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Reaction on the Stability of Stone Matrix Asphalt Using Bamboo Fibre as Stabilizer and Slag as Aggregate Alternate

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ABSTRACT- Stone matrix asphalt (SMA), originating in Germany in the 1960s, now provides substantial benefits such as improved resistance to permanent deformation, greater durability, extended service life, enhanced aging characteristics, and heightened resistance to cracking, fatigue, wear, and skidding, while also reducing noise levels. It comprises a gap-graded aggregate mixture maximizing asphalt-cement content and coarse aggregate fractions, resulting in a stable, rut-resistant, and tough blend reliant on aggregate-aggregate contact for strength. The addition of a rich mortar binder further bolsters durability. SMA samples are prepared by blending coarse aggregate, fine aggregate, and filler based on standard code gradation charts, with or without stabilizers. Bamboo fiber, chosen as a cost-effective stabilizer, boasts high strength, tensile, flexural, and impact strength, as well as thinness, durability, tenacity, and stability. This project involves crafting SMA mixes using stone as coarse aggregate, partially replacing coarse aggregate with slag, and employing various stabilizers, with results compared across different bitumen content levels ranging from 4% to 7%. Stabilizers are added at an optimum rate of 0.3% of the sample weight.

KEYWORDS: Ageing, Flexural Strength, Permanent Deformation Resistance, Durability, Service Life

I. INTRODUCTION

When it comes to road paving, rigid pavement design is usually favoured above its more flexible counterparts. The increased strength, durability, and resistance to tear and wear under pressure are the primary reasons for this. The bituminous pavement on the road's surface is mostly responsible for the road's desirable characteristics. SMA has a layer of this gap graded mixture above it, and the resulting strength comes from the frictional forces generated between the stones. As a result of extensive in-lab research, the optimal binder content and stability of the SMA are established. SMA is a type of asphalt pavement mixture that is designed to provide superior durability, rut resistance, and skid resistance compared to traditional asphalt mixes. SMA is composed of a high %age of coarse aggregate, typically granite or limestone, which provides a strong stone-on-stone skeleton structure within the asphalt binder.The key components of SMA include a high asphalt binder content, typically polymer-modified to enhance durability and flexibility, and a high %age of coarse aggregate. The coarse aggregate is coated with a thin layer of asphalt binder to improve adhesion and prevent moisture intrusion. Additionally, SMA mixtures may contain fibers, such as cellulose or polyester, to further enhance strength and resistance to cracking.The design of SMA mixtures focuses on optimizing the aggregate gradation to maximize stone-on-stone contact and interlock, which improves stability and resistance to deformation under extreme traffic loads. SMA pavements are known for their excellent rut resistance, which makes them particularly suitable for high-traffic roads, highways, and intersections.One of the main advantages of SMA is its resistance to rutting and deformation, even under high temperatures and heavy traffic loads.

II. LITERATURE SURVEY

Putman, B. J.[1] investigated adding carpet fibers and used tires to SMA mixtures to create rut-resistant roads. The purpose of these fibers is to stop the asphalt binder treated with polymer from draining too much. The cellulose and polyester fibers that are frequently used in hot mix asphalt (HMA) were compared. The results did not reveal any appreciable variations in performance between combinations containing waste fibers and those containing polyester or cellulose. When compared to cellulose fibers, all three types of fibers increased the toughness of SMA mixes. Overall, the study raises the possibility of utilizing carpet and waste tire fibers in SMA, which could improve the sustainability and performance of highway pavement.

Awanti, S. S. [2], in this investigation, SMA mixes containing coconut fibers and polymer-modified bitumen (PMB 70 with SBS) were prepared. These mixtures were contrasted with traditional SMA mixtures that included cellulose and coconut fibers together with plain bitumen (VG 30 grade). The performance of the various blends was assessed using a variety of tests, such as permanent deformation tests, indirect tensile fatigue tests, and static indirect tensile strength tests. In comparison to the control mixes, the results showed how well the modified SMA mixes enhanced strength, fatigue resistance, and rutting resistance.

Parimita, P. [3], look into the viability of adding natural fibers to combinations of Stone Mastic Asphalt (SMA) for pavement building. This strategy looked at eco-friendly substitutes in an effort to overcome the drawbacks of synthetic fibers, such as their high price and restricted supply. The study assessed the effects of these natural fiber additives on the volumetric, mechanical, and drain-down properties of SMA by means of comparative analysis. The findings showed that natural fibers have the ability to improve cracking and rutting resistance, which will improve pavement performance. The study, taken as a whole, highlighted the significance of additives in SMA and suggested a sustainable method for building roads out of locally accessible resources.

Poornachandra Thejaswi [4], assessed how well sugarcane bagasse fibers (SBFs) stabilized combinations of stone mastic asphalt (SMA). To create distinct formulations, several combinations of SBF content, ranging from 0% to 0.60%, were added to the SMA mixtures. The performance of these combinations in flexible or bituminous pavements was then evaluated by testing them for important characteristics like drain down, tensile strength, and Marshall Stability.

Bhanu, V. U. [5], evaluated the effects on the stability of Stone Mastic Asphalt (SMA) mixtures for flexible pavement applications of the addition of Class-C Glass fibers (Glass-C) and Alkali Resistant Glass fiber (ARGF). The addition of glass fibers improved the SMA mixes' characteristics, especially when added at a concentration of 0.4% with a 6% binder component, according to the results. Increased stability values and decreased draindown demonstrated this improvement, underscoring the SMA mixes' potential for enhanced performance.

Hussain Ali Alshehri [6] examined the performance of recycled polyethylene (RP) as an asphalt modifier and waste fibers as stabilizers in Stone Mastic Asphalt (SMA) mixtures. The results showed that adding recycled fibers (RF) and RP considerably increased the SMA mixes' capacity to hold asphalt and other SMAll particles, resolving drain-down problems by as much as 81.43%. Additionally, RP increased resistance to rutting and moisture by 93% and 47.5%, respectively, demonstrating its potential as a useful asphalt modification. These results highlight the potential contribution of waste fibers and recycled materials to improving the sustainability and performance of SMA mixes, providing important information for the creation of environmentally friendly pavement solutions.

Marathe, S. P. [7], a summary of multiple research studies on SMA, covering its use with CRMB-55 binder, the effect of fibers on SMA characteristics, examinations of various fillers, and inquiries into the general features of SMA. Additionally, it investigates the use of glass fiber, carbon fiber, and organic fibers like pineapple and coir. These results improve knowledge and SMA optimization for a range of applications.

Liu, H. [8], examined the effects of lignin, polyester, and polypropylene fibers on the performance of SMA-13 asphalt mixture for high-speed vehicle pavements. The properties of the micro-surface were investigated using SEM and image analysis. Marshall Tests for splitting strength and stability were performed, while field assessments assessed skid resistance. The purpose of the findings was to comprehend how fiber affects mechanical behavior and skid resistance under practical circumstances.

Arabani M. [9], examined the use of tire cord mesh as an asphalt pavement reinforcement, concentrating on assessing how well it prevents cracks. The results, which were analyzed using experimental approaches, showed a significant improvement in the asphalt pavement's resistance to cracking. As a result, the application of tire cord mesh demonstrated encouraging potential to increase pavement longevity and lower related maintenance and rehabilitation costs.

III. SMA METHODOLOGY

Results for the creation of SMA, a gap graded combination, may vary greatly depending on the specific protocols, tools, and raw materials used; as a consequence, the mix can only be considered optimal within its specific environmental and topographical constraints. Coarse and fine aggregate, filler, binder, and stabiliser choices are crucial to this discussion. The flowchart of SMA methodology is shown below

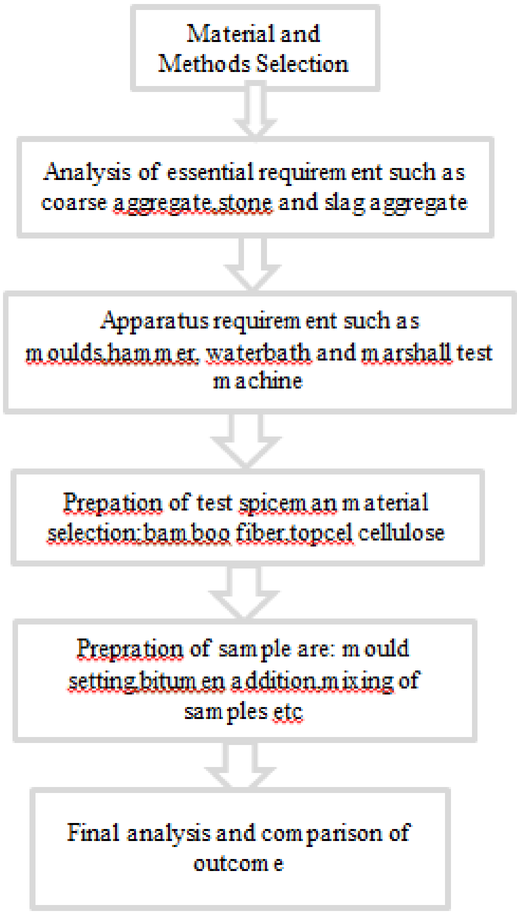

Figure 1: Flow chart of SMA Methodology

Step 1: To selecting appropriate material and methods that increased strength, durability and resistance to tear and wear pressure are primary reason for this.

Step 2: Coarse aggregates is sourced from two sources here stone aggregate and slag. Stone dust is used as the fine aggregate material in every scenario. As a stabiliser, we use a combination of bamboo fibre and top cell cellulose, bitumen of grade 60 to 70 is utilised as a binder.

Step 3: The gradation of the materials is mandated by the regulation IRC:SP79. Grading is accomplished by sieving; hence the corresponding IS sieve size is necessary .Once the sample has been sieved, it must be heated to 155c to 160c, a process that requires an oven. A binder, such a bitumen, is then added and the sample is combined in a special machine. Castings that need a heavy, predetermined falling hammer require moulds. The sample is water bathed at 60c for 30 minutes before to testing.

Step 4: Bitumen is favoured by engineers over other binders for use in the SMA Mix. This is because bitumen has excellent cementing characteristics in addition to being watertight, long lasting and resistant to powerful acids. Because of its low production cost, high strength and low environmental impact compared to other traditional fibres, bamboo has been suggested as available alternative.

Step 5: Before sending a SMA sample to be tested for stability and flow values by the marshall testing machine, the following steps are taken for the 13mm SMA composition, sampling of coarse and fine aggregates is performed in accordance with IRCSP79. Bitumen is measured by weight and heated in increments to between 170c and 190c .The gathered material is then extracted, taken to a mixing basin, and cocked. Next, the binder is added and the mixture is worked by hand to coat the aggregates evenly. The mixing temperature is controlled to remain below the maximum permitted by the binder.an extension collar and base plate are included with the 101.6mm by 63.5mm mould that has been thoroughly cleaned .Once the filter paper has been placed in the mould ,the mixture is poured in. Following careful removal from the mould, the specimen is placed on the flat, smooth surface and cooled at room temperature for 24hours

Step 6: Finally, the result obtained are discussed in the next section of the paper

IV. EXPERIMENTATION

A. Marshall Test on Specimen

Before the prepared sample is moved to the marshal test equipment, it is first maintained in a water bath at a temperature of 60 degrees Celsius for a period of thirty minutes. In order to guarantee precision while obtaining a dial reading, a dial gauge with a capacity of 25 kN is often used. Once the Marshall stability testing apparatus has been loaded, the rate of deformation is maintained at 50 millimetres per minute up to the point of failure. Marshall Stability is the load in kN at which the specimen fails, and it is obtained from the maximum load recorded in dial gauge by using the co-relation factor that is given for the standard 25 kN dial gauge. This is done so in order to determine the Marshall Stability.

When the maximum load is applied, the amount of deformation in increments of 0.25 mm is measured and recorded as Flow Value. The specific gravity of the sample, determined by the difference in mass between the wet and dry versions of the sample, is used to get the VA and VMA values.

Table 1: Find the Co-Relation Factor

Volume Of Specimen(cm)	Approximate Thickness of Specimen		Correlation Ratio
	mm	in.	
200 to 213	25.3	1	5.4488
214 to 225	27.0	1 1/16	4.9
226 to 237	28.5	1 1/8	4.459
238 to 250	30.1	1 3/16	4.0866
251 to 264	31.7	1 ¼	3.773
265 to 276	33.2	1 5/16	3.4986
277 to 289	34.8	1 3/8	3.2634

V. RESULTS AND ANALYSIS

In this section, we conduct an analysis of the Test Results that were acquired from the laboratory tests that were carried out using various types of gradation in accordance with the IS code for the different SMA Mixes. The examined findings are compared to one another, and then all comparisons are made to decide the results precisely in tabular and graphical form. Here, the co-relation technique is mainly used to calculate the Stabilized value, along with other essential values such as the bulk volume, the volume of the sample, the Gmb,Gmm,Ps value, and so on, so that the GSB, VA, and VMA values may be computed and presented on the graph.

A. Calculations

Gmb = Mmix/Bulk Volume of the Mix Ps=Magg/Mmix

VA= [(Mmix/Gmb-Mmix/Gmm)/(Mmix/Gmb)]*100

Gmm=W1+W2+W3+Wb/W1/G1+W2/G2+W3/G3+Wb/Gb

Where, W1 represents the total mix weight of coarse aggregate, W2 represents the total mix weight of fine aggregate, W3 represents the total mix weight of filler, and Wb represents the total mix weight of bitumen. Apparent specific gravities are denoted as follows: G1 for coarse aggregate, G2 for fine aggregate, G3 for filler, and Gb for bitumen.

Vb = Wb/Gb/W1+W2+W3+Wb/Gmm VMA= VA + V

Table 2: Using Stone Aggregate with Bamboo Fibre

A-2	4%	472.1444	2.4108	472.1444	2.3618	2.9302	15.4342	21.6384	5.9339
A-3	4%	476.1722	2.401	476.1722	2.3422	2.9302	15.9144	22.0598	5.8898
B -1	5%	479.0044	2.4206	479.0044	2.2834	2.891	15.8368	19.2276	8.24082
B -2	5%	474.2122	2.4206	474.2122	2.3128	2.891	15.9642	17.5812	8.26826
B -3	5%	479.1122	2.4108	479.1122	2.2834	2.891	15.288	18.1398	8.1478
C-1	5.5%	432.3956	2.6362	432.3956	2.5284	2.891	8.0066	18.9728	8.0948
C-2	5.5%	435.2278	2.6264	435.2278	2.5186	2.891	12.3774	19.355	7.8302
C-3	5.5%	441.8722	2.6068	441.8722	2.4794	2.891	10.6134	19.6882	8.5298
D-1	6%	438.1678	2.6362	438.1678	2.4696	2.8714	8.6338	22.6666	8.4084
D-2	6%	464.7356	2.5088	464.7356	2.3324	2.8714	9.065	22.8928	7.0756
D-3	6%	453.8478	2.5578	453.8478	2.3912	2.8714	9.4472	25.284	7.693
E-1	7%	434.14	2.6362	434.14	2.4696	2.8126	6.0466	25.3428	7.23044
E-2	7%	423.1444	2.695	423.1444	2.5284	2.8126	5.1258	25.4506	6.3896
E-3	7%	427.1722	2.6754	427.1722	2.5088	2.8126	5.524	25.774	6.8012

It is clearly shown in the above table2 that the at the bitumen content of 4%,5% our stability is increasing from 5.8% to 8.5% at the same time VA value is decreasing from 15.9 to 4.7. As we increase bitumen content its decreasing and from these values we can conclude that Slag aggregate with bamboo fibre is the best option as compared to the previous work. The tubular form is clearly shown in the comparison graphs below.

B. Comparison for Result Graphs Using Bamboo Fibre

In the figure 2 shown below the graph is placed between stability and bitumen percentage and we have calculated the results which is the green colour. Result obtained from the laboratory test conducted using various percentage of bitumen content. And the required results like effects of bamboo fiber slag and stone aggregate comparison is made between them and it is observed that increasing bitumen content from 4% to 5.5% the stability is continuously increasing from 5.8% to 8.4 and beyond 5.5% of bitumen content stability value start decreasing .

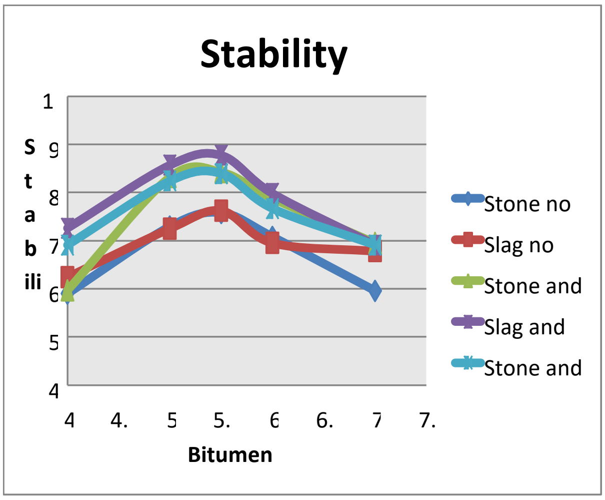

Figure 2: Stability comparison

In the figure 3 shown below the graph is placed between VA and bitumen percentage and we have calculated the results which is the green colour. Result obtained from the labourtary test conducted using various percentage of bitumen content.and the required results like effects of fiber slag and stone aggregate comparison is made between them and it is observed that increasing bitumen content from 4% to 7% the VA value will decrease from 15.5 to 5.

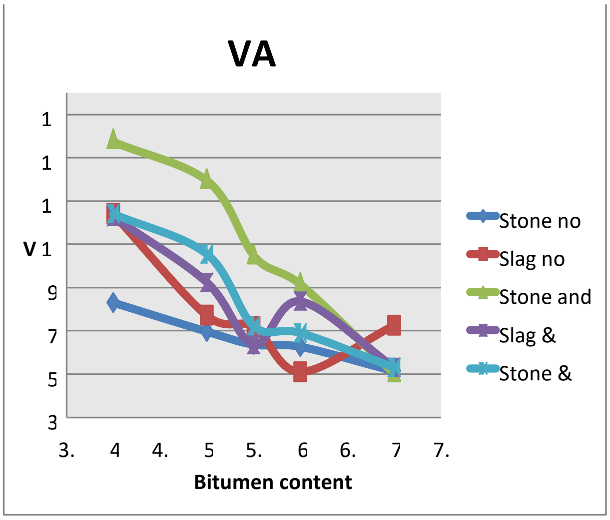

Figure 3: VA comparison

In the figure 4 shown below the graph is placed between VMA and bitumen percentage and we have calculated the results which is the green colour. Result obtained from the laboratory test conducted using various percentage of bitumen content. And the required results like effects of fiber slag and stone aggregate comparison is made between them and it is observed that at bitumen content of 4% and we get the VMA value 22.5 after the increasing bitumen content beyond 4% our VMA value get decrease upto 5.5%. Stone aggregate made with bamboo fibre is favoured over SMA mixes without fibre because it provides a better return on investment. Bamboo fibre may be used to provide more stability than a cellulose fibre and SMA mix without the usage of fibre.

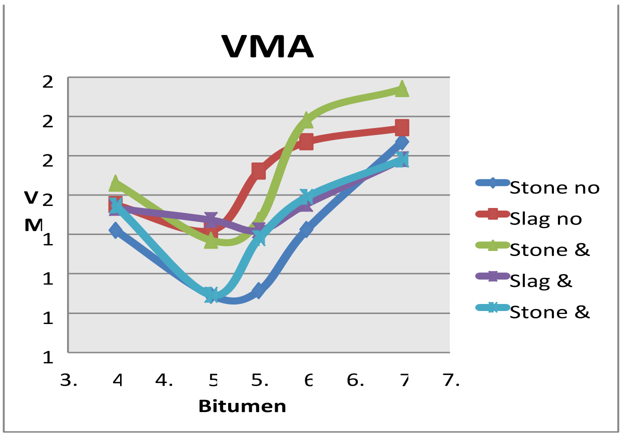

Figure 4: VMA comparison

VI. DISCUSSION

The SMA blend with Bamboo fibre has produced predictable outcomes with practical use. It's demonstrated that the quality of SMA mixes made without the use of stabilisers is much worse than that of SMA mixes prepared with any stabiliser. With regards to stability, coarse aggregate as slag reinforced with bamboo fibre performs best, followed by stone aggregate reinforced with bamboo fibre, and finally stone aggregate reinforced with Topcel Cellulose. In light of the prospective benefits to stability and Flow Value, using Bamboo Fibre as a stabiliser rather than Topcel Cellulose is strongly recommended.

VII. CONCLUSION

As a consequence of looking at every result, every graph, and comparing every result, we have found that:

Slag aggregate with bamboo fibre attained the highest stability, 8.4 %.

When it comes to the SMA Mix, the combination of the slag as coarse aggregate and the bamboo fibre is the best option.

Stone aggregate made with bamboo fibre is favoured over SMA mixes without fibre because it provides a better return on investment. Bamboo fibre may be used to provide more stability than a cellulose fibre and SMA mix without the usage of fibre.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] B. J. Putman & S. N. Amirkhanian, "Using leftover fibers in SMA blends," Resources, Recycling and Conservation, vol. 42, no. 3, pp. 265-274, 2004.

[2] S. S. Awanti, "SMA mixes made with plain bitumen and SBS modified are evaluated in a lab," in Procedia-Social and Behavioral Sciences, vol. 104, pp. 59–68, 2013.

[3] P. Pamiita, "Natural fibers' impact as an additive on the properties of stone-mastic asphalt," in Materials Science and Engineering, IOP Conference Series, vol. 970, no. 1, p. 012021, Nov. 2020.

[4] P. Thejaswi et al., "Using Sugarcane Bagasse Fibers to Improve Stone Mastic Asphalt's Moisture Susceptibility Properties," Advances in Materials Science and Engineering, vol. 2023, Article ID 5378738, 13 pages, 2023.

[5] N. P. Kumar and V. U. Bhanu, "Glass fibers' impact on stone-mastic asphalt," in Materials Science and Engineering, IOP Conference Series, vol. 1025, no. 1, p. 012020, 2021.
[6] H. I. A. A. Wahhab, M. A. Al-Osta, and H. A. Ashehri, "Performance of the modified SMA Mix made of waste fiber and plastic," Case Studies in Materials for Construction, vol. 19, e02566, 2023.
[7] S. S. Huddar and S. P. Marathe, "Flexible Pavement Based on SMA," International Journal of Science, Research, and Engineering Trends, vol. 5, no. 3, pp. 670-677, 2019.
[8] H. Liu et al., "Using an anti-skid surfacing and reinforced asphalt mixture design, fiber-based high-speed vehicle field testing is conducted on pavements," Resources, vol. 16, no. 2, p. 549, 2023.
[9] M. Arabani, S. M. Mirabdolazimi, and A. R. Sasani, "Examining the impact of waste tire thread mesh on asphalt mixes' dynamic behavior," Construction and Building Materials, vol. 24, no. 7, pp. 1156-1162, 2010.