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A Review on the Utilization of Natural Fibers in Bituminous Concrete

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ABSTRACT

This study investigates the effects of adding natural fibers, specifically Sisal and Coir fibers, to Bituminous Concrete (BC) mixtures. BC is a type of Hot Mix Asphalt made of coarse and fine aggregates, filler, and binder, and is commonly used for road construction. Aggregate gradation followed MORTH specifications, with binder content ranging from 4.5% to 6% and fiber content from 0.2% to 0.8%. Stone dust was used in preliminary testing and was found to result in satisfactory Marshall Properties. The Optimum fiber Content (OFC) for both Sisal and Coir fibers was determined to be 0.6%, while the Optimum Binder Content (OBC) was found to be 5.3% and 5.2% for Sisal and Coir fiber, respectively, using the Marshall Procedure. The BC mixtures were subjected to performance tests such as Indirect Tensile Strength and Tensile Strength Ratio, which showed that the addition of Sisal and Coir fiber improved the mix properties, including Marshall Stability and Indirect Tensile Strength. Overall, this study highlights the potential benefits of using natural fibers as additives to enhance the performance of BC mixtures.

Key Words: Bituminous concrete (BC), Coir fiber, Sisal fiber, Marshall Properties, Indirect tensile strength, Tensile strength ratio

INTRODUCTION

Transportation infrastructure is crucial for the economic development of a country, and in India, highways are a primary mode of transportation. As such, the Indian government has invested heavily in the construction and maintenance of pavement for these roads. A thorough engineering study can save significant amounts of money and pavement materials, while also ensuring reliable performance of the highways over time. Flexible pavement and Rigid Pavement are the two main types of Pavement used in road construction. This study focuses specifically on the mixed design of flexible pavement, with the aim of optimizing its performance for use on Indian highways.

The quality of a bituminous mix depends on various factors such as strength, durability, resistance to fatigue and permanent deformation, eco-friendliness, and cost-effectiveness. Mix designers perform several tests on different mix proportions to achieve the desired properties. This study aims to highlight the challenges in bituminous mix design and the current research trends to address these issues.

The development of transport infrastructure is essential for economic growth and human civilization, and the Government of India invests heavily in the construction and maintenance of highways. Bituminous concrete is a commonly used material in road construction, consisting of coarse and fine aggregates, filler, and binder. A well-designed bituminous mix should possess properties such as strength, durability, resistance to fatigue and deformation, and eco-friendliness, while also being cost-effective. To achieve these goals, researchers ften experiment with different mix proportions and additives. In this particular study, the focus is on the addition of natural fibers, namely coir fiber and sisal fiber, to the bituminous concrete mix. The objective is to investigate the effects of these fibers on the performance of the mix and to determine the optimum proportion of fibers to be added to achieve the desired properties.

LITERATURE REVIEW

Kar (2012)

The paper explores the effect of varying binder and fiber content on Bituminous Concrete and Stone Matrix Asphalt mixes. The researchers tested binder content ranging from 4% to 7% and fiber content ranging from 0% to 0.5% of the total mix. The Marshall stability test was used to determine the optimum fiber content, which was found to be 0.3% for both mix types. Additionally, the optimal bitumen content (OBC) was found to be 5.2% for Bituminous Concrete and 5% for Stone Matrix Asphalt.

To investigate the impact of fiber content on the mixes, the researchers performed three tests: the drain down test, static creep test, and static indirect tensile strength test. These tests were conducted on mixes prepared with the optimal bitumen and fiber content.

Overall, the study aimed to determine the optimal binder and fiber contents for these mix types and investigate how fiber content affects their performance. The results of the tests can provide valuable insights into designing and optimizing these mixtures for road construction projects.

Hadiwardoyo et al. (2013)

This study evaluated the effect of skid resistance on asphalt by adding pulp and coconut fibers as additives. Fibers with a length of 0.5-1.25 cm were mixed with 60/70 penetration asphalt to produce mixtures with fiber content of 0%, 0.75%, and 1.5%. The specimens were then tested using a British pendulum tester at various temperatures ranging from 26°C to 50°C.

The results showed that the skid resistance of the asphalt mixes decreased as pavement temperature increased. However, the addition of 0.75% coconut fiber to the asphalt mix improved skid resistance, primarily at lower temperatures. The study also found that skid resistance decreased as the number of vehicles on the pavement increased.

Overall, the study aimed to investigate the influence of fiber additives on skid resistance in asphalt mixes. The results of the tests conducted in this study can provide valuable insights into designing and optimizing asphalt mixtures for road construction projects, particularly in improving their skid resistance.

Satyavathi et al (2016**)**

This study investigated the use of coir and pineapple fibers in two grades of asphalt mixes, grade-I according to MORTH and grade-II according to IRC. The researchers used various percentages of bitumen, ranging from 5.5% to 7%, and conducted the Drain Down test to determine the optimal fiber content.

The study found that the optimal coir fiber (OCF) content was 0.3%, and the optimal pineapple fiber (OPF) content was 0.1% for both grade-I and grade-II mixes. The optimal binder content was found to be 6.6% and 6.7% for coir fiber and 6.25% and 5.75% for pineapple fiber in grade-I and grade-II mixes, respectively.

Both coir and pineapple fibers reduced the drain down of the mix and increased the stability of the samples in both grades. However, coir fiber showed better stability than pineapple fiber.

Overall, the study aimed to determine the optimal fiber content and binder percentage for coir and pineapple fiber in asphalt mixes. The results of the tests conducted in this study can provide useful insights for designing and optimizing these mixtures for road construction projects.

Kumar and Sunitha (2016)

This study investigated the use of sisal fiber as an additive in stone matrix asphalt (SMA) with bitumen VG-30. The researchers used different percentages of the binder for mixes with selected aggregate grading to find the optimal binder content. They also studied the drain down characteristics for modified and unmodified SMA.

The study found that adding only 0.28% sisal fiber improved the Marshall properties of the SMA mixes. The optimal binder content (OBC) was obtained from Marshall Stability tests and was found to be 6.21%. At this OBC, the maximum stability was 11.575 KN, and the flow value obtained was 3.09mm. For the modified bitumen, the Marshall stability was 14.82%, and the flow value was 3.6mm.

Furthermore, the study found that adding 0.28% of sisal fiber improved the drain down specifications of the SMA mixes with conventional bitumen. Overall, the use of sisal fiber in SMA can provide better performance in terms of stability and drain down characteristics, which can be useful for road construction projects.

Dash and Panda (2016)

This study focused on improving the strength of dense graded bituminous mixtures using sisal fiber as an additive. Natural aggregates were used as coarse aggregates, while bottom ash served as fine aggregates, and fly ash was used as filler. Slow setting emulsion coated sisal fiber was added in varying percentages and lengths to the mix. Marshall tests were conducted to determine the optimal composition, including the best fiber length, and

DBM samples before Marshall testing

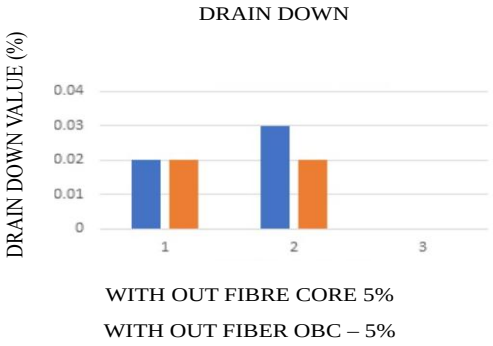
bitumen content. To assess the performance strength tests and moisture susceptibility tests were conducted to determine the tensile strength ratio and retained stability of the bituminous mix.

Thakur and Singh (2017)

The study focused on enhancing the performance of flexible pavements by adding coir/coconut fiber to bituminous concrete mix. A percentage of 5% bitumen was used, and the percentage of fiber varied from 0.2% to 0.8%. The addition of coir fiber showed a significant improvement in the performance of the mix. The stability value of bituminous concrete increased up to 0.4% of fiber content and then slightly decreased. The maximum stability value was obtained at 0.4% of fiber content. The flow value decreased up to 0.2% and then started to increase, with the maximum value obtained at 0.8% of fiber content. The percentage of voids filled with bitumen (VFB) slightly increased from 0% to 0.8%, with the maximum value obtained at 0.8% of fiber content. The voids in mineral aggregate (VMA) slightly decreased from 0% to 0.8%. The addition of coir fiber led to a reduction in the percentage of air voids in the mix.

Pooja et al. (2018)

The aim of this study was to investigate the effects of using SISAL fiber, a locally available natural fiber, as a stabilizer in SMA and an additive in BC. The mixes were prepared with MORTH-specified aggregate gradation and varying binder content (4% to 7%) and fiber content (up to 0.5% of the total mix). Fly ash was used as a filler material as it had satisfactory Marshall properties in the preliminary study. Optimum fiber content for both BC and SMA mixes was found to be 0.3% using the Marshall Procedure, while optimum binder content for BC and SMA was found to be 5% and 5.2%, respectively.



Kundal and Goel (2019)

This study aimed to investigate the use of natural fiber (specifically, sisal fiber) in bituminous mixes, with a focus on environmentally sustainable design. Two tests were conducted: the Marshall Mix design test and the Drain Down test. The binder content was varied from 4% to 6%, while the fiber content was varied from 0% to 0.8% of the total aggregate weight, with stone dust used as a filler. The results showed that the use of bitumen and fiber in the bituminous mixes increased stability and durability, while decreasing air void and flow value. Most importantly, it decreased the drain down of bitumen. The optimum binder content was found to be 5%, while the optimum fiber content (OFC) was found to be 0.4%.

Mashaan et al. (2021)

This paper provides a literature review on road surfacing in pavement engineering and highlights the importance of fiber-reinforced asphalt pavement in providing durable and effective surfacing for heavily-trafficked roads. The paper aims to clarify some of the terms and concepts related to this topic to help readers understand the experiments and discussions. The review found that the use of fiber in asphalt mixtures improves the optimum bitumen content and prevents bitumen leakage due to its asphalt absorbing property. Fiber also improves the viscoelastic response, resistance to moisture, resistance to rutting, and reduces pavement fatigue cracking.

Oyedepo et al. (2021)

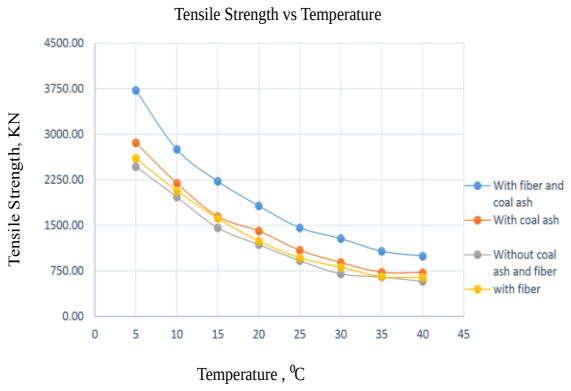
The researchers investigated the effects of adding natural fibers to hot mix asphalt at varying proportions (0.1% to 0.5% by weight). They conducted a Marshall stability test to determine the strength of the fiber-reinforced asphalt concrete. The results showed that Sisal fiber had a higher tensile strength (167.43 N/mm2) compared to sponge gourd fiber (24.58 N/mm2). The Marshall Stability test results indicated that Sisal fiber had a minimum and maximum stability values of 4.46 KN and 5.54 KN, respectively, which exceeded the minimum stability value required for the wearing course in the

Nigerian General Specification for Roads and Bridges (3.5 KN). The flow values obtained were more than the minimum value of 4 mm, except for the 0.1% Sisal fiber dosage, which had a value of 3.99 mm. The high flow values obtained indicated that the fibers had a reinforcing effect, making the asphalt concrete stronger and more resistant to plastic deformation.

Sample extruder

Dwivedi and Joshi (2022)

The study found that the best bituminous mixes were produced with a bitumen content of 5.6%, fiber content of 0.5%, and fiber length of 10mm. The mixes were prepared using bottom ash and fly ash, with aggregate sizes of 300-75-micron and passing 75 micron, which satisfied the Marshall requirements. It was noted that when the coal ash content was less than 15%, the Marshall stability and flow characteristics were acceptable. The study also observed that increasing fiber content and length led to a decrease in air-void and flow, and an increase in Marshall Quotient due to higher stability value. Finally, it was found that increasing the amount of fiber and the length of the fibers required more bitumen and emulsion to coat the fibers.



Graph between Tensile strength vs Temperature

CONCLUSION

In this study, a bituminous concrete (BC) mix was prepared using VG 30 grade bitumen as a binder, and two types of natural fibers, sisal fiber and coir fiber, were added at varying concentrations (0% to 0.8%). The Marshall Method of mix design was used to determine the optimum binder content (OBC) and optimum fiber content (OFC). It was found that adding 0.6% of fiber improved the properties of the mix. The results of the indirect tensile strength and tensile strength ratio tests showed that BC with sisal fiber had very good performance and could be used in flexible pavements.

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