A REVIEW OF USING SISAL FIBER AND COIR FIBER AS ADDITIVES IN STONE MATRIX ASPHALT

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Abstract - *This paper provides a review of using Sisal fiber and Coir fiber as additives in stone matrix asphalt. Stone matrix asphalt is part of hot mix asphalt and it is gap-graded asphalt. Represented by high coarse of aggregates, the contents of asphalt is high, fibers and polymers are additives used to the SMA as stabilizers. Coarse aggregates are playing an important role in maximizes the stone-to-stone liaison and intermixing in the mixture that provides the strength and provides durables rich mortar. In stone matrix asphalt used fibers and polymer as an additive to SMA to prevent drain down of the SMA mix. In the highway industry using natural fibers like Sisal fiber, coir fiber, banana fiber, hemp fiber, etc. Some studies showed that SISAL fiber and coir fiber are added in SMA. the stability is increased, by increasing fibers in SMA mixes the stability gradually decrease. The use of sisal fiber and coir fiber gives better strength, durability and prevents from drain down of the mix. All studies showed that for finding optimum bitumen content and fiber content used Marshall Stability test, by used Marshall Mix Design determine the stability, Flow value, and calculate volumetric properties of the mix. Some studies used another test by the name of Drain Down test was determined the amount of Drain Down in uncompact Stone Matrix Asphalt (SMA). Addition some studies are also used Indirect Tensile Strength to determine the tensile strength of SMA Mixes.*

Key Words: **Stone Matrix Asphalt, Sisal fiber, Coir fiber, Marshall Stability Test, Marshall Mix Design, Drain down Test, Indirect Tensile Strength Test.**

1. INTRODUCTION

Stone matrix asphalt (SMA) is a sturdy, durable and damp-resistant blend that depends on rock-to-stone liaison to create durability and a rich mortar adhesive for durability. Those purpose and objectives obtained with a gap graded aggregates joined with fibers and polymers as modified, and high asphalt content matrix[1]. Even though the conventional dense mix is cheaper than stone matrix asphalt, and SMA is costly than Conventional dense mixes approximately 20 to 25%, SMA has advantages to increase the durability and decrease rutting, reduced surface noise and these reasons increase the cost of this kind of asphalt. the higher expense of stone matrix asphalt is related to the mineral filler, fibers (natural fibers or synthetic fibers), modified binders, and asphalt contents[1]. The Stone Matrix Asphalt (SMA) or asphalt mastic mixture is well known in Germany since the 1960s by Dr. Zeicher. Dr. Zeicher is a Garman engineer and director of the Central Laboratory of Road Construction (CLRC) at StrabagBau AG, was the inventor of SMA. That person tries to resolve the damages caused by the wear and tear of corrupted tires. At that time in Germany used Gus asphalt (mastic asphalt) for wearing course mixtures and also Asphalt concrete is used with a small number of coarse aggregates [2]. These types of surfaces were exposed to the rapid wear of vehicles equipped with independent tires. Both components, mastics, and aggregates, were too weak to provide adequate durability. At the beginning of the 1980s, Stone Matrix Asphalt just is known only in Germany after that time this application in other European countries was limited[2]. Stone matrix asphalt is a gap-graded asphalt has 70 – 80 % coarse aggregates from total aggregates mass, 6 – 7 % of binder content, 8 - 12 % of a mineral filler, and about 0.3 - 0.5 % of fiber or modifier[3].

2. Advantages of Stone Matrix Asphalt

Stone matrix asphalt present a tough, persistent, and damp - resistant and hardness wearing course, They are highly resistant to continual Deformation and high wear resistance. They have slower aging and durability than early asphalt cracking. The service life of stone matrix asphalt is longer; noise is less than dense-graded pavements. Stone Matrix Asphalt has good effectively used in the intersection and other high traffic stress situations. Stone matrix asphalt is costly and this cost is related to the addition of mineral fillers such as hydrated lime, stone dust and fly ash, fibers like Natural fiber and synthetic fiber, modified binder, and higher asphalt contents may be possible[3][4].

3. Materials in Stone matrix asphalt

3.1 Coarse Aggregates

In SMA, the quality and structure of aggregates play an important role in resisting mixing against caries. The stability of the entire structure is essential to assure the suitable design of the mixture. Coarse grains should be clean, hard, durable in cubic form, free from dust, soft organic matter, and other harmful substances.

- ❖ The aggregate should be Sufficient hardness to withstand heavy fracture traffic loads.
- ❖ High resistance to polishing
- ❖ High abrasion resistance
- ❖ Aggregates must be cube-shaped and coarse-textured to withstand staining and movement.

Aggregates gradation is selected from MORTHs Specifications[3][4].

Table -1: Gradation of Aggregate for SMA

SMA Determination	19mm SMA
Course where used	Binder (intermediate) course
Nominal aggregate size	19mm
Thickness of layer	45-75mm
Indian Standard sieve (mm)	% of aggregate passing from each sieve
26.5	100
19	90-100
13.2	45-70
9.5	25-60
4.75	20-28
2.36	16-24
1.18	13-21
0.60	12-18
0.30	10-20
0.075	8-12

3.2 Mineral Filler

The mineral filler directly affected the quality of the stone matrix asphalt therefore it is taken by an adequate part is SMA. hence, it is necessary to study the filler effect on the stone matrix asphalt. Mineral filler has various types those types are also used in stone matrix asphalt Such as Stone dust, hydrated lime, cement etc. the use of those are sufficient for SMA and prevent the rutting and the Drain Down is become lowering [4].

3.3 Bitumen

Stone matrix asphalt uses higher bitumen content compared to conventional Bitumen Concrete. Bitumen used in SMA for bonding materials, such as aggregates, mineral Fillers, and stabilizing additives. In the other papers used different bitumen grades in SMA. In Stone Matrix Asphalt also used modified bitumen to obtain a better result. For optimum binder content to SMA that is calculated 4% of air voids identically as per IRC specification[4].

3.4 Additives

In Stone Matrix Asphalt (SMA) Fibers are used as stabilizers. Fibers have decreased the drain down of the mix and also increase the resistance. The usually used in SMA fibers are natural fibers, synthetic fibers, mineral fibers, etc. various studies are used natural fibers like Coconut fiber, Hemp fiber, Sisal fiber, Coir fiber, and synthetic fibers used Jute fibers[4].

3.5 Sisal fiber

Sisal fiber is made from large tropical leaves of agave sisal Ana (Figure-01). Sisal Fiber with low maintenance and minimally durable and recyclable wear & tear. The external blade extracts the sisal fiber that removes the pulp from within the plaid herringbone and fine fibers are available. Sisal is anti-static and will not easily absorb water or moisture and does not attract dust particles or trap them. The smooth texture easily takes colors and gives all-natural fibers the widest range of colors. It has good absorbing properties for sound and effect. The natural borax used for the treatment of its leaves for fire resistance. Sisal is traditionally the most selected agricultural material for twine binders due to strength, long-term strength, ability to stretch, some dyestuffs affinity, and resistance to saltwater deterioration. In the fiber crops, Sisal ranks sixth, accounting for 2% of the world's plant fibers production increasing (plant fiber make 65% of the world's fibers). Sisal is one of the most important natural fiber in the world during the International Year of Natural Fiber 2009 (Figure-02).

Fig -1: Sisal fiber – Source: www.Indiamart.com

3.6 Coir fiber

Coir fiber is a hundred percent natural fiber and it is taken from the outer husk of the coconut, And it comes from the coconut palm seeds. It is one of the natural fiber abundantly available in tropical regions. It is mainly extracted from the Coconut fruit shell. The structure of the coir fiber cell is slim and vacant, it is made up of thick walls of cellulose. Mature fiber contains a complex woody chemical, more lignin, but the cellulose is less than other fibers like flax or cotton. it makes coir much powerful, coarser and has less malleable. Coir fiber is relatively waterproof.

Fig -1: Coir fiber – Source: www.Indiamart.com

4. Literature Review

Putman & Amirkhanian (2004) The researcher used polyester fibers, tire, and carpet to improve the stability and strength of the blend compared to cellulose fiber, and waste fiber was economical than compared to cellulose fiber. The researchers found no difference in moisture sensitivity and permanent deformation in SMA mix including waste fibers as compared to SMA mix including cellulose fiber or mineral fiber[5].

Muniandy & Huat (2006) conducted a study that used Cellulose oil palm fiber (COPF) And while cellulosic fibers showed a rheological property before mixing in PG64-22 bond used with percentage fiber such as 0.2 %, 0.4 %, 0.6 %, 0.8 % and 1.0 % by weight of aggregates. This represented that PG64-22 binding could be rectified and increased the grade of PG70-22. In order to improve the fatigue performance of mixed-diameter SMA design, cellulose oil palm fiber was found. The fatigue life increased 0.6 % of fiber content, While tensile stress and hardness also showed equivalent trends in yield. Preliminary mixed strains were lowest in 0.6% of fiber content[6].

Zhong & Wei (2007) Sisal fiber directly affects loading on mechanical properties such as impact strength, flexural strength, and wear resistance were investigated. Composed of 30 wt% sisal fiber shows great flexural strength, water absorption and especially abrasion resistance, which shows the highest bonding and linkage in composites. That investigation represents the capability of Sisal fiber to upgrade wear resistance of the composite and to be used in fiberboard[7].

Xue et al (2009) conducted use Municipal Solid Waste Incinerator (MSWI) recycled ash as partial replacement of fine aggregate or mineral filler in SMA mix and use basic oxygen furnace slag or BOF slag that was as part of coarse aggregate with polyester fiber obtained from recycled raw materials with 6.35mm in length, and this makes SMA mixtures consist of solid waste materials by mass more than 90%. Performed PG76-22 band in SMA blend and Marshall design and super pave design method are obtained suitability for use in SMA blend [8].

A. Suchismita (2009) in this study used only 0.3% adding of Coconut fiber importantly improve the Marshall stability of SMA mixture. With this addition of 0.3% nominal fiber continuously, improve the drain down, Indirect Tensile Strength (ITS) and the fatigue characteristics of the stone matrix asphalt mixes be improved. It is based on the fact that a fiber concentration of 0.3% continuously improves the Marshall properties of the SMA mixes although similar for bitumen 80/100. The OBC is found to diminish continually by addition to fiber. By using the modified binders and fibers in the mix have achieved Drain Down and Moisture susceptibility to those are improving. The researcher found that with the addition of fiber, the tensile strength of mixtures with any type of adhesive increased substantially[9].

N. Panda (2010) conducted a study of Laboratory investigation on SMA using Sisal fiber for Indian Roads. This paper also evaluated sisal fibers as stabilizing agents in the mixture by laboratory tests. The binder content had different percentages such as 4 %, 4.5 %, 5 %, 5.5 %, 6 %, 6.5 %, 7 % and added to the mix by weight of aggregate and fiber use in this investigation was 0.3 % by total weight of aggregates, cement as a filler and 60/70 grade of bitumen as a binder in this study. The optimum binder content was found 5.3%, max stability is 13.8 KN, flow value increase from 2.4% to 4.03%, the VMA increase as binder increases, and by increase bitumen content VA of Marshall sample decrease and also VFB increase by increases in bitumen contents[10].

Sani et al. (2011) Most of the researchers are using these fibers (coir fiber and kenaf fiber) because these are economical material and the strengths are adequate. The laboratory tests and the result was shown that these two it means both of them are useful and effective in increasing the Marshall stability of hot mix asphalt, and the marshall stability of ordinary in HMA is increased with the used of coir fiber and kenaf fiber 3.2% and 9.7% respectively. By increasing fiber in HMA it performance is become better[11].

kar (2012) In this paper, varied 4 % to 7 % of binder contents and fiber content varied 0 to 0.5 % maximum of the total mix. By using Marshall stability Optimum fiber content for Bituminous Concrete and Stone matrix asphalt mixes to be 0.3 %. OBC for Bituminous concrete and SMA was found 5.2 % and 5 % respectively. The tests consider in this paper for both of them SMA and BC mix prepared at (optimum bitumen content) and (optimum fiber content) are drain down test, static creep test, and static indirect tensile strength test to find and how the fiber has an effect to the mix performance [12].

Hadiwardoyo et al. (2013) This paper evaluated the influence of skid resistance on the asphalt. In this investigation pulp, coconut fibers used as additives. The length of fiber 0.5 – 1.25 cm used in the mixed with 60/70 of penetration asphalt to produce fiber content of 0%, 0.75%, and 1.5%. Specimens were following tested with a British pendulum tester is varied at the different temperature from 26 °C up to 50 °C. the temperature of skid resistance decrease with the increase in pavement performance. 0.75% of coconut fiber by improving skid resistance the asphalt mix primarily improved. Skid resistance decrease when the number of vehicles is increasing[13].

Rajo & Sreenivasa Rao (2015) conducted a study on the characterization of fiber-reinforced bituminous mixes. in this paper use, coir fiber as a stabilizer is SMA. Binder content has been varied 5 % to 7 % and fiber content also varied from SMA 0.2%, 0.3% and 0.4% and the fiber length varied 10mm and 15mm. in this paper different tests are conducted on Stone Matrix asphalt such as the Marshall Stability test, drain down test, indirect tensile test, moisture susceptibility, repeated load test with a rest period. 0.3% of fiber was found to be the OFC, the Marshall Stability value on Stone matrix asphalt with OFC was found to be 16.237KN, flow value of SMA was found 4.32 mm[14].

Kumar & Babu (2016) In this paper use Sisal fiber. 4% up to 7% varied the binder content and also fiber content from 0% up to 0.5% is varied by the total weight of aggregate. By using the Marshall procedure 0.3% of Optimum fiber content was found for both Stone Matrix Asphalt (SMA) and Bituminous Concrete (BC). Optimum binder content (OBC) for SMA and BC was found 5.2% and 5% respectively. Different tests are used in this paper such as static indirect tensile strength (ITS) test, drain down test, and static creep test. By use of those tests, the sisal fiber gives an adequate result [15].

Kumar & Sunitha (2016) experimental investigation of SMA with Sisal fiber. In this paper use bitumen VG-30 with natural fiber sisal fiber on stone matrix asphalt. For finding the optimum binder content used a different percentage of the binder for mixes with selected aggregate grading. Drain down characteristics for modified and unmodified stone matrix asphalt studied. Only 0.28% adding of sisal fiber because to improve the Marshall properties of Stone Matrix Asphalt mixes. By adding 0.28 % of fiber improves the Drain Down specifications of the stone matrix asphalt mixes with conventional bitumen. OBC obtained 6.21% from Marshall Stability, Max stability 11.575 KN from OBC of 6.21%, flow value obtained 3.09mm. For modified bitumen, Marshall stability was 14.82% and flow value 3.6mm[16].

Satyavathi et al (2016) In this paper fibers (coir fiber and pineapple fiber) used in two grades, grade-I is according to (MORTH) and grade-II (IRC) mixes. various percentage of bitumen used as 5.5%, 6%, 6.5% and 7%. The Drain Down test was used in this paper and also used optimum fiber content purposed to reduce the drain down and find max stability value for grade I and grade II. optimum coir fiber (OCF) 0.3 % and optimum pineapple fiber (OPF) contents 0.1% obtained from grade-I & grade-II. Optimum binder content for Coir fiber is 6.6% and 6.7% and for pineapple fiber also found 6.25% and 5.75% for grade I – II respectively. Coir fiber has shown better stability than pineapple fiber, both of two fibers reduce the drain down of the mix and increase the stability of the sample in both two grades [17].

Bikiya et al (2016) conducted a study on the effect of coir fiber in the bituminous concrete mix. In this paper, fiber length was 10mm, 15mm, and 20mm and used 0.3%, 0.5% and 0.7% by weight of the mix. In this paper, those tests were conducted such as indirect tensile Strength test (ITS), short and long-term aging test and stiffness modulus test. The OBC for the conventional mix is 5.21% and OBC for coir fiber mix is 5.3% by weight of the mix. The max stability of the modified mix of coir is found 22.16 KN and for Normal mix 18.06 KN. By increasing the fiber content the air void is decreased. In coir fiber air void is 8% less than the normal mix. The tensile strength for coir fiber has been increased to 14.8 comparing to the normal mix[18].

Shravan & Reddy (2017) the percentage of cellulose fiber and coir fiber was 0.2, 0.3%, 0.4% and 0.5% by total mix weight. The fiber content 0.3% was found to be optimum satisfying the drain down of the binder. The optimum binder obtained 6.23% and 6.43% for coir fiber and cellulose fiber respectively. The drain down percentage at OBC was obtained between 0.0021% - 0.0648%, conducting the coir fiber to be better than the cellulose fiber. The stability value for coir fiber and cellulose fiber was 1135 kg and 1026.643 respectively at OBC and fiber content is 0.3%. the flow value for coir and cellulose fiber was 3.56mm and 3.55mm respectively[19].

Thakur & Singh (2017) conducted a study of the performance of bituminous concrete with the addition of Coir/coconut fiber. In this paper, the researcher conducted research to improve the performance of flexible pavements. Marshall Parameters it was found when the addition of coir fiber to the bituminous concrete mix help significantly in improving the performance of the mix. Percentage of bitumen is taken 5%, and percentage of fiber is varies from 0.2%, 0.4%, 0.6% and 0.8%. The stability value of BC started increasing up to 0.4% and then decrease slightly. At 0.4% of fiber, stability value was maximum. The flow value of BC was decreasing up to 0.2% and then start to increase, at 0.8% of fiber content the flow value was maximum. VFB slightly increase from 0% up to 0.8% max value was 0.8% of fiber. VMA slightly decrease from 0% to 0.8%. with the adding of coir fiber, the percentage of air void is decreased[20].

Baby et al (2018) in this paper marble waste is a filler, 8% of marble waste be used as a filler. The percentage of bitumen varied as 5%, 5.5% and 6% as by the weight of aggregate. The OBC was found 5.84% as 4% of air void and the OFC was found to be 0.3%. By the adding of coir fiber, the stability of the mix increase, the stability value increases up to 5.5% when the percentage of bitumen increase and this continues and then stability gradually decrease. The stability increase up to 0.3% of fiber, the flow value decrease by increase the addition of coir fiber. Waste marble and coir Fiber is the economic option for making SMA construction [21].

Karunakar et al (2018) Carbon fiber are easily available in India, the percentage of fibers used on SMA 0.3%, 0.4% and 0.5% by weight of the total mix. In this paper, various strength tests such as Marshall stability would be conducted. The fiber content was found at 0.3%. the optimum binder content was evaluated to be 6.55% and 6.605% for Glass fiber and carbon fiber respectively. The percentage of drain down was found 0.0021% and 0.0648%. the stability value was found 1021.86 kg and 1156.078 kg for glass fiber and carbon fiber respectively. The flow value was found 3.1693 mm and 3.3087mm for carbon and glass fiber respectively[22].

Kundal & Goel (2019) conducted a study on a study of bituminous mixes with natural fiber (sisal fiber) by experimental. This paper studied the benefit of the use of natural fiber and environmentally sustainable design. Two tests were conducted in this research, the Marshall Mix design test and the Drain Down test. The percentage of the binder is varied from 4% up to 6% and additive of fiber also varied from 0% up to 0.8% of total aggregate weight, stone dust as a filler. Optimum binder content was found 5% and Optimum fiber content (OFC) was found 0.4%. the result of the test shown when bitumen and fiber content used for bituminous mixes that help the stability become increase and also the durability increase, air void, and flow value became decrease, and the important was that to decrease the drain down of bitumen[23].

5. CONCLUSIONS

All number of studies in this review paper To appraise performance characteristics of Stone Matrix Asphalt (SMA) mixtures with different natural and waste fibers as stabilizing additives. Fibers are helpful to increase adhesion between stone to stone of aggregate and continue to increase resistance between them. By adding fibers, the mix has a great effect on reducing the drain down of binders. As the percentage of additives in the SMA mixture increases, Marshall stability and Marshall quotient values increase when compared to the control mixture showing better resistance to permanent deformation. Maximum values are obtained at 0.3 percent fiber content for these products. The flow value of SMA mixtures decreases due to the addition of fibers. The mixes become less flexible resulting in a low flow value. Due to the enhanced adhesion property, the role of the additive in increasing the indirect tensile strength value of the SMA mix is more influence in the conditioned state. As an effective stabilizing agent, all the additives used in the SMA mixture provide significant stabilization of the mixture as compared to the control mixture.

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