MOISTURE SUSCEPTIBILITY OF SISAL-PLASTIC MODIFIED OPEN GRADED ASPHALT

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Abstract

This study was done to determine how to improve moisture susceptibility of Open Graded Asphalt Concrete mix through the use of sisal fibre and waste plastics. The indirect tensile strength is an indicator of tensile properties of the Open Graded Asphalt (OGA) mixture. This test is generally associated with cracking behavour of the road pavement. The higher the results, the stronger the pavement to resist crack development. Further, the tensile strength ratio of asphalt concrete shows its ability to resist moisture susceptibility. The test is also a measure of water sensitivity of the asphalt mix. Cleaned waste plastics were shred into sizes such that they passed through 2-3mm sieve using shredding machine. Aggregates size 12/6mm were heated and mixed with shredded waste plastics. The heating and mixing were done until the plastics effectively coated the aggregate. Sisal fibre was treated using sodium hydroxide solution and cut into 5mm length fibres prior to mixing with hot bitumen. The plastic-coated aggregate was mixed with mixer of treated sisal fibre and bitumen and the resultant mix was analyzed for tensile strength and moisture susceptibility. It was observed that when 0.3% sisal fibre is mixed with 5% waste plastics to modify open graded asphalt, the indirect tensile strength improved to

1.23 MPa as compared to control samples. The tensile strength ratio of 99.9% of the Sisal-Plastic modified samples shows that the sample is resistant to moisture susceptibility.

Keywords: 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

Tensile strength of asphalt mix is an indicator of cracking resistance. Therefore, the test is important in road construction to evaluate the failure phenomena as a result of cracking. Indirect tensile strength test (IDT) is evaluated to assess the tensile strength of the sisal-plastic modified asphalt mix (Zhang et al., 2001). This would help in assessment of cracking properties of a pavement.

IDT can be calculated as indicated in the equation below.

$$S_t = \frac{2000P}{\pi t D}$$

where

S_t = IDT strength, kPa

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

Indirect tensile strength is used to evaluate the performance behavior of asphalt mix to resist cracking and moisture damage. Higher tensile strength values indicate a stronger cracking resistance. Samples which produce high strain values before failure are likely to resist cracking (Tayfur et al., 2007). Many experimental have been done on the performance of bituminous mixes to evaluate the tensile strength (Behbahani et al, 2009). High values of tensile strength show that the mix is highly resistance to low temperature cracking phenomena (Huang et al. 2004). Indirect tensile strength test gives indication on pavement material characteristics of per on fatigue, permanent deformation and tensile strength.

Asphalt concrete mix resistance to fatigue cracking depend on its tensile properties. These properties are tensile strength and extensibility. Asphalt concrete fatigue is the characteristic of fracture under repeated or fluctuating stresses (Anderson et al., 2001). Flexible pavement roads are exposed to continuous flexing as a result of the traffic loads, which result into tensile stresses and strains at the bottom layers. Therefore, the indirect tensile strength test is done on bitumen mixtures since it expresses pavement strength and resistance against fatigue, rutting and cracking. The test is generally a performance indictor for pavements made of modified open graded asphalt, since simulates the tensile stresses at the lower section of the surface course when under load.

Indirect tensile strength results are used to determine the quality of asphalt mix, assessing cracking and moisture resistance of the pavement when results are obtained on both waters conditioned and unconditioned samples (Kandhal,2002; Ibrahim, 2000).

Pavement moisture damage refer to the loss of serviceability due to the presence of water. This damage due to moisture is known as moisture susceptibility. It is measured by performing tensile strength ratio (TSR) test which indicates water sensitivity. TRS is ratio of the tensile strength of water conditioned samples to the tensile strength of unconditioned samples. High TSR value shows that the mix samples are resistance to damage by water. Higher TSR values shows that there is less reduction of the pavement strength which ultimately indicates higher water-resistant. the control mix for the subsequent studies.

2.0 Materials and Methods

2.1 Materials

Materials used were bitumen grade 80/100, graded aggregate of nominal size 12/6 mm, treated sisal fibre of diameter 0.1 to 0.4 mm, 5mm long and shredded waste plastics of 2-3 mm. The optimum binder content adopted in this research is 5.5%.

2.2 Laboratory Test Procedure

The test was performed in accordance with standard test method as outlined in AASHTO T 283-14. This was done to determine the moisture susceptibility of modified mixtures utilizing indirect tensile strength (ITS) and retained tensile strength ratio (TSR) after vacuum saturation and moisture conditioning. Six cylindrical samples of each modified bituminous mixes were prepared and divided into two groups to determine the tensile strength values. The first group was preconditioned by vacuum saturation, 55–80% of the air voids were filled with water. The samples were wrapped in plastic bags and put in a freezer for 16 hours at -18°C. Thereafter were put into a water bath for 24 hours at 60°C. They were finally placed in a water bath for 2 hours at 25°C. Each cylindrical modified bituminous sample was loaded with vertical compressive loads to failure, at 25°C and 50.8 mm/min deformation rate.

Tensile strength ratio (TSR), $TSR = \frac{ITS_{Con}}{ITS_{uncon}} x100$

where

ITS_{con} is the indirect tensile strength of conditioned samples

ITS_{unco}n is the indirect tensile strength of unconditioned samples

3.0 Moisture Susceptibility of Sisal Plastic Modified OGA

The results of modified open graded asphalt for both conditioned and unconditioned samples are given in Table 1.

Table 1: Modified Open graded asphalt Indirect tensile strength results

Additive	**%**	**ITS Unconditioned (MPa)**	**ITS Conditioned (MPa)**	**% TSR (MPa)**
Nil	0	0.8335	0.4350	52.19
Sisal Fibre (SF)	0.1	0.8273	0.6876	83.12
	0.2	1.0624	1.0112	95.18
	0.3	**1.1035**	**1.0739**	**97.33**
	0.4	1.0503	1.0113	96.29
Waste Plastics (WP)	1	1.0140	0.8951	88.27
	3	1.1810	1.1409	96.61
	5	**1.2036**	**1.1769**	**97.78**
	7	1.1806	1.1407	96.62
Sisal Fibre and Waste Plastics (SP)	0.3% SF 5% WP	**1.227**	**1.2270**	**99.94**

The results shown in table 1, shows improve tensile strength. The samples modified with sisal fibre or waste plastics showed higher tensile strength compared to control mixtures. This could be associated with enhanced stiffness of modified OGA samples compared to the non-modified samples. Modifier additives added to OGA, the bonding between the aggregate particles and bitumen are reinforced. This makes the mix sample strong by forming a stiffened matrix. As the modifier content was increased, the tensile strength increased until the maximum value was achieved. Thereafter, there was decrease in strength as modifier content was increased. When the samples were conditioned, the tensile strength decreased when compared to unconditioned samples. This is associated with wetting of the samples which weakened the bond that held the particles together. Strength reduction as a result of conditioning was nearly 48 % for control sample, 3% for waste plastics and 2% for sisal plastics at optimum contents. However, the decrease in strength for modified samples using combination of sisal fibre and plastics at optimum contents was 0%.

3.1 Sisal Fibre Stabilized OGA

Figure 1, shows results for indirect tensile strength of modified asphalt mixtures with different of contents of sisal fibre. The indirect tensile strength results for unconditioned modified mix samples, show high values, compared to conditioned sample. 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. For both conditioned and conditioned samples, the strength increased as sisal fibre content was increased up maximum content of 0.3%. when more sisal fibre content was added beyond 0.3%, the indirect tensile strength started declining. The aggregates particles are held together by bitumen as a binder and sisal fibre acts as a reinforcing agent in stiffening the mix. Hence tensile strength is dependent on binding properties of bitumen and reinforcement ability of sisal fibre. When sisal fibre reinforces the bond formed by bitumen and aggregates, a stiff matrix is formed. However, addition of sisal fibre beyond 0.3%, the fibre weakens the sample as a result of reduction of grain to grain contact of the aggregates. Increase in sisal fibre results in more absorption of bitumen leaving little bitumen to coat and bind the aggregates together. This results into weakened bond and adhesion between the aggregates thus having weakened bond.

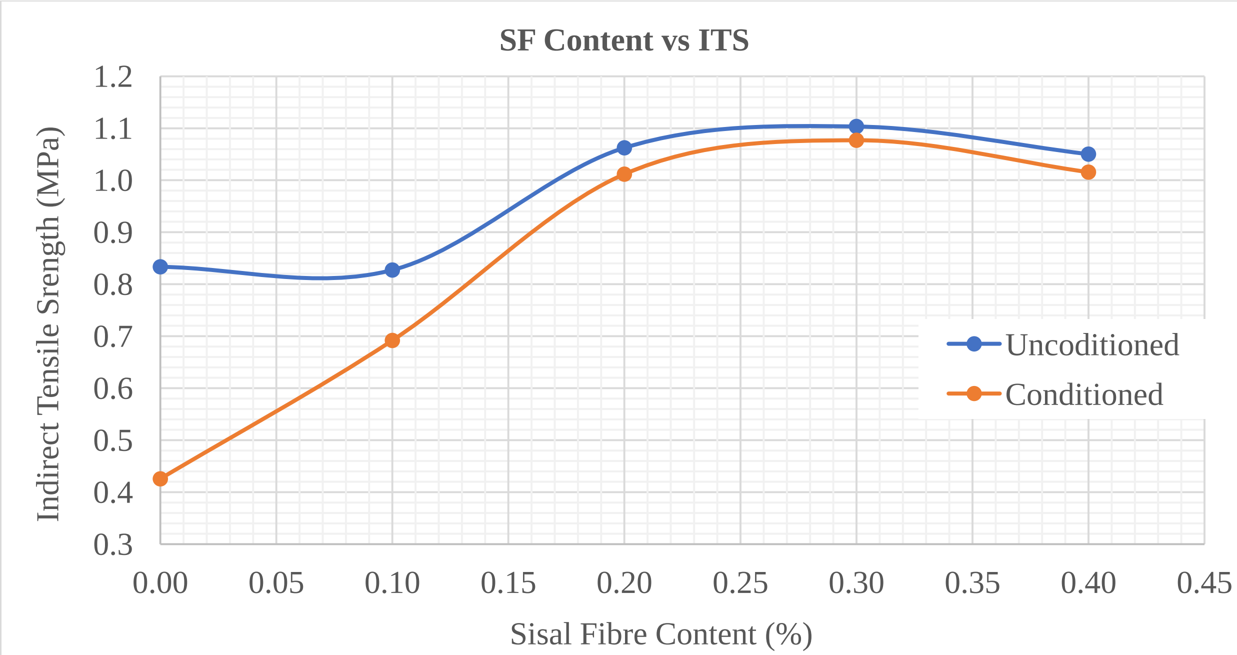

Figure 1: Indirect Tensile Strength of sisal fibre modified open graded asphalt concrete

3.2 Waste Plastic modified open graded asphalt

Figure 2 shows indirect tensile strength results when open graded asphalt was modified with Waste plastic. The indirect tensile strength results for unconditioned modified mix samples, show slightly high values, compared to conditioned sample. 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 conditioned samples, the strength increased as waste plastic content increased up maximum content of 5%. When more waste plastic content was added, the indirect tensile strength decreased. Waste plastics used to modify OGA increases the adhesion between aggregate and bitumen. The plastics coat the aggregates and together with bitumen binds the particles together. This ultimately leads to a decrease in the stripping of particles, thus resulting in increased tensile strength. The addition of waste plastics improves the cracking résistance of pavements since if can withstand higher tensile strains.

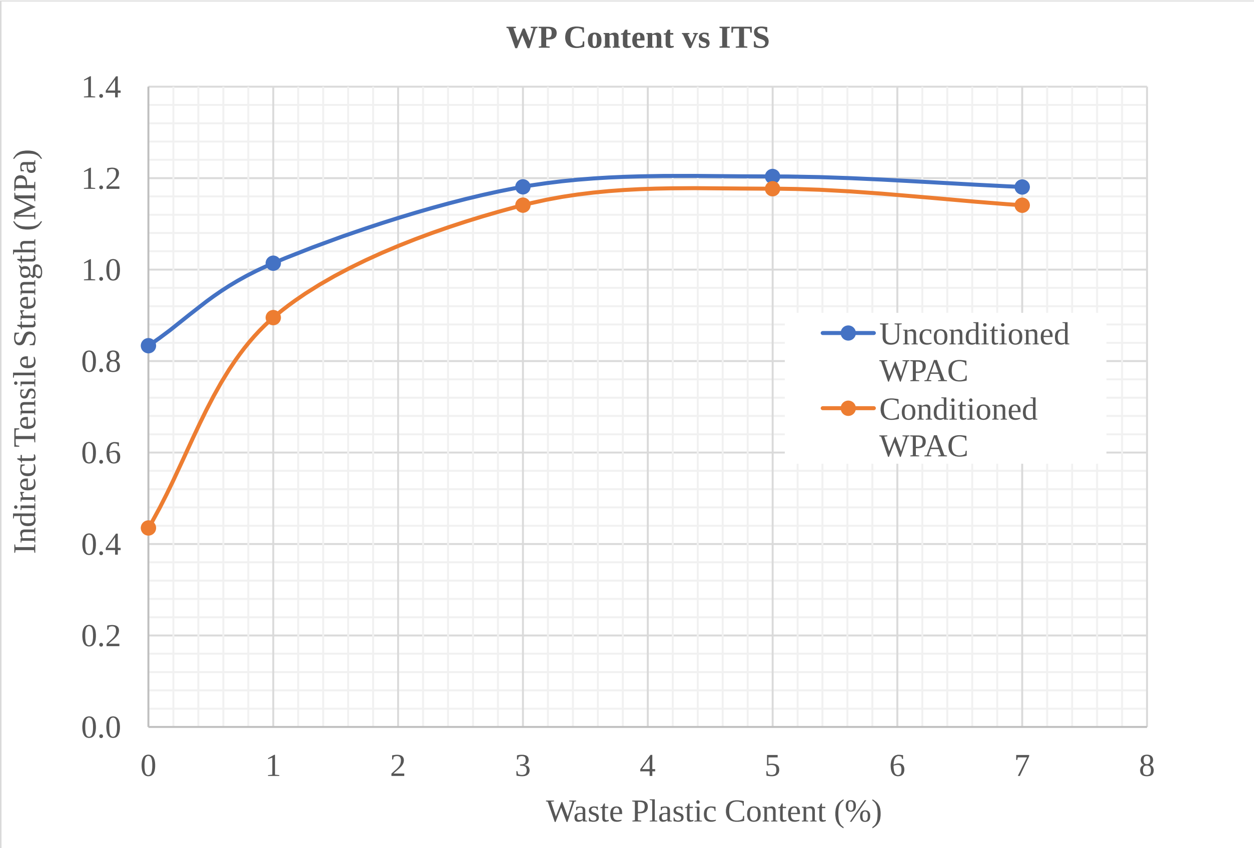

Figure 2: Indirect Tensile Strength of waste plastic modified open graded asphalt concrete

3.3 Sisal-Plastic Modified OGA (SPMOGA)

Figure 3, shows indirect tensile strength results of open graded asphalt when modified with combination of sisal fibre and waste plastics at optimum contents. The change in indirect tensile strength for control samples when conditioned and unconditioned shows a reduction by 48%. The reduction in indirect tensile strength was 3% for sisal modified, 2% for plastic modified and 0% for sisal-plastic modified samples. For none control sample, the conditioning weakened the bond between the particles more when compared with modified samples. These means that sisal fibre held the particles together by forming a stiff matrix. However, the plastic modified samples were more impermeable to water. Hence less reduction in strength. The tensile strength value for specimens with combination of 0.3% sisal fibre and 5% waste plastics is higher as compared to that with sisal and waste plastics only. The sisal-plastic modified samples had no reduction in indirect tensile strength. This is associated with a combination of firm matrix formed as a result of fibre reinforcement and water impermeable properties of waste plastic modified samples. This resulted into strengthened bond between the aggregates.

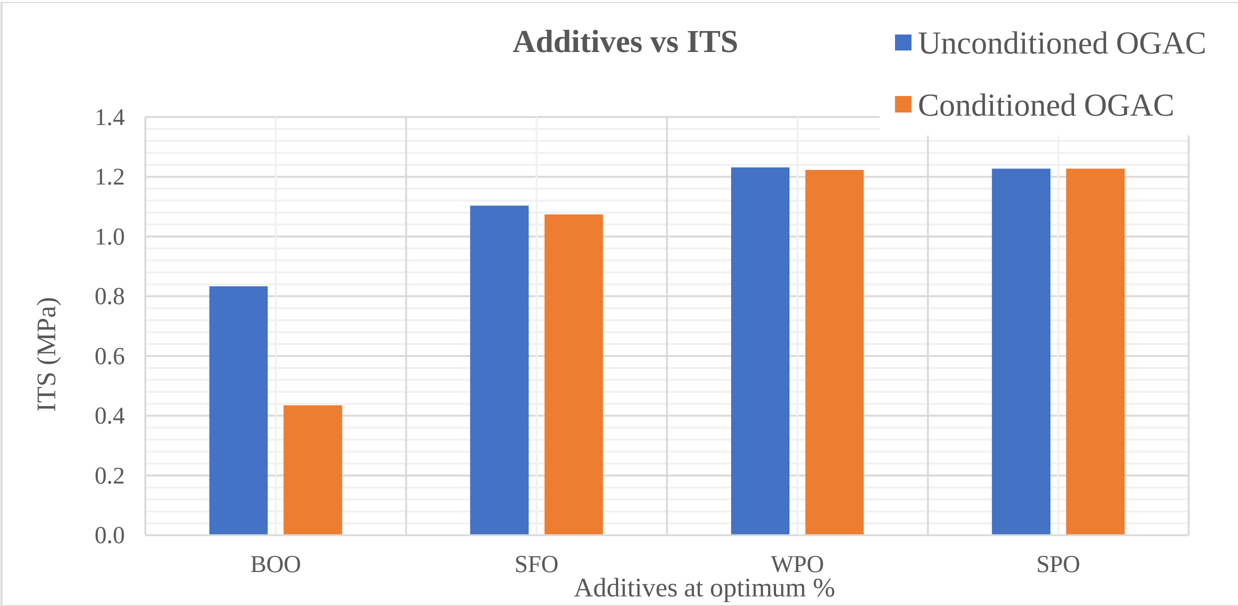

Figure 3: Indirect Tensile Strength of sisal -plastic modified open graded asphalt concrete

Sisal plastic modified asphalt concrete (SPMAC) samples had the highest percentage increase in strength at both unconditioned and conditioned samples as compared to sisal fibre or 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 a slightly better cracking resistance as compared to sisal fibre and waste plastics modifiers only.

3.4 Moisture susceptibility of modified open graded asphalt

Figure 4, shows test results for moisture susceptibility of modified open graded asphalt. The tensile strength ratio (TSR) results of the control sample was 52 %, less than minimum TSR value set forth by AASHTO T283 of 70%. 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, waste plastics and sisal-plastic modifiers have TSR greater than the specification limit. The sisal-plastic modified asphalt has the highest TSR of 99.9 %.

Therefore, the presence of sisal and waste plastic additives greatly reduces water-induced damage to the pavements. The decrease in TSR at higher fibre content beyond the optimum content is associated with balling effect of the fibres in the mix. For waste plastic modified samples with more than 5% plastics, the reduction in TSR is associated with weakening of the bond between the aggregate and binder as more waste plastics coat the aggregates particles.

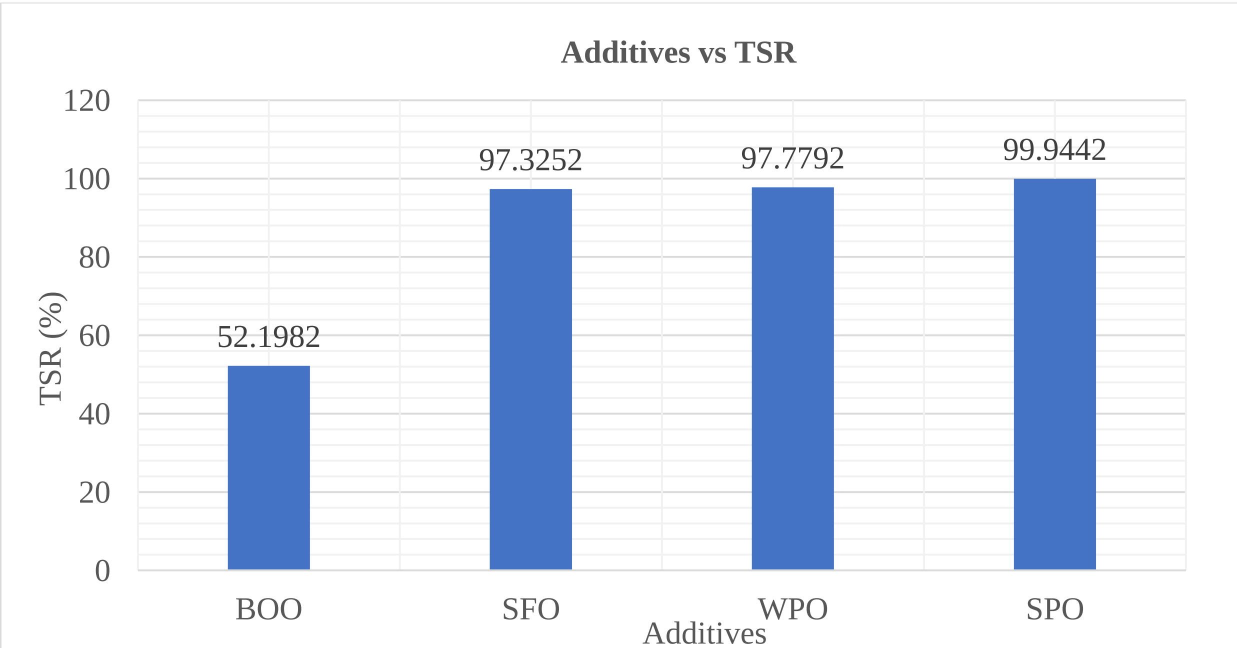

Figure 4: Variation of tensile strength ratios of modified open graded asphalt with different additives.

4.0 Conclusion

In can be concluded that the modification of OGA with sisal fibre and waste plastics improves the cracking resistance of pavements due to high results of TSR of 99.9%. Indirect tensile strength values of sisal-plastic modified samples were much higher compared to control samples. Tensile strength decreases by conditioning the sample from 0.8335 MPa to 0.435 MPa for control specimen. Strength reduced from 1.1035Mpa to 1.0739 MPa for sisal fibre modified samples and from 1.2036MPa to 1.1769MPa for waste plastic modified samples after conditioning. However, there was no reduction in strength for sisal-plastic modified samples after conditioning. The sisal-plastic samples indirect tensile strength remained at 1.227% after conditioning. The decrease in strength of control mixture below the specification limits when conditioned substantiates the need for use of additives in the modification of open graded asphalt. Sisal-plastics modified samples had the highest strength followed by the mix with waste plastics and sisal fibre modified mix. Therefore, modifying open graded asphalt with combination of 0.3% sisal fibre and 5% waste plastics gives an excellent water resistance characteristic able to resist moisture induced damage to pavements.

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