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Laboratory study of stone matrix asphalt by using bamboo fibre

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***Keywords*— Bamboo Fibre, Drain Down Test, Marshall Stability Test, Optimum Fibre Content, Optimum Binder Content, Stone Matrix Asphalt.**

***Abstract*—** *This study has been undertaken to investigate the modification of Stone Matrix Asphalt by using Bamboo Fibre. Now a days with increased traffic and maintenance costs there is need of construction of better long lasting roads that avoid pavement damage. Because of the presence of water in rainy season most common pavement damage starts. Moisture induced damages are a major source of concern on Indian roads. Stone Matrix Asphalt has a higher percentage of coarse aggregates and mineral filler and a low amount of fine aggregates. It also has a macro texture, low air voids, and high binder content, result in waterproof and good surface drainage. Stone Matrix Asphalt Mixture include a higher amount of coarse aggregate and a higher percentage of bitumen binder than standard Hot Mix Asphalt mixtures which consist of homogeneous aggregate and less bitumen binder. The Stone Matrix Asphalt mixes offer a long lasting surface. In India the idea of stone matrix asphalt is not well known because of lack of suitable standards. For the past few decades researchers have been focusing their efforts on developing stabilized mixes for enhanced pavement efficiency all over the world. Many attempts have been done to modified SMA mixes using Synthetic Fibres and polymers. Natural Fibres as Bamboo Fibre are being used to replace Synthetic Fibres and polymer as additives. India is a one of the world largest agricultural economy, generates a large amount of Natural Fibres. In according to this idea the focus of this study is on using Bamboo Fibre as additives to increase Stone Matrix Asphalt performance. The main object of this work is to find the effects of Bamboo fiber on the properties of SMA mixes. Stone Matrix Asphalt mix is prepared by varying bitumen content from 5.5% to 6.5% to obtain optimum bitumen content after that Bamboo Fibre is added during preparation of mix at varying content of 0.1% to 0.4% , then Marshall Stability Test and Drain Down Test are conducted to find Optimum Fibre content. All of these data back up the idea that Bamboo Fibre as additives in Stone Matrix Asphalt mixes have an impact. On the basis of volumetric, mechanical, and drain down properties of the various modified mixes, optimal Fibre content for Bamboo Fibre mixtures is 0.3 percent by weight of mix, which lead to rise in Marshall Stability value and fall in Flow Value when compared to traditional SMA mix.*

I. INTRODUCTION

India road infrastructure is rapidly expanding the increase in traffic and vehicle loads reduces the life of roads constructed with traditional bituminous mixtures. There is a lot of study going on in country to overcome the difficulties with pavements. The Stone Matrix Asphalt combination has been found to be an excellent choice for long lasting Indian highways. Bituminous paving mixtures that meet MoRTH criteria (MoRTH, 2001) are widely employed. Overloading is a big worry in India unlike most developed countries. Axle loads are heavy and speeds are low with many stop and start conditions resulting in deformation of the currently employed bituminous mixture. Permanent deformation in flexible pavement is often limited in the range of 10 to 15 cm from top of the flexible pavement according to several studies. Stone Matrix Asphalt mix is recommended for severe traffic loads and high tyre pressures. Because of stone on stone contact the weight is carried directly by the coarse aggregate. Bitumen modification and strengthening have played a vital role in improve the performance of flexible pavements. The transportation industry developed this technology in response to the poor functioning of road materials when subjected to significant change in traffic patterns. Natural Fibres are used as additives to stiffen the mastic during manufacture and application at high temperatures as well as to achieve even greater binder content for enhanced durability there is the increasing demand of various natural Fibre in various part of country for various purpose because these natural Fibre are environmental friendly. Stone matrix asphalt is made up of coarse and fine aggregates (70% to 80%), filler (10%), bitumen (min 6%) and stabilizer. When Stone Matrix Asphalt mixture is compacted a stone skeleton combination forms from a gap graded aggregate that can withstand severe load, avoid deformation, and ensure durability. Cement as filler, sand and bitumen form glue that holds the stone network together and makes the material cohesive. Stabilizer like Fibres added to keep the mastic in place. The mastic fills the gaps, holds the aggregate in place and provides further stabilization while also reducing air voids resulting in extremely durable bitumen. Mineral fillers and additions help to reduce binder drain down and increase the quantity of binder. Due to high percentage of coarse aggregate concentration stone to stone contact occurs resulting in a combination that is extremely resistant to deformation. The void free, binder rich mastic will give excellent durability and fracture resistance. The high concentration of big stones which is 3–4 more times traditional dense graded mixture will provide excellent wear resistance. The rough surface roughness will provide better skid resistance.

II. RESEARCH OBJECTIVES

Main object is to provide long lasting surface of pavement by using bamboo fibre as additives in stone matrix asphalt this will provide a environmentally friendly surface.

1. To find out the volumetric parameter of traditional stone matrix asphalt mix by varying bitumen percentage content in order to find out optimum bitumen content.
2. To find out the effect of varying bamboo fibre content at optimum bitumen content in stone matrix asphalt.
3. Effect of varying bamboo fibre content is measured by Marshall Stability Test and flow value.
4. To find optimum fibre content using drain down test by varying bamboo fibre content in a mix.
5. To draw various graph on volumetric parameter, Marshall Stability Test and provide proper results and conclusion.

III. REARCH METHODOLOGY

In the way of obtaining the object of this study, Methodology has been used and present in a form of flow chart. First off all material use in experiment are tested to obtain their material characteristic, material testing include bitumen test, aggregate test are done, after the basic testing of material, specimen is prepared from stone matrix asphalt mix. Marshall Stability Test is conducted for specimens of varying percentage of bitumen content to obtain optimum bitumen content, after that optimum Fibre content is obtained by varying the percentage of Fibre content in a Stone Matrix Asphalt mix of optimum bitumen content by conducting Marshall test and drain down test. Volumetric characteristic such as air void, Voids in Mineral Aggregate(VMA), Voids Filled with Bitumen(VFB) and bulk specific gravity are calculated during testing of specimen. Now modified Stone Matrix Asphalt specimen is prepared by using varying percentage of Bamboo Fibre as additives and Marshall Stability Test and Drain Down Test is performed to obtain stability and flow value. After this result of both control Stone Matrix Asphalt sample and modified Stone Matrix Asphalt sample is compare and conclusion.

IV. MATERIALS

The type and quantity of materials used in flexible pavement surface have a significant impact on its performance. Aggregates, Bituminous, Cement, and Bamboo Fibre are all required for the creation of Stone Matrix Asphalt mixes.

4.1 Aggregate

Aggregates are the most common type of material used in road building. They must withstand heavy traffic, deterioration and sufficient stability. The Techniques of testing for aggregates in road building are outlined in IS 2386-1963. In this study, 20mm and 10mm aggregates, as well as stone dust. Table No. 4.1 Property of aggregate shows the results obtained for various aggregate characteristics.

Table 4.1 Property of Aggregate

Property	**Value Obtain from Tests**	**Standards**
Impact value	14.3	IS:2386 Part 4
Combined Elongation & Flakiness Index	23.828	IS:2386 Part 1
Specific Gravity	2.9	IS:2386 Part 3
Water Absorption%	0.133%	IS:2386 Part 3

4.2 Cement

The main aim of cement as Mineral Filler material is to make the bitumen binder stiff in the mix. Cement, bitumen binder and stabilizing ingredient is used to fill gaps and produce strong mastic. It improves the mix cohesiveness. As the filler increases stiffen of the mix increases, making it harder to compress and perhaps resulting in a crack composition. The quantity of material that passes from 0.075 mm sieve accounts for 10% of the aggregate in the mix, Ordinary Portland Cement 43 grade as mineral fillers is used. This investigation utilized cement, which has a stronger binding with aggregate, bitumen, and Bamboo Fibre as additive. Table No. 4.2 Property of cement shows the physical characteristics of the filler utilized.

Table 4.2 Property of Cement

Property	***Values Obtain from Tests***
Specific Gravity	*3.11*
% Passing 0.075 mm sieve	*78*

4.3 Stabilizing Additive

During mixing, shipping, and placement processes a stabilizing ingredient is added to retain the binder in a Stone Matrix Asphalt mixture consists of high binder content. Bamboo Fibres can be added to the mixture as stabilizing additives to avoid the undesirable drain down. Bamboo Fibre employed as stabilizing additives in this investigation.

4.4.1 Bamboo Fibre

India having large supply of Natural Fibres such as jute, Bamboo, Banana Fibre, Sisal Fibre, Coconut Fibre and many other which may be utilized for construction projects. Fibres used as a stabilizing agent, during the mixing process have numerous benefits such as improved binder content, thick film and mixture stability. Bamboo Fibre is utilized in this investigation at varying percentages to obtain Optimum Fibre content. Bamboo Fibre is shown in Fig.4.1. Bamboo Fibre is use because it is easily available in all parts of India, Bamboo is the only plant which grows fast in a single day at the rate of 40 mm per hour, Bamboo grow in forest of central part of India. They mainly grow in Madhya Pradesh, Maharashtra, Chattisgad and Odisha. Bamboo Fibre is obtained from natural Bamboo stem.

Fig. 4.1: Bamboo Fibre

4.4.2 Bitumen

The binder in Stone Matrix Asphalt mixture is bitumen. In different mixtures such as hot-mix and gap graded mix different grades of bitumen are employed. In the production of SMA mix samples VG30 grade bitumen is utilized. The physical characteristics of bitumen have

been discovered and bitumen property is shown in Table No. 4.3 Property of bitumen.

Table 4.3 Property of Bitumen

Property	**Value Obtain Tests**	**Specification**
Softening point ºC	49	IS:1205-1978
Flash & fire point	230 260	IS:1209-1978
Specific gravity	1	IS:1202-1978
Ductility at 27ºC (cm)	74	IS1208-1978
Penetration at 25ºC	65	IS:1203-1978

V. TESTS

5.1 Marshall Stability Test

A total 1200gm weight of aggregates and mineral filler are heated togeather at a temperature of 150-160°C . Bitumen is heated at a temperature of 150°C. After heating aggregates and bitumen they are completely blended at temperature ranging from 150 to 160°C . To create laboratory sample of hight 63.5mm mix is filled in a mould which is preheated and compacted by a hammer of weight 4.5 kg and free fall is allowed at the hight of 45.8 cm by providing 50 blows of hammer on each side as per NCHRP Report 425. 75 blows were not provided as they were provided in dense graded bituminous mixes because 75 blows will break down the aggregate more in the gap graded mixes. The effort required to compact Stone Matrix Asphalt mixes to the necessary density on the highway was less than that required for standard Hot Mix Asphalt combinations. All of the samples in this study were compacted with 50 Marshall Hammer blows on each side. Marshall Stability test is performed on stable Stone Matrix Asphalt sample as shown in Figure 5.1 and 5.2 having a diameter of 100 mm and height of 63.50 mm, using 50 blows on each face. Bituminous mixtures are made by combining aggregates with bitumen and additives. In this study, the Bamboo Fibre content was changed between 0.1%, 0.2%, 0.3%, and 0.4% by weight of the mix. The Marshall Stability Test Sample is made in the same way as control mixture with the exception that the additives as Bamboo Fibre are added to bitumen during initial stage of heating .The Fibre length is a constant value of 6 mm which is used in a mix.

Fig. 5.1: SMA Mix Sample Specimen

The sample height is measured and the sample is submerged at 60°C water bath for 30minutes. The samples are immediately withdrawn from the bath tub filled with water and loaded into the Marshall loading head.

Fig 5.2: Marshall Test

Sample is applied with the compressive load at the rate of 50.80 mm per min. Sample before getting failure is used to obtain the values of Marshall Stability and Flow Value, when the maximum load is applied to it.

5.2 Drain Down Test

The Drain Down of SMA mixes produced at optimal binder concentration is evaluated, As per NCHRP Report 425 in this test bituminous mix is prepared after that it is weighted and place it in a wire basket in loose condition without compaction before placing wire basket in pan weight of pan is taken and then kept in oven for 1 hour at temperature of 170 after that pan is taken out along with wire basket then final

weight if pan is taken and drain down is calculated as below.

Drain down(%) = (C-B)/A*100 (1)

Where, A = Mass of initial total sample (g)

B = Mass of initial pan (g)

C = Mass of final pan (g)

VI. RESULTS AND DISCUSSION

6.1 Marshall Stability Test

6.1.1 Marshall Stability and Flow Value

The addition of Bamboo Fibre in Stone Matrix Asphalt mixes efficiently increases stability values, resulting in an increase in mixture toughness, as shown in Table 6.1. This suggests that the Fibre-based combination would perform better than the control. Figures show the variation in Marshall Stability and flow value of Bamboo Fibre content.

As shown in Figure 5.1 & 5.2 the stability of Bamboo Fibre stabilized mixes rises at first then reach a maximum value and subsequently declines as the Bamboo Fibre concentration increases. Bituminous mixture is a combination of aggregates and bitumen that is inconsistent, non-uniform, and multi phased. Excess Bamboo Fibres may not distribute evenly, coagulating together to produce weak spots within the mixture. As a result when Bamboo Fibre content is high, stability suffers.

Table 6.1 Marshall Stability Properties

Additive	**Bamboo Fibre (%)**	**Marshall Stability (kN)**	**Flow value (mm)**	**Marshll Quotient (kN/mm)**	**Air Void (%)**	**Bulk Specific Gravity**	**VMA (%)**	**VFB (%)**
Nil	0	7.852	3.81	2.060	3.984	2.506	19.057	79.094
Bamboo Fibre	0.1	8.213	3.64	2.256	4.09	2.503	19.154	78.599
	0.2	9.835	3.61	2.724	4.29	2.498	19.316	77.78
	0.3	11.671	3.56	3.278	4.40	2.495	19.413	77.303
	0.4	8.311	3.50	2.374	4.63	2.489	19.607	76.355

It should be highlighted that at 0.3% Bamboo Fibre content, Bamboo Fibre modified mixes have the Marshall Stability of (11.671 KN) suggesting that they had greater rutting resistance. When bitumen mixture crack Bamboo Fibre acts as a bridge preventing crack from spreading farther. Bamboo Fibre also enhances the viscosity and stiffness of bitumen by absorbing light components.

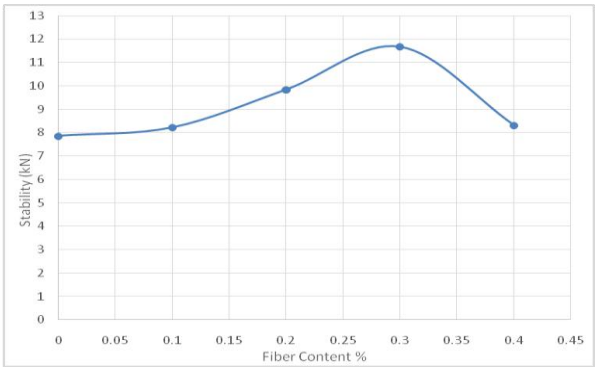

Fig 6.1: Stability v/s Fibre Content (%)

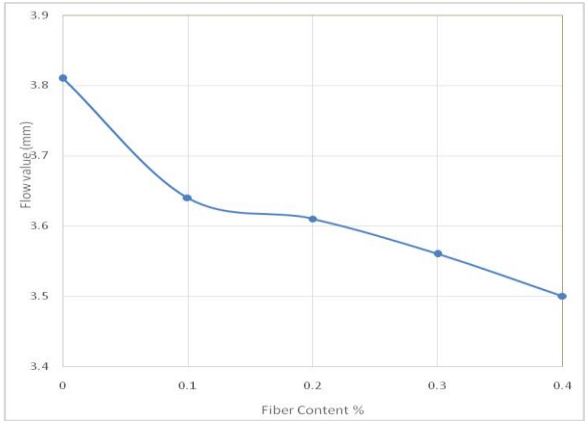

Fig. 6.2: Flow Value v/s Fibre Content (%)

6.1.2 Bulk Specific Gravity

The elastic behaviour of the mix improves as the Bamboo Fibre concentration rises because of elastic behaviour of Bamboo fiber. As Bamboo fiber content increases in the stone matrix asphalt mix specific gravity decreases as shown in Fig. 6.3.

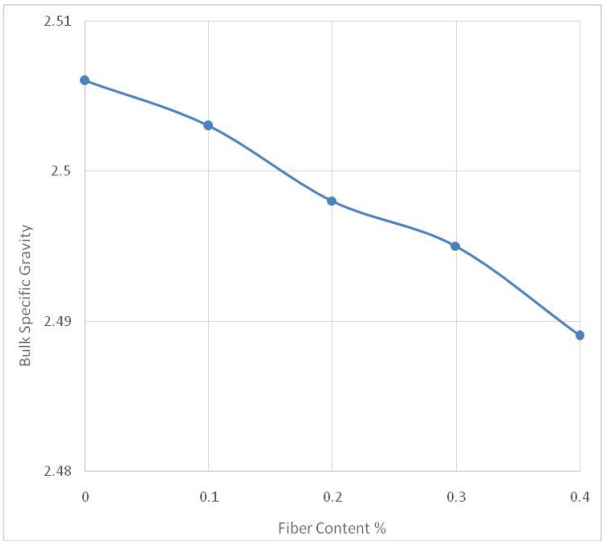

Fig 6.3: Bulk Specific Gravity v/s Fibre Content (%)

6.1.3 Air void, Voids in Mineral Aggregate and Voids mFilled with Bitumen

With increasing air gaps in the mix it will cause crack because there will be less bitumen binders to provide proper coating to the aggregates surface whereas little air void will cause greater plastic flow and bleeding problem of bitumen. The test findings Figure.5.4, 5.5 & 5.6 demonstrate that adding Bamboo Fibres to bituminous mixes increases the air void. However, the air spaces in mixes are in the limit of 3% to 5% indicating that Bamboo fiber can be used as additives.

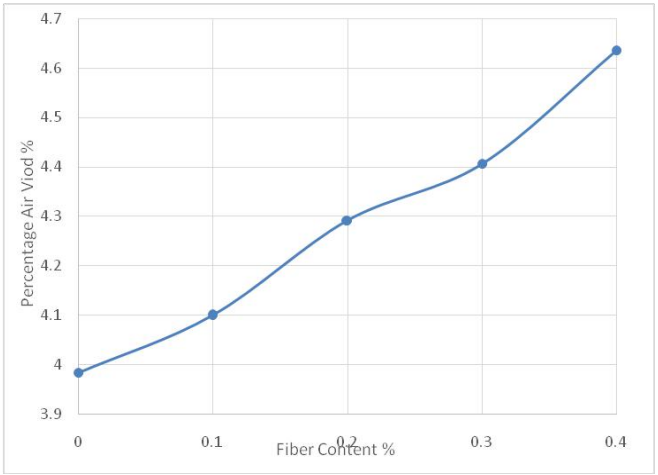

Fig.6.4: Air Void v/s Fibre Content (%)

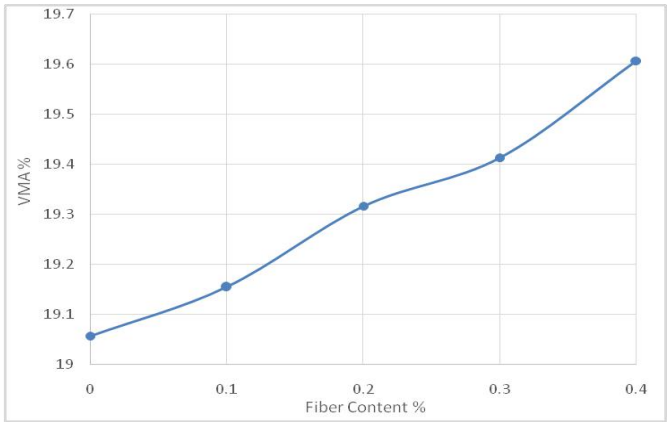

Fig.6.5 Voids in Mineral Aggregate v/s Fibre Content (%)

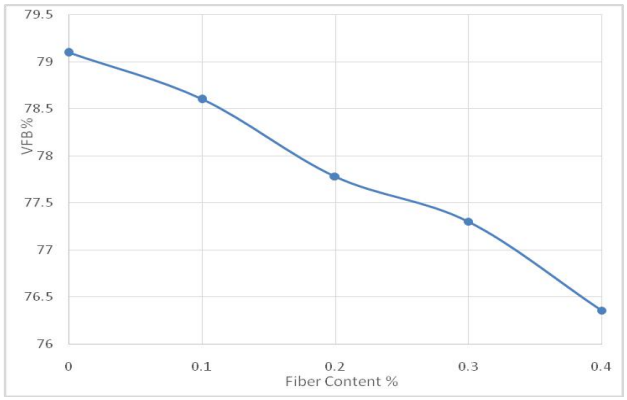

Fig.6.6 Voids Filled with Bitumen v/s Fibre Content (%)

6.2 Drain Down Test

Bamboo fiber additions significantly stabilize the combination when compared to the control mixture. According to AASHTO T305 the drain down of the traditional mixture is 6.658% which is well above the allowed limitations which is 0.3% of weight of mix. The values of drain down in all stabilized stone matrix asphalt mixes shown in Table 6.1 drop significantly with increasing Bamboo fiber concentration as shown in Figure No.6.2 and approach the permissible limit at 0.3% Fibre content. The possible benefit of adding Bamboo Fibre as additives to SMA Mixes is to reduce drain down and bleeding problem of SMA mix. As a stabilizing agent Bamboo Fibre additive can be used successfully.

Fig. 6.1: Drain Down Apparatus

Table 6.1 Drain Down Value

Bamboo Fibre (%)	Drain Down (%)
0	6.658
0.1	2.895
0.2	0.547
0.3	0.234
0.4	0.156

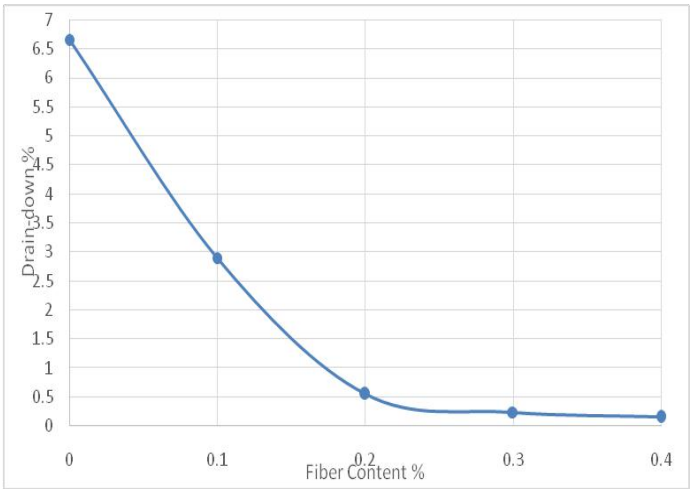

Fig. 6.2: Drain Down v/s Fiber Content

VII. CONCLUSION

1. It is noted that as the amount of Bamboo Fibre in Stone Matrix Asphalt increases with increase in the value of stability and Marshall Quotient, maximum value is obtained at 0.3% Bamboo Fibre content.
2. The highest values of Marshall Stability of stone matrix asphalt mixes are attained at 0.3 % Fibre content.
3. Bamboo Fibre has the highest stability (11.671 kN), indicating that it is more resistant to rutting.
4. Bamboo Fibre as additives utilised in the Stone Matrix Asphalt mixture for this study function of Bamboo fiber is to be an effective stabilizing agents and give considerable stability to the mixture.
5. The conventional mixture is exposed to significant drain down of 6.658%, which is over 0.3 percent by weight of mix because of stone to stone contact and rich binder concentration in Stone Matrix Asphalt. The addition of additives in the Stone Matrix Asphalt mix reduces Drain Down to the required level.

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