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A REVIEW STUDY ON THE USE OF FIBERS IN BITUMINOUS WORK

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Abstract: The aim of this analysis is to present, evaluate, and talk about the literature related to the earlier findings on road surfacing in pavement engineering reinforcement. In order to bolster the argument for the importance of fiber-reinforced asphalt pavement, this paper also reviews the history and current state of road surfacing. The development of transportation plays an important role in the development of nation. With flexible pavements being widely used in India, steps must be taken to increase the life of the bituminous pavements. Flexible pavements are often plagued with problems of cracking and rutting due to repeated traffic loads. Hence one needs to address these problems in order to improve the performance of flexible pavements. In this paper, a review of the background and present status of road surfacing is also provided for supportive explanation of the significance of fiber-reinforced asphalt pavement HMA and its role in providing effective and durable surfacing for heavy-trafficked roads. Numerous research' findings support the notion that the fiber particularly improves the optimum bitumen content in the design of the mixture and halts the bitumen leakage due to its asphalt absorbing susceptibility. Fiber modifies the visco-elastic response, susceptibility against moisture, increase resistance to rutting, as well as lowers the pavement fatigue cracking.

Index Terms – Fibers, Natural Fibers, Asphalt Pavement, Marshal Properties, Bitumen Durability.

I. INTRODUCTION

India's economy depends heavily on its transportation infrastructure, with highways serving as the main means of public transportation. As a result, the Indian government has made significant investments in the creation and upkeep of these roads' pavement. In addition to guaranteeing that the highways will function dependably over time, a comprehensive engineering study can save a substantial amount of money and pavement materials. The two primary types of pavement used in road construction are rigid and flexible pavement. In order to maximize the performance of flexible pavement for use on Indian highways, this study focuses exclusively on its mixed design. Strength, longevity, resistance to fatigue and permanent deformation, environmental friendliness, and cost-effectiveness are just a few of the variables that determine a bituminous mix's quality. To attain the desired properties, mix designers test various mix proportions multiple times. The purpose of this study is to draw attention to the difficulties in bituminous mix design as well as the current directions in research to solve these problems.

A pavement structure can be designed as either a flexible or rigid pavement depending on its structural behavior. Because flexible pavement is more practical and affordable than rigid pavement, it is extensively used in India. Flexible pavements exhibit a relatively flexible structural action under load, despite having a low or non-existent flexural strength. While bitumen is used as the binding material in flexible pavement, cement is used in rigid pavement. Flexible pavement is composed of four layers.

a. Sub grade
b. Sub base course
c. Base course
d. Surface course

According to Figure 1, the structure of the pavement surface is meant to withstand high traffic volumes and offer protection against water infiltration during rainy seasons, which can cause the pavement's lower layers and surface to deteriorate. As a result, preventing water from getting near the pavement surface is crucial and can extend its lifespan. This is because liquid is forced into the pavement and its lower layers by heavy vehicles' tires, which over time can cause the pavement to fail and deteriorate. Pavement deterioration is frequently linked to with cracking, rutting, raveling and bleeding.

Figure 1

II. Applications and Classifications of Fiber

There are certain benefits to using fibers as a stabilizer in bituminous mixtures. Additionally, it raises the mixture's ideal bitumen content and void percentage. By absorbing light bituminous components, the fibers modify the degree of visco-elasticity of the mixture and help to solve the bitumen drain down issue. Additional benefits of fiber-modified mixtures in bituminous mixtures include increased resistance to rutting and improved moisture susceptibility (albeit at the expense of thicker bitumen layers). There are two methods for processing fibers: wet and dry. While in the dry process, the fiber is blended with the aggregate before bitumen is added to the mixture, in the wet process, the fibers are mixed with the asphalt cement before the binder is added. Consequently, for the following reasons, the dry process is usually better than the wet process: The dry process minimizes the chance of fibers clumping or balling in the mixture and is the most practical method to use because it allows fibers to be easily injected and distributed throughout the mixture without melting in the bitumen. Note that in order to ensure sufficient adherence to the bitumen binder and eliminate any chance of moisture-induced stripping, the fiber must be dried as much as possible before being added to the mixture.

Fibers can be divided into a number of groups using diverse methods. One method could be to categorize them as either apparel or non-apparel. While some natural fibers like cotton, jute, sisal, ramie, and silk and some synthetic ones like nylon, polyester, and spandex are used in apparel, non-apparel fibers include aramid, polyethylene, steel, copper, carbon, glass, silicon carbide, and alumina. The non-apparel fibers can be used to create geotextiles, cords and ropes, and other structural uses like reinforcing different composite materials. Compared to the fibers used in clothing, these fibers are much stronger, more rigid, and rarely break. Non-apparel fibers are typically less durable due to their intricate processing and abrupt degradation with minute imperfections. Fibers can also be categorized based on their length, where they are separated into continuous and staple fibers. Indeed, the length of a continuous fiber is infinite, whereas a staple fiber is discrete and short (10–400 mm). The use of fibers in structural engineering is dependent upon three key characteristics of the material: diameter, high elasticity, and high aspect ratio (length/diameter, L/d), which allows a significant portion of the load to be transferred from the matrix to the stiff and strong fiber in a fiber-reinforced composite.

Types of Fibre used in Bituminous Pavement

a. Asbestos Fiber
b. Polyester Fiber
c. GLASS Fiber
d. Cellulose Fiber
e. Waste Fiber

III. LITERATURE REVIEW

To purpose and defend the research work, a number of research papers are analyzed. Following are the excerpts from the different research work performed by number of academicians and researchers.

Satyavathi et al (2016) In this study, two grades of asphalt mixes—grade-I according to MORTH and grade-II according to IRC—were examined for the usage of coir and pineapple fibers. To find the ideal fiber concentration, the researchers employed several bitumen percentages, ranging from 5.5% to 7%, and carried out the Drain Down test. According to the study, for both grade-I and grade-II mixtures, the ideal coir fiber (OCF) percentage was 0.3% and the ideal pineapple fiber (OPF) level was 0.1%. For grade-I and grade-II mixtures, the ideal binder contents were determined to be 6.6% and 6.7% for coir fiber and 6.25% and 5.75% for pineapple fiber, respectively. Pineapple and coir fibers both improved the stability of the samples in both classes and decreased the mix's drain down. In contrast, pineapple fiber was less stable than coir fiber. The overall goal of the study was to ascertain the ideal fiber percentage and content for coir and pineapple fiber in asphalt mixtures. In order to design and optimize these mixtures for road building projects, valuable insights can be gained from the test results carried out in this study.

Thakur and Singh et al (2017) The goal of the project was to improve the performance of flexible pavements by mixing bituminous concrete with coir or coconut fiber. The bitumen content was 5%, whereas the fiber content ranged from 0.2% to 0.8%. The performance of the mix significantly improved with the inclusion of coir fiber. After reaching a maximum of 0.4% of fiber content, bituminous concrete's stability rating somewhat declined. At 0.4% of the fiber content, the highest stability value was attained. After declining to 0.2% of fiber content, the flow value began to rise, reaching its maximum value at 0.8% of fiber content. With a maximum value of 0.8% of fiber content, the percentage of voids filled with bitumen (VFB) increased significantly from 0% to 0.8%. The percentage of voids in mineral aggregate (VMA) dropped from 0% to 0.8%. There was a decrease in the percentage of air spaces in the mixture after the addition of coir fiber.

Mashaan et al. (2021) The relevance of fiber-reinforced asphalt pavement in offering strong and long-lasting surfacing for heavily-traveled roads is highlighted in this paper's survey of the literature on road surfacing in pavement engineering. In order to make the experiments and discussions easier for readers to grasp, the paper attempts to define some of the terms and concepts associated with this subject. According to the review, because fiber absorbs asphalt, it increases the ideal bitumen content and stops bitumen leaks in asphalt mixtures. Fiber also lessens pavement fatigue cracking and enhances the viscoelastic response, moisture resistance, and rut resistance.

Dwivedi and Joshi et al (2022) According to the study, bitumen contents of 5.6%, fiber contents of 0.5%, and fiber lengths of 10 mm were the most effective for producing bituminous blends. The mixes met Marshall standards with aggregate sizes of 300-75 microns and passing 75 microns, made with bottom ash and fly ash. It was observed that the Marshall stability and flow characteristics were acceptable when the coal ash level was less than 15%. The study also found that when fiber length and content increased, air-void and flow decreased and Marshall Quotient increased as a result of a higher stability value. Ultimately, it was discovered that more bitumen and emulsion were needed to coat the fibers when the amount and length of the fibers increased.

Ali, A et al (2013). Bitumen binder, one or more supporting courses, and a surface layer of mineral aggregate make up a bituminous pavement surface. The principal components that comprise this layer are (i) a bitumen-aggregate mixture that forms the bituminous base; (ii) certain stones, gravel, or slag; and (iii) cement. Above the prepared sub-grade, bituminous pavement typically consists of unbound (gravel or stone) layers and bitumen-bound layers. The uppermost layers of pavement are made up of a bituminous surface that can be either high-quality HMA (suitable for parking lots and high-volume roads) or a chip seal (fit for low-volume roads). In order to create a smooth but skid-resistant bituminous pavement surface that can withstand distortion

Ratnasamy, M.; Bujang et al 2006 There are various types of cracks in bituminous pavement, such as slipping, longitudinal, edge, block, and alligator cracks. The most common is the cracking of alligators. Usually occurring on HMA pavement surfaces, alligator cracking, often referred to as fatigue cracking, is a sequence of interconnecting cracks. This type of cracking is called alligator cracking because it seems to resemble the cracks on an alligator's skin. Continuous loads of high traffic on the tire pressure area of asphalt pavement frequently cause alligator cracks. The main causes of fatigue cracking include inadequate pavement thickness, high loading, deterioration in the subgrade or base coarse, or a combination of any or all of the aforementioned elements.

Wu,Y.S.; Li et al, 2009 Road construction uses fiber, particularly in gap-graded mixtures like stone mastic asphalt, SMA, and OGFC (open graded friction course), to increase the mixtures' resistance to rutting, fatigue life, and asphalt pavement drain-down. The "stone on stone" foundation of SMA's construction refers to the high percentage of large aggregates or stones that adhere to one another, creating a robust structure with a great resistance to plastic deformation. Although open graded friction asphalt (OGFC) has some advantages, including increased skid resistance, it has a greater concentration of large stones and a lower percentage of smaller, finer stones and particles (less than 1.18 mm). However, SMA typically contains a higher proportion of fine and bigger stone. OGFC fibers can be divided into two groups: (1) high elasticity modulus fibers, like carbon, glass, and asbestos, which are less suitable for asphalt random desperation; and (2) low elasticity modulus fibers, which are more adaptable and can be used in the construction of road pavements because during the pavement process, heavy traffic loading causes compaction, which increases the risk of damage from sharp angular stones. This makes high elasticity modulus fibers particularly prone to breaking and damage.

Wu,S.; Chen, Z.; Ye, Q.; Liao, W et al 2006. The effects of adding fiber to bitumen concrete are contingent upon the characteristics of the fiber (e.g., fiber length, diameter, surface texture, etc.) An issue called "balling" may arise from overly long fibers. Balling is a condition where fibers gather and lump together, making it difficult for the fibers to mix with the bitumen efficiently. In a similar vein, fibers that are too short might be able to sufficiently and successfully reinforce the mixture. The length/diameter ratio of the fiber is another important factor affecting the effects of fiber reinforcement. Greater length to diameter ratios make it easier for fibers to intertwine and create networking systems.

Mahrez et al 2005 The ideal fiber content in a mixture is between 0.3% and 0.4%, depending on the kind of fiber utilized, as numerous other studies and researchers have confirmed. Mixing more fibers than the ideal concentration is also not cost-effective because too much reinforcement can produce brittle mastic, which could eventually cause the pavement to deteriorate quickly. An even, uniform distribution of fibers in a mixture is the best way to address this issue.

IV. RESEARCH METHODOLOGY

The plan and procedure used to perform the study are described in the methodology section.

MATERIAL USED.

i) **LIME**: This study used Lime Powder.

TEST OF LIME: -

a. Sieve Analysis
b. Specific Gravity –

ii) **AGGREGATE**: The aggregate is classified as fine aggregate and coarse aggregate. Fine aggregate is material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. According to IS 383:2016, the fine aggregates classification, the study used dust.

a. Sieve Analysis-
b. Specific gravity –
c. Elongation & Flakiness
d. Aggregate Impact Value –
e. Water Absorption

iii) **FIBRE**: The characteristics and performance of fiber changes with varying bitumen binder formulation as well as the fibre material type, fibre geometry, fibre distribution, fibre orientation and fiber concentration.

a. High flexibility-
b. Diameter

c. High aspect Ratio (L/d)

iv) **BITUMEN**: Because of its many qualities and benefits over other materials for paving, bitumen is used in road construction. Throughout the manufacturing process, bitumen acquires certain special qualities.

a. Absolute Viscosity.
b. Softening Point
c. Penetration
d. Ductility
e. Solubility
f. Flash & Fire Point

v) **BITUMINOUS MIX AND MATERIAL TESTING**

The various tests were conducted on material used to prepare the bituminous containing various proportion of fibre in accordance with the American Standard for Testing of Materials (ASTM) and Indian standards (IS). The following tests were performed:

a. Sieve Analysis: Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963
b. Water Absorption: This test helps to determine the water absorption of coarse aggregates as per IS: 2386 (Part III) – 1963. For this test a sample not less than 2000g was used.
c. In order to produce a mix of appropriate and consistent quality with fully coated aggregates, pre-mixed bituminous materials must be prepared in a hot mix plant with sufficient capacity. The proper mixing temperatures in accordance with the MoRTH specification. No more than 14°C can be allowed to pass between the aggregate and binder's temperatures. The hot mix plant should undergo periodic calibration in order to guarantee consistent quality of the mix and improved aggregate coating.
d. Maximum Specific Gravity of Mix (Gmm): The estimation of air void content during HMA pavement construction involves the use of theoretical maximum specific gravity, as it is necessary to compute air void content. Compaction is gauged by measurements of the air void in-place. Compaction causes a decrease in the air volume in HMA, which explains why. The air volume inside the compacted HMA is therefore the feature of compaction to be concerned about. Usually reported as "percent air voids," this volume is measured as a percentage of air voids by volume. Comparing a test specimen's bulk specific gravity (Gmb) to its theoretical maximum specific gravity (Gmm) and assuming that the discrepancy is caused by air allows one to compute the percentage of air voids.
e. Marshal Stability Test: Marshal Stability Test was performed to determine the stability and flow of the bituminous mix properties following the ASTM D 1559 code.

V. OBJECTIVE

The major objectives of the study are given below:

a. To assess bituminous concrete's performance
b. To evaluate bituminous concrete's flow value and stability and contrast it with a regular mix
c. In order to generate the affordable construction materials.
d. To reduce the environmental impact of industrial and agricultural waste materials.
e. To offer a substitute lightweight substance.

VI. CONCLUSIONS

The results verify that the fibers can effectively increase the asphalt binders' resistance to flow and rutting as well as their dynamic shear modulus. Asbestos appears to have a smaller network impact than polyester and polyacrylonitrile, while lignin's antenna feature further strengthens it. When compared to asbestos and lignin fibers, polyester and polyacrylonitrile fibers appear to have a larger network effect, with the antenna characteristics amplifying the effect that is created. Conversely, glass fiber possesses exceptional insulating qualities, a high tensile strength, and is highly resistant to changes in temperature and chemical composition. Glass fiber has a high resistance to breakage and damage, which is typical of roofing shingles. According to the results, the mixture reinforced with cellulose did not significantly improve its low temperature performance, even though the polymer modified mixture's resistance to cracking had improved. This suggests that the polymer had a significant role in the mixture samples' positive modification. The results obtained from applying cellulose fiber and mineral to the specimen and examining the effects of these factors on SMA rutting performance indicated that the fiber content and type had the potential to alter SMA rutting performance. The mixture reinforced with cellulose fiber has a higher optimum bitumen content and indirect tensile strength.

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