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# USE OF NATURAL FIBRE AND BINDER QUALITY IN STONE MATRIX ASPHALT MIXTURE

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**Abstract: There are three major types of asphalt surfacing, characterized by a mixture of bitumen and stone aggregate. These are: Dense Graded asphalt (DGA); Stone Mastic Asphalt (SMA) and Open Graded Asphalt (OGA).Stone Matrix Asphalt (SMA) is a gap graded mix, characterized by high coarse aggregates, high asphalt contents and polymer or fiber additives as stabilizers. In comparison to dense graded mixtures SMA has higher proportion of coarse aggregate, lower proportion of middle size aggregate and higher proportion of mineral filler. It resists permanent deformation and has the potential for long term performance and durability. Four of different aggregate gradations with two types of fillers, such as Bamboo Fibre and Cellulose Fibre have been tried for preparation of mixes. About 2450 gm of sample aggregates were taken and kept in oven until it dried. Heating of aggregates was done up to 135$^{o}$C before the addition of bitumen. Bitumen mix was added varying from 3 to 7% at an increment of 1%. Also the fillers, bamboo fiber and artificial stabilizer- Topcel cellulose were mixed as per design.**

## 1.0 INTRODUCTION

Stone Matrix Asphalt (SMA) is a gap-graded hot mix asphalt concrete that combines high quality coarse aggregate with a rich proportion of asphalt cement. This blend produces a stable paving mixture with a strong stone-on-stone skeleton that provides outstanding rutting resistance and durability. Stone Matrix Asphalt was developed in Germany in the mid of 1960's and it has spread throughout Europe and across the world in 1980's and 1990's respectively. The excellent performances include resistant to mechanical and temperature deformation, cracking, and particularly rutting, resistant to weathering actions such as aging and low temperature cracking. Durability is excellent even under slow moving heavy traffic. The textured surface increases skid resistance and provides environmental and driving comfort by reduced noise level, and improved visibility in rainy days. SMA provides a deformation resistant, durable, surfacing material, suitable for heavily trafficked roads. SMA has found use in Europe, Australia and the United States as a durable asphalt surfacing option for residential streets and highways. SMA has a high coarse aggregate content that interlocks to form a stone skeleton that resist permanent deformation. The stone skeleton is filled with mastic of bitumen and filler to which fibres 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 fibre. 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 of flexibility. Addition of a small quantity of cellulose or mineral fibre prevents drainage of bitumen during transport and placement. 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 is characterized by a stone-on-stone structure. SMA uses a high proportion of larger stones or aggregate that contacts each other. This skeleton of larger stones resists heavy loads by transmitting them to the pavement below. If the under laying pavement is sufficiently strong then the SMA will resist the heavier loads effectively. (A surfacing cannot compensate for a weak pavement). The bituminous mastic is intended to hold the aggregate in place and to inhibit the ingress of moisture into the pavement and to provide durability. The mastic consists of bitumen and fine aggregate particles; it may also include a polymer modified bitumen and filler material to increase the mastic’s strength. Fibres may also be added to stabilize the bitumen and to prevent the binder segregating from the aggregate during transport and placement. It is important that the aggregate material consist of only the larger stones (in the structure) and fines to provide effective mastic. The intermediate size aggregates are not included, as these keep the larger aggregate apart and reduce the strength of the SMA.

## 1.1 PERFORMANCE CHARACTERISTICS OF SMA

The development of modern pavement technology is needed to accelerate significant improvement of pavement quality of highways, airport runways and urban roads. Following are the various performance characteristics of SMA:

- Good stability at high temperatures
- Good flexibility at low temperatures
- High wearing resistance

 

- High adhesive capacity between the stone granules and the bitumen
- A mix with no tendency to separate
- Good skid resistance
- Reduced water spray
- Lower traffic noise

1. **Good stability at high temperatures**
   SMA Mix has a self-supporting stone skeleton of crushed high quality coarse aggregate, which provides an increase in internal friction and shear resistance and hence it's extremely high stability.
2. **Good flexibility at low temperatures**
   SMA Mix has a binder rich mastic mortar which has superior properties over dense graded asphalt in resisting thermal cracking.
3. **High wearing resistance**
   SMA Mix has low air voids, which make the mix practically impermeable, and provide satisfactory ageing resistance, moisture susceptibility and durability.
4. **High adhesive capacity between the stone granules and the bitumen**
   With the increase of the amount of filler, cellulose fibres are added as stabiliser. The three dimensional structure of cellulose fibre assists the bitumen to maintain a high viscosity, thickens the bituminous film and improves the bitumen/aggregate adhesion.
5. **A mix with no tendency to separate**
   An efficient stabilisation of the mastic in order to prevent its segregation from the coarse particles.
6. **Good skid resistance**
   Because of the macro-texture of the road surface and the use of coarse aggregates with a high Polished Stone Value, SMA pavement achieves a better level of skid resistance.
7. **Reduced water spray**
   Because of its greater texture depth, there is less water spray, and at night there is fewer glares reflected from the road surface and better visibility of road markings.
8. **Lower traffic noise**

SMA road surfaces generally offer lower levels of noise due to the texture properties.

## 2.0 LITERATURE REVIEW

**Shaopeng Wu et al** studied the Evaluation of Stone Matrix Asphalt Mixtures Performance Using Blast Oxygen Furnace Steel Slag as Aggregate. This paper discusses the feasibility of BOF steel slag used as aggregate in asphalt pavement by two points of view including BOF steel slag's physical and micro properties as well as steel slag asphalt mixtures' materials and pavement performances. For the former part, this paper mainly concerns the physical changes of the steel slag, studied by performing XRD, SEM and Mercury Porosimeter analysis and testing method. During laboratory test procedure, this paper uses volumetric design method to make sure stone-stone contact; By using traditional rutting test, soak wheel track test, the high temperature stability and water resistance ability were tested. Uniaxial compression test and indirect tensile test were performed to evaluate the low temperature crack resistance performance and fatigue characteristic. Simultaneously, by observing steel slag SMA pavement which was paved successfully, this paper performs British Pendulum test and surface structure texture test to evaluate driving performance of vehicles. A follow-up study to evaluate the performance of the experimental pavement confirmed that the experimental pavement was comparable with a conventional asphalt pavement, even superior to the latter in some aspects. The main purpose has been to validate the opinion that using BOF slag in asphalt concrete is feasible. So this paper suggests that treated and tested steel slag should be used in a more extensive range, especially in asphalt mixture paving projects in such an abundant steel slag resource region.

**Naveen Kumar R et al** studied the Drain down Analysis of Bituminous Mix Modified with Natural Fibre. This present study investigates the draindown property of mixtures of stone matrix asphalt made with conventional bitumen 60/70 with a non-conventional natural fibre, namely sisal fibre. By Marshall Method Optimum Bitumen Content has been found. Thereafter, the draindown characteristics for modified and unmodified SMA (Stone Mastic Asphalt) mixes have been studied. It is observed that only 0.28% addition of sisal fibre significantly improves the Marshall properties of SMA mixes. Addition of nominal 0.28% fibre considerably improves the draindown characteristics of the SMA mixes with conventional bitumen, which would otherwise have not been able to meet the prescribed criteria. Based on the results and discussions of experimental investigations carried out on different SMA mixes it is concluded that SMA mixes value of optimum binder content is quite high that makes it very costly.

**A. Behnood et al** experimentally investigated the stone matrix asphalt mixtures containing steel slag. The disposal of steel slag occupies a significant portion of landfills and causes many serious environmental problems. This study aims to investigate the feasibility of utilizing steel slag aggregates in Stone Matrix Asphalt (SMA) mixtures. The results show that the use of steel slag as the coarse portion of aggregates can enhance Marshall Stability, resilient modulus, tensile strength, resistance to moisture damage and resistance to the permanent deformation of SMA mixtures. n this paper, the feasibility of utilizing steel slag as aggregate in Stone Mastic Asphalt (SMA) mixtures is researched. On the basis of the data obtained in this study, it is concluded that According to the results obtained from Marshall Stability, indirect tensile strength, and resilient modulus tests, it should be noted that mixtures with steel slag have shown encouraging results in comparison with those containing limestone. Also, replacing the coarse portion of limestone aggregate with steel slag leads to better results in comparison with mixtures that contain steel slag as the fine portion. Steel slag used as the coarse portion in SMA mixtures increased Marshall Stability and decreased flow values. Hence, mixtures with steel slag coarse aggregate have higher MQ values, which is an indicator of high stiffness and resistance to permanent deformation. n this paper, the feasibility of utilizing steel slag as aggregate in Stone Mastic Asphalt (SMA) mixtures is researched. On the basis of the data obtained in this study, it is concluded that According to the results obtained from Marshall Stability, indirect tensile strength, and resilient modulus tests, it should be noted that mixtures with steel slag have shown encouraging results in comparison with those containing limestone. Also, replacing the coarse portion of limestone aggregate with steel slag leads to better results in comparison with mixtures that contain steel slag as the fine portion. Steel slag used as the coarse portion in SMA mixtures increased Marshall Stability and decreased flow values. Hence, mixtures with steel slag coarse aggregate have higher MQ values, which is an indicator of high stiffness and resistance to permanent deformation.

**Ratnasamy Muniandy et al** studied the Fatigue Performance of Stone Matrix Asphalt with Cellulose Oil Palm Fiber. In this study, cellulose fibers were pre-blended in PG64-22 binder with fiber proportions of 0.2%, 0.4%, 0.6%, 0.8% and 1.0% by weight of aggregates. The fiber-modified binder showed improved rheological properties and showed that the PG64-22 binder can be modified and raised to PG70-22 grade. The cellulose oil palm fiber (COPF) was found to improve the diameteral fatigue performance of SMA design mix. The fatigue life increased to a maximum at a fiber content of about 0.6%, whilst the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fiber content of 0.6%.

**H. Behbahni et al** studied the effects of fibre type and content on the rutting performance of stone matrix asphalt. The purpose of this study is to evaluate the effect of fiber type and content on the rutting performance of stone matrix asphalt mixtures. In this research two types, cellulose fibers (made in Iran and Germany) and mineral fibers (rock wool) with various percentages (0.1-0.5%) of the total weight of the Stone Matrix Asphalt (SMA) mixture were used and after determining optimal bitumen content for each fiber percentage, we examined their effect on SMA bulk specific gravity, Void in Mineral Aggregate (VMA), void content, Marshall stability, Indirect Tensile Strength (ITS) and flow parameters. Also results of dynamic creep test were used as an indicator of rutting performance of SMA specimens. Results of the laboratory tests showed that variation of fiber type and content can lead to considerable changes in rutting performance of SMA. Specimens made with 3% cellulose-GER (made in Germany) has resulted to highest value of ITS and least permanent deformations. Also with considerations of potential rutting, optimum percentage for each fiber type has been concluded.

**A. Suchismita et al** studied the Fatigue Characteristics of Stone Matrix Asphalt Mixes in Warm Climate. This study presents the details of a laboratory study of stone mastic asphalt mixes, with emphasis on engineering characteristics under repeated load conditions. In this study, conventional binders namely locally used penetration grade bitumen 80/100 and 60/70, with locally available aggregates and cement as filler have been used. Non-conventional natural fibers, namely coconut fiber to the extent of 0.3% by weight, have been added to the mix to act as a stabiliser. It is observed that the natural fibres improve the engineering properties of the SMA mixes considerably. Addition of fibres results in higher tensile strength for a given bitumen sample at a given temperature. The resilient modulus value does not change significantly with applied tensile stress. It has been observed that a mere 0.3% incorporation of binder results in considerable increase of the resilient moduli and fatigue life of the mixes at all tested temperatures, which is an added advantage to the paving industry, particularly in the context of prevailing warm temperatures in tropical countries and even beyond to produce durable paving mixes, particularly when dense graded aggregates are not easily available.

## 3.0 SMA METHODOLOGY

Materials used for the SMA Mix for the sample preparation and testing to obtain and compare the project work are mainly coarse aggregate, fine aggregate, filler and stabilizer. Fine aggregate for the all the case is taken as stone dust. And stabilizer taken is bamboo fiber. The binder used is the bitumen of grade 60-70 as it's the grade which is most favorable in Indian condition.

About 2450 gm of sample aggregates were taken and kept in oven until it dried. Heating of aggregates was done up to 135$^{o}$C before the addition of bitumen. Bitumen mix was added varying from 3 to 7% at an increment of 1%. Also the fillers, bamboo fiber and artificial stabilizer- Topcel cellulose were mixed as per design. For each binder content 3 samples were prepared by compacting to 75 blows on both sides of sample in Marshall Compactor. Then the sample was de-moulded and the weight of sample in air and in water was noted down to determine the bulk density of mix. For the determination of stability and flow value on Marshall Apparatus, sample was immersed in water bath at 60$^{o}$C for 40 minutes before testing. The total load obtained in dial gauge is been noted as stability value, which is calculated again using the co-relation factor given for the standard 25 KN dial gauge to obtain load in KN causes the specimen to fail and is taken as Marshall stability. The total amount of deformation in units of 0.25 mm is observed and noted which occurs when maximum load is applied is recorded as Flow value.

**4.4 MARSHALL STABILITY TEST**

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 results of the Marshall test of specimens prepared with bamboo fiber and artificial stabilizer- Topcel cellulose as filler for varying bitumen contents have been presented in table 1 and 2 respectively.

**Table 1: Marshall Properties of Specimens with Filler bamboo fiber**

| Bitumen Content (%) | Unit Weight (kg/m$^3$) | Stability (KN) | Flow Value (mm) | Air Void VA (%) | VMA % |
|---|---|---|---|---|---|
| 3 | 2380 | 15.04 | 2.52 | 6.3 | 19.5 |
| 4 | 2390 | 15.70 | 2.63 | 5.8 | 18.8 |
| 5 | 2408 | 16.21 | 2.74 | 5.1 | 17.7 |
| 6 | 2417 | 16.47 | 3.04 | 4.7 | 16.3 |
| 7 | 2425 | 17.02 | 3.17 | 4.2 | 15.7 |

**Table 2: Marshall Properties of Specimens with Topcel cellulose fiber**

| Bitumen Content (%) | Unit Weight (kg/m$^3$) | Stability (KN) | Flow Value (mm) | Air Void VA (%) | VMA % |
|---|---|---|---|---|---|
| 3 | 2302 | 14.32 | 1.8 | 8.24 | 18.60 |
| 4 | 2319 | 15.58 | 2.3 | 7.64 | 17.53 |
| 5 | 2327 | 16.75 | 2.87 | 6.87 | 17.48 |
| 6 | 2332 | 16.93 | 3.24 | 6.14 | 16.87 |
| 7 | 2347 | 18.95 | 3.78 | 5.62 | 15.9 |

 

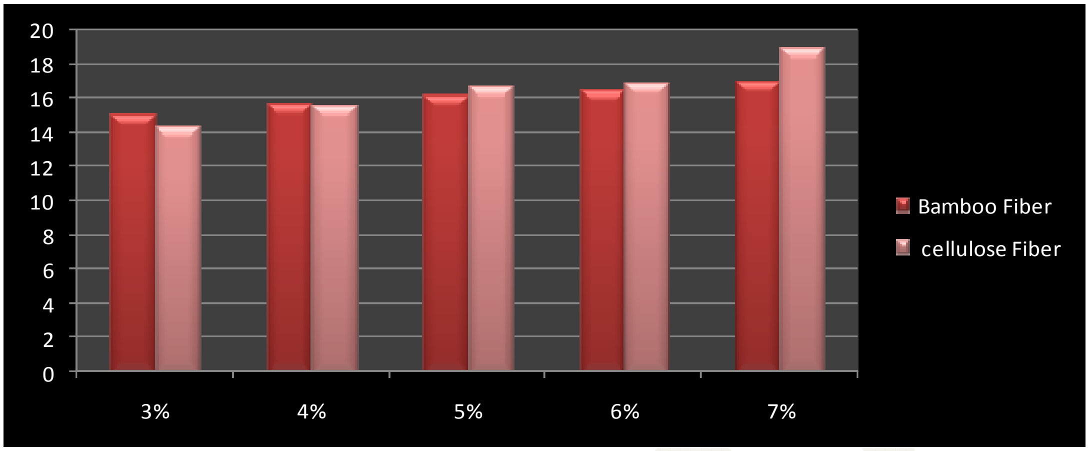


**Figure 1: Variation of Stability With %age of Bitumen**

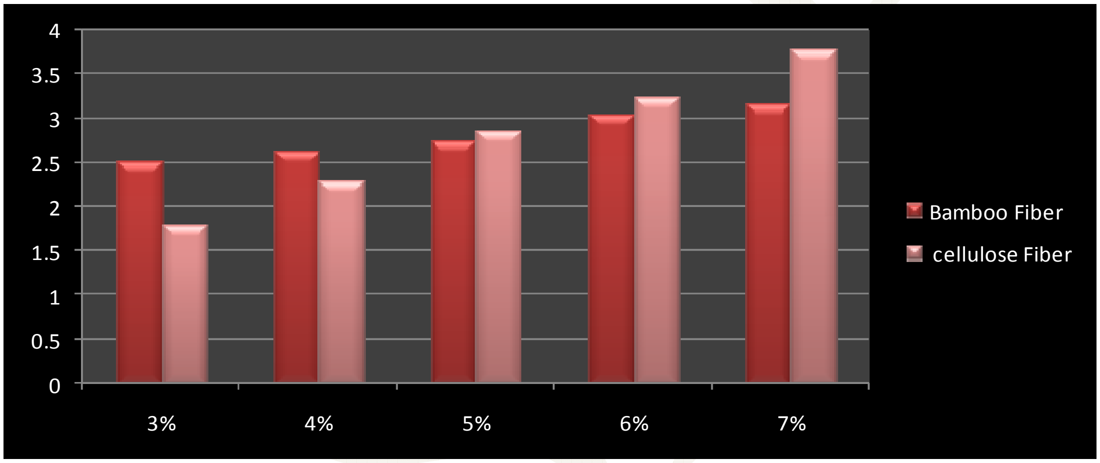


**Figure 2: Variation of Flow value with %age of Bitumen**

## CONCLUSION

Based on the results and discussions of experimental investigations carried out on different SMA mixes the following conclusions are drawn.

1. Bituminous mixes containing bamboo fibre as fillers are found to have Marshall Properties almost same as of Topcel cellulose fibre fillers.
2. It was observed that the addition of fiber favourably affects the properties of bituminous mixtures by increasing its stability and voids and decreasing the flow value.
3. In addition to filling the voids, the fillers' components interact with the binder present in the mix, potentially making it stiff and brittle. The change in mix properties is strongly related to the properties of the filler.
4. Bituminous mixes containing bamboo fibre as filler displayed maximum unit weight at 7% content of bitumen having an increasing trend up to 7%. In case of bamboo fibre, also maximum unit weight at 7% content of bitumen was achieved.
5. It is observed that with increase in the bitumen content the volume of voids decreases.
6. The voids filled with mineral aggregate and the voids filled with bitumen both increases with increase in the bitumen Content.
7. Filler type and particle size directly affect the engineering properties of the asphalt mixtures.
8. The bulk density increases with increase in the bitumen content. It is found that the bulk density of SMA with 7% plastic content is higher than the control mix.
9. It is concluded that, the fibre reinforced bituminous concrete pavement will sustain on various climatic condition in India.

10. The results of the laboratory tests show that fillers improve the overall mixture properties of asphalt. The use of these special fillers improves pavement performance, thus reducing the maintenance and rehabilitation costs of the pavement.

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