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LABORATORY INVESTIGATIONS ON STONE MATRIX ASPHALT USING CELLULOSE FIBER INDIAN HIGHWAYS

Ravi Kumar[1]
1 M.Tech Scholar

Mr. Mohit[2]
2 Guide

Dr. Amit Gupta[3]
3 Co-Guide

(Geeta University Panipat HR)

ABSTRACT : Stone Matrix Asphalt (SMA) has better qualities than traditional asphalt mixes, it has attracted a lot of interest recently. In order to improve SMA combinations' performance on Indian highways, cellulose fiber incorporation is being investigated in this laboratory investigation. The aim of the study was to assess the impact of cellulose fiber on the mechanical characteristics and longevity of SMA, with particular attention to its capacity to withstand rutting,moisture damage, and fatigue cracking.

As part of the investigation, SMA samples with varied cellulose fiber percentages by asphalt binder weight were prepared. In accordance with Indian norms, laboratory experiments were carried out to evaluate the mixtures' rutting resistance, flow, indirect tensile strength, and Marshall stability. Furthermore, Hamburg wheel tracking and repetitive load axial testing were used to assess the SMA mixes' fatigue behaviour and moisture susceptibility, respectively.

The findings show that adding cellulose fiber generally increases SMA's resistance to rutting and dampness. Beyond a certain fiber level, nevertheless, performance begins to decline , especially in terms of fatigue resistance and mixed workability The results imply that cellulose fiber can be utilised to improve SMA's engineering qualities for Indian highway conditions in an efficient manner, extending the life and durability of road pavements.

This study offers suggestions for optimising fiber content depending on particular performance parameters, as well as insightful information about the possible advantages and difficulties of employing cellulose fiber in SMA. Future studies can concentrate on long-term performance tracking and field validation of SMA pavements treated with cellulose fiber in India's various traffic and climate scenarios.

In the current work, the percentage of additional fibers is 0.1%, 0.2%, 0.3%, and 0.4% by mix weight. According to the test results, regardless of the kind of mix, the ideal fiber content for all fiber mixtures is 0.3% of the mix's weight. Out of all the fibers, coir fiber performs the best, although sisal and banana fibers exhibit similar stabilising qualities.

Keywords- Stone Matrix Asphalt, stabilizing additives, volumetric characteristics, stability and strength characteristics.

1. INTRODUCTION

Stone Matrix Asphalt (SMA) outperforms traditional asphalt mixes in terms of rutting resistance, durability, and fatigue life, it has attracted a lot of interest recently. SMA produces a dense and long-lasting pavement structure appropriate for high traffic and heavy load scenarios by incorporating a larger percentage of coarse particles and a higher concentration of asphalt binder.

Research on adding fibers or other additives to SMA has been conducted with the goal of improving the material's mechanical characteristics and performance in a range of environmental settings. As an addition to asphalt mixes, cellulose fibers which come from sustainable resources like wood and agricultural waste have demonstrated encouraging outcomes. These fibers strengthen the asphalt mix's cohesiveness and stiffness, possibly lowering the need for long-lasting and environmentally friendly materials for road construction has been highlighted by India's quick infrastructure expansion. Stone Matrix Asphalt (SMA) has become a viable pavement choice because of its exceptional performance qualities, especially with regard to longevity and rut resistance.

SMA is a bituminous mixture that has been graded to enhance stone-to-stone contact, resulting in a strong structure that can resist high traffic volumes. Finding the ideal combination that is both cost-effective and preserves structural integrity and durability is one of the major problems in SMA design. To improve the SMA mix's performance, adding fibers has been thoroughly investigated and binder (PMB 70-10E). Particularly cellulose fiber has demonstrated a great deal of promise. This natural fiber is a perfect addition for Indian highways that are exposed to a variety of climatic conditions and large traffic volumes because it not only increases the mix's stability but also strengthens its resistance to deformation and moisture damage.

This work focuses on laboratory studies of SMA with cellulose fiber that are specially designed for Indian highway environments. This study attempts to offer important insights into the possible advantages and real-world uses of cellulose fiber-reinforced SMA by investigating its mechanical qualities and performance characteristics. The results of these lab studies may open the door to more durable and sustainable road infrastructure in India.

Scope Of Work

Water stagnation has harmed the majority of Indian roads. Recent research has demonstrated that gap-grading mixes, such as SMA, mitigate water-induced damages more effectively than traditional mixes. The SMA tradition in India is quite new because there aren't many requirements. This obtains appropriate research in several areas of SMA, India. It makes economic sense to replace these pricey synthetic fibers with natural fibers or other renewable materials. A evaluation of the effects of natural fibers as stabilised additives in Stone Matrix asphalt and their role in the mixture's engineering properties is recommended in the current investigative work.

Hot-mix asphalt: In a hot mix plant, the binder is heated to a specified temperature and blended. It is the most widely utilised composition in pavement made of asphalt.

Cold laid mix: It is made from a mixture of aggregates specified in a bituminous mixing plant. liquid bitumen without the appliance of heat.

Mixed-in-place or road mix: It is created by mixing bituminous coatings as emulsions (medium hard or moderately hard) in moderate amounts on the road surface using methods designed for exceptional road mixing equipment.

Penetration macadam: Penetration macadam is made from layers of coarse and uniformly sized aggregate that are spread and rolled onto the pavement and a certain amount of asphalt is sprayed to penetrate the aggregate. On the basis of method of composition and characteristics bituminous mixtures are classified as.

Dense-graded mixtures: They are usually used as surface and fixed layers of bituminous asphalts. Dense graded bitumen is again divided into two types which are dense bitumen macadam and bituminous concrete.

Open-Graded mix: Loose mixes contain a minimum of fine aggregate and are water permeable.

Stone Matrix Asphalt (SMA): Stone Matrix Asphalt (SMA) is a gap graded bituminous blend which maximizes coarse aggregate content and high in binder and filler with similarly less medium estimated aggregates. Hence it provides better stone to stone contact.

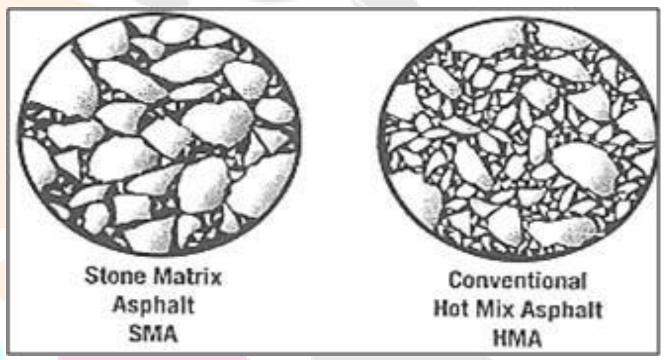


Fig. 1: Comparison of SMA and conventional HMA

Objective:

The main objectives focused in the present work are as follows.

- Investigate the properties of the SMA mixture with the addition of natural fibers as stabilizing additives.
- Investigate the production of fibers with SMA mixture and complete the mixture with optimal additive concentration.
- Recommend the best natural fiber of all the fibers added to the mix.

Kamaraj C., G. Kumar, G. Sharma, P.K. Jain and K.V. Babu (2004) carried laboratory investigations on natural rubber powder as stabilizing additive with VG-10 bitumen in SMA by wet process in addition to dense graded bituminous mix with cellulose fiber and stone dust and lime stone as filler material.

Ahmed Ebrahim Abu El-Maaty Behiry(2013) has stated that, the usage of steel slag , calcium carbonate as aggregate chips improves the mechanical properties of the SMA mix.

Mahabir Panda, Arpita Suchismita and Jyoti Prakash Giri (2013) has studied the performance of coir fiber as stabilizing additive and crumb rubber modified binder (CRMB) in SMA mix. He stated that addition of coir fiber up to 0.3% along with CRMB give better results.

Bindu C.S, Beena K.S had studied the drain down characteristics of SMA by the addition of the natural fibers along with waste materials and polymers**.** They found that, fiber additives show the good drain down characteristic's based on their absorptive nature.

Ahmad Nazrul Hakimi Ibrahim, Amar Syafudin Ahmad , Norliza Moh'd Akhir and Muhamad Nazri Borhan (2016) has studied the performance evaluation of SMA using geo- polymer as asphalt modifier. In this study, they discussed about the control mechanism of highly alkaline solution (NaOH and Na2SiO3) and fly ash and essential aspects of the performance of SMA mixture through geo-polymerization process were investigated

I. CHARACTERISATION OF MATERIALS

Aggregates

Sieve size in mm	% passing		%retained adopted	amount of aggregate taken in this binder content in gm						
	Intermediate	adopted		4%	4.50%	5%	5.50%	6.10%	6.50%	7%
				1152	1146	1140	1134	1128	1122	1116
16	100	100								
13.2	90-100	94	6	69.12	68.76	68.4	68.04	67.68	67.32	66.96
9.5	54-70	62	32	368.6	366.72	364.8	362.9	360.96	359.04	357.12
4.75	26-39	34	28	322.6	320.88	319.2	317.5	315.84	314.16	312.48
2.36	21-28	24	10	115.2	114.6	114	113.4	112.8	112.2	111.6
1.18	17-25	21	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.6	15-22	18	3	34.56	34.38	34.2	34.02	33.84	33.66	33.48
0.3	13-19	16	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
0.15	09-15	12	4	46.08	45.84	45.6	45.36	45.12	44.88	44.64
0.075	08-13	10	2	23.04	22.92	22.8	22.68	22.56	22.44	22.32
Filler	0	0	10	115.2	114.6	114	113.4	112.8	112.2	111.6

Aggregates with sizes 20mm, 10mm, and stone dust draw on the present investigation are extracted from local quarry. The properties of aggregates are shown below.

Properties	Obtained Values
Aggregate impact value (%)	14
Los Angeles Abrasion Value	23
Combined Flakiness and Elongation Index (%)	18
Water Absorption (%)	1.1
Specific gravity	2.56

The rich cover SMA is essentially meant to be hardened by the mineral filler portion. In the current work, OPC from the local market is employed as filler material, often making up 8%– 12% of the mixture that passes through a 0.075mm sieve. The filler material's physical characteristics that are used are given below.

properties	Obtained Values
Specific gravity	3.10
% passing 0.075 mm sieve (ASTM C117)	95

Tabulation for determination of Flakiness and Elongation Index

Size In mm	Wt. of sample taken in gm.	Aggregate passing in the gauge in gm.	Flakiness index	Average flakiness index	Aggregate retained in the elongation gauge in gm.	Elongation index	Average elongation index
25-20	392	60	15.36	18.83	130	33.16	21.5
20-16	734	135	18.39		131	17.84	
16-12.5	547	91	16.6		103	18.8	
12.5-10	280	78	27.2		54	19.28	
10-6.3	90	15	16.6		38	18.4	

Stabilizing additives

In order to improve the behaviour of the bituminous mix, various stabilising additives, such as fibres, rubbers, polymers, carbon black, artificial silica, or a combination of all materials, are added. Since Stone Matrix Asphalt is focused in the present work, which has a higher air void content and a high concentration of binder needed stabilising additive to prevent drain down effect, bitumen modification has been carried out to improve the performance of the asphalt pavement. Fiber as a stabilizing additive.

The earliest known application of fibres dates back 4,000 years, to China, when they were used to build an arch out of fiber- infused clay. However, contemporary research on fibres in bituminous blends began in the early 1960s (Mahrez, 2003).

As reinforced materials, fibres are affixed to the bituminous mixes. Fibres lessen the SMA mix's draining impact while also boosting strength and stability. The various fibre types that are added to the SMA mix include natural, mineral, polymer, and cellulose fibres.

In the current study, different weight percentages of cellulose fibre are used to represent cellulose in the blend. The fibres' images and each fiber's characteristics are displayed are shown in Table 2.

Cellulose Fiber

Bitumen

Bitumen works as a binder in the mix. Bitumen of VG-40 acquired from (IOCL Panipat) Refineries was utilized the current investigation. The Physical properties of bitumen are illustrated and the test results are shown.

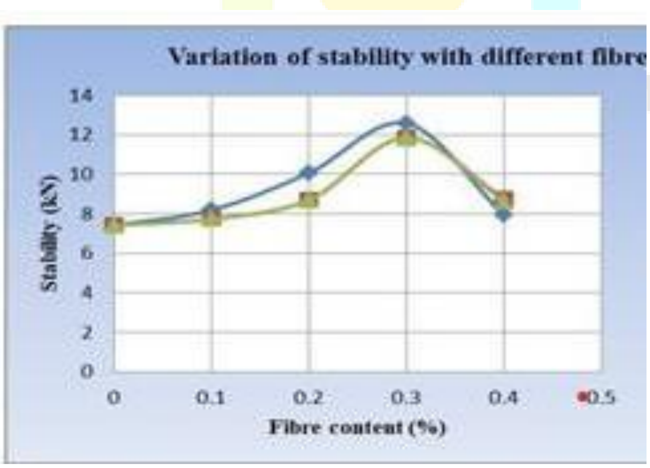
Physical properties of bitumen

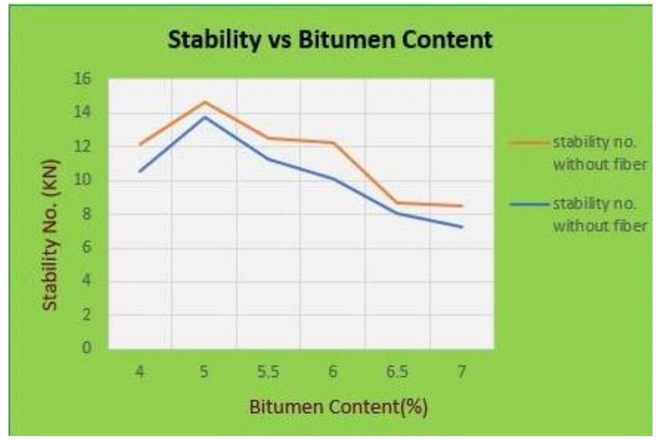
Properties	Results obtained
Specific Gravity	1.04
Softening Point (°C)	52
Penetration @ 25°C	62
Ductility @ 27°C (cm)	72
Flash Point (°C) Fire Point (°C)	190 240
Viscosity at 60 °C(Poise)	1100

RESULTS AND DISCUSION

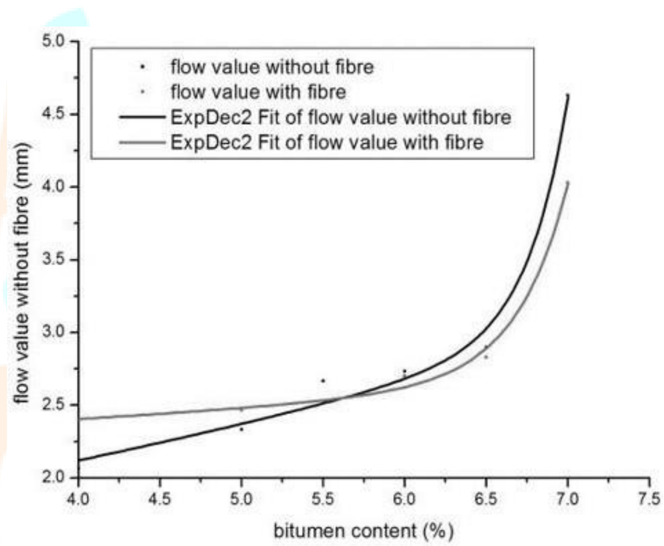
Results and discussions of Marshall mix design Marshall Stability and flow value

It is evident that the presence of fibre in the SMA mixtures greatly improves the stability values, which will cause the mixture's toughness to increase. Figures 3 and 4 show how the Marshall Stability and flow value vary with different fibre contents. According to Fig. 3, when the fibre concentration increases, the stability of the mixes stabilised by fibre increases initially, reaches a maximum value, and subsequently drops.





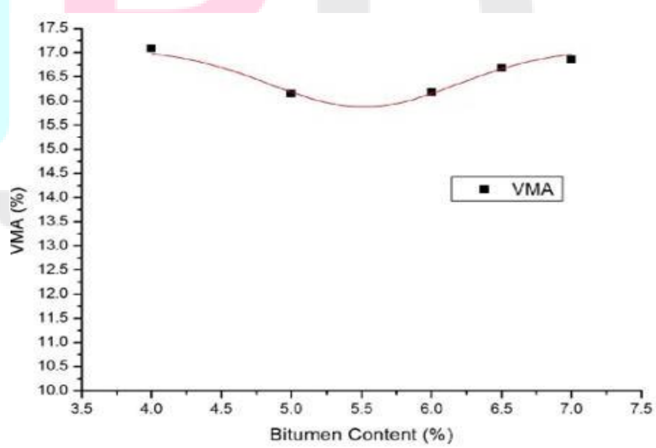
Stability vs. Bitumen Content



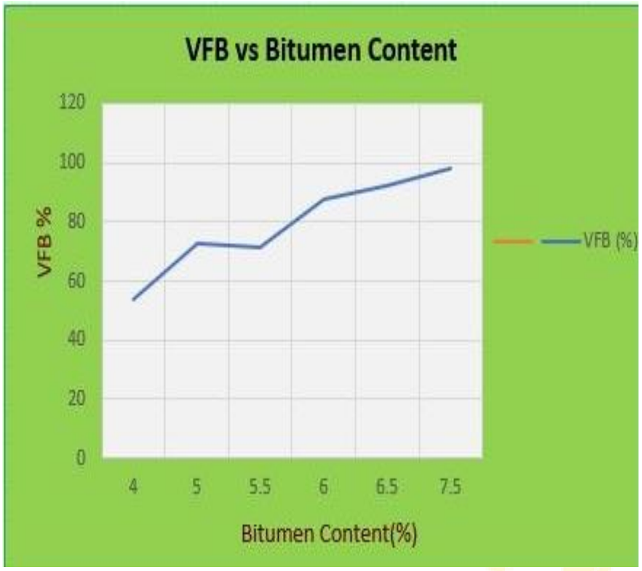
FLOW VS. BITUMEN CONTENT

Bulk Specific Gravity

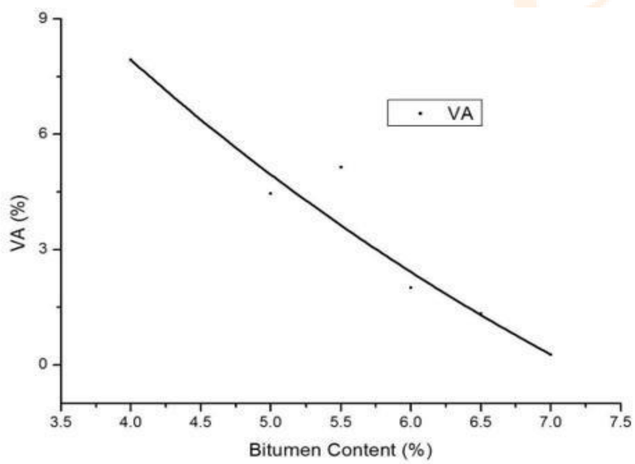
The bulk specific gravity of bituminous mixture decreases with increasing fiber content in SMA.



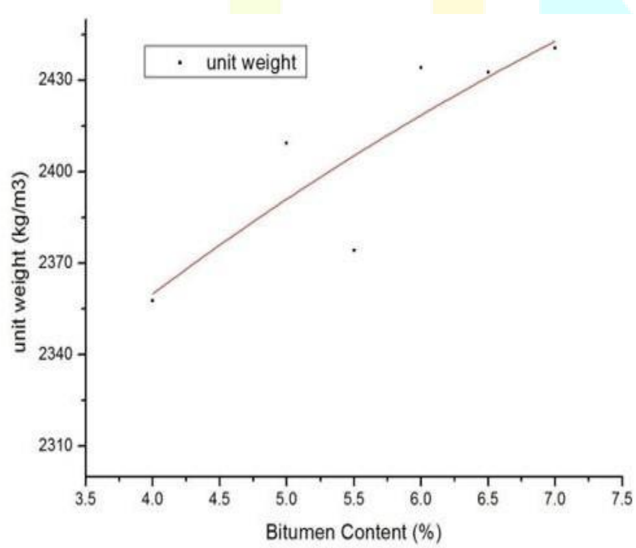
VMA vs. bitumen content



VFB VS. BITUMEN CONTENT



VA vs. bitumen content



Unit wt. vs. bitumen content

CONCLUSION

Stability And Volumetric Characteristics

- Regardless of fiber type, the maximum values of stability, Marshall coefficient and bulk density of SMA mixtures are obtained with 0.34% fiber content.
- When comparing different types of fiber-stabilized SMA mixtures, the mixtures containing coconut fiber have the best stability (12.58 kN), indicating their higher flow resistance and better performance than mixtures with other fibers. The percentage increase in stability compared to the control mixture is approximately 70% when cellulose is used in SMA and approximately 60% in SMA with other fibers
- The flow ability of SMA mixtures decreases after the addition of fibers. Due to the stiffness of the fibers in the mix, the mixes become less flexible, resulting in low flow ability. However, the flow values of all SMA compounds are within the required specification range of 2-4 mm.
- The Marshall index of the coir stabilized SMA mixture at 0.34% fiber content is almost double that of the reference mixture, which indicates its better resistance to permanent deformation and also shows that these mixtures can be used in pavements where a stiff bituminous mixture is required.
- Cellulose fiber stabilized SMA has the highest volume specific gravity compared to other fibers. Because higher specific gravity results in better engineering mixes, coke stabilized mixes perform better than other stabilized mixes.
- Considering bulk properties, at 0.34% fiber content, air voids increase by 11.5%, VMA increases by 2.2%, while VFB decreases by 2.4% in mixtures stabilized with cellulose fibers. The percentage changes are respectively 9.25% increase in air void, 5.4% increase in VMA and 1% decrease in VFB in cellulose fiber stabilized mixtures. While in mixtures stabilized with banana fiber, an increase in air content of 8.5%, VMA by 5.9% and a decrease in VFB by 1% are observed. However, all volumetric properties are within the required specification range, which also supports the use of these fiber additives.

Strength Characteristics

- All fiber-stabilized SMA mixes have a maximum tensile strength of 0.34% fiber content. Cellulose stabilized SMA has the highest tensile strength, indicating its higher fracture resistance compared to other fiber-stabilized composite materials. The percentage increase in strength compared to the control mixture is 160% for the untreated and 160% treated samples for the coir stabilized mixture and approximately 35% and 153% for both the lizard and banana fiber stabilized mixtures, respectively. Fiber reinforcing effect increases initially with increasing fiber content in SMA, but at high fiber content (more than 0.34%) induce coagulation and thus reduce its reinforcing effect, resulting in less stiff mixture with lower strength values.

- The test results converge to the conclusion that the best performance of the Stone Matrix Asphalt mixture is at 0.34% fiber content and with cellulose fiber.

Moisture Susceptibility

- The presence of fibers in SMA mixtures gives better retention, tensile strength ratio and retention strength index of 0.34% fiber content by weight of the mixture, and SMA has the best properties of cellulose, which indicates its better resistance to moisture damage.

- Based on the volumetric and mechanical properties of different fiber-stabilized mixtures, it can be concluded that the optimal fiber content of the fiber-stabilized Stone Matrix Asphalt mixture is 0.34% of the mass of the mixture and cellulose fiber additive is the best among the fibers investigated.

Future Scope Of The Project

Further investigate is urged on the subsequent aspects: -

- Only VG-40 control bitumen's were used in this research report. Other bituminous mixtures may be tested and analyzed.

- Natural fibers such as coir, sisal and banana were used in this research. Other fibers such as jute can be added to the bitumen mixture.

- Only one scale has been introduced here, so let's try to make a comparison in different scales• proposed by different agencies.

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