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A Review on Comparative Study on Bitumen Modification Using Synthetic and Natural Fiber

Midhila V S[1], Veena G Raj[2]

Abstract: ***Transportation sector is showing immense growth in the recent decades, modern vehicles introduced require a more stable platform to run better. In terms of road construction, we are not yet reaching the modernized standards adopted by other countries and usage of modern and innovative road construction materials are yet to be used in transportation infrastructure sector. The available roads are also getting damaged due to improper maintenance of top layer of the road and no bond strength between the bitumen and coarse aggregate. To avoid this kind of cracks and failure of surface bitumen, this is the main binder in the road construction need modification. In this study, there is a comparison between the bitumen modification using synthetic fiber and natural fiber. The bitumen used is the VG-30 which has a penetration value of 50-70 mm. The synthetic fiber used is polypropylene fiber and the natural fiber is the sisal fiber.***

Keywords: VG-30 Bitumen, Sisal fiber, PP fiber, marshall stability test

1. Introduction

Fiber-modified mixtures are basically composed by the matrix and fibers. The performance of these mixtures is mainly based on the content and length of fibers and on the physical properties and adhesion of fibers and matrix. The use of fibers emerges as a need for improving the flexibility and tensile strength of the bituminous mixtures submitted to a higher volume of traffic and to the increase of loads by axis of heavy vehicles. These are some of the causes which cause the plastic and viscoelastic deformations in the mixture and, consequently, the rutting formation and the progressive propagation of cracks. Fibers are included in the bituminous mixtures to improve some of their properties such as adhesion and flexibility, in order to increase the resistance of the mixture and to prevent premature distress. Some of the main practical examples of the application of fibers in flexible road pavements are referred below, namely through the incorporation of nylon, carbon, synthetic, natural, polymer, glass, acrylic fibers etc.

Currently, synthetic fibers, such as: glass, carbon, polymer and aramid fibers are used as modifiers because of their high stiffness and strength properties. Natural fibers such as hemp, coir, jute, sisal and flax are a new class of materials which have good potential in bituminous mixes. Depending on their origin, natural fibers can be grouped into bast (jute, banana, flax, hemp, kenaf, Mesta), leaf (pineapple, sisal, henequen, screw pine), seed or fruit fibers (coir, cotton, palm). Different fiber arrangements, such as: short-randomly oriented, long-unidirectional and woven fabrics have been fabricated for natural fiber composites. Therefore, reinforcement of the bituminous mixes is one approach to improve the tensile strength and fibers are the most suitable reinforcing material.

Natural Fiber

O.S.Abiola et al (2013) sisal fiber is one of the most widely used natural fibers and is very easily cultivated. Nearly 4.5 million tons of sisal fibers are produced every year throughout the world. Tanzania and Brazil are the two main producing countries. Sisal fiber is a hard fiber extracted from leaves of the sisal plant. A sisal plant produces between 200 and 250 leaves and each leaf contains between 1000 and 1200 fiber bundles, which are composed of: 4% fiber, 0.75% cuticle, 8% dry matter and 87.25% water. Therefore, a leaf which weighs about 600 g will yield about 3% by weight of fiber with each leaf containing 1000 fibers. The advantages of sisal fibers are: they have good resistance against moist, heat and short fibers delay restrained plastic shrinkage thereby controlling crack development at early ages. In developing countries, sisal fibers are used as reinforcement in houses.

Oda et al. evaluated the use of asphalt rubber binder and natural fibers (sisal and coconut) in discontinuous stone asphalt mixture (d-SMA). Comparison was done between the performances with: (i) mixture without fibers, (ii) polyester fibers and (iii) cellulose. The results of the mechanical tests (tensile strength and modulus of resilience) demonstrated that blends with natural fibers showed high resistance, while preventing the asphalt drain down. The result of fatigue analysis showed that the mixture with an asphalt modified rubber had the best behavior and the results obtained with cellulose fibers, sisal and coconut shells were not significantly different.

Delgado and Arnaud investigated the potential use of hemp fibers as reinforcement for asphalt paving materials. Four different lengths of fiber and three different proportions were investigated in order to assess the influence of fiber content and length on the fatigue behaviour of the composite. The results indicated that there is a reduction in the complex modulus and phase angle (damping)of the fiber-modified asphalt mixtures in comparison with the con-trol. Fatigue life was improved for fiber-modified asphalt mixtures with fibers of 5 cm length and percentage of 0.4%.

Coir fiber was reported to have improved fatigue life of bituminous mixes. Thulasirajan and Narasimha presented a study on stability, flow and volumetric properties of the coir fiber reinforced bituminous concrete by varying the binder content, fiber content and fiber length. The results indicated that the addition of coir increased the stability and voids with decrease in the flow rate. Fiber length of 15 mm with a fiber content of 0.52%and a binder content of 5.72% provided good stability and volumetric properties. It can be said that coir fiber has the potential to improve the structural resistance to distress occurring in flexible pavement due to traffic loads .

2. Synthetic Fiber

According to SHIVRAJ (2015) The generation of waste plastics is increasing day by day..The major polymers namely polyethylene, polypropylene, polystyrene show adhesion property in their molten state. The plastic coated aggregate bitumen mix and plastic modified bitumen forms better materials for flexible pavement construction as the mixes shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods of easy disposal of waste plastics. The use of polymer coated aggregate is better than the use of polymer modified bitumen in many aspects. For example, if all the roads in India (3.3 million km) are converted into plastic tar road, all the waste plastic available will be used on the road and the disposal of waste plastics will no longer be a problem. But as the burning of plastic waste creates health hazards and also air pollution, the use if this should be restricted to open areas or in lesser populated areas. Also; the workers involved should be provided with proper safety devices. These processes are socially highly relevant, giving better infrastructure. Let us grow with these newer technologies.

According to Disha Rajyaguru, RohitKumarAddition PP fibers showed an increase in Marshall Stability as well as increase in percent of air void is noted while decreases in flow property is seen considerably. As a result, the data show that PP modified asphalt-concrete samples can be considered as high performance asphalt-concrete mixtures. Increasing the percent of air void, in modified treatments, they are useful for hot regions where bleeding and flushing are critical distresses. Finally, the study concluded that 5.0% of polypropylene of 12 mm length is better than other percentages used in the experiment, because the air void increased to 17.45% at this percentage.

According to MAHESH M BARAD (2015) Polymer Modified Bitumen is used due to its better performance. But in the case of higher percentage of polymer bitumen blend, the blend is a more polymer dispersion in bitumen, which get separated on cooling. This may affect the properties and quality of the blend and also the road laid using such blend. In the modified process (dry process) plastics-waste is coated over aggregate. This helps to have better binding of bitumen with the plastic-waste coated aggregate due to increased bonding and increased area of contact between polymer and bitumen. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reduced rutting, ravelling, and there is not pothole formation. The road can withstand heavy traffic and show better durability.

Wang et al., 1994 Nylon is a usual fiber used in carpet production. After being recycled this type of fiber can be used in the production of mixtures for pavements. According to Serfass and Samanos´s conclusions (1996), the addition of nylon fibers allows mixtures rich in bitumen to obtain an enhanced behavior concerning resistance to fatigue cracking, aging and moisture.

Kim et al. (1999) state that mixtures strengthened with nylon fibers increase the fatigue life of a pavement, approximately 20 to 25 times when compared with mixtures without fibers. In fracture processes, when cracks occur in a material with fibers, these fibers "build" a bridge which will bond both sides of the crack, thus giving additional resistance to its propagation and opening before the rupture of the mixture. By using indirect tensile strength tests, Lee et al. (2005) also conclude that adding nylon fibers to asphalt concrete may improve fatigue cracking resistance by increasing the fracture energy, a fundamental mechanical property of bituminous mixtures. The fracture energy of fiber composite asphalt concretes with a fiber length of 12 mm and a volume fraction of 1% shows an increase of about 85%, higher than that of regular asphalt concretes.

The company S&P (2007) studied the use of carbon fibers in several areas of civil construction due to their successful practical uses implemented already. The last development by S&P refers to the metallic nets of carbon fibers covered with bitumen to reinforce cracked areas of asphalt concrete pavements. The metallic nets of carbon fibers prevent and delay the occurrence and progression of reflective cracks. Ultra-thin coverings, armed with carbon fibers, offer new possibilities for future innovative solutions.

Rowlett and Uffner (1985) studied the behavior of bituminous mixtures in road overlays or strengthening of distressed pavements using glass fibers together with polymer modified bitumen to minimize the propagation of cracks. This system was also used to reduce the scaling of deteriorated cracks and joints (avoiding the occurrence of potholes) before the construction of a new road overlay. Bitumen with polymers adheres to the old pavement, to the glass fibers and to the new overlay. It protects the strengthening material (the glass fibers) and works as a membrane to reduce the stress state near the cracks, transferring the stresses for the new road overlay. The glass fiber strengthening system distributes the stresses on the rehabilitated pavement into a value below the fracture strength of the new overlay. The authors verified that the strengthening system of polymer modified bitumen 2 together with glass fibers was effective in the reduction of reflective cracking. The referred system demonstrated a successful reduction in the maintenance costs (in the order of ten to one), with an equivalent or better performance than the traditional milling and replacement of the material.

The Spanish centre of research CEDEX (2003) has carried out an extensive study on bituminous mixtures modified with acrylic fibers, concluding that the addition of these fibers in the bituminous mixtures reduces the thermal susceptibility, increases the resistance to permanent deformations and to fatigue cracking, what, jointly, highly enhance the durability of pavements. Acrylic fibers form a three-dimensional net which acts as an armor by increasing the consistency of the mixture, which is thus improved in its mechanical properties, especially those related to shear and tensile strength. Using acrylic fibers improves the following properties of bituminous mixtures: resistance to fatigue cracking and to permanent deformation, durability and the performance of the binder at high temperatures. The behavior of the internal structure of the mixture with fibers improves its cohesion and tenacity, thus guaranteeing a greater resistance to impacts, a decrease of the abrasive effect of traffic and delaying the beginning and propagation of cracks

3. Conclusions

The use of fibers provides a need for improving the tensile strength and flexibility of the bituminous mixtures as pavement experiences higher volume of traffic and increase in loads, especially coming from heavy vehicles. These cause plastic and viscoelastic deformations in the mixture, thus resulting in rutting formations and progressive propagation of cracks. Different researchers have reported the results emanating from the addition of a large variety of fibers to asphalt concrete. Reinforcement with natural fibers has been shown to possess certain advantages over such as: their ease availability, low density, acceptable specific properties enhanced energy recovery and biodegradability other fibers. The main drawbacks in the use of natural fibers in various polymer matrixes are the poor compatibility between the fiber sand the matrix and the inherent high moisture absorption, which brings about dimensional changes in the lignocellulosic-based fibers. Therefore, chemical treatments are considered in modifying the fiber surface. Some compounds such as: sodium hydroxide, silane, and acetic acid maleated coupling agents peroxide have shown to promote adhesion to the material.

Most of the chemical treatments achieved various levels of success in improving fiber strength, fiber fitness and fiber adhesion in natural fiber reinforced asphalt composites. Efforts at improving the properties of the fibers have made researchers to focus on the study of effect on mechanical properties due to hybridization of natural fibers with synthetic fibers. Owing to high initial cost, adverse effects on the environment and the requirement for a large quantum of energy to produce synthetic fibers, researchers started exploring natural fiber-based hybrid composites. There is little or no work reported on the possibility of two or more natural fiber based hybrid composites in asphalt reinforcement. Modification of bituminous mixes is expected to enhance the material strength, fatigue characteristics and at the same time, exhibit excellent mechanical properties and increase the ductility of the composite. Various studies on the use of natural fibers have been on SMA, which is a gap-graded mixes, while little or no work has been reported on dense-graded mixes. Fibers are used in SMA mixes to act as a stabilizer thereby preventing the draining down of the asphalt binder.

Different researchers have reported the results of the addition of a large variety of fibers to bituminous mixes. The result shows that fiber improves the fatigue life by increasing the resistance to cracking and permanent deformation. The fiber reinforcement thus provided additional tensile integrity in the mixes and hence increasing the strain energy absorption thereby inhibiting the formation and propagation of cracks. Researchers on natural fibers agreed that uniform distribution, fiber length, percentage and orientation are the keys to mixture performance. In order to understand the mechanical properties of fiber reinforced bituminous mixes, it is recommended that the orientation of fibers through the mixes should be examined with the aid of optical and/or scanning electron microscopy

Recently, one of the main lines of research is the study of recycled fibers as an environmentally friendly material to be used in bituminous mixtures. Labib and Maher (1999) stated that the use of recycled fibers in asphalt mixtures was considered advantageous when using fishing nets. As a result, fibers could be uniformly and consistently incorporated into the asphalt mixture without segregation or introduction of excessive air voids. However, the same authors refer that fibers typically obtained from recycling operations such as those from carpets and car seats were difficult to be utilized with the dry mixing process used in laboratory. Thus, a first stage to study these fibers should comprehend the use of virgin fibers to clearly understand how fibers affect the mechanical properties of the mixture, and then apply the results to the use of recycled fibers.

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