RHEOLOGICAL PROPERTIES OF COARSE COIR POWDER MODIFIED SMA

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ABSTRACT
This study aimed at change in rheological characteristics of coarse coir powder modified SMA mixture. The project studied the suitability of coarse coir powder as a reinforcing material in bituminous mixes. Fibers reinforced bituminous mixture is widely used specially in stone mastic asphalt (SMA). Among natural fibers more attention is nowadays being paid to coir fiber due to its easy availability, good wearing resistance and more durable property. Complex shear modulus (G*) and phase shift angle (δ) are the main rheological parameter used to predict the pavement performance. It was found that an increase in the percentage of coir powder causes an increase in rutting factor (G*/sinδ) indicating higher resistance against rutting.

Index Terms: Coarse Coir powder, Rheological properties, Rutting factor

1. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper. The growth of traffic and over loading of vehicles decreases the life span of roads laid with conventional bituminous mixes. Continuous increase of wheel loads tyre pressure and change in climatic condition severely affect the performance of bituminous mix pavements. Providing durable roads has always been a problem for a country like India with varied climate, terrain condition, rainfall intensities and soil properties. Lot of research is going on all over the country in this field to solve the problems associated with pavements.

Bitumen modification/reinforcement has received considerable attention as viable solution to enhance flexible pavement performance. The introduction of this technology to the transportation industry was mainly prompted by the unsatisfactory performance of traditional road materials exposed to remarkable increase and changes in traffic pattern. The performance of bituminous mixes used in the surfacing course of road pavement can be improved by the addition of various types of modifiers like fibres, polymers etc. Fibres are added as reinforcement in bituminous mixtures. The principal functions of fiber reinforcement in bituminous mixes are to provide additional tensile strength in the resulting composite and increasing strain energy absorption of the bituminous mix to inhibit the formation and propagation of cracks that can reduce the structural integrity of the road pavement.

Previous researchers have reported fiber's reinforcing effects in asphalt mixtures and pavements. Fiber can stabilize asphalts to prevent asphalt leakage especially for the open-graded-friction course (OGFC) and stone–mastic–asphalt (SMA) mixtures during the material transportation and paving. Fiber changes the visco-elasticity of mixture, improves dynamic modulus, moisture susceptibility, creep compliance and rutting resistance and reduces the reflective cracking of asphalt mixtures and pavements. (AbdelazizMahrez, 2010) Fibers reinforced bituminous mixture is widely used specially in stone mastic asphalt (SMA). Among natural fibers more attention is nowadays being paid to coir fiber due to its easy availability, good wearing resistance and more durable property. In Kerala, coir fibers are cheap and locally available. Coir fiber is now a day used in order to improve the properties of the bituminous mix. This study aims at change in rheological characteristics of coarse coir powder modified SMA mixture.

2. OBJECTIVES

- To study basic properties of virgin and coarse coir powder modified bitumen.
- To study various rheological properties of the modified bitumen and unmodified bitumen.

3. LITERATURE REVIEW

Ratnasamy et al., (2006**)** conducted a laboratory fatigue performance of SMA with cellulose oil palm fiber to evaluate the effect of cellulose oil palm fibers (COPF) on the fatigue performance of SMA. The fiber modified binder showed improved rheological properties and showed that the PG 64-22 binder can be modified and raised to PG 70-22 grade. The COPF was found to improve the diameteral fatigue performance of SMA design mix. The fatigue life increased to a maximum at a fiber content of about 0.6%, while the tensile stress and stiffness also showed a similar trend in performance. Mahrez and Karim (2010) studied fatigue characteristics of stone mastic asphalt mix reinforced with fiber glass. This paper presents the characteristics and properties of glass fiber reinforced Stone Mastic Asphalt. Laboratory tests were conducted to evaluate such related properties of asphalt mixture with different fiber contents. The results indicated that the fiber has the potential to resist structural distress that occur in road pavement as result of increased traffic loading, thus improving fatigue life by increasing the resistance to cracking and permanent deformation especially at higher stress level. Abiola et al. (2013)studied the concept of utilization of natural fibers and its composites in asphalt modification. Asphalt binder with additives like crumb rubber, natural rubber and polymers have been used to overcome rutting and raveling in flexible pavements. Fiber reinforcement improves fatigue life by increasing the resistance to cracking and permanent deformation. Sigit (2013) carried out study on the evaluation of the addition of short coconut fibers on the characteristics of asphalt mixtures. The addition of 0.75% 5mm fibers by weight of the asphalt increased the value of the Marshall stability by 10-15% and produced lower penetration-grade bitumen. K. Natarajan (2013) carried out the mechanical and morphological study of coir fiber reinforced modified epoxy matrix composites. The SEM micrographs show that the coir fibers are firmly embedded in the modified epoxy matrix leading to increased area of bonding at the interfacial region of the matrix and coir fibers, resulting in an increase in mechanical properties of the composite. Subramani (2014) conducted an experimental investigation on coir fiber reinforced bituminous mixes. The project studies the suitability of coir as a reinforcing material in bituminous mixes. Performance of the mix was improved by the addition of coir fiber. Vivek and Sowmya (2015) studied the utilization of fibre as a strength modifier in stone matrix asphalt. The study investigates the potential use of shredded waste plastic as a modifier for asphalt concrete and with the addition of coconut fibre to stabilize the asphalt from SMA mixes. Loui et al. (2015) conducted a comparative study of the effect of treated coir fiber and natural rubber modified bitumen on open graded friction course mixes. The mix prepared with NRMB and coir fiber was selected as optimum mix which provides adequate strength and adequate air void in order to drain the rain water quickly. 50 blows were selected as optimum compaction level to satisfy maximum stability and minimum percentage air void in the OGFC mix. Rosli Haininaet. al (2015)studied the Performanceof Modified Asphalt Binder with Tire Rubber Powder. Addition of tire rubber powder to the asphalt binder enhances the properties of modified binder. Increase in the percentage of tire rubber powder causes an increase in rutting factor ($G^*/\sin\delta$) and decrease in fatigue factor ($G^*\sin\delta$) indicating higher resistance against rutting and fatigue cracking.

4. EXPERIMENTAL

1.1Materials

The binder used for the study was VG30 bitumen procured from BPCL Kochi refinery. This bitumen is then modified with coir powder, which is passing through 150μ IS sieve. Coir powder is added to the bitumen in varying percentages of by weight of bitumen such as 0.2, 0.4, 0.6, 0.8 and 1.0 and mixed thoroughly in bitumen blending oven at a temperature of 163 ˚C at 200 RPM for half an hour.

1.2 Dynamic shear Rheometer

Dynamic Shear Rheometer is used to measure visco-elastic properties and rutting resistance at high and intermediate temperatures. DSR measures both viscosity and the elastic properties of the bitumen at medium to high temperatures. It is also defined as a binder characterization procedure and used to determine the fail temperatures of bitumen. This device used to make dynamic oscillatory load, where sinusoidal shear stress or strain is applied in the form of sinusoidal time function. DSR device was utilized to measure different binder properties before and after using the modification. Test results at intermediate and high temperatures, which can be used to predict resistance to rutting in asphalt concrete pavements. The test can be done when the bitumen's sample is sandwiched between two parallel plats the lower plate is fixed while the upper plate oscillates back and forth across the sample to create a shearing action and then the rheological parameter is recorded. The complex shear modulus (G*) can be considered the sample's total resistance to deformation when repeatedly sheared, while the phase angle (δ), is the lag between the applied shear stress and the resulting shear strain. The larger the phase angle (δ) means, more viscous the material.

5. RESULTS AND DISCUSSION

5.1 Basic Properties of Bitumen

TABLE 1Basic Properties of Modified and Unmodified Bitumen

Property	Results(VG30 Bitumen with % of coir added)				
	0%	0.40 %	0.6 0%	0.8 0%	1%
Penetratio n (mm)	70	65	60	58	40
Ductility(c m)	61. 5	40	55	50	40
softening Point(°C)	50	51	51. 5	53	53. 5
Specific Gravity	1	1.01	1.0 2	1.0	0.9 9
Viscosity at 135 °C (Cp)	560	600	700	480	51 5

From TABLE1 it can be seen that by the addition of coir powder the properties of virgin bitumen is changing**.**

5.2 Rheological Properties

The rheological characteristics are studied using Dynamic Shear Rheometer. The DSR measures a specimen's complex shear modulus (G*) and phase angle (δ). The complex shear modulus (G*) can be considered the sample's total resistance to deformation when repeatedly sheared, while the phase angle (δ), is the lag between the applied shear stress and the resulting shear strain. For evaluating these parameters at various test conditions amplitude sweep, frequency sweep, temperature sweep and viscosity curve were performed.

5.2.1 Amplitude Sweep

Strain sweep test results for modified and unmodified binders at various loading frequencies are shown in fig.1. Tests were performed at 60˚ C with shear strain range from 0.5 Pa to 10 Pa at a frequency equal to 10 Hz. In SHRP study it is reported the linear visco-elastic range (LVR) was defined as the point where complex modulus decrease to 95% of its initial value. The results were to compare between bitumen, which could be help to choose the input parameter for frequency sweep test. Based on these liner limits, rheological tests using the DSR were performed at strain level well inside the linear region and the liner rheological properties for modified and unmodified bitumen. For the majority of binders; it has been found that the Linear Visco-elastic Range is 10 %.

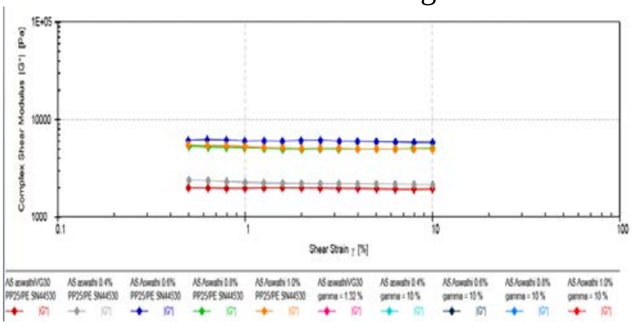

Fig.1Amplitude Sweep

5.2.2Frequency Sweep

Stiffness was measured at 60˚C over a wide range of frequencies from 0.1 Hz to 100 Hz. The highest loading frequency was selected because it is intended to simulate highway traffic speeds, and the lowest testing frequency was selected because it simulates loading in slow moving traffic conditions. It is clear from the fig. 2 that the shear modulus (G*) increases with the testing frequency. Modified bitumen with 0.6% and

0.8% coir powder modified bitumen shows highest complex shear modulus.

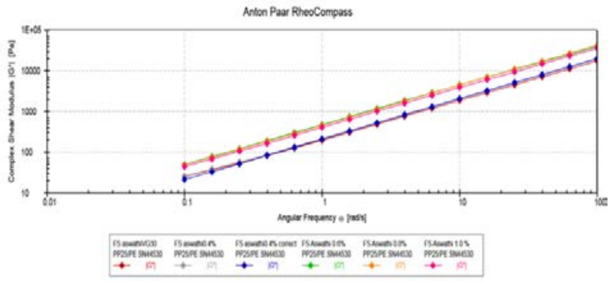

Fig.2Effect of coir powder modified bitumen on complex shear modulus

5.2.3 Temperature Sweep

A relation between storage modulus, loss modulus, complex shear modulus and phase angle with temperature is illustrated in fig. 3-7.

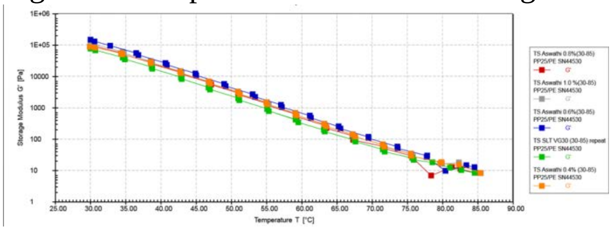

Fig.3 Effect of coir powder modified bitumen on storage modulus

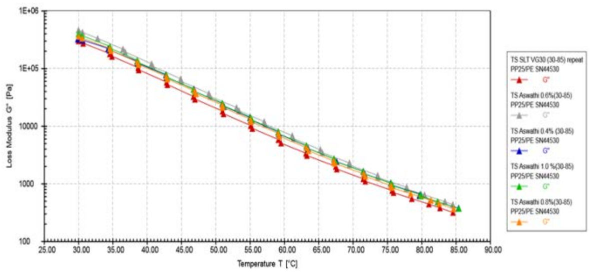

Fig.4Effect of coir powder modifiedbitumen on loss modulus

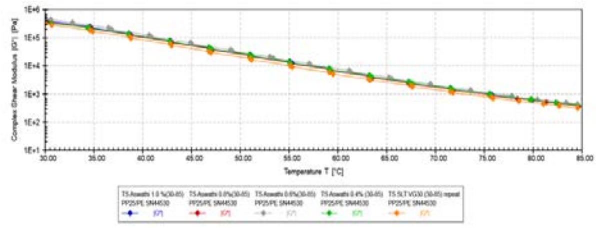

Fig.5Effect of coir powder modified bitumen on complex shear modulus

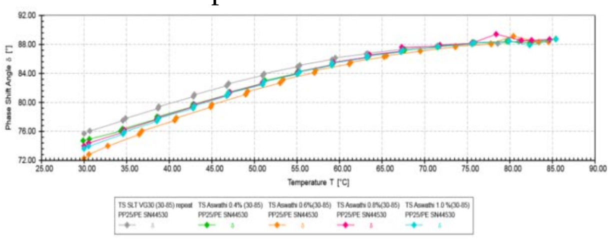

Fig.6 Effect coir powder modified bitumen on phase shift angle

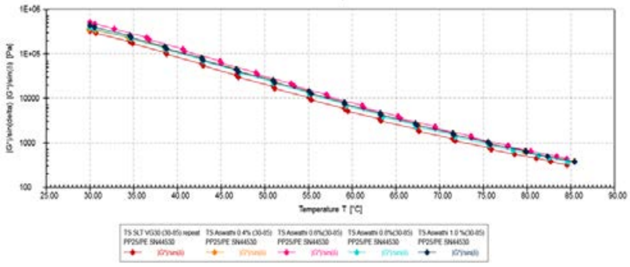

Fig.7Effect coir powder modified bitumen on G*/sin (δ) in temperature sweep

From fig. 3 and fig. 4 it is clear that the G' and G'' value decreases with increase in temperature. The coir powder modified binders shows much better results than unmodified binder at higher temperatures also. The increase in storage modulus G' reflects the increase in the stiffness of the coir powder modified bitumen, compared with that of unmodified bitumen. But the increase in loss modulus G'' indicates an increase in the viscous response. The maximum storage modulus is for bitumen modified with 0.6% coir powder. The loss modulus of modified bitumen is significantly higher than unmodified bitumen as shown in fig. 4.Higher values of loss modulus indicate more resistance binder to permanent deformation.

From fig. 5 it can see that complex shear modulus of modified and unmodified bitumen decreases with increase in temperature. Higher complex modulus at high temperature indicates better resistance to permanent deformation (rutting). Higher values of complex shear modulus are obtained for bitumen with 0.6 % coir powder modification. Fig 5.9 shows that the phase angle (δ) of coir powder modified bitumen was lower than that of unmodified bitumen. The phase angle of 0.6 % coir powder modified bitumen was considerably lower than that of unmodified bitumen. Lower phase angle indicates lower viscous flow and higher elastic response. This indicates that coir powder modified binders have high consistency and elasticity. Fig. 5.10 shows there was an increase in the G*/sinδ parameter of the original binder when the coir powder was mixed. This indicates that the stiffness of the modified binder increases with the increase in the percentage of coir powder and decreases with the increase in the temperature.

It can be seen that as coir powder percentage increases the rheological properties are significantly improved. From the graphs it is clear that rheological properties are strongly depend on coir powder content and reduction in complex shear modulus for modified bitumen is less than unmodified bitumen by increase of temperature. In conclusion 0.6% coir powder modified bitumen can resist deformation at high temperature than unmodified bitumen.

In conclusion coir powder is found to improve the rheological properties of the unmodified bitumen. From the results it is clear that the coir powder modified bitumen have the ability to maintain their high strength and elasticity at high service temperature. Effects of coir powder modification as a decrease in phase angle and an increase in complex shear modulus depends on the degree of modification. The magnitude and extent of these changes depends on degree of modification. Decrease in phase angle and increase in complex shear modulus indicate an increased hardness or stiffness of the modified binders. In addition to this increase in hardness indicate an improvement in temperature susceptibility with coir powder modification. The final performance of modified bitumen is determined by chemical nature of base bitumen, source and grade as well as the polymer molecular weight and modification level. From results it can see that 0.6% coir powder shows better rheological properties than other percentages. Complex shear modulus was increased by 60% and the phase shift angle was decreased by 5%.

5.2.4Viscosity curve

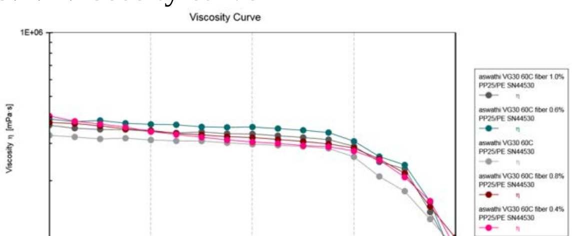

Fig.8Viscosity curve

From fig. 8 it can see that viscosity of modified and unmodified binder decreases with increase in shear rate. At higher shear rates the unmodified bitumen shows sudden decrease of viscosity but the modified bitumen shows higher values at higher shear rate. From fig. 8 it can also see that 0.6% coir modified bitumen shows much better viscosity values than other percentages with increase in shear rate.

6. Conclusions

- An improvement in basic properties by use of coir powder was studied.
- Coir powder modified bitumen is more viscous than unmodified binders, and tend to show improved adhesive bonding to aggregates.
- Thicker binder coatings usually take longer to become brittle, so the durability of the pavement can be improved.
- Among different percentages of coir powder modification, 0.6% shows the most improved rheological properties. Complex modulus was increased by 60 % and phase shift angle was decreased by 5%.
- Increase in G*/sinδ indicates modified bitumen exhibited better rutting compared to the unmodified bitumen.

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