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Comparison of performance of Stone Matrix Asphalt (SMA) using ViaTop pellets and Sisal Fibers

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Abstract— **During the last few years, the technology of asphalt materials and mixtures has vastly improved. Especially for surface layers, more durable and rut resistant mixtures have been developed such as gap-graded mixtures like Stone Matrix Asphalt (SMA) which consists of 70-80% of coarse aggregates, 6-7% of binder, 8-12% of filler and 0.3-0.5% of fibre. Since SMA has higher coarse aggregate content, it provides more strength and consequent rutting resistance, and higher binder content improves the durability of asphalt mixtures. The fibres added will help to hold the binder in the mixture during production, transportation and construction processes. The present study investigates the performance of ViaTop pellets, a natural fibre coated with bitumen and Sisal fibre, also a natural fibre. The Optimum Fiber Content (OFC) for mixes produced using ViaTop and Sisal fibres was determined to be 0.3% by weight of the total mixture based on drain down test results. The bitumen used for the present investigation was VG-30 which is used for most applications for Indian climatic conditions. The Optimum Binder Content (OBC) was determined by adding bitumen from 5% to 7% by weight of the total mix in increments of 0.5%. Various tests were conducted such to determine Marshall properties, volumetric properties, Indirect Tensile Strength test, Moisture susceptibility test, rutting tests using Immersion Wheel Tracking Device (IWTD) and fatigue tests. The results indicate that ViaTop pellets can be used in SMA mixtures as a replacement for Sisal fibres.**

Keywords— **Stone Matrix Asphalt, ViaTop pellets, Sisal fibres, drain down, Optimum Fiber Content**

I. Introduction

One of the main objectives of research in pavement engineering is to improve the quality of pavement materials and pavement itself. This can be achieved either by exploring new materials which can be used in pavements or improving the characteristics of the available materials. In the present study, the latter approach was taken, and an attempt has been made to prepare Stone Matrix Asphalt (SMA) mixture using two natural fibres viz. ViaTop pellets and Sisal fibres.

SMA is a gap graded mixture which was developed in the 1960s to resist the rutting caused by studded tyres. The general idea of SMA is to fracture hard, durable, good quality stones into cubical shape and size consistent with the proposed layer thickness and then glue them together with the right quantity of moisture-resistant, durable mortar in such a way to possess stone-stone contact between the coarse aggregates. It consists of 70% of coarse aggregates which forms an aggregate skeleton, and the stone-stone contact between the aggregate particles renders strength and load-bearing capacity to the mixture. (Sarang, Lekha, Krishna, & Ravi Shankar, 2016).

SMA can be defined as a Hot Mix Asphalt (HMA) prepared with a gap-graded aggregate gradation in order to maximize the asphalt binder content and coarse aggregate fraction ("nchrp_rpt_425.pdf," n.d.).

A study to determine the feasibility of using waste fibres such as those obtained from processing scrap tyres and carpet manufacturing. It was determined that there was no significant difference in permanent deformation or moisture susceptibility in mixes containing the waste fibres compared to cellulose or polyester but the tyre, carpet and polyester fibres exhibited a significant improvement in toughness over cellulose fibres (Putman & Amirkhanian, 2004). Utilization of coconut fibre as a non-conventional fibre in SMA was evaluated and an addition of 0.3% fibre was able to contain the drain down within permissible limits and also vastly increased the Marshall properties of the mix (Panda, Suchismita, & Giri, 2013). Asphalt rubber produced by blending ground tyre rubber and asphalt was evaluated for its potential use in SMA. The tests revealed that asphalt rubber prepared with AC-20 and 30% ground tyre rubber with a maximum size of 0.85 mm was not feasible but SMA mixtures were produced meeting the volumetric requirements with AC-20 mixed with 20% ground tyre rubber with a maximum size of 0.60 mm (Chiu & Lu, 2007). SMA mixes were

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prepared using Asbuton, a natural rock asphalt obtained from Buton island in Indonesia which behaved both as a stabilizer and filler material. The results obtained indicated that Asbuton was effective in reducing the drain down and also increased the filler content. It also increased the dynamic stability and fatigue resistance of bituminous mixes (Suaryana, 2016). Three different types of fibres were used in the production of SMA mixes for tropical regions at abnormally high temperatures namely lignin, basalt and polyester. The results indicated that the dynamic stability and Marshall stability decreased with the increase in pavement temperatures (Thanh & Pei, 2013). Laboratory evaluation on SMA mixes prepared with glass fibres was made to determine the Marshall properties, rutting and fatigue characteristics. The results revealed that there was increased resistance to permanent deformation and fatigue life especially at higher stress levels (Mahrez & Karim, 2010). A laboratory study was conducted to investigate the use of waste nylon wires generated from industries producing toothbrush, paintbrush and hairbrush in SMA mixtures as a stabilizer. The results indicate that waste nylon wire can effectively improve moisture susceptibility, low temperature cracking and stability at high temperatures (Yin & Wu, 2018). Shredded waste plastics were used as stabilizer in SMA mixes and their percentages were varied from 0% to 16% in increments of 4%. Specimens were prepared in Superpave Gyratory Compactor to determine the Marshall properties of the mixes. At an optimum waste plastic content of 8%, the results obtained were comparable to that of SMA mixes prepared with PMB and no stabilizer. Hence, shredded waste plastic can also be used a stabilizer (Sarang et al., 2016)

A. Objective

The main objective of the present investigation is the laboratory evaluation of SMA using ViaTop pellets and Sisal fibres, both being natural fibres.

II. Materials used

A. Binder and stabilizing agent

Bitumen plays a vital role in bituminous mixes in imparting durability characteristics because of its viscoelastic nature. For the present study, a virgin binder VG 30, which is widely used for Indian climatic conditions has been used. The physical properties were determined based on the specifications laid down by the American Society of Testing and Materials (ASTM) and the results have been presented in Table 1.

The stabilizing agents used were ViaTop pellets and Sisal Fibers. Both the fibres are natural fibres and ViaTop pellets are natural fibres coated with bitumen. Tables 2 and 3 show the characteristics of ViaTop pellets and Sisal fibres, respectively.

B. Aggregates

The crushed granite aggregates which satisfied the requirements of SMA as per IRC SP 79 2008 were used for the present investigation. Various aggregate tests were conducted and the results obtained along with their specifications have been tabulated in Table 4

Table 1 Properties of bituminous binder

Property Tested	**VG-30**	
	Results obtained	**IS requirements***
Penetration, mm at 25°C	62	50-70
Softening point, °C	58	Min. 47
Ductility, cm at 25°C	78	-
Specific Gravity	1.0	-
Flash point, °C	256	Min. 220
Absolute viscosity, Poises, 60 °C	2950	2400-3600
Kinematic viscosity, Poises, 135 °C	390	Min. 350

Table 2 Properties of Sisal Fiber

Property	**Sisal Fiber**
Diameter (μm)	50-200
Density (g/cm^3)	1.40
Cellulose content (5%)	67
Lignin content (%)	12
Elastic Modulus (GN/m^2)	9-16
Tenacity (M N/m^2)	568-640
Elongation at break	3-7

Source:(Kumar & Ravitheja, 2019)

Figure 1. Sisal Fibers

Figure 2. ViaTop Pellets

Table 3 Properties of ViaTop pellets

Property	ViaTop pellets
Content ARBOCEL ZZ 8/1	83%
Pellet length (mm)	2-8
Pellet thickness (mm)	4±1
Density (g/l)	450-550

Table 4 Properties of aggregates

Test	Results obtained	Requirements as per IRC SP 79 2008
Aggregate Impact Value	22%	Max. 24%
Los Angeles Abrasion value	21%	Max. 25%
Water absorption	0.48%	Max. 2%
Specific Gravity	2.72	-
Combined Index	23%	Max. 30%

III. Results and Discussion

A. Drain down test

Initially, the aggregates, binder and filler material were proportioned as per the standards mentioned in IRC SP 79 2008. When no stabilizer was added to the SMA mix, the drain down was exceeding the maximum permissible limit of 0.3% by weight of the mix. Hence, to control drain down, a stabilizer was required. In the present study, in order to determine the optimum fibre content, ViaTop pellets were added at 0.2%, 0.3% and 0.4% by weight of the mix.

Similarly, Sisal fibres were also added to the mix in the same percentages of 0.2%, 0.3% and 0.4% by weight of the mix. To determine drain down, the maximum recommended bitumen content was added at 7% by weight of the mix and the temperature maintained was the anticipated plant production temperature of 160°C and 170°C for a period of one hour. In both the fibre types, the optimum fibre content was found to be 0.3% by weight of the mixture.

B. Determination of Optimum Bitumen Content (OBC)

SMA mixes were prepared with optimum fibre content and bitumen contents of 5.5%, 6.0%, 6.5% and 7.0% respectively to determine the optimum bitumen content. Specimens were then cast in Superpave Gyratory Compactor by applying a ram pressure of 600 KPa, 100 gyrations and angle of internal gyration of 1.25°. From the Marshall tests carried out, the OBC content for SMA mix with ViaTop pellets was 5.9% and that using Sisal fibres was 6.3% respectively.

C. Indirect Tensile Strength Test (ITS)

The ITS test provides a measure of the tensile strength of bituminous mixes. The test was conducted as per AASHTO T 283. The tests were conducted on both conditioned and unconditioned samples prepared at OBC. Unconditioned samples were prepared by placing the samples in a water bath maintained at 25°C for 2 hours. The conditioned samples were prepared by placing them in a freezer maintained at -18±3°C for 16 hours and then placed in a water bath maintained at 60±1°C for 24 hours. Table 5 shows the results obtained for SMA mixes using ViaTop pellets and Sisal Fibers

Table 5 Indirect Tensile Strength test results

SMA mix	Indirect Tensile Strength (Mpa)		TSR, %
	Unconditioned	Conditioned	
Using ViaTop pellets	0.881	0.791	89.78
Sisal fiber	0.892	0.784	87.89

D. Rutting tests

For conducting rutting tests using Immersion Wheel Tracking Device (IWTD), slabs of dimension (600*200*50) mm were cast. The test results are as tabulated below:

Table 6 Deformation of SMA in rutting test

No. of Passes	Deformation (mm)	
	ViaTop pellets	Sisal Fiber
0	0.0	0.0
1000	2.0	1.6
2000	3.3	2.6
3000	4.1	3.4
4000	5.2	4.3
5000	5.7	5.0
6000	6.1	5.4
7000	6.4	6.0
8000	6.6	6.7
9000	6.8	7.1
10000	7.0	7.2

E. Repeated Load tests

Pavement distresses arising out of repeated loading on flexible pavements is one of the common problems. Hence, to consider the effect of repeated loads, fatigue tests were carried out in the laboratory on cylindrical specimens by applying a compressive load. The tests on both the SMA mixes were carried out at a frequency of 1Hz, rest period of 0.1second, by applying 15%, 33% and 50% of the minimum failure loads in ITS tests for all samples and the temperature maintained was in the range of 38° to 40°C. The fatigue life is the number of cycles to failure, as obtained in the repeated load test. Table 7 shows the data of the repeated load test.

Table 7 Repeated Load Test

SMA mix	Applied Load (N)	Loading (%)	Initial Tensile stress (MPa)	No. of cycles
With ViaTop pellets	4798.17	49.81	0.438	62
	3186.29	33.08	0.292	426
	1495.04	15.52	69.03	8156
With Sisal Fiber	4812.39	79.27	0.692	53
	3192.37	33.25	0.293	381
	1461.59	15.22	0.134	5669

F. *Discussions*

The drain down test was conducted using the wire mesh basket apparatus as mentioned in ASTM D6390 at maximum prescribed bitumen content for SMA at 7%. It was found that the drain down was exceeding the prescribed limits. Hence there was a need to incorporate fibres to the mixture. The optimum fibre content for ViaTop pellets and Sisal fibres were found to be 0.3% by weight of the mixture.

The Optimum Bitumen Content obtained after carrying out tests to determine Marshall and volumetric properties were found to be 5.9% and 6.3% respectively for both the type of fibres.

Marshall stability tests were conducted at various bitumen contents. They were found to increase with an increase in bitumen content up to a specific limit and after that it was found to reduce. The Marshall stability values of SMA mixes at OBC prepared with ViaTop pellets and Sisal fibres were found to be 11.89 kN and 10.71 kN respectively.

The flow of both the bituminous mixes was in the range of 2.60 to 3.70 mm.

The stone to stone contact in the SMA mixes used in the present study was ensured by determining the Voids in coarse aggregates of both the mixes. The VCA of the SMA mixtures varied in the range of 0.80 to 0.89 times that of the coarse aggregates in the dry rodded condition.

The rut depths after 10000 cycles do not show much variation. The deformation after 10000 cycles was found to be 7.0 mm and 7.2 mm respectively for SMA mixes incorporated with ViaTop pellets and Sisal fibres respectively.

The ITS tests were conducted on conditioned and unconditioned samples at 7±0.5% air voids using the Superpave Gyratory Compactor. The Tensile Strength Ratios (TSR) calculated were found to be higher than 85%.

Repeated load tests were conducted on SMA mixes with both the fibres at 15%, 33% and 50% of the minimum failure loads in ITS test. The fatigue life of the SMA mix with ViaTop pellets was observed to be higher than that of Sisal fibres.

IV. Conclusions

From the laboratory tests conducted, the following conclusions may be drawn:

- The drain down test results prove that on the addition of 0.3% ViaTop pellets and 0.3% of Sisal fibres were effective in controlling the drain down of bitumen from the bituminous mixes.
- The Optimum Bitumen Contents for mixes with ViaTop pellets and Sisal fibres were determined to be 5.9% and 6.3% respectively.
- Voids in Coarse Aggregates of the SMA mixes is in the range of 0.80 to 0.89 times that of the dry rodded condition.
- From Immersion Wheel Tracking Device, it was observed that the SMA mix with ViaTop pellets was less susceptible to permanent damage than the mix prepared with Sisal fibres.
- The Tensile Strength Ratio was found to be more 85% for both the mixes. A higher Tensile Strength Ratio was observed for the bituminous mix with ViaTop pellets which indicates better cohesive strength compared to that of the mix prepared with Sisal fibres
- Repeated load tests conducted on both the mixes proved that the SMA mix with ViaTop pellets is higher than the mix with Sisal fibres.

Hence, from the above conclusions, it can be observed that the laboratory performance of SMA mix with ViaTop pellets is similar to that of the mix with Sisal fibres.

Hence, ViaTop pellets can be used as an alternative to Sisal fibres in the production of SMA mixtures.

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