International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

IMPACT OF ASPHALT MIX DESIGN ON VARIOUS PARAMETERS OF PAVEMENT CHARACTERISTICS

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ABSTRACT :- This research is an attempt to study the influence of additives on the characteristics of SMA mixtures and to propose an ideal surface course for the pavements. The additives used for this investigation are coir, sisal, banana fibres (natural fibres), waste plastics (waste material) and polypropylene (polymer). A preliminary investigation is conducted to characterize the materials used in this study. Marshall test is conducted for optimizing the SMA mixtures (Control mixture-without additives and Stabilized mixtures with additives). Indirect tensile strength tests, compression strength tests, triaxial strength tests and drain down sensitivity tests are conducted to study the engineering properties of stabilized mixtures. The comparison of the performance of all stabilized mixtures with the control mixture and among themselves are carried out.

Based on the volumetric, mechanical and drain down characteristics of the various stabilized mixtures it is inferred that the optimum fibre content is 0.3% fibre by weight of mixture for all fibre mixtures irrespective of the type of fibre. For waste plastics and polypropylene stabilized SMA mixtures, the optimum additive contents are respectively 7% and 5% by weight of mixture.

The coir fibre additive is the best among the fibres investigated. Sisal and banana fibre mixtures showed almost the same characteristics on stabilization. Waste plastics, which is the best additive among all the additives investigated, can replace the expensive polymers in SMA mixtures and shows even better performance than coir fibres. The statistical analysis authenticates the experimental findings.

The present study brings out the importance of the use of additives in Stone Matrix Asphalt and suggests an eco-friendly alternative to synthetic fibres and polymer additives. Extensive laboratory investigations carried out provide a thorough understanding of the engineering behaviour of the SMA mixture with various additives, which increases the level of confidence in the field application of this material. Waste plastics stabilized Stone Matrix Asphalt is the best among the mixtures investigated which is an ideal surface for Indian highways contributing to environmental sustainability by replacing energy intensive synthetic fibres and polymers along with finding out an effective solution for the disposal of waste plastics.

Keywords:
Stone Matrix Asphalt, stabilizing additives, volumetric characteristics, stability and strength characteristics, drain down sensitivity, moisture susceptibility.

I INTRODUCTION

Bituminous mixes are used in a flexible pavement to serve the following three important functions such as improved structural strength, facilitating subsurface drainage and providing surface friction especially in wet condition. The bituminous paving mixes as specified in MoRTH specifications (MoRTH, 2001) are commonly used in India. Mixes like bituminous concrete, semi-dense bituminous concrete, premix carpet, mix-seal surfacing etc., are commonly provided as wearing courses.

Unlike most developed countries, overloading is a major concern in India. The axle loads in India are quite heavy and further the speed is low with many stop/start condition which leads to the rutting of currently used bituminous mixes in India. Several studies have shown that permanent deformation (rutting) within flexible pavement is usually confined to the top 100 to 150 mm of the pavement. This means that both the binder and wearing course mixes should be designed to be resistant to rutting. That is why in cases of heavy traffic loads and high tyre pressures, it is considered prudent to use Stone Matrix Asphalt (SMA) mix which is the apt specification as per international practice (Kandhal, 2002). The load is carried directly by the coarse aggregate skeleton due to stone-on-stone contact. This will result in a long-lasting pavement with minimum maintenance which is going to be the future concern in India. The advantages of such specifications lie not only in long life but also in the reduced cost of travel with better serviceability. Recently, the Indian Roads Congress (IRC) has adopted a tentative SMA specification, (IRC SP 79:2008) which could be used under such circumstances.

OBJECTIVES

- The main objective of this study is to propose a durable surface course with Stone Matrix Asphalt by exploring the utilization of various additives such as Natural fibres and waste plastics which are abundantly available and to provide an eco friendly surface for Indian highways.
- To evaluate the role of additives
- On the mechanical and volumetric characteristics of SMA mixtures.
- On the moisture susceptibility of SMA mixtures.
- To study the effect of additives in SMA and to arrive at the optimum additive content of the mixtures.
- To propose the best natural fibre additive from the fibre stabilized SMA mixtures.
- To investigate the suitability of waste plastics to replace the expensive polymer additives in SMA.
- To suggest the best additive from all the SMA mixtures investigated.

METHODOLOGY

Literature Review:-

Literature review has to be conducted to identify the existing situation of roads in India, issues in maintenance and other problems related with durability. Secondary data can be collected from Government documents and reports published by the research institutions. Thorough literature study has to be carried out to analyse various researches on bituminous mixtures (Dense graded, Open graded and Gap graded mixtures) with and without additives.

Experimental Research:-

Based on the literature review, experimental research programme has to be formulated. As a preliminary investigation, procurement of various ingredients of

SMA and the evaluation of its properties has to be carried out. Marshall tests are proposed for the mix design of SMA (with and without additives). Indirect tensile strength test, compressive strength test and triaxial test are proposed for assessing the strength characteristics of SMA mixtures. The effects of additives against moisture induced damages on SMA mixtures can be studied by determining the retained stability, tensile strength ratio and index of retained strength of various mixtures. Drain down test is proposed on different SMA mixtures to assess the binder drain down. A comparative study on different characteristics (volumetric, mechanical and drain down) of various stabilized mixtures with varying additive contents and types has to be carried out for optimization. The ideal mix has to be proposed from the various SMA mixtures with optimum additive content.

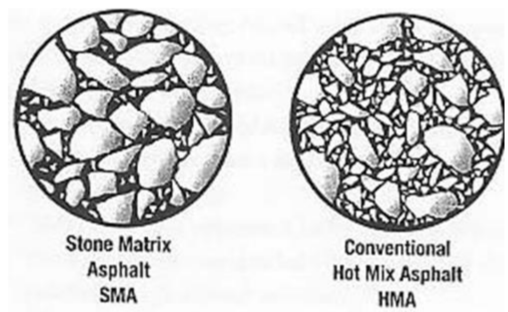

Fig. -1Comparisons between SMA and conventional HMA

- The Stone Matrix Asphalt (SMA) mixtures provide a durable surface course.
- Proven field performance of test track at Delhi recommends Stone Matrix Asphalt as a right choice to sustain severe climatic and heavy traffic conditions.
- But the concept of SMA in India is not so popularized and its application is very limited mainly due to the lack of proper specifications.
- This research is an attempt to study the influence of additives on the characteristics of SMA mixtures and to propose an ideal surface course for the pavements.
- The additives used for this investigation are coir, sisal, banana fibres (natural fibres), waste plastics (waste material) and polypropylene (polymer).
- Presently, synthetic fibres or polymers are used as stabilizing additives in SMA.
- Replacement of expensive imported synthetic fibres and polymer additives with

renewable/waste material in SMA is an environmental necessity.

- Here, a study on the impact of natural fibre / waste material as additives in Stone Matrix asphalt and their role in the volumetric, mechanical and drain down characteristics of the mixture is proposed.
- Emphasis is also given to assess the effect of water immersion on the performance of SMA mixtures with different additives.

Materials Used:-

- Aggregate of sizes 20mm, 10mm and stone dust
- OPC from a local market which makes a better bond with aggregate, bitumen and additive has been used in this study.
- Three natural fibres namely coir, sisal and banana fibre, a polymer, polypropylene and waste plastics in shredded form are used as stabilizing additives for the present study.
- In this study, three natural fibres namely coir, sisal and banana fibre at different percentages by weight of mixture are used.
- Bitumen of 60/70 penetration grade.

MARSHALL MIX DESIGN

Strength is measured in terms of the 'Marshall's Stability' of the mix following the specification ASTM D 1559 (2004), which is defined as the maximum load carried by a compacted specimen at a standard test temperature of 60˚C. In this test compressive loading was applied on the specimen at the rate of 50.8 mm/min till it was broken. The temperature 60˚C represents the weakest condition for a bituminous pavement.

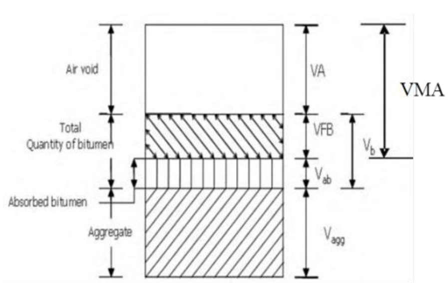

Fig-2 Phase diagram of the bituminous mix

Table-1 SMA mixture design criteria

Design Parameter	Design Criteria
Percent Air Voids	3 – 5%
Percent voids in mineral aggregate (VMA)	17 (minimum)
Stability value	6200 N(minimum)
Flow value	2 – 4 mm
Retained Stability (LS-283).	70% (minimum)
Draindown @ Production Temperature(AASHTO T305)	0.3 % (maximum)

MARSHALL TEST RESULTS

It may be noted that all fibre stabilized mixtures gave the maximum stability at 0.3% fibre content. Comparing different fibre stabilized mixtures, it is evident that the 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. This result could be attributed to fibre's adhesion and networking effects in the stabilized mixtures.

In plastics stabilized and polypropylene stabilized SMA mixtures, the coating of molten-plastics or polypropylene over the aggregate results in lesser voids and a reduction in the water absorption of the mix. This, obviously results in higher retained stability for the stabilized mixtures than the control mixture.

Optimum Binder Content at various % of WP and PP content

Additive content (%)	**Optimum bitumen content (%)**	
	SMA with WP	**SMA with PP**
0	**6.42**	**6.42**
1	**6.45**	**6.44**
3	**6.50**	**6.47**
7	**6.52**	**6.50**
9	**6.48**	**6.50**

Table 4.5 Retained stability of SMA mixtures with fibres

Additive (%)	Retained stability (%)		
	Coir fiber	Sisal fiber	Banana fiber
0	69	69	69
0.1	84	82	81
0.2	90	89	88
0.3	**95**	**93**	**93**
0.4	92	90	90

Table 4.7 Optimum Binder Content at various % of fibre content

Additive (%)	Retained stability (%)		
	Coir fiber	Sisal fiber	Banana fiber
0	**6.42**	**6.42**	**6.42**
0.1	**6.46**	**6.45**	**6.45**
0.2	**6.52**	**6.51**	**6.52**
0.3	**6.58**	**6.56**	**6.57**
0.4	**6.54**	**6.52**	**6.53**

Table 4.8 Optimum Binder Content at various % of WP and PP content

Additive content (%)	Optimum bitumen content (%)	
	SMA with WP	SMA with PP
0	6.42	6.42
1	6.45	6.44
3	6.50	6.47
5	**6.52**	6.50
7	6.50	**6.52**
9	6.48	6.50

INDIRECT TENSILE STRENGTH CHARACTERISTICS

1. Fibre stabilized SMA

The tensile strength of SMA mixes with fibre additive shows increasing trend up to 0.3% and it is found to be decreasing at 0.4% fibre content. This behaviour is because, the tensile strength is related primarily to a function of the binder properties, and its stiffness influences the tensile strength. Presence of fibre in the mixture makes it stiffer. The addition of fibre beyond a certain level can increase the viscosity of binder, which results from the effects of increase in volume of fibre particles due to the absorption of binder. Therefore, this increase in viscosity inhibits the ability of the binder to coat adequately on the surface of aggregates, thereby lead to the potential loss of bonds between the fibre, binder and the aggregate.

2. SMA stabilized with WP and PP

The waste plastics and polypropylene stabilized SMA mixtures show an increase in tensile strength up to 7 % and 5% respectively. The presence of additive in the SMA mixture enhances the adhesion between aggregate and bitumen, which leads to a decrease in the stripping of SMA and results in an increased tensile strength.

SMA mixture stabilized with 7% waste plastics shows a percentage increase (maximum) of 53% and 189% with respect to the control mixture for unconditioned and conditioned samples respectively and with 5% polypropylene the corresponding values are 44% and 168% respectively. This indicates that the mixtures containing additives have higher values of tensile strength at failure under static loading and the inclusion of additives improve the cracking potential. This would also suggest that stabilized mixtures are capable of withstanding larger tensile strains prior to cracking.

COMPRESSIVE STRENGTH CHARACTERISTICS

1. Fibre stabilized mixtures

In the case of fibres, coir fibre stabilized SMA shows the maximum compressive strength as compared to sisal and banana fibre mixtures. It is evident that all fibre stabilized mixtures show the maximum value of compressive strength at 0.3% fibre content. It can also be seen that fibre reinforcing effect increases initially with increasing fibre content, but at high fibre content, they could induce coagulation of fibres and thus reduce its reinforcing effect.

This can be the reason why the strength of SMA mixes decreases beyond 0.3% fibre content.

It show the percentage increase in compressive strength for fibre stabilized SMA mixtures at 25˚ C and 60˚C with respect to the control mixture. It can be observed that the percentage increase in strength with respect to the control mixture at 0.3% fibre content for coir fibre stabilized mixes at 25˚ C and 60˚ C are 17% and 42% respectively. Similarly, the percentage increase in strength is about 14% and 13% at 25˚C for sisal and banana fibre respectively and the respective increase at 60˚C are about 37% and 35%. Thus coir fibre stabilized mixture shows the higher resistance to crushing than the other fibre stabilized mixtures.

2. **SMA mixtures with WP and PP**

It can be observed that the maximum value of compressive strength is obtained for the SMA mixtures at 7% WP content and 5% PP content and the strength decreases beyond this additive content. This decrease in strength maybe due to the decrease in interlocking offered by the bitumen binder and the additive coated aggregates. It is evident that at 25˚ C, the percentage increase in compressive strength with respect to the control mixture is 25% and 18% respectively and at 60˚C, the percentage increase is 52% and 43% respectively for SMA stabilized with 7% waste plastics and 5% polypropylene. The waste plastics stabilized mixture shows the higher percentage increase as compared to PP stabilized mixtures.

SHEAR STRENGTH CHARACTERISTICS

The cohesion and angle of internal friction cannot be evaluated and compared in isolation. When comparing the performance of several mixes, the maximum shear stress that the mixture can withstand is of importance. This is dependent both on cohesion and angle of internal friction.

Table 7.2 Shear strength of various SMA mixtures

Type of mixture	Shear strength (kPa)
Control mixture	319.12
SMA with coir	384.63
SMA with sisal	368.64
SMA with banana	364.55
SMA with WP	363.51
SMA with PP	355.63

Data show that, all mix prepared with fibres, the higher values of stabilized mixture cohesion and shear strength can be associated to the fibre content of 0.3%, no matter the type of fibre. For waste plastics and polypropylene stabilized SMA mixtures, the highest cohesion and shear strength can be at 7% WP and 5% PP content respectively. Analysis however suggests that the high additive content beyond this percentage prevents the mixtures to develop aggregate interlock and therefore less cohesion and shear resistance. Among the stabilized SMA mixtures, the SMA mixes with coir fibre has the highest cohesion and shear strength. When compared with the control mixtures, these mixtures have 1.5 times higher cohesion and waste plastics stabilized mixtures has 1.3 times higher value. It is evident that cohesion is more influenced by the additive type.

CONCLUSION:-

Volumetric and stability characteristics:-

- The air voids of stone matrix asphalt mixtures increase after adding fibres into the mixture due to the networking effect of the fibres within the mix.
- Owing to the filling property offered by the additives waste plastics and polypropylene resulted in less air voids in the mixture as compared to the control mixture.
- However, the air voids of all mixtures are located within the required specification range of 3 to 5% (AASHTO T 312) which support the use of these additives.

Strength characteristics:-

- The mixtures containing additives have higher values of indirect tensile strength at failure under static loading as compared to the control mix, indicating the improved cracking potential of SMA mix.
- The effect of additive in increasing the indirect tensile strength value of SMA mix is more influential in the conditioned state due to the improved adhesion property.
- Presence of additives strengthen the bonding between the aggregates provided by the binder and thereby enhancing the stone to stone contact which will result in increasing the resistance to crushing. This gives rise to a stiffer and tougher

mix with considerable improvement in compressive strength.

Compressive Strength:-

- It can be observed that the percentage increase in compressive strength with respect to the control mixture at 0.3% fiber content for coir fiber stabilized mixes at 25˚C and 60˚C are 17% and 42% respectively.
- Similarly, the percentage increase in strength is about 14% and 37% at 25˚C and 60˚C respectively for SMA with sisal fiber and is about 13% and 35% at 25˚C and 60˚C when banana fiber is added.
- All the stabilized mixtures give the highest cohesion at 0.3% fiber content, irrespective of the type of fiber.
- The cohesion values are found to be decreasing when additive contents increased beyond this percentage.

Comparison of various stabilized mixtures:-

- Regarding the volumetric characteristics, fiber stabilized mixtures show higher air voids and voids in mineral aggregates than the other mixtures, but the voids filled with bitumen is more in waste plastics stabilized mixtures.
- It is observed that SMA mixes with 7% waste plastics has the highest Marshall stability, Marshall quotient, bulk specific gravity, indirect tensile strength and compressive strength showing its better resistance against permanent deformations, cracking and crushing as compared to other stabilized mixtures.
- The flow values of fiber stabilized mixtures are slightly more than that of waste plastics stabilized mixture.
- All the stabilized SMA mixtures show higher retained stability, tensile strength ratio and index of retained strength. The addition of 7% waste plastics in the SMA mixture gives the best result and exhibit superior water resistance property.
- When compared with the control mixtures, coir fiber stabilized mixtures has 1.5 times higher cohesion and waste plastics stabilized mixtures has 1.3 times higher value. Coir stabilized mixtures has the maximum shear strength when compared to other mixtures.

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