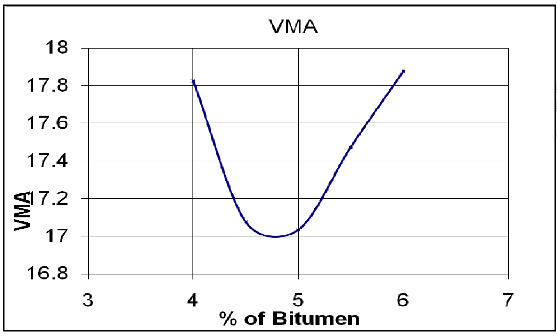

Fig 4 Graph between % of bitumen and Voids in mineral aggregate

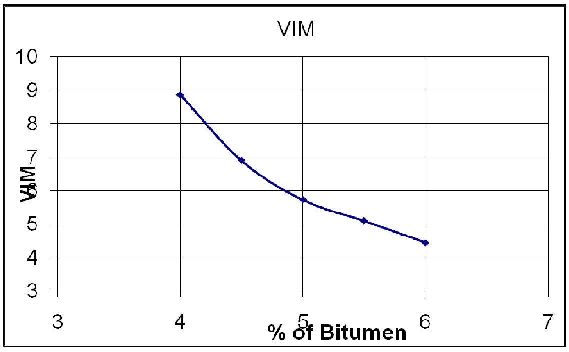

Fig 5 Graph between % of bitumen and air Voids in mineral

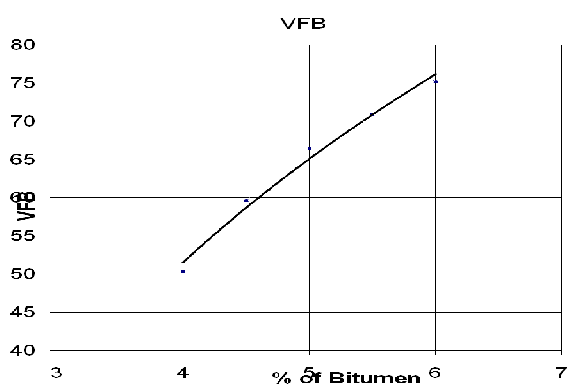

Fig 6 Graph between % of bitumen and Voids filled with bitumen.

5. CONCLUSION

This research paper suggested that bitumen mix design for DBM attempt a trail mixes .Laboratory compacted specimens are use for volumetric and mechanical testing in order to predict flow and stability of mix.This paper focus on the Marshall mix design for DBM at various bitumen proportion.
Adequate mix stability to prevent unacceptable distortion and displacement when traffic load is applied. Adequate voids in the total compacted mixture to permit a small amount of compaction when traffic load is applied without bleeding and loss of stability. Adequate workability to facilitate placement of the mix without segregation.

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