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Review Paper on Utilization of Fiber as a Strength Modifiers in Stone Matrix Asphalt

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ABTRACT

Stone Matrix Asphalt (SMA) is a robust and durable asphalt mixture designed to resist rutting and deformation, making it an ideal choice for high-traffic areas. However, its susceptibility to cracking, especially at low temperatures, and the challenges related to its stiffness necessitate innovations in mix design. One such innovation involves the use of fiber additives to enhance the mechanical properties and performance characteristics of SMA. This review paper explores the role of fibers as strength modifiers in SMA, providing an overview of various fiber types, their mechanisms of action, the impact on SMA performance, and the challenges associated with their use. The paper concludes with a discussion of future research directions and the potential for further improvements in SMA technology.

Keywords: - Stone Matrix Asphalt, Cellulose Fibers, Marshall Properties, Volumetric Properties, Optimum Bitumen Content, Optimum Fiber Content

1.1 INTRODUCTION

Stone Matrix Asphalt (SMA) is a high-performance asphalt mixture known for its ability to resist rutting and deformation. It is typically composed of a high percentage of coarse aggregates and a rich binder, which provide superior performance under heavy traffic conditions. SMA is characterized by its gap-graded structure, which leaves a higher proportion of voids filled with the binder. Despite its benefits, SMA faces challenges related to cracking, especially at low temperatures, and poor fatigue resistance under repetitive loading. As a result, efforts have been made to enhance the performance of SMA, with fiber reinforcement emerging as a promising solution. Fibers are increasingly being used in SMA to modify its mechanical properties and improve its resistance to cracking, fatigue, and rutting. This paper aims to review the utilization of fibers as strength modifiers in SMA, examining the different types of fibers, their impacts on SMA performance, and the challenges associated with their use.

Overview of Stone Matrix Asphalt (SMA)

SMA was developed to provide superior rutting resistance, which is crucial for roads subject to heavy traffic and high temperatures. It is characterized by:

- **High Binder Content**: The rich binder content (typically polymer-modified bitumen) aids in providing enhanced durability and rutting resistance.
- **Coarse Aggregates**: The gap-graded structure of SMA leads to a high percentage of coarse aggregates and a low percentage of fine aggregates.
- **Performance Benefits**: SMA offers resistance to rutting, surface wear, and fatigue cracking, making it suitable for high-performance road surfaces, particularly in hot climates or areas with heavy traffic.

Types of Fibers Used in SMA

Fibers added to SMA can be broadly categorized into natural, synthetic, and mineral fibers. The choice of fiber influences the performance of the asphalt mixture, particularly in terms of strength, durability, and cracking resistance.

- **Natural Fibers**: These include cellulose, jute, sisal, and coconut fibers. Natural fibers are biodegradable, environmentally friendly, and cost-effective. However, their durability can vary depending on environmental conditions.
- **Synthetic Fibers**: These include polypropylene, polyester, and aramid fibers. Synthetic fibers are known for their excellent durability and resistance to chemical degradation. They tend to improve the tensile strength and cracking resistance of the mixture.

- **Mineral Fibers**: Mineral fibers, such as basalt and glass fibers, are commonly used to improve the fracture toughness of SMA. They provide excellent reinforcement, especially in terms of high-temperature resistance and wear

1.2 LITERATURESURVEY &BACKGROUND

In order to ascertain the ideal dosage at which the drain down study yields less than 0.3% by weight of mix, E S Dinesh Babu and K Banupriya (2022) assess the performance of CS as stabilizing additives and wasted lime as filler in SMA combination. Three main forms of asphalt surface, distinguished by a combination of bitumen and stone aggregate, were examined by Gazia Khurshid Khan and Ar. Sukhmanjit (2017). These include Stone Mastic Asphalt (SMA), Open Graded Asphalt (OGA), and Dense Graded Asphalt (DGA). The gap-graded mix known as Stone Matrix Asphalt (SMA) is distinguished by its high asphalt concentration, high coarse aggregate content, and stabilizers such as fiber or polymer additives. SMA contains a larger percentage of coarse aggregate, a smaller percentage of middle-sized aggregate, and a higher percentage of mineral filler than dense graded mixes. It has the capacity for long-term performance and durability and is resistant to irreversible deformation. For the creation of mixes, four distinct aggregate gradations have been tested using two kinds of fillers, such as cellulose and bamboo fiber. Sample aggregates weighing around 2450 grams were collected and dried in an oven. Before bitumen was added, the aggregates were heated to 135 degrees Celsius. Bitumen mix was added in increments of 1%, ranging from 3 to 7%. Jyoti Narwal and Gazia Khurshid Khan (2017) investigated the characteristics and uses of SMA mixtures. This study also reviews the research conducted by different writers.

Abhishek Mendigeri and Dr. H S Jagadeesh (2017) used locally accessible aggregates and other materials to achieve the appropriate gradation as specified by IRC: SP: 79: 2008, as well as to identify the ideal fiber content and binder content for warm mix additives. Variable percentages of binder content (from 5.8%, 6%, 6.2%, 6.4%, and 6.6%), fiber content (0.30%, 0.35%, 0.40, and 0.45% by total weight of aggregates), and warm mix additives (Sasobit from 1%, 2%, and 3%, Zychotherm from 0.05%, 0.1%, and 0.15%) have all been taken into consideration for the research project in order to ascertain the aforementioned properties.

M. Satyavathi et al. (2016) used the Marshall Stability test to analyze the flow and stability parameters in order to determine if fibers might be used as stabilizing additives. Several bitumen percentages, including 5.5%, 6%, 6.5%, and 7%, were used for this investigation. The purpose of the drain down test is to determine the ideal fiber content first, and then the ideal bitumen content. When compared to pineapple fiber, the test findings for both grade-1 and grade-2 mixes showed that the usage of fibers decreased the drain down value and that the greatest stability value for both grade-1 and grade-2 mixes was achieved for coir fiber.

Anuj Narwal (2016) examined the effects of using SISAL fiber, a naturally occurring and locally accessible fiber, as an additive in BC and as a stabilizer in SMA. In accordance with the MORTH standard, the aggregate gradation was prepared by varying the fiber content from 0.33 to a maximum of 0.5% of the overall mix and the binder concentration often ranging from 4% to 7%. Fly ash was employed as a mix in the final works after preliminary research revealed that it had adequate Marshall Properties. The Optimum Fiber Content (OFC) for each BC and SMA blend, as determined by the MarshallProcedure, was 0.3%. Similarly, it was discovered that the Optimum Binder Content (OBC) for SMA and BC was 5.2% and 5.1%, respectively. Kavalakuntla Kiran Kumar (2016) investigated the impacts of using SISAL fiber, a naturally occurring and locally accessible fiber, as an addition and stabilizer in SMA in British Columbia. The mix's aggregate gradation was prepared in accordance with the MORTH standard, with the binder concentration fluctuating regularly between 4% and 7% and the fiber content ranging from 0% to a maximum of 0.5% of the mix. Fly ash has been employed for mixes in later works after early research revealed that it has good Marshall Properties. According to P. Bakiya (2016), the structural layer commonly utilized in flexible pavements is bituminous concrete mixtures. Fibers like coir fibers can be added to bituminous mixtures to improve their properties. 10 mm, 15 mm, and 20 mm fiber lengths were maintained and employed at rates of 0.3%, 0.5%, and 0.7% by mix weight. Indirect tensile strength (ITS), short- and long-term ageing, and stiffness modulus tests were among the mechanical parameters that were examined. It has been determined that adding coir fiber to the mixture improves bituminous concrete's qualities.

Veena G. Raj and Midhila V. S. Raj (2015) evaluated bitumen modification with natural fiber and synthetic fiber. The VG-30 bitumen, which has a penetration value of 50–70 mm, is utilized. Polypropylene fiber is the synthetic fiber utilized, whereas sisal fiber is the natural fiber. The effects of adding carbon fiber, a mineral fiber, to dense bituminous macadam (DBM) were investigated by K. Karthik et al. (2015). Conventional bitumen and fiber-modified binder are the subjects of an experimental investigation. The Marshall Procedure is used to determine the DBM's optimal fiber content (OFC) and optimal binder content (OBC). at order to prepare asphalt concrete mixes for detailed laboratory research, carbon fiber will be used at doses ranging from 0.5% to 2.5% by weight of binder. In addition to determining the mixes' volumetric characteristics, many strength tests, including Marshall stability, will be carried out.

In their 2015 study, Bindu C.S. and Beena K.S. examined how additives such as coir, sisal, and banana fibers (natural fibers) affected the compressive strength of SMA mixes. The materials are characterized by an initial examination. To investigate the ability to withstand the pressures caused by traffic loads, compressive strength tests are performed. At 0.3% fiber concentration, the compressive strength of all stabilized combinations reaches its maximum value. Higher compressive strength in SMA including coir fiber indicates greater crushing resistance. All blends' retained strength indices meet the 75% limitation threshold. However, it is only around 60% for the control combination, proving that additives are required in SMA mixes.

The impact of additives on the drainage characteristics of stone matrix asphalt mixtures was the subject of an experiment by Bindu et al. (2014). The impact of additives such as coir, sisal, and banana fibers (natural fibers) at 0.1, 0.2, 0.3, and 0.4, as well as waste plastics (waste material) and polypropylene (polymer) at 1, 3, 5, 7, and 9 on the drain-down properties of SMA mixes is the main topic of this article. The ideal fiber percentage for all fiber mixes, regardless of fiber type, is 0.3% by weight of combination, according to the drain down properties of the different stabilized mixtures. The ideal additive amounts for waste plastics and polypropylene stabilized SMA combinations are 7% and 5% by mixture weight, respectively. The waste plastics mix's drain values fall within the necessary standard range. Of the fibers examined, the coir fiber additive is the best. Upon stabilization, sisal and banana fiber mixes had nearly identical properties.

A review of the use of natural fiber as a modifier in bituminous mixtures was conducted by O.S. Abiola et al. (2014). Traffic-related pavement distresses were caused by an increase in axle loads and excessive tire pressure from large trucks. One strategy to enhance pavement performance is to modify the asphalt binder. Natural fibers are currently a center of scientific and engineering research. The types of natural fibers are discussed, along with how to treat their surfaces and strengthen asphalt concrete with them. Overall, the research showed that pavement modifications improved fatigue life and structural resilience to distresses.

Rajmane et al. (2013) investigated the adhesion properties of the main polymers, polyethylene, polypropylene, and polystyrene, in their molten form. Bitumen's melting point will rise due to plastics. Because it has a greater Marshall Stability value and an appropriate Marshall Coefficient, the waste plastic bitumen mix makes excellent material for pavement construction. Therefore, one of the greatest ways to dispose of waste plastics easily is to utilize them for pavement. India's hot and muggy environment, where temperatures regularly rise beyond 50°C and heavy rains cause chaos and leave most roads with large potholes, would benefit greatly from plastic roads.

The 60/70 grade bitumen that was acquired from Cochin refineries Ltd. was modified by Rema et al. (2013) using polythene carry bags (less than 30 microns) and subsequently shredded in a shredding machine (particle size 2-3mm). Ordinary Portland cement was utilized as the filler material, and three grades of aggregate (A, B, and C) were employed to achieve the necessary gradation. In order to achieve a uniform distribution, the shredded plastic was added to the heated aggregate while it was continuously mixed. The aggregate was heated to between 140 and 150°C. Using the Rutherfoth technique, the aggregates were proportioned as follows: 15% for aggregate A, 32% for aggregate B, 51% for aggregate C, and 2% for cement (filler). The optimal bitumen percentage was found to be 4.583% for aggregates coated with plastic and 4.658% for aggregates mixed with ordinary aggregate. This indicates that using plastic coated aggregate reduces the optimum binder level. The Marshall Stability value increased significantly from 1135.78 to 2091.59 when plastic was added at a rate of 4-5% by bitumen weight. Tests revealed that the use of plastic coated aggregate enhanced the characteristics of aggregates that primarily induce rutting action, such as water absorption, stripping value, and soundness. According to research by Amit et al. (2012), modified bitumen that contains 5–10% processed waste plastic (size 2-4mm) by weight of bitumen significantly improves the Marshall stability, strength, fatigue life, and other desirable properties of bituminous concrete mix. This enhances pavement performance and longevity while using a small amount less bitumen.

The potential of coir as a reinforcing element in bituminous mixtures was investigated by T Subramani (2012). In order to find the ideal bitumen content, fiber content, and fiber length for bituminous mixes reinforced with coir fibers, the Marshall test of mix design was used for the mixes, and their performance was examined. Following investigation, the ideal fiber content was 0.46%, the ideal bitumen percentage was 5%, and the ideal fiber length was 17.25 mm. According to an analysis of the Marshall parameters, adding coir fiber to a semi-dense bituminous concrete mix greatly enhances the mix's performance. Sandra Oda and colleagues (2012) investigated the use of natural fibers in SMA mixtures. The fiber standard (DER-SP, for instance) that is typically advised for use in SMA is costly and imported, which raises the whole cost. Since Bahia is one of Brazil's top producers of coconut and sisal, and hence of coconut shells and sisal fibers, we plan to employ locally available leftovers (coconut and sisal) to cut costs and satisfy criteria. Asphalt mixes including four fibers—coconut, sisal, cellulose, and polyester—were created in this project. Blends including natural fibers demonstrated strong resistance while keeping the asphalt from draining down, according to the findings of mechanical testing (tensile strength and modulus of resilience).

Sayyed Mahdi Abtahi et al. (2010) examine FRAC materials modified by random fiber insertion, concentrating on the first side of the coin. Additionally, the impact of various fibers, mixing techniques, and executive issues on asphalt concrete will be examined. Thus, various examinations of the literature demonstrated that the use of fibers in AC material has been associated with three distinct goals: the development of a new market to handle the waste fibers, the construction of electrically conductive mixes, and mechanical improvement.

2.1 OVERVIEW OF THE SURVEYED LITERATURE

The literature review provides a summary of the studies conducted on bituminous mixes, such as dense graded mixtures and stone matrix asphalt (SMA). Bituminous concrete (BC) and SMA materials, together with their composition and associated test techniques, have been selected for the current study with the key findings of the research in mind. Here, an effort has been made to compare the various characteristics of SMA and BC using various tests, including as the Marshall Test, the Indirect Tensile Stress Test, and the Static Creep Test, in which fly ash is used as filler and 60/70 penetration grade bitumen is used as binder. The consequences of adding a wide range of fibers to bituminous mixtures have been documented by various studies. The outcome demonstrates that fiber extends fatigue life by raising the resistance to irreversible deformation and cracking. Thus, the fiber reinforcement increased the strain energy absorption and gave the mixtures more tensile integrity, which prevented fractures from forming and spreading. The key to mixture performance, according to natural fiber researchers, is homogeneous distribution, fiber length, proportion, and orientation. It is advised that the orientation of the fibers through the mixes be investigated using optical and/or scanning electron microscopy in order to comprehend the mechanical characteristics of fiber reinforced bituminous mixes.

The inclusion of cellulose fiber and other components in the mixes to stop the binder mortar from draining down has been the primary focus of investigators. The use of non-traditional fibers, including banana fiber and SISAL, which are widely and inexpensively accessible worldwide and largely contain cellulose on their outer side, has not been documented in previous research, especially in SMA mixtures. Therefore, in the creation of BC and SMA mixes, this substance has been utilized as a stabilizing component. In addition to exploring the prospect of employing a non-conventional waste material in a normally non-conventional combination like SMA, this would address the solid waste management issue to a good degree.

1.3 CONCLUSION

The utilization of fibers as strength modifiers in Stone Matrix Asphalt presents a promising avenue for enhancing the performance and durability of pavements. Fibers significantly improve SMA's resistance to rutting, fatigue, and cracking, thus contributing to the extended service life of road infrastructure. However, challenges related to mix design, cost, and the selection of appropriate fiber types need to be addressed through further research and field applications. As technology advances, fiber-modified SMA has the potential to play a key role in the development of more sustainable, durable, and cost-effective road systems.

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