Some Considerations in Bituminous Mix Design Awaiting Implementation in Highway Construction

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Abstract: Bituminous mix design is a delicate balancing act between the proportions of aggregate sizes and bitumen content. For a given aggregate gradation, the optimum bitumen content is estimated by satisfying a number of mix design parameters recommended in the specifications. In this paper, some of new considerations related to the bituminous mix design are discussed. Bituminous mix design, with these considerations included, are expected to yield better performance if implemented in highway construction.

1.0 Introduction

Construction of highway involves huge outlay of investment. A precise design may save considerable amount of investment, as well, a reliable performance of the in-service highway can be achieved. Two things are of major considerations in this regard – pavement design and the mix design. The present paper emphasizes some of the new considerations involved in the concept of mix design. Though there are a few equipment used for estimation of stability of the bituminous mixes in the laboratory, the Marshall test is the most popular one, possibly due to its simplicity and low cost. The Superpave recommendations [1,2] have rationalized the concepts of bituminous mix design to a great extent, however, this involves evaluation of mix properties through a number of costly equipment. The discussion in this paper has been kept confined to the Marshall and fatigue testing only.

Discussion has been covered in two parts in this paper. The first part contains some of the new considerations in the bituminous mix design, and the second part discusses about the concepts awaiting field implementation.

2.0 Some New Considerations in Mix Design Concept

The mix volumetrics, reliability of bituminous mix design and the incorporation of fatigue considerations in bituminous mix design are the three aspects covered in this section.

2.1 Mix volumetrics

In a mix design problem by Marshall method, the volumetric parameters and the Marshall flow and stability values are to be satisfied simultaneously. The volumetric parameters

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(refer Figure 1) can be checked from the Marshall samples, prior to Marshall test. The following are the equations that could be used to estimate volumetric parameters (*VMA, VA, VFB*) and absorbed bitumen content (P_{ba}). The equations are arrived from the phase diagram of various volume components of the bituminous mix as shown in Figure 1. The absorbed bitumen is an important parameter [2], which is sometimes ignored in bituminous mix design. However, Optimum Bitumen Content (OBC) without due regard to the absorbed bitumen may not perform well when laid in the field.

$$VMA = \left(1 - \frac{Gmb}{Gsb} \times Ps\right) \quad \text{..... (1)}$$

$$VA = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \quad \text{..... (2)}$$

$$VFB = \left(\frac{VMA - VA}{VMA}\right) \quad \text{..... (3)}$$

$$Pba = 100\left[\frac{1}{Gsb} - \frac{1}{Gse}\right] \times Gb \quad \text{..... (4)}$$

Where,

P_{ba} = Absorbed bitumen content as a percentage by weight of aggregates
G_{mb} = Bulk specific gravity of the mix
G_{mm}= Maximum theoretical specific gravity of the mix
G_{sb} = Bulk specific gravity of aggregates
G_{se} = Effective specific gravity of aggregates
G_b = Specific gravity of bitumen
VMA = Voids in Mineral Aggregates
VA = Air Voids
VFB = Voids filled with Bitumen.

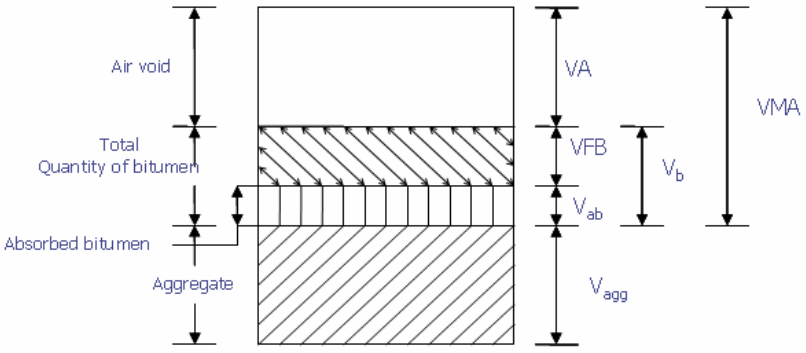

Figure 1 Volumetric phase diagram

Marshall stability and flow values are independent parameters, but there is a possibility that the values of *VMA*, *VA*, and *VFB* of a mix would be dependent on each other. Even if they are dependant, there is a chance that if one of them is satisfied within the given range, the others may not. A study has been initiated in this direction, based on the Indian mix specification (3rd revision MOST specifications) for Bituminous Concrete (BC) [3], and it is seen [4] that the volumetric specifications are mutually satisfied over a practical range of G_{mm} and G_{mb}. No upper limit of *VMA* has been specified in the Indian recommendations. However, study [4] showed that the theoretical upper limit of *VMA* is 20%. In separate studies on permeability of bituminous mix [5,6], it was felt that there is a need of having an upper limit of *VMA* from permeability considerations as well.

2.2 Reliability of mix design

Due to inherent variability in the test results, there exists different probabilities of the mix design parameters being satisfied individually. The probability of all the parameters satisfied simultaneously would therefore be lower than their individual probabilities. This concept has been explained [7] in Figure 2, where only *VMA*, *VA* and *VFB* are considered.

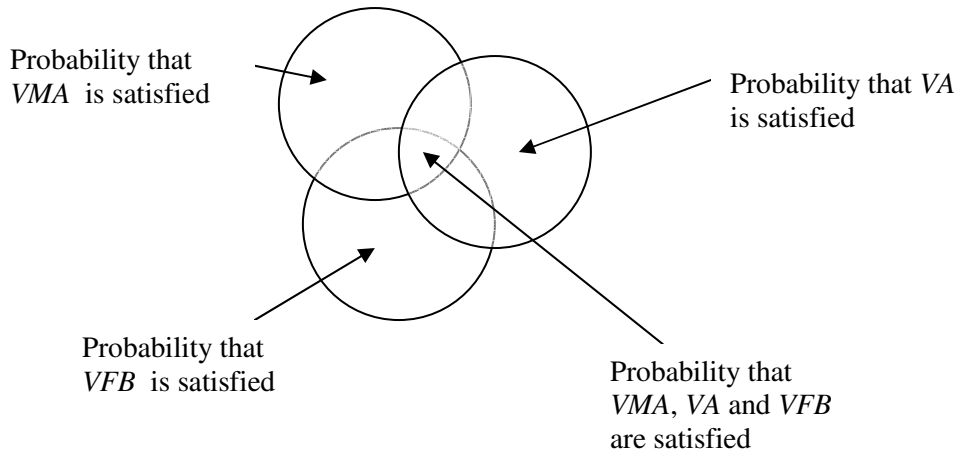

Figure 2. Probability diagram showing mutual satisfaction of *VMA*, *VA* and *VFB*.

The determination of joint probability for all the parameters being satisfied simultaneously can not be obtained through simple multiplication, as the volumetric parameters are mutually dependent. Study has been carried out [4] on BC (MOST specification, 3rd revision) [3], and it is concluded that the if the minimum bitumen content, satisfying all the Marshall parameters, is chosen as OBC, 55% of them would satisfy the specifications of all the parameters at a time. In a similar way, it is found that the probability of satisfying all the Marshall parameters increases if OBC is chosen higher than the minimum. Thus it is recommended that the minimum bitumen content satisfying all the Marshall parameters may not always be a good decision for field

application. It is, therefore, justified to use bitumen content more than the minimum required.

2.3 Fatigue considerations

Fatigue on bituminous mixes is an important parameter related to the structural failure of the pavement. Experiments by a number of researchers [8] have suggested that increase in bitumen content enhances the fatigue life. Thus the higher is the bitumen content, the better is the mix design, provided all the other parameters are within the limit. For example, from Figure 4 (which represents a sample Marshall test data), minimum bitumen content satisfying all the mix design requirements is obtained as 4.70%, whereas taking fatigue also into account, the OBC is obtained as 5.1%.

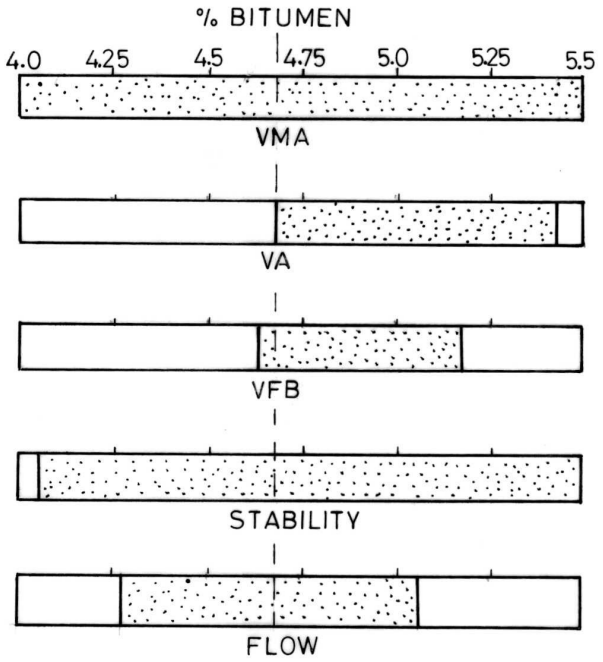

Figure 3. Determination of Optimum Bitumen Content.

3.0 Concepts Awaiting Field Implementation

Two aspects have been discussed in this section (i) evolution of non-standard bituminous mix specification and the (ii) use of different grades of bitumen in different pavement layers.

3.1 Evolution of non-standard mix specification

The bitumen content of a mix should be high enough so that there exist sufficient free bitumen for binding. Insufficient bitumen content makes a mix brittle under traffic. On the other hand, higher bitumen content causes thicker film around the aggregates which makes the mix more durable. It enhances the fatigue life also. However, increase in

bitumen content not accompanied by adequate amount of air voids will result in the fall of stability value of the mix. This happens as the buoyant action of bitumen comes into play and load starts transmitting more through bitumen than through aggregates [9]. Thus, the only way to increase bitumen content (i.e. *VFB*) keeping sufficient air voids (*VA*) is by maximizing *VMA*. So a gradation with high *VMA* value and sufficiently high *VFB* needs to be evolved.

The gradation of BC possibly was derived from the density maximization concept. Figure 4 shows the mid point gradation of BC, which is close to the Fuller's maximum density curve [10]. Studies have been conducted [4,8] on skip gradations, where it is found that with these gradations the *VMA* is increased, yet the fatigue performance and Marshall parameters are satisfactory. Thus there is a need to validate these laboratory findings from the performance study in the field, so as to evolve better performing aggregate gradation and bituminous mix than what is recommended presently.

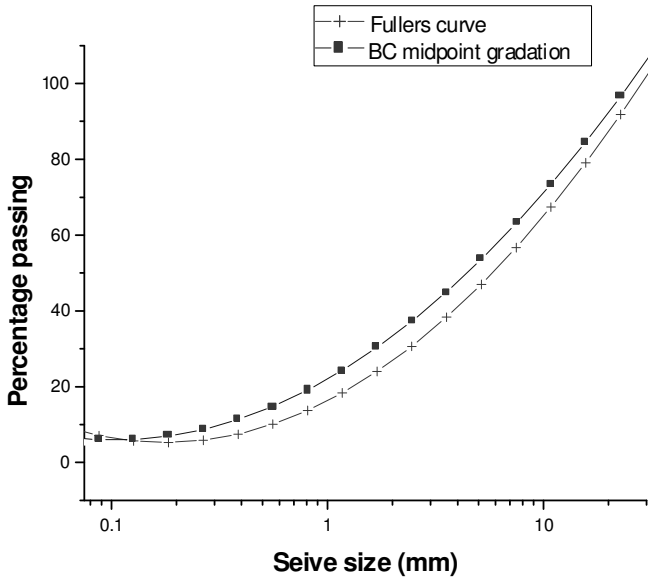

Figure 4. Comparison between mid-point BC gradation and Fuller's curve.

3.2 Use of different grades of bitumen in different pavement layers

Heavy duty bituminous pavements are composed of bituminous binder course and wearing course, for example, Dense Bituminous Macadam (DBM) and BC [3]. Same grades of bitumen are generally used for construction of these layers. Generally same grades of bitumen are used for construction of these layers.

Stiffer grade of bitumen has higher value of elastic modulus, and it causes lesser stains to the pavement layers and also it is expected to show lesser rutting. On the other hand, higher fatigue life as observed for bituminous mixes with softer grade of bitumen [11], indicates greater longevity of the pavement against fracture. It can be shown theoretically [12], that if a pavement is constructed with softer grade of bitumen at the lower layer, and harder grade at the top layer, the pavement is expected to last longer, than a pavement constructed with same grades for both the layers. Further confirmation can only be achieved through field performance.

4.0 Conclusion

The present paper has discussed some of the new considerations involved in bituminous mix design. The concepts discussed in this paper are expected to give reliable performance as well relative economy in construction. These can be validated further by implementing them in actual highway construction.

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