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# An Experimental Study of Bituminous Mixes Using a Natural Fibre

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*ABSTRACT*

***Generally a bituminous mixture is a mixture of coarse aggregate, fine aggregate, filler and binder. A Hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes (DGM) known as Bituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fibbers, mineral fibres or polymers to prevent drain down of the mix.***

***In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibre called SISAL fibre is used as stabilizer in SMA and as an additive in BC. For preparation of the mixes aggregate gradation has been taken as per MORTH specification, binder content has been varied regularly from 4% to 7% and fibre content varied from 0% to maximum 0.5% of total mix. As a part of preliminary study, fly ash has been found to result satisfactory Marshall Properties and hence has been used for mixes in subsequent works. Using Marshall Procedure Optimum Fibre Content (OFC) for both BC and SMA mixes was found to be 0.3%. Similarly Optimum Binder Content (OBC) for BC and SMA were found to be 5% and 5.2% respectively. Then the BC and SMA mixes prepared at OBC and OFC are subjected to different performance tests like Drain down test, Static Indirect Tensile Strength Test and Static Creep Test to evaluate the effects of fibre addition on mix performance. It is concluded that addition of sisal fibre improve the mix properties like Marshall Stability, Drain down characteristics and indirect tensile strength in case of both BC and SMA mixes. Ii is observed that SMA is better than BC in respect of indirect tensile strength and creep characteristics.***

*Key Words:* ***Bituminous Concrete (BC), Stone Matrix Asphalt (SMA), Sisal Fibre, Marshall Properties, Static Indirect Tensile Strength, Static Creep***

## INTRODUCTION

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well a reliable performance of the in-service highway can be achieved. Two things are of major considerations in flexible pavement engineering–pavement design and the mix design. The present study is related to the mix design considerations. A good design of bituminous mix is expected to result in a mix which is adequately (i) strong (ii) durable (iii) resistive to fatigue and permanent deformation (iv) environment friendly (v) economical and so on. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions and finalizes with the best one.

## BITUMINOUS MIX DESIGN

Asphaltic/Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size , typically less than 25 mm, through the fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. 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 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 permit easy placement without segregation
5. Sufficient resistance to avoid premature cracking due to repeated bending by traffic
6. Sufficient resistance at low temperature to prevent shrinkage cracks

The desirable properties of a bituminous mix can be summarized 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, esp. in cold season sufficient workability for construction
- Economical mix

## OBJECTIVE OF PRESENT INVESTIGATION:-

A comparative study has been made in this investigation between Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA) mixes with varying binder contents (4% - 7%) and Fibre contents (0.3% - 0.5%). In the present study 60/70 penetration grade bitumen is used as binder and Sisal fibre is used as stabilizing additive.

The whole work is carried out in four different stages which is explained below.

1. Study of Marshall Properties of BC mixes using three different types of fillers without fibre( fly-ash, cement, stone dust)
2. Study of BC mixes with fly ash as filler and sisal fibre as stabilizer
3. Study of SMA mixes with fly ash as filler and sisal fibre as stabilizer
4. Evaluation of SMA and BC mixes using different test like Drain down test, Static Indirect tensile Strength test, Static Creep test

## REVIEW OF LITERATURE

Pavement consists of more than one layer of different material supported by a layer called subgrade. Generally pavement is two type flexible pavement and Rigid pavement. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out then passes on these loads to the next layer below. Typical flexible pavement structure consisting of:

Surface course: This is the top layer and the layer that comes in contact with traffic. It may be composed of one or several different HMA sub layers. HMA is a mixture of coarse and fine aggregates and asphalt binder

Base course: This is the layer directly below the HMA layer and generally consists of aggregate (either stabilized or un-stabilized).

Sub-base course: This is the layer (or layers) under the base layer. A sub-base is not always needed.

### Dense-Graded Mixes

This type of bituminous concrete is a well-graded HMA has good proportion of all constituents are also called Dense bituminous macadam. When properly designed and constructed, a dense-graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size and can further be classified as either fine-graded or coarse-graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes. It is Suitable for all pavement layers and for all traffic conditions. It offers good compressive strength. Materials used are Well-graded aggregate, asphalt binder (with or without modifiers)

**Fig. 2.1 Dense graded HMA surface**

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Fig.2.2 Dense-Graded Core sample

### Stone Matrix Asphalt (SMA)

Stone matrix asphalt (SMA), sometimes called stone mastic asphalt, is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability in heavy traffic road. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resists permanent deformation. The stone skeleton is filled with mastic of bitumen and filler to which fibers are added to provide adequate stability of bitumen and to prevent drainage of binder during transport and placement. Typical SMA composition consists of 70−80% coarse aggregate, 8−12% filler, 6.0−7.0% binder, and 0.3 per cent fiber. The deformation resistant capacity of SMA stems from a coarse stone skeleton providing more stone-on-stone contact than with conventional dense graded asphalt (DGA) mixes. Improved binder durability is a result of higher bitumen content, a thicker bitumen film, and lower air voids content.

This high bitumen content also improves flexibility. Addition of a small quantity of cellulose or mineral fiber prevents drainage of bitumen during transport and placement. There are no precise design guidelines for SMA mixes. The essential features, which are the coarse aggregate skeleton and mastic composition, and the consequent surface texture and mixture stability, are largely determined by the selection of aggregate grading and the type and proportion of filler and binder. SMA improved rut resistance and durability. It has good fatigue and tensile strength.SMA is almost exclusively used for surface courses on high volume roads.

Materials used for SMA are Gap-graded aggregate, modified asphalt binder, fiber filler. Other SMA benefits include wet weather friction (due to a coarser surface texture), lower tire noise (due to a coarser surface texture) and less severe reflective cracking. Mineral fillers and additives are used to minimize asphalt binder drain-down during construction, increase the amount of asphalt binder used in the mix and to improve mix durability.

Fig.2.3 SMA Surface

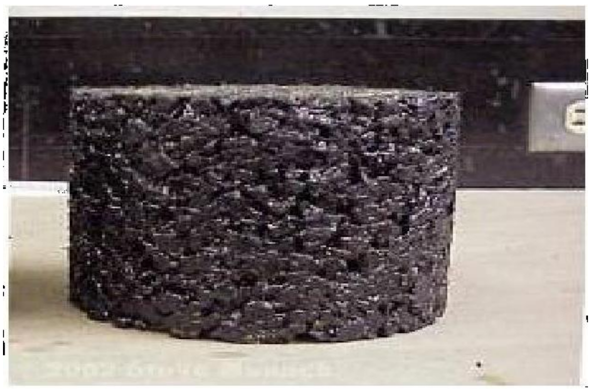

Fig.2.4 SMA Lab Sample

### Open-Graded Mixes

Unlike dense-graded mixes and SMA, an open-graded HMA mixture is designed to be water permeable. Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands. The two most typical open-graded mixes are:

### Open-graded friction course (OGFC)

Typically 15 percent air voids and no maximum air voids specified.

Asphalt treated permeable bases (ATPB). Less stringent specifications than OGFC since it is used

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only under dense-graded HMA, SMA or Portland cement concrete for drainage.

OGFC – Used for surface courses only. They reduce tire splash/spray in wet weather and typically result in smoother surfaces than dense-graded HMA. Their high air voids reduce tire-road noise by up to 50%.

ATPB – Used as a drainage layer below dense-graded HMA, SMA or PCC.

Material used aggregate (crushed stone or gravel and manufactured sands), asphalt binder (with modifiers). OGFC is more expensive per ton than dense-graded HMA, but the unit weight of the mix when in-place is lower, which partially offsets the higher per-ton cost. The open gradation creates pores in the mix, which are essential to the mix's proper function. Anything that tends to clog these pores, such as low-speed traffic, excessive dirt on the roadway can degrade performance.

Fig.2.5 OGFC Surface

Fig 2.6 OGFC Lab Samples

### Table 2.1 Main differences of SMA and bituminous mix (Bose et al., 2006)

| Properties | SMA | BC |
|---|---|---|
| Definition | SMA is a gap graded mix which consists of high amount of coarse aggregate firmly bonded together by a strong asphalt matrix Consisting of fine aggregate, filler, bitumen and stabilizing additives. | BC consists of well graded coarse and fine aggregate, filler and bitumen. |
| Sample fig. |  |  |
| Mass of Coarse Aggregate Content, ( %) | 75 – 80 | 50-60 |
| Mass of Fine Aggregate (%) | 20 – 25 | 40 - 50 |
| Mass of Filler content,( % ) | 9 – 13 | 6 – 10 |
| Binder Type | 60/70, PMB- 40 | 60/70, 80/100 and modified binders |
| Minimum binder content by weight of mix, (%) | >6.5 | 5 - 6 |
| Stabilizing Additives by weight of mix,(%) | 0.3 – 0.5 | -------- |
| Air Voids(%) | 3—4 | 3--6 |
| Layer Thickness, mm | 25-75 | 30-65 |

## Results and discussions

## EFFECT OF DIFFERENT TYPE OF FILLER ON BC:-

Variation of Marshall Properties of bituminous concrete (BC) with different type of filler is explained below.

### Marshall Stability

It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases. Variation of Marshall Stability value with different binder content with different filler is given fig 4.1.

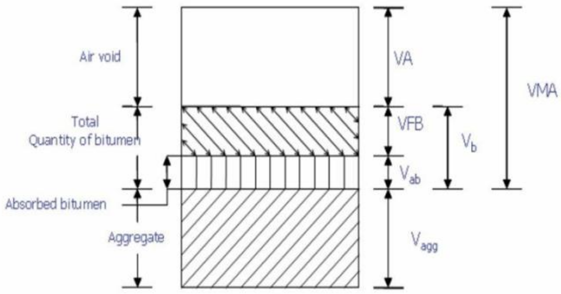


Fig 4.1 Phase Diagram of bituminous mix

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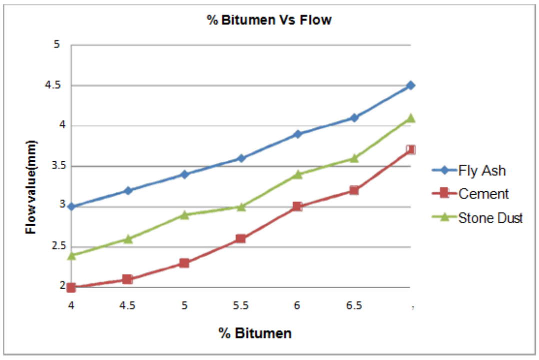


Fig 4.3 Variation of Flow Value of BC with different binder content (With different type of filler)

## EFFECT OF FIBRE ON BC:-

For preparation of mix binder content vary from 4 to 7% and fibre content vary from 0.3% to 0.5%. Here OBC, OFC and other Marshall properties is calculated by Marshall Method.

Marshall Stability

It is observed that stability value increases with increase binder content up to certain binder content; then stability value decreases. Also stability value increases with increase fibre content and further addition of fibre it decreases. Variation of Marshall Stability value with different binder content with different fibre is given fig 4.7.

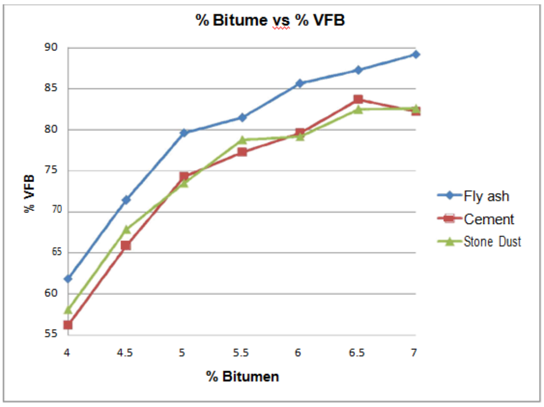


Fig 4.7 Variation of VFB of BC with different binder content (With different type of filler)

## EFFECT OF FIBRE ON SMA

Here result of variation of Marshall Properties with different binder content where fibre content is taken as 0%, 0.3%, and 0.5% is explained below.

## Marshall Stability

It can be observed that with increase binder content stability value increases up to certain binder content and there after it decreases. Similarly by addition of fibre stability value also increases up to certain limits and further addition of fibre stability value starts decreasing. May be this is due to excess amount of fibre which is not able to mix in asphalt matrix properly. The result is given below in fig 4.13

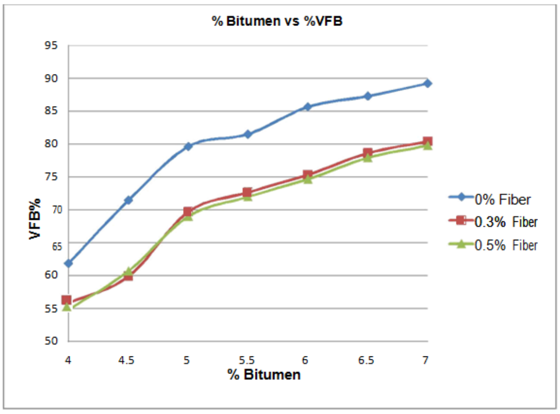


Fig 4.13 Variation of VFB of BC with different binder content (With different fibre content)

## Conclusion

Here two type of mix i.e. SMA and BC is prepared where 60/70 penetration grade bitumen is used as binder. Also a naturally available fibre called sisal fibre is used with varying concentration (0 to 0.5%). OBC and OFC is found out by Marshall Method of mix design. Generally by adding 0.3% of fibre properties of Mix is improved. From different test like Drain down test, Indirect Tensile Strength and static creep test it is concluded that SMA with using sisal fibre gives very good result and can be used in flexible pavement.

## Future Scope

Many properties of SMA and BC mixes such as Marshall properties, drain down characteristics, tensile strength characteristics have been studied in this investigation. Only 60/70 penetration grade bitumen and a modified natural fibre called sisal fibre have been tried in this investigation. However, some of the properties such as fatigue properties, moisture susceptibility characteristics, resistance to rutting and dynamic creep behaviour can further be investigated. Some other synthetic and natural fibres and other type of binder can also be tried in mixes and compared. Sisal fibre used in this study is a low cost material, therefore a cost-benefit analysis can be made to know its effect on cost of construction. Moreover, to ensure the success of this new material, experimental stretches may be constructed and periodic performances monitored.

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