Laboratory Investigations of Stone Matrix Asphalt By Using Natural Fibres

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Abstract- *Road network is important to the economic development, social integration and trade of a country. Inadequate transportation facilities could have an effect on socio-economic and cultural development of a country. In India, increase in the volume of traffic and significant loading conditions requires a huge development for better, durable, and more effective roads that prevents or reduces the distress of bituminous asphalt. In Indian highways, the wearing coat is laid by dense graded bituminous mixtures; hence the major distress is due to moisture induced damages. The SMA mixture is used to restrain the distresses and provide better durability in the bituminous pavements.*

In this study, it is proposed that the effect of various natural fibres on the behaviour of the SMA mixes as stabilizing additives. Natural fibres for instance coir, sisal and banana are applied as stabilizing to determine Marshall test and indirect tensile test to evaluate properties if the asphalt mix.

The percentage of fibres added in the present work is 0.1%, 0.2%, 0.3%, and 0.4% by the weight of the mix. The test results illustrates that, the optimum fibre content of the mix is 0.3% by the weight of mix for all the fibre mixes irrespective of type of the mix. Among all the fibres, coir fiber shows better results where as sisal and banana fibers show same properties on stabilization.

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

I. INTRODUCTION

The socio economic status of a country is directly symbolized by the road network patterns in it. Inadequate transportation facilities may diminish the social, economical and cultural growth of a country. In India the road development was started when independence and therefore the traffic demand is also increased gradually. The principal distresses like rutting and cracking in bituminous roads is mainly occurred because of induced water and intense traffic loads. The existence of moisture on surface material of pavements leads to change the mechanical properties and gets reduced the serviceability of roads. To meet up the results of such demands a rapid growth within the progress of conventional bituminous mix is necessary. Hence to attain the great strength and durability of paving roads SMA mix is suggested particularly in the tropical climatic conditions where average rainfall occurs.

According to Ministry of Road Transportation and Highway (MORTH, 2001) the bituminous mixes are classified as dense, semi-dense and open graded are commonly used as wearing coat materials in India.

Based on the method of production, bituminous mixtures are classified as follows.

Hot-mix asphalt: In the binder is heated and mixed in a hot mix plant at specific temperature. It is the most common mixture used in asphalt pavements.

Cold laid mix: It is produced at a bitumen mixing plant by a mixture of controlled quantity of aggregates specified liquid bitumen without the appliance of heat.

Mixed-in-place or road mix: It is created by blending total with the bitumen covers as emulsions (medium setting or moderate setting) in reasonable extents on the surface of street by methods for extraordinary street mixing equipment.

Penetration macadam: Penetration macadam is manufactured by layers of coarse and uniform sized aggregate, spread and rolled on the pavement, and squirt with certain amounts of asphalt to penetrate the aggregate.

On the basis of method of composition and characteristics bituminous mixtures are classified as

Dense-graded mixtures: These are normally utilized as surface course and fastener courses in bituminous asphalts. The Dense graded bitumen is again divided into two types namely Dense Bitumen Macadam and Bituminous Concrete.

Open-Graded mix: Open graded mixes has a minimum amount of fine aggregate and are permeable to water.

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.

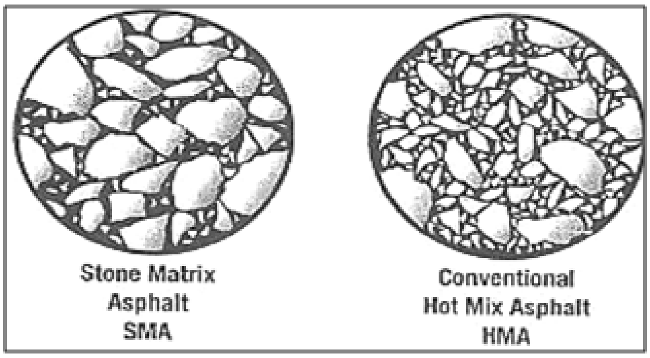

Fig. 1: comparison of SMA and conventional HMA

Research objective

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

- To study the characteristics of SMA mix along with the addition of natural fibres as stabilizing additives.
- To study the produce of fibres on SMA mix and to appear at the optimum additive content of the mix.
- To suggest the best natural fibre among all the fibres those are added in the mix.

Scope of work

Most of the Indian roads are damaged due to the stagnation of water. In recent studies it was exemplify that the water induced damages are reduced by gap-grading mixes like SMA rather than conventional mixes. In India the tradition of SMA is very frontier due to be short of of specifications. This acquires proper investigations in various portions of SMA, in India. Replacement of these expensive synthetic fibres with renewable materials like natural fibres is economically significant. In the current investigational work, a review on the impact of natural fibres as stabilized additives in Stone Matrix asphalt and their part in the engineering characteristics of the mixture is suggested.

II. LITERATURE REVIEW

SMA was first developed in German in 1960 later the investigations are being carried out.

Bradely et.al. (2004) examined that utilization of waste fibres such as carpet, tire and polyester fibres in SMA mix and evaluate the results through cellulose fibre. They found that there is no difference in moisture susceptibility and permanent deformation in the SMA mix enclosing waste fibres as compared to SMA mix that enclosed with cellulose or mineral fibre.

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 fibre 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 fibre as stabilizing additive and crumb rubber modified binder(CRMB) in SMA mix. He stated that addition of coir fibre 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 fibres along with waste materials and polymers**.** They found that, fibre additives shows the good drain down charecteristics 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.

III. CHARACTERISATION OF MATERIALS

Aggregates

Aggregates with sizes 20mm, 10mm, and stone dust draw on the present investigation are extracted from local quarry. The properties of aggregates are shown in table-1.

Table 1: Physical properties of the aggregate

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

Mineral filler

The part of mineral filler is basically to harden the rich cover SMA. Generally 8%-12% of the mixture which passing from 0.075mm sieve is used as filler material OPC from local market is used in the present work. The physica1 properties of filler material utilized are given in Table 2.

Table 2: Physical properties of the cement

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

Stabilizing additives

Bitumen modification has carried out to enhance the performance of the asphalt pavement. The main purpose of this is to decrease the drain down effect of the binder added in the surface coarse. Hence to improve the behaviour of the bituminous mix various stabilizing additives for instance fibres, rubbers, polymers, carbon black, artificial silica, or combination of all materials are added. Since Stone Matrix Asphalt is focused in the present work which has a more air void content and had a high concentration of binder needed stabilizing additive to prevent drain down effect.

Fibre as a stabilizing additive

The history of the application of the fibres is as old as 4000 years back has traced out in china, a construction of an arch made of clay mixed with the fibres. on the other hand, the modern investigations of fibres on the bituminous blend is started at early 1960s(Mahrez, 2003).

Fibres are attached as reinforced materials in the bituminous mixtures. Fibres helps to increase strength and stability and reduce the drain down effect of the SMA mix. The different types of fibres added in SMA mix are cellulose fibre, polymer fibre, mineral fibre and natural fibre.

In the present research work, three normal fibres are utilized to be specific, coir, sisal and banana fiber at various rates by weight of blend. The photos of the three fibres are appeared in Fig. 2, and the properties of all the fibres are shown in Table 3.

Fig. 2: Coir fibre, Sisal fibre, Banana fibre

Table 3: Properties of fibres

Properties	Coir fibre	Sisal fibre	Banana fibre
Diameter (µm)	100 – 450	50 – 200	80 – 250
Density (g/Cm^3)	1.45	1.40	1.35
Cellulose content (%)	43	67	65
Lignin content (%)	45	12	5
Elastic modulus(GN/m^2)	4-6	9 -16	8-20
Tenacity (MN/m^2)	131 – 175	568 – 640	529 – 754
Elongation at break (%)	15 – 40	3 – 7	1.0 – 1.2

Bitumen

Bitumen works as a binder in the mix. Bitumen of VG-30 acquired from Vishakhapatnam Refineries was utilized in the current investigation. The Physical properties of bitumen are illustrated and the test results are shown in Table 3.

Table 4: 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

IV. RESULTS AND DISCUSION

Results and discussions of Marshall mix design

Marshall Stability and flow value

It is marked that the existence of fibre in the SMA mixtures significantly enhancing the stability values, which will result in an expansion of toughness of the mixture. Variation in the Marshall Stability and flow value with various fibre contents are described in Fig. 3 and Fig. 4. Fig. 3 refers that the stability of the fibre stabilized mixtures enhance initially and reaches a maximum value then decreases with increased fibre content.

Table 5: Variation of Marshall Properties of SMA mix with different % of fibres as additive

Additive	%	Stability value (kN)	Flow value(mm)	Marshall Quotient (kN/mm)	Air void (%)	Bulk specific gravity	VMA (%)	VFB (%)
zero	0	7.518	3.18	2.332	4	2.32	18.865	78.769
Coir fibre	0.1	8.01	3.14	2.609	4.14	2.318	18.935	78.135
	0.2	10.252	3.05	3.303	4.31	2.315	19.039	77.363
	0.3	12.08	2.83	4.445	4.46	2.308	19.284	76.872
	0.4	7.125	2.72	2.918	4.64	2.298	19.634	76.265
Sisal fibre	0.1	7.743	3.17	2.443	4.09	2.31	19.214	78.714
	0.2	8.562	3.07	2.834	4.24	2.3	19.564	78.328
	0.3	11.526	2.86	4.148	4.37	2.291	19.879	78.017
	0.4	8.489	2.77	3.156	4.54	2.278	20.333	77.542
Banana fibre	0.1	7.826	3.16	2.447	4.09	2.308	19.284	78.791
	0.2	8.713	3.19	2.817	4.22	2.296	19.704	78.583
	0.3	11.154	2.86	4.145	4.34	2.286	20.030	78.333
	0.4	8.043	2.76	3.132	4.50	2.275	20.438	77.982

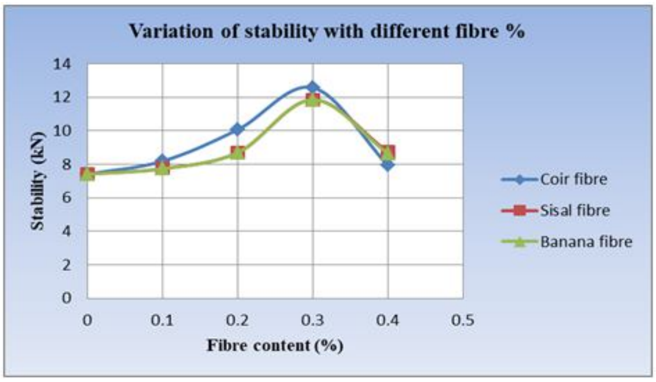

Fig. 3: Variation of stability with various fibre %

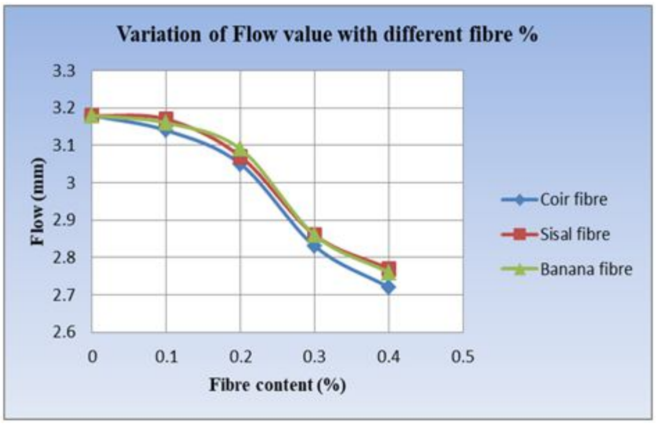

Fig. 4: Variation of flow value with various fibre %

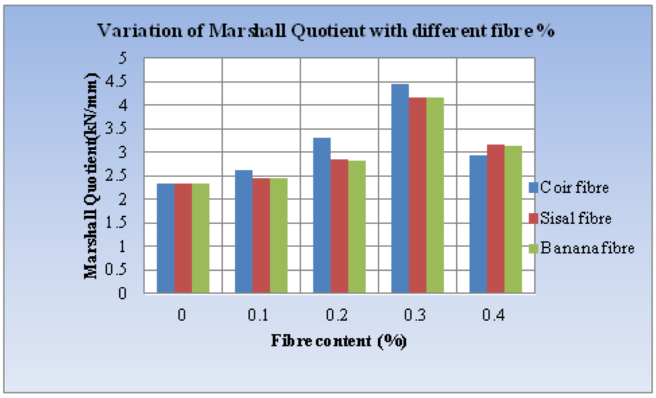

Fig. 5: Variation of Marshall Quotient with various fibre %

Bulk specific gravity

The bulk specific gravity of bituminous mixture decreases with increasing fibre content in SMA as depicted in Fig. 6

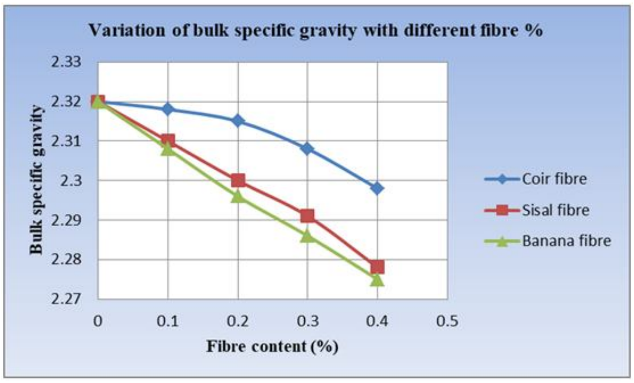

Fig. 6: Variation of bulk specific gravity with various fibre %

Air void, VMA and VFB

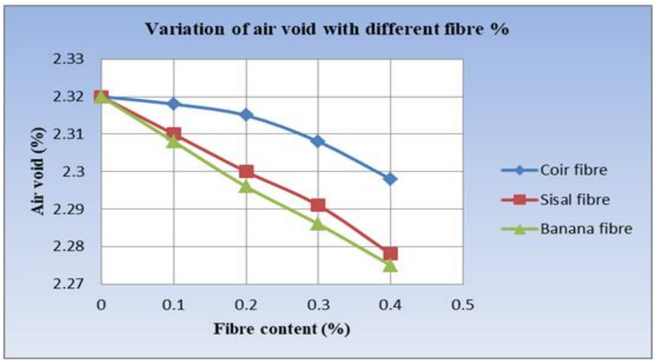

Fig. 7: Variation of air void with various fibre %

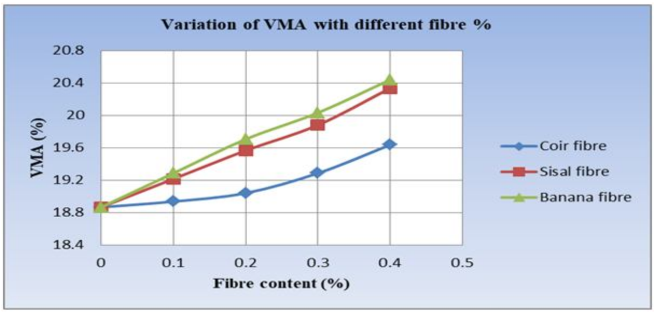

Fig. 8: Variation of VMA with various fibre %

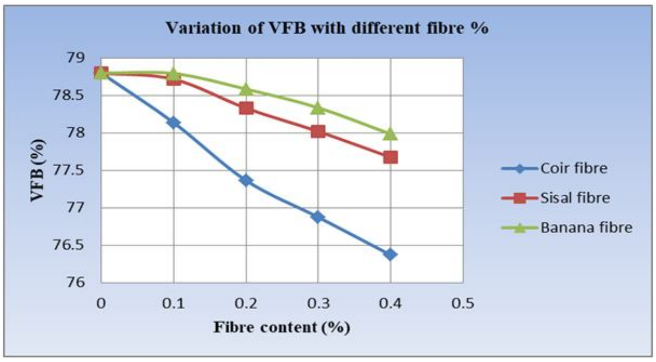

Fig. 9: Variation of VFB with various fibre %

RESULTS AND DISCUSSIONS OF INDIRECT TENSILE STRENGTH

Table 6: test results of indirect tensile strength

Type of additive	% added	ITS, Unconditioned (MPa)	ITS, Conditioned (MPa)	% TSR (MPa)
zero	0	0.8143	0.4253	52.23
Coirfibre	0.1	0.851	0.709	83.31
	0.2	1.0183	0.908	89.16
	0.2	1.065	1.0107	94.90
	0.4	0.8313	0.6915	83.18
Sisal fibre	0.1	0.8313	0.6915	83.18
	0.2	1.0619	1.0114	95.24
	0.3	1.1057	1.0766	97.37
	0.4	1.0538	1.0153	96.35
Banana fibre	0.1	0.8272	0.6941	83.91
	0.2	1.065	1.0107	94.90
	0.3	1.1018	1.0762	97.68
	0.4	1.054	1.015	96.30

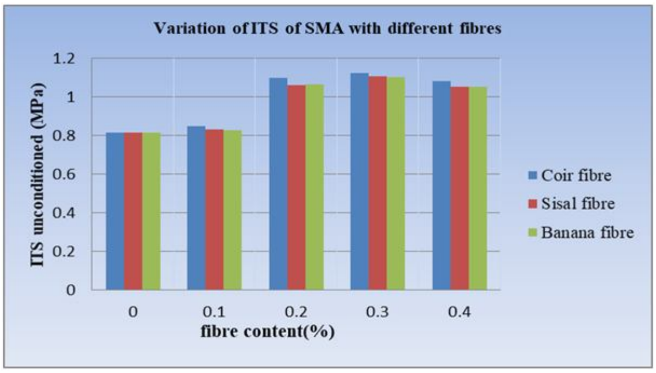

Fig. 10: Variation of ITS of SMA (unconditioned) with different fibre contents

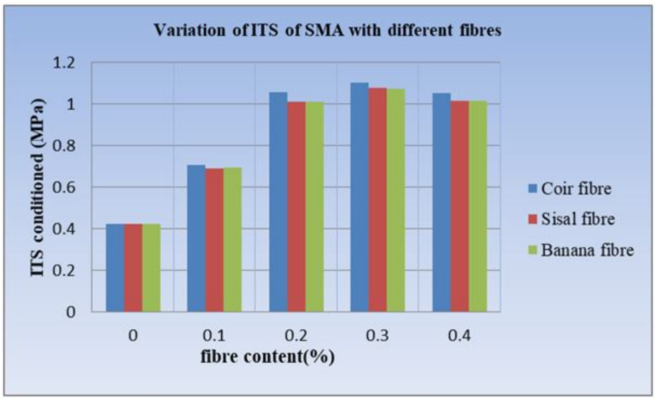

Fig. 11: Variation of ITS of SMA (conditioned) with different fibre contents

Moisture susceptibility of SMA mix

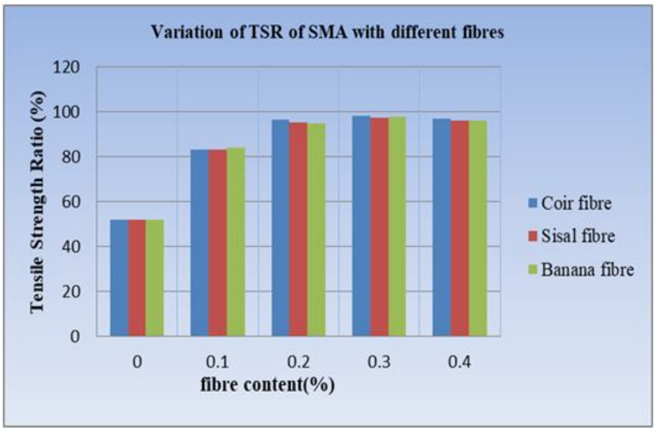

Fig. 12: Variation of the tensile strength ratios of the SMA with different fibre contents

V. CONCLUSION

Stability and volumetric characteristics

- Irrespective of the type of fibre, the maximum values of stability, Marshall Quotient and bulk specific gravity of SMA mixtures are obtained at 0.3% fibre content.
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- Comparing different types of fibre stabilized SMA mixtures, mixtures with coir fibre have the highest stability (12.58 kN), indicating their higher rutting resistance and better performance than mixtures with other fibres. The percentage increase in stability with respect to the control mixture is about 70% for SMA with coir fibre and about 60% for SMA with other fibres.

- Flow value of SMA mixtures decreases after adding fibres. Owing to the stiffness of fibres in the mixture, the mixes become less flexible resulting in a low flow value. However, flow values of all SMA mixtures are located within the required specification range of 2 to 4 mm.

- The Marshall quotient of coir fibre stabilized SMA mixture at 0.3 % fibre content is almost doubled with respect to the control mixture, indicating its better resistance against permanent deformations and also indicates that these mixtures can be used in pavements where stiff bituminous mixture is required.

- Coir fibre stabilized SMA has the highest bulk specific gravity when compared to mixes with other fibres. Since higher specific gravity results in better design mixes, the coir fibre stabilized mixtures perform better than other stabilized mixtures considered.

- Considering the volumetric characteristics, at 0.3% fibre content, air void increases by 11.5%, VMA increases by 2.2%, while VFB decreases by 2.4% for coir fibre stabilized mixtures. The percentage changes are respectively 9.25% increase for air void, 5.4% increase for VMA and 1% decrease for VFB in sisal fibre stabilized mixtures. Whereas 8.5% increase in air voids, 5.9% increase in VMA and 1% decrease in VFB are observed in banana fibre stabilized mixtures. But all the volumetric characteristics are within the required specification range which also supports the use of these fibre additives.

Strength characteristics

- All the fibre stabilized SMA mixtures has the maximum tensile strength at 0.3% fibre content. The coir fibre stabilized SMA exhibits the highest tensile strength showing its higher cracking resistance as compared to the other fibre stabilized mixtures. The percentage increase in strength with respect to the control mixture is 38% for unconditioned and 160% for conditioned samples for the coir fibre stabilized mixture, whereas around 35% and 153% for both sisal and banana fibre stabilized mixtures respectively.
- Fibre reinforcing effect increases initially with increasing fibre content in SMA, but at high fibre content (more than 0.3%) 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 0.3% fibre content and with coir fibre.

Moisture susceptibility

- The presence of fibres in SMA mixtures gives the higher retained stability, tensile strength ratio and index of retained strength at 0.3 % fibre content by weight of mix and the best performance is exhibited by SMA with coir fibre indicating its higher resistance to moisture induced damages.

Based on the volumetric and mechanical characteristics of the various fibre stabilized mixtures it can be concluded that ***the optimum fibre content of the fibre stabilized Stone Matrix Asphalt mixture is 0.3% by weight of mixture and the coir fibre additive is the best among the fibres investigated.***

Future scope of the project

Further investigate is urged on the subsequent aspects:-

- Only VG-30 review bitumen is used in the current investigation report. The other bitumen blends can be attempted and analyzed.
- The natural fibres like coir, sisal and banana has been utilized in this research work. The other fibres like jute may be put to the bituminous blend.
- Only one gradation was adopted here, so an attempt be able to made a comparison for different gradations suggested by various agencies.

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