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A REVIEW ON STONE MATRIX ASPHALT BY USING STABILIZING ADDITIVES

Uma Maruthi Venkatesh V[1], Siva Gowri Prasad S[2]

[1] *Postgraduate Student, Civil (Transportation) Engineering, GMR Institute of Technology,Rajam,*
[2]*Assistant Professor, Department of Civil Engineering, GMR Institute of Technology, Rajam,*

ABSTRACT—The advanced technology of materials which is used in asphalt mixtures is developed in some countries like Europe and North America. The SMA (stone matrix asphalt) mixture is a gap graded open bituminous mixture which consists of high proportion of coarse aggregates, less medium sized aggregates with mineral filler and high binder content with low air voids. It resists permanent deformation and has the potential for long term performance and durability. The durability is provided by rich mortar binder. The flow and mechanical properties of the mix areto check the suitability of natural fibers as stabilizing agent in the mixture. The Stabilizing additives which includes fibers, polymers or waste materials in SMA mixture areused to stiffen the mastic at high temperature by reducing the asphalt drain down. This study compares the strength of pavement wearing course made with SMA mix without and with different fibers.The Optimum Fiber Length of 6 to 8mm was found at Fiber Content of 0.3%. The SMA mix with Nominal maximum aggregate size shows better performance without using the stabilizing additive.The Stability and Bulk density are high for coconut fiber when compared with other fibers. Natural fibers shows better performance for preventing asphalt drain down compared to the polymer fibers.

Key words: Binder, Drain down, Flow, Mineral filler, Natural fibers, Stone matrix asphalt, Stabilizing additive.

I INTRODUCTION

The life span of roads is decreased by conventional bituminous mixes due to the development of traffic and overloading of vehicles which leads to the reduction in the riding quality of vehicle. For a country like India, the rutting roads are a major problem with varied climatic condition, type of soil, rainfall intensity, binder grade. To resolve the issues related to pavements, the research is going on everywhere throughout the country.

SMA was developed in Germany and Sweden in the mid-1960’s to achieve a pavement more resistant to studded tire wear. SMA is also referred as Stone Mastic, Split Mastic, Grit Mastic, or Stone Filled Asphalt.To increase rutting resistance and durability, it is a gap-graded Hot mix asphalt (HMA) by applying the structural base of stone-on-stone contact. For heavily trafficked roads, SMA provides a deformation resistant, durable surfacing material. SMA is used as a hard-wearing asphalt developing for residential streets and highways in Europe, Australia, US and Canada **(Ibrahim et al., 2005).**

SMA incorporates a high degree of coarse aggregates content that interlocks with one another to outline a frame like stone skeleton that resists permanent deformation. The stone skeleton is stacked with a mastic of bitumen with filler to give sufficient stability of bitumen and finally the fibers are added to avoid drainage of binder during transport and placement.Typical SMA composition consists of 70−80% high and less medium sized coarse aggregate, 8−12% filler, 5.0−7.0% binder, and 0.3−0.5% fiber **(Roberts et al., 1996)**.

II STONE MATRIX ASPHALT COMPOSITION

SMA is a mixture of high proportion of coarse aggregates, less proportion of medium sized aggregates, mineral filler, bitumen and stabilizing additive. Fig. 1 indicates the major components of SMA mixtures. These open-graded stone-on-stone structure carry the heavy traffic moving loads, keep away from rutting, and provides long term toughness. To produce a cohesive mixture, fine aggregate, mineral filler and bitumen gives the binder adhesive and tendency to bond the stone skeleton together. Finally, the stabilizing additives (fibers or polymers) are utilized to hold the mastic within the structural layer. They harden the mastic form and avoid the draining off bitumen during storage, transportation and placing of SMA. The mastic fills those voids in the mixture for providing low air voids and highly durable bitumen **(AAPA, 1993)**. To minimize the binder drain down, Mineral fillers and Stabilizing additives plays a significant role for increasing the amount of bitumen binder used in the mix and improving the mix durability.

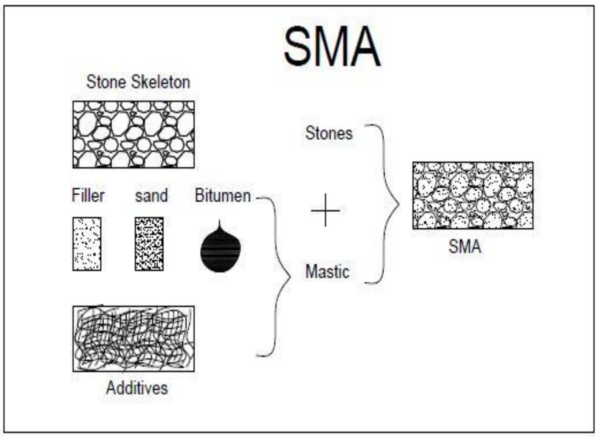

Fig. 1 Major components of SMA mixtures

High amount of coarse aggregate results in stone-on-stone contact between the aggregate particles in a mixture whichcreates highly resistant to rutting. These open gaps graded bituminous mixture results in a structurally extreme skeleton (Fig. 2). In summary, the high stone substance forms a skeleton type mineral structure which offers high resistance to deformation due to stone to stone contact, which is free of temperature.

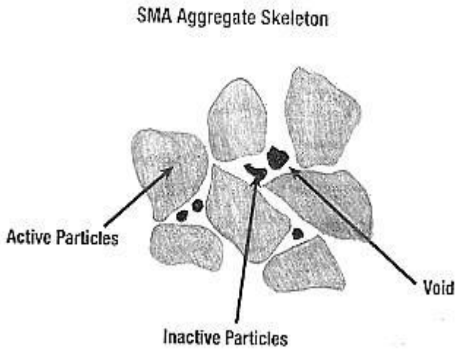

Fig. 2 SMA aggregate skeleton (NAPA, 1999)

SMA is designed by selection of materials. The materials are aggregates, mineral filler, binder and stabilizing additives. The coarse aggregate should be a durable, fully pulverized rock with a cubicle shape. Fine aggregate should be a minimum of 50% crushed aggregates. Mineral filler can be cement, stone dust, hydrated lime or fly ash. In general, materials of similar quality which is utilized as a part of dense graded bituminous wearing courses are required.

2.1 AGGREGATES

The strength, toughness and rut resistance of SMA mix depends mostly on the aggregate in the mix which being 100% crushed aggregate with cubical shape and have a rough surface texture. Fine aggregate used must be crushed as the internal friction of the fine portion generally contributes to the overall stability of SMA.

2.2 MINERAL FILLER

Mineral filler is a finely separated material which is passing through 0.075 mm sieve such as cement, hydrated lime, rock dust, fly ash etc which stiffens the rich binder SMA mix. Due to high percentage of filler in SMA mix, it is difficult to compact and results in cracking **(Brown and Haddock, 1997)**. In SMA mix, mineral filler is about 8-12% of the total aggregate mass. The mineral filler, bitumen binder and fiber make the mixture in the form of mastic which holds the mix together.

2.3 BINDER

Stone matrix asphalt contains more binder percentage ranging from 6 - 7.5% comparing with conventional dense graded mixes. The performance of the mix is normally improved with polymers and fibers. To prevent the drain down during transportation and placement of SMA mix, the binder helps to provide a thick coating to the aggregate. Polymer modified binders (PMB) can be utilized to give more deformation resistance. **Brown et al., 1997** reported that SMA with unmodified binder produces less rut resistant mixes than SMA by incorporating styrene butadiene styrene (SBS).

2.4 ADDITIVES

To reduce the drain down and bleeding problems, stabilizing additives have been introduced into SMA mixes. This stabilizing additive are added to stiffen the mastic at high temperature. In SMA mix, fibers andpolymers are used as stabilizing additives. Fibers are the best stabilizing additive to prevent drain down, where polymers are to improve the bitumen properties at low and high temperatures. **Brown and Cooley** 1999 concluded in NCHRP Report 425 thatfibers do better performance than polymers for preventing drain down.

The addition of fibers or polymer during the mixing process as a stabilizing agent has several advantages including increased binder content, increased film thickness on the aggregate, increased mix stability, interlocking between the additives and the aggregates which improves strength and reduction in the possibility of drain down during transport and placement. The stabilizing additives which includes plant fibers (coconut, sisal, banana, cotton, flax, hemp, jute, abaca etc.), animal fibers (silk, wool etc.), mineral fibers, cellulose fibers, glass fibers, and polymers.

III DISCUSSIONS

Aline Colares do Vale et. al **(March,2014)** have done the investigation on natural fibers namely coconut and cellulose fibers on SMA mixtures using two different design methods (Marshall and Superpave). The tests have been conducted for drain down, indirect tensile strength, resilient modulus, fatigue life, and moisture susceptibility. To prevent asphalt drain down during preparation, drain down test results shows that coconut fiber can be used in SMA mixtures as a replacement for cellulose fiber.

A.N.Meghana et. al **(March 2017)** have investigated on ZycoTherm additive which has been utilized as a part of different dosages at different temperatures to prepare warm mix asphalt in the laboratory. ZycoTherm additive can be utilized with an optimal dosage of 0.07% by weight of bitumen at 135^0 C mixing temperature for Warm mix asphalt (WMA) and 30% Reclaimed asphalt pavement (RAP) with 70% original aggregates containing 0.07% ZT WMA at 135^0 C gives better stability and performance than other mixes.

Bradley J.Putmanet. al **(February,2004)** have studied the possibility of using waste tire and carpet fibers in stone matrix asphalt (SMA). Stabilizing additive which includes fibers in SMA mixtures are used to avoid excessive drain down caused by moderately high contents of PMB. Cellulose and Mineral fibers are the commonly available fibers used in SMA. In this study, the performance of SMA mixture with waste tire and carpet fibers were compared with the commonly used cellulose and other polyester fibers. By comparing the mixtures of waste fibers with the cellulose or polyester, there is no difference in permanent deformation or moisture susceptibility. The tire, carpet, and polyester fibers improved the durability of the mixtures compared to the cellulose fibers.

EsmaeilAhmadinia et. al **(June 2011**) have determined the effect of incorporating waste plastic bottles (Polyethylene Terephthalate (PET)) on the engineering properties ofSMA mixture. The volumetric and mechanical properties of asphalt mixes that include various percentages of PET (0%, 2%, 4%, 6%, 8% and 10%) were calculated and assessed with laboratory tests. The appropriate amount of PET was found to be 6% by weight of bitumen. The outcomes were statistically analyzed and the determination of the significance at certain confidence limits was performed with the two-factor variance analysis (ANOVA). Moreover, some studies conducted on polyethylene modified asphalt mixture have also been taken into consideration in this paper. The results show that the addition of PET has a significant positive effect on the properties of SMA and it can promote the re-use of wastematerial in industry in an environmentally friendly and economical way.

Goutham saranget. al **(April,2015)** have prepared the SMA mix with two Nominal maximum aggregate sizes (NMAS) gradations of 16 and 13 mm. The laboratory tests were conducted to compare the two aggregate gradations. PMB was used as a binder material without using the stabilizing additive. Due to the usage of PMB as a binder material, drain down was in acceptable limits for both mixtures. Conventional samples were prepared in super pave gyratory compactor with bitumen contents of 5.0 %, 5.5 %, 6.0 %, 6.5 %, 7.0 % by weight of aggregates of the total mix. The Marshall properties of SMA mix is also determined.

K.Naresh et. al **(February 2015)** have studied the influence of recycle aggregates (RA) on characteristics of warm mix asphalt. Performance characteristics were assessed through Stability and Indirect Tensile Strength (IDT). Recycled aggregate was added proportionately at 10%, 15% and 20% of original warm mix asphalt. It was observed that the stability values are higher for WMA of recycled aggregate as compared with conventional asphalt mix. 15% RA has showed improved characteristics when compared with the other two percentages of recycled aggregates.

Mahabir panda et. al **(December,2013)** have conducted the laboratory tests on commonly available conventional Viscosity Grade (VG) 30 bitumen and another modified binder, namely Crum Rubber Modified Bitumen (CRMB) 60 along with a non-conventional natural fiber, namely coconut fiber which is richly available in India to provide improved engineering properties and preventing the usual draining of binder in SMA. The role of a particular binder and fiber with respect to their concentrations in the mix is studied for various engineering properties. Marshall procedure is followed to determine the optimum binder and optimum fiber contents and also to study the relative advantages of fiber addition in the SMA mixtures. Thereafter, the engineering properties under both static as well as repeated load conditions and moisture susceptibility characteristics have been studied. It is observed that only a marginal 0.3% coconut fiber addition brings significant improvement in the engineering properties of SMA mixes.

Majid Zargar et. al **(June 2012)** have conducted an experimental research on the application of waste plastic bottles (Polyethylene Terephthalate (PET)) as an additive in SMA. Wheel tracking, moisture susceptibility, resilient modulus and drain down tests were done on the mixtures with various percentages of waste PET as 0%, 2%, 4%, 6%, 8% and 10% by weight of bitumen content. By experimentation, the appropriate range for the amount of waste PET was determined to be 6% by weight of the bitumen content. The results show that the addition of waste PET into the mixture has a significant positive effect on the properties of SMA which could improve the mixtures resistance against permanent deformation, increase the stiffness of the mixand recycling of waste materials in a more environmentally and economical way.

Mario Manosalvas-Paredes et. al **(June 2016)** have studied the two SMA 11 mixtures designed with the same grading curve but with two different binders. The first binder used was modified with elastomeric polymers, styrene butadiene-styrene (SBS) and is termed PMB 45/80-65. The second binder was modified with rubber – end of life tyres (ELT's) and SBS, termed PMB 45/80-65 R. The study results show that both bituminous mixtures SMA11 –PMB 45/80-65 with fibers and PMB 45/80-65 R without fibers effectively satisfy the water sensitivity tests, binder drainage and resistance to permanent deformation.

Manojkumar et. al **(December 2016)** have done the experiments by adding basalt fiber to the SMA mix. The mix shows lesser stiffness and rutting value.Rutting characteristics of the mix were enhanced by adding the basalt fiberto the conventional cellulose fibers of 0.3%. Marshall Properties, Rutting characteristics, Stripping value and Drain down characteristics were enhanced when SMA Mix is prepared with basalt fiber.

M.S.Ranadiveet. al **(October,2017)** have used the fiber extracted from refrigerator door panels (FERD) and waste plastic in bituminous mixes for road construction. The effect of modification of bituminous mixes like SMA and Asphalt concrete (AC) with FERD and processed waste plastic in granular form was studied. The FERD was used to modify the SMA and AC, whereas waste plastic was used to modify AC. Different mixes of SMA and AC were prepared with and without filler material. Furthermore, the study was done with varying lengths of fibers (2, 4, 6, and 8 mm), which were added to the SMA and AC mixtures. Asphalt concrete mixtures with 0, 4, 6, 8, 10, and 12% waste plastic by weight of bitumen were prepared. The effect of the preceding on drain down, Marshall stability, and indirect tensile strength was promising.

S.S. Awanti (2013) have conducted the experimental investigations carried out on SMA mix which is prepared using PMB 70 with SBS and coconut fibers to prevent drain down of asphalt. Results were compared with SMA mixes prepared with neat bitumen VG 30 grade and coconut & cellulose fibers to prevent drain down of asphalt. Experimental work includes SMA mix design, static indirect tensile strength test at different temperatures, indirect tensile fatigue test and permanent deformation test. From the test results it was observed that SMA mixes with PMB 70 and coconut fiber shows higher static indirect tensile strength at different temperatures, higher fatigue life and higher rut resistance when compared to control mix of SMA.

Sharanyaet. al **(December 2015)** have done the investigation for improving the rutting characteristics on WMA with the addition of Polyester (PE) fibers. The Marshall properties such as stability, flow, bulk density, air voids, Voids in Mineral Aggregate (VMA) and Void Filled with Bitumen (VFB) were determined as per ASTM D 1559 and Optimum Binder Content (OBC) was determined as per Ministry of Road Transport and Highway (MoRTH) 5th revision 2013 guidelines. WMA prepared with bituminous concrete grade – I (MoRTH) was considered for the study and was modified with Polyester (PE) fibers. Performance characteristics of PE modified mix are supported with immersion type of wheel tracking device for evaluation of rut depth. From the test results, it is observed that WMA provides lower rut depth with increase in PE fiber content at optimum content when compared with conventional WMA mix.

IV CONCLUSION

1. The addition of fiber will affect the properties of bituminous mixtures by increasing its stability & flow value and decreasing the air voids.

2. The quantity of binder content is high for SMA mix due to gap graded mixture. This binder content can be reduced to prevent the asphalt drain down by adding the stabilizing additives such as fibers and polymers. However, the use of waste plastics as an additive is also used for giving significant positive effect on Marshall properties of SMA mix.

3. Compared to the other fibers, Coconut fiber shows better performance as a stabilizing additive.The optimum coconut fiber length was found to be 6 to 8mm and the optimum fiber content was 0.3% in most of the studies.

4. The Optimum amount of waste PET content was found to be 6% for improving the stiffness of the mix and resistance against the permanent deformation.

5. The SMA mix with PMB 70 and coconut fiber shows higher static indirect tensile strength, higher fatigue life and higher rut resistance when compared with conventional mix of SMA.

6. The SMA mix with nominal maximum aggregate size shows better performance without using the stabilizing additive.

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