MOISTURE SUSCEPTIBILITY CHARACTERISTICS OF SISAL-POLYETHENE MODIFIED OPEN GRADED ASPHALT CONCRETE

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Abstract

The objective of the study was to evaluate if sisal fibre and polyethene waste plastics can be used in road construction of flexible pavement to improve strength and reduce moisture susceptibility. The indirect tensile strength test is used to determine the tensile properties of the Open Graded Asphalt (OGA) mixture which can be further related to the cracking properties of the pavement. The tensile strength ratio of bituminous mixtures is an indicator of their resistance to moisture susceptibility and a measure of water sensitivity. Clean polyethene waste plastics comprising of High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) were shred into sizes 2-3mm using shredding machine. The open graded aggregates were heated and shredded plastics effectively coated over the aggregate by heating while mixing. Treated sisal fibres of 5mm length were mixed with hot bitumen. Sisal fibre was treated using 0.5N solution of sodium hydroxide solution (NaOH) at a temperature of 15-18°C, by immersing in a bucket of the solution for 12 hours, then removed and air-dried. Sisal fibre treated with 0.5N solution of sodium hydroxide makes sisal fibre become less porous with high density thus making more rigid asphalt concrete mix. The plastic-coated aggregate was mixed with mixture of sisal fibre and bitumen and the resultant mix was analyzed for tensile strength and moisture susceptibility to assess its suitability for road construction. It was observed that tensile strength of modified OGA increased from 0.44 MPA to 1.23MPa representing 180% increase for conditioned state samples when modified using 0.3% sisal fibre and 5% polyethene waste plastics by mass of dry aggregates. The tensile strength ratio of 99.9% of the Sisal-Plastic modified OGA indicated that the sample is highly impermeable to water as compared to sisal fibre modified or non-modified control samples. In conclusion, the use of sisal fibre and polyethene waste plastics in the modification of asphalt concrete for road surfacing will strengthen the road pavements thereby increasing the road service life. Disposal of polyethene waste plastics by utilizing them in road construction will help improve the environment and further their successful application as construction materials in flexible pavement to improve road performance.

Key words: Polyethene waste plastics, sisal fibre, open graded asphalt (OGA), sisal-plastic modified open graded asphalt (SPMOGA), Marshall test, stability, flow, voids, drain down. Indirect tensile strength (ITS), tensile strength ratio (TSR)

1.0 Introduction

The tensile properties of bituminous mixtures are of interest to pavement engineers because of problems associated with cracking. Though open graded asphalt (OGA) is not nearly as strong in tension as it is in compression, its tensile strength is important in pavement applications (Chen *et al*., 2019). The indirect tensile strength test (IDT) is used to determine the tensile properties of the bituminous mixture which can further be related to the cracking properties of the pavement. A higher tensile strength corresponds to a stronger cracking resistance (Wu *et al*., 2015). At the same time, mixtures that are able to tolerate higher strain prior to failure are more likely to resist cracking than those unable to tolerate high strains (Tayfur et al., 2007). A lot of research work has been reported on the performance of bituminous pavements relating the tensile strength of bituminous mixtures (Zhang et al., 2001; Behbahani et al, 2009; Anderson et al., 2007). A higher tensile strength corresponds to a stronger low temperature cracking resistance. The resistance of bituminous mixtures to fatigue cracking is dependent upon its tensile strength. Flexible pavements are subjected to continuous flexing as a result of the traffic loads that they carry, resulting in tensile stresses and strains at the bottom of the bituminous layer (Abiola *et al*., 2014). Hence, indirect tensile strength test of asphalt concrete is an indicator of strength and adherence of pavement against fatigue, temperature cracking and rutting. Tensile strength is typically used as performance measure for pavements because it better simulates the tensile stresses at the bottom of the surface course when it is subjected to loading (Huaxin *et al*., 2009). The values of indirect tensile strength are used to evaluate the relative quality of bituminous mixtures for estimating the resistance of pavement to cracking. The results are also used to determine the resistance to field pavement moisture when results are obtained in both, water conditioned and unconditioned states (Rokade, 2012).

Moisture damage in bituminous mixes refers to the loss of serviceability due to the presence of moisture. The extent of moisture damage is called the moisture susceptibility. The Indirect Tensile Strength test is a performance test which is used to evaluate the moisture susceptibility of a bituminous mixture. Moisture susceptibility is the ratio of the tensile strength of water conditioned sample, (ITS wet, 60°C, and 24 h) to the tensile strength of unconditioned sample (ITS dry) which is expressed as a percentage. A higher TSR value typically indicates that the mixture will perform well with a good resistance to moisture damage. The higher the TSR value, the lesser will be the strength reduction by the water soaking condition, or the more water-resistant it will be (Ahmed and Mahmood, 2015).

2.0 Materials and Methods

Materials used were aggregates size 6/12mm, 5.5% bitumen grade 80/100, polyethene waste plastics sizes 2-3mm and 5mm long sisal fibre. The procedure used to determine the tensile strength and moisture susceptibility was done in accordance with standard test method (AASHTO T 283-14). The fibre content in this research was varied between 0.1%, 0.2%, 0.3% and 0.4% and polyethene waste plastics content varied from 1%, 3%, 5% and 7% by weight of dry aggregate mix. 0.3% Sisal fibre and 5% polyethene waste plastics content gave the highest stability and were used to prepare sisal-plastic modified open graded asphalt (SPMOGA) concrete samples. Six cylindrical samples of each modified bituminous concrete mixes were prepared and divided into two groups to determine the tensile strength values. The first group was preconditioned by vacuum saturation, that is, 55–80% of the air voids were filled with water. Samples showing above 80% saturation after the vacuum soaking were discarded since they were viewed to be severely saturated (Chen *et al*., 2005). This process was repeated with a new sample. If saturation had not reached 55% in a conditioned sample after the initial vacuum soaking, then the specimen was returned for additional vacuum soaking until a minimum saturation level of 55% was reached. The samples were wrapped in plastic bags and put in a freezer for 16 hours at -18°C. After 16 hours in the freezer, the samples were put into a water bath for 24 hours at 60°C and finally placed into another water bath for 2 hours at 25°C (Dash *et al*., 2016). Each cylindrical modified bituminous concrete mix sample was loaded with vertical compressive loads to failure. The test was performed at 25°C in indirect tension at 50.8 mm/min deformation rate. Failure occurred by splitting along the loaded plane. This generates a relatively uniform tensile stress along the vertical diametrical plane. The average of three normal tests was reported. Indirect tensile strength and tensile strength ratio were calculated using Equations 1 and 2 below (Shukla *et al*., 2014);

$$\mathrm{ITS} = \frac{2\mathrm{P}_{\max}}{\pi \mathrm{td}} \quad \text{......Eqn 1}$$

Where

ITS is Indirect tensile strength, MPa

P_{max} is peak load (N),

t is the average height of specimen (mm)

d is the diameter of specimen (mm).

$$\mathrm{TSR} = \frac{\mathrm{ITS_{Con}}}{\mathrm{ITS_{uncon}}} \mathrm{x}100 \quad \text{......Eqn 2}$$

ITS_{con} is tensile strength of water conditioned sample

ITS_{uncon} is tensile strength of unconditioned sample

The average of three tests was determined as the moisture susceptibility of the modifier.

3.0 Tensile strength characteristics for modified open graded asphalt

3.1 Tensile strength of sisal modified asphalt concrete

Open graded asphalt concrete was modified using varying proportion percentages of sisal fibre. The samples were tested for tensile strength before and after conditioning the samples by putting them in water bath. The indirect tensile strength test result for sisal fibre modified asphalt mix are presented in Figure 1. The tensile strength results for unconditioned modified asphalt concrete mix samples increases with proportion increase in sisal fibre content up to optimum value of

1.10MPa. When the asphalt concrete samples were conditioned, tensile strength results reduced to 1.07MPa. This is associated with weakened bond by wetting as a result of conditioning. Weak bonds are as a result of reduced cohesion when friction between particles reduces. The tensile strength of sisal ***fibre*** modified OGA increased from 0.83MPa to 1.10MPa and from 0.43MPa to 1.07 MPa for unconditioned and conditioned samples respectively. The aggregates particles are held together by bitumen as a binder and sisal fibre acts as reinforcing agent in stiffening the mix thus increasing tensile strength. When sisal fibre reinforces the bond formed by bitumen and aggregates, a stiff matrix is formed. However, addition of sisal fibre beyond 0.3% content, the sisal fibre weakens the sample as a result of bitumen absorption, which would coat and bind the aggregates and reduction of grain to grain contact of the aggregates. This results into weakened bond and adhesion between the aggregates thus having weakened bond. At optimum sisal fibre content of 0.3%, the modified asphalt concrete has tensile strength that produce road pavements that resist low temperature cracking, fatigue and rutting.

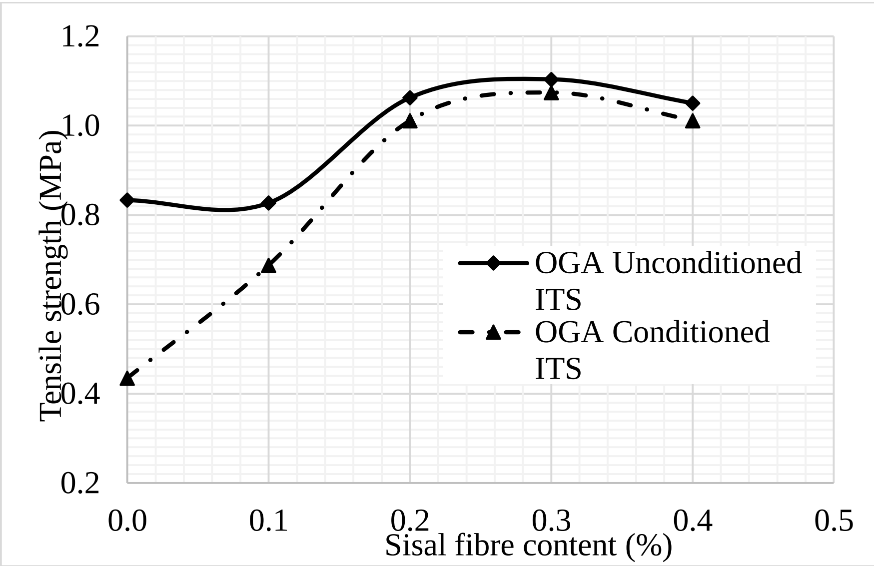

Figure 1: Tensile strength of sisal fibre modified asphalt concrete

3.2 Tensile strength of waste plastic modified open graded asphalt

The tensile strength results for unconditioned and conditioned waste plastic modified mix samples are presented in Figure 2. Tensile strength increased with increase in proportion increase in waste plastic content. The tensile strength values increased from 0.83MPa to 1.20MPa and from 0.43MPa to 1.17MPa for unconditioned and conditioned modified OGA respectively. This is as a result of weakened bond by wetting when conditioning took place. Wetting reduced the friction between particles and thus reducing cohesion. For both conditioned and unconditioned samples, the strength increased as waste plastic content increased up to maximum content of 5%. Polyethene waste plastics increases the adhesion between aggregate and bitumen by coating and binding the aggregates together with bitumen. This ultimately leads to a decrease in the stripping of particles, thus resulting in increased tensile strength. The addition of polyethene waste plastics improves the cracking résistance of pavements since it can withstand higher tensile strains.

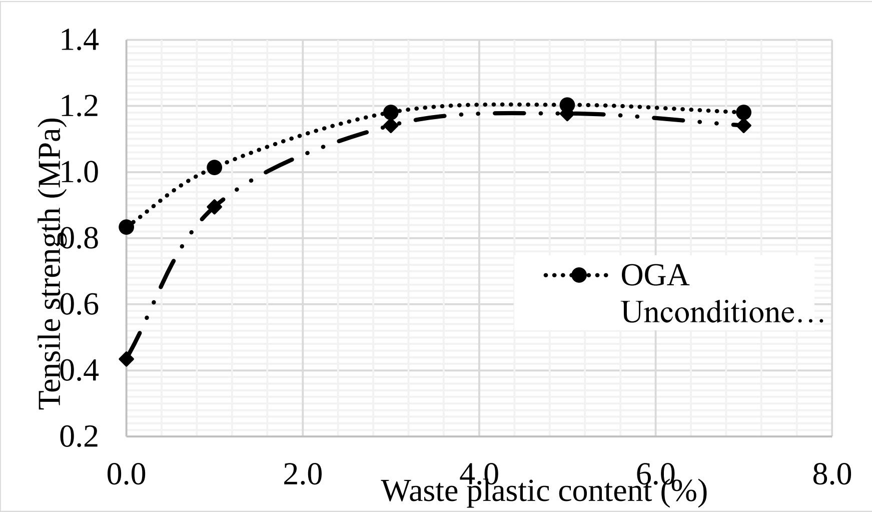

Figure 2: Tensile strength of waste plastic modified open graded asphalt concrete

3.3 Tensile strength for Sisal-Plastic modified open graded asphalt concrete

Tensile strength results for open graded asphalt and stone matrix asphalt when modified with both 0.3% sisal fibre content and 5% polyethene waste plastics are presented in Figures 3. Tensile strength for unconditioned OGA are 0.83MPa for control samples but increases to 1.1MPa, 1.2MPa and 1.23MPa for Sisal fibre, polyethene waste plastics and sisal-plastic modified asphalt concrete respectively. This represent 32%, 44% and 47% increase when sisal fibre, polyethene waste plastics and sisal-plastic were used to modify OGA respectively. Sisal-plastic modified asphalt concrete (SPMAC) samples had the highest percentage increase in strength of 47% unconditioned OGA as compared to sisal fibre or polyethene waste plastics stabilized samples. This is associated with the fact that the samples with sisal-plastic are more firm and stronger due to fibre reinforcement and waste plastic coating that form stiffer matrix samples compared to use of plastic or sisal fibre alone. It can be concluded that sisal-plastic additive demonstrates better cracking resistance as compared to sisal fibre and polyethene waste plastics modifiers only. Road pavement made from sisal-plastic modified asphalt concrete has sufficient strength to accommodate heavy traffic load without cracking.

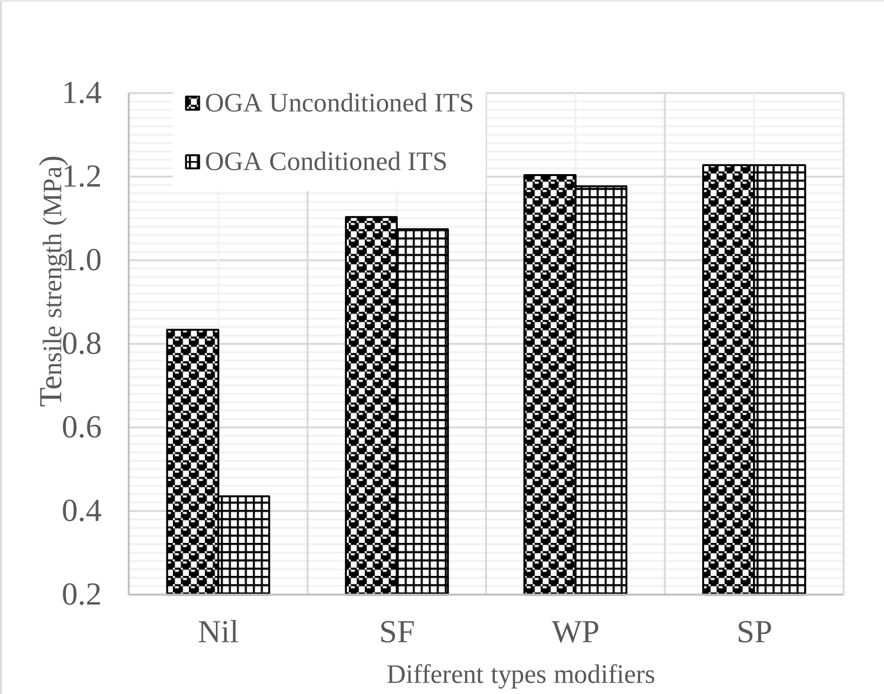

Figure 3: Tensile strength of modified open graded asphalt concrete

3.4 Moisture Susceptibility of modified open graded asphalt.

Moisture susceptibility is measured by tensile strength ratio (TSR) by dividing tensile strength of unconditioned and conditioned asphalt concrete samples. Test results for moisture susceptibility of modified OGA samples are shown in Figure 4. The tensile strength ratio (TSR) for the control samples is 52.2 %. However, TSR increased to 97.3%, 97.7% and 99.9% when OGA was modified using sisal fibre, polyethene waste plastics and sisal-fibre respectively. This means that the control mix has more moisture susceptibility, which would result into pavement damage by water.

However, the tensile strength ratios for the samples with sisal fibre, polyethene waste plastics and sisal-polyethene plastic modifiers have TSR greater than the specification limit, AASHTO T283 of 70%. The sisal-plastic modified asphalt has the highest TSR of 99.9 %. Asphalt concrete samples modified using sisal fibre and polyethene waste plastics are more firm and stronger due to fibre reinforcement and polyethene waste plastics coating that form stiffer matrix. This reduces water-induced damage to the pavements thus preventing the development of cracks.

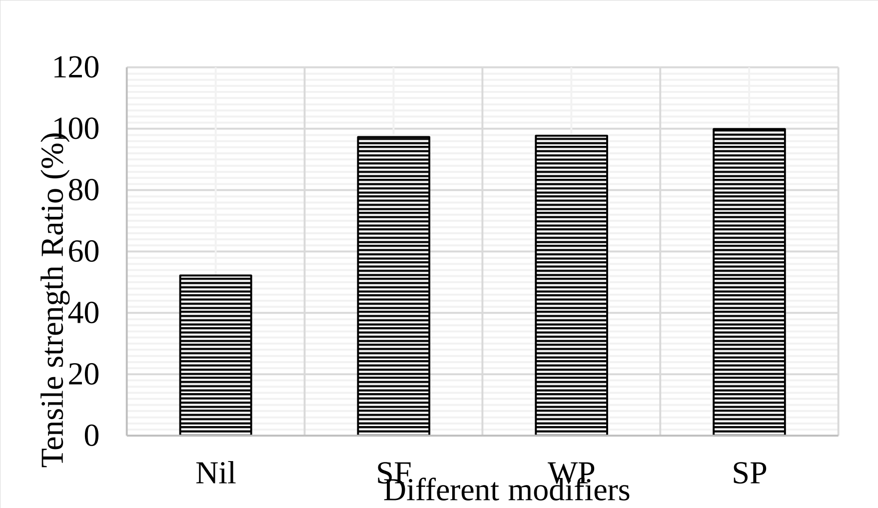

Figure 4: Tensile strength ratios for asphalt concrete with different additives

4.0 Conclusion

Based on results obtained, the modification of OGA with sisal fibre and polyethene waste plastics improves the cracking resistance of the mixture compared to the control mix. All the additives improve the adhesion property of the bitumen to aggregate. The indirect tensile strength values are much higher when additives are incorporated in OGA mixtures and the effect is more influential in the conditioned state. It is also observed that the tensile strength of conditioned samples decreased by 48% and 0% for control and SPMOGA samples respectively. The decrease is considerable in the control mixture and the tensile strength ratio goes below the specification limits. This substantiates the need of additives in OGA mixtures. OGA mixtures with sisal-polyethene plastics have the highest strength followed by the mix with polyethene waste plastics. Even though all stabilized OGA mixtures show higher indirect tensile strength and tensile strength ratio, OGA samples with 0.3% and 5% sisal fibre and polyethene waste plastics resulted in the highest tensile strength (1.227Mpa) and exhibit superior water resistance property (99.9%).

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