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Effect Of Toluene As Disperser On The Bitumen Modified With Epoxidized Natural Rubber With Aging Simulation

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Abstract: This paper investigates the viability of using solvent, Toluene, to increase the dispersion of the Epoxidized natural rubber ENR and use it as a modifier with bitumen. 5% ENR by weight of bitumen was blended with 80/100 paving grade asphalt under optimum temperature and mixing time. Two methods of mixing were used, the first one was done with using of high shear mixer equipment and coded as (HSMP), and the other was done with using of low shear mixer, and Toluene as solvent, and coded as (LSMP). Unmodified and modified bitumen were subjected to many tests by using the dynamic rheometer shear (DSR) for unaged, short and long term aged binders to observe the effects of the solvent on the bitumen binder. The performance tests including Rheological analysis, morphology, penetration, softening point and ductility tests were carried out on unmodified and modified bitumen. It was observed that adding Toluene to the bitumen doesn't really change the Rheological properties of the virgin bitumen. The results showed increasing in complex modulus G*, decreasing in phase angle δ and improving in dispersion of ENR in bitumen with using of LSMP. This indicates that using of solvent can improve the modified bitumen performance without deteriorating the physical properties of bitumen for short and long term.

Key word: Bitumen, polymers, Epoxidized natural rubber, Toluene, DSR, aging, Morphology.

INTRODUCTION

Using polymers as bitumen modifiers expanded more and more due to its performance on bitumen properties. These kinds of modifications, polymers, classified as a physical modifiers.

Chemical modifications with bitumen are not commercialized. In physical modification the chemical properties is not supposed to be changed. However, There are many polymers have been used as modifiers such as polymers- elastomers (Styrene butadiene styrene SBS- Styrene butadiene rubber latex (SBR)- Natural rubber (NR)) (Yousefi 2002) and polymers- plastomers (Ethylene vinil acetate (EVA) - Polyethylene (PE)- polypropylene (PP)) (Jian-Shiuh Chen 2002; Routes/Roads July 1999). These kinds of polymers showed a good improvement in asphalt pavement conditions especially in term of permanent deformation. Natural rubber (NR) and epoxidised natural rubber (ENR) are preferred due to their low prices (Yousefi 2002). Toluene is a chemical liquid, solvent, which is able to dissolve rubbers. This solvent will be used in this study in case of using the normal mixer (stirrer) in order to dissolve ENR which will be used as a modifier in this study to improve its dispersion.

Many methods have been done to evaluate the effect of aging on the bitumen to see its behaviour during application and service life. RTFOT (Rolling Thin Film Oven Test) as short term aging and PAV (Pressurized Aging Vessel) as long term aging are most utilised tests to simulate ageing for bitumen(ASTMD2872 1997; ASTMD6521 2000). For both tests, the aging evaluated by observing how complex modulus (G*) and phase angle (δ) change with ageing.

This study was done to evaluate the conventional way to mix bitumen with the ENR as a modifier and using the stirrer for mixing after adding the Toluene. The evaluation will be done in terms of the rheological properties for short and long term aging and in term of the morphology of the binders.

Experimental:

Materials:

The virgin bitumen used in this study was 80/100 grade bitumen. Epoxidised natural rubber (ENR) will be used as a modifier. The source of this ENR was from Malaysian Rubber Board under the name of ENR 50 and with 53% epoxidisation and passed through 2.36mm mesh sieve. The physical properties for the virgin bitumen and ENR where found with using ASTM standards (ASTMD5 1997; ASTMD36 1995; ASTMD70 1997; ASTMD113 1999) and are given in Table 1.

Silverson L4R HEAVY DUTY was used as high shear mixer and IKA RW 20 Digital Dual-Range Mixers was used as low shear mixer in this study.

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Table 1: Material properties

Material		Value	Standard
Bitumen 80/100	Specific Gravity	1.028	ASTM D70
	Penetration at 25˚C	86	ASTM D5
	Softening point (˚C)	49	ASTM D36
	Ductility (cm) at 25˚C	>100	ASTM D113
ENR	Size	2.36mm	-
	Specific Gravity	0.94	-
	Quantity	5% of Bitumen	-

Preparation of binders:

High shear mixing process (HSMP): Bitumen was heated up to 160˚C in container and mixed by high shear mixer under 2000rpm of speed. ENR (5% by weight of bitumen) was put in the bitumen container after the temperature was stable at 160˚C. The speed of mixing was 2000 rpm and continued for 1 hour.

Low shear mixing process (LSMP): ENR (5% by weight of bitumen) was immersed in Toluene for 24 hours with ratio of 1:3 by weight (ENR: Toluene) at room temperature. After 24 hours the solution was added to the bitumen which was stable at 160˚C of temperature and mixed by the low shear mixer, stirrer, under 2000 rpm of speed for 1 hour.

The process of mixing of bitumen with ENR by high shear mixing will be called as (HSMP) wheres the mixing of bitumen with ENR by Low shear mixing with using the Toluene will be called as (LSMP).

Short And Long Term Aging:

Aging happens for bitumen due to chemical and/or physical causes changes which happen during the construction of the pavement and service life.

The rolling thin film oven (RTFO) D2872 and pressure aging vessel (PAV) ASTM D6521 are good simulations for the hardening. For RTFO the bitumen samples were aged at 163±1 ˚C for 85 min. using the RTFO bitumen residue, the virgin bitumen and the binders were placed in the PAV oven at 100±1 ˚C for 20 h. RTFO oven simulated the short term aging and the PAV oven simulated the long term aging of the asphalt binder specimens.

Rheological Properties:

Rheometer HAAKE RheoStress 600 from Thermo Electron Corporation (Dynamic shear Rheometer DSR) with a 25mm diameter parallel plate and gap of 1mm was used for the rheological properties. The temperature was ranged between 30 and 80˚C and fixed frequency of 10rad/sec (1.159Hz) and controlled strain. Using dynamic shear rheometer (DSR), many tests were conducted to determine complex shear modulus (G*) and phase angle (δ). Three test replicates were conducted for this procedure.

Morphology:

Fluorescence Microscopy- Olympus ColorView III was used for dispersion morphology of ENR in the virgin bitumen. After mixing, for both LSMP and HSMP, binder was poured on a slide of glass and left to be cold in room temperature and then put under the microscope without disturbing. Thickness of every sample is about 2mm. Many images were taken from the computer screen which is connected with the microscope.

RESULTS AND DISCUSSIONS

Rheological Properties:

Some conventional tests were done for the virgin and modified bitumen. The properties for the virgin bitumen and the modified bitumen are shown in Table 2.

Isochronal plot of complex modulus with temperature for unagged, short term aging and long term aging is shown in Figures 1,2 &3. Isochronal plot of phase angle with temperature is shown in Figure 4,5 &6, and same last figures show a comparison in the rheological properties of modified bitumen with HSMP and LSHP. As it shown G* decreased and δ increased with the increasing of the temperature for all binders. Using of the LSMP led to decrease the G* and increase the δ more than using of the HSMP, which indicates that the dispersion of the ENR in the bitumen improved and the elasticity of the modified binder was effectively improved. Its observed that the rheological properties did not significantly affected due to the aging process, which means that there is no negative effects of adding Toluene to bitumen.

Toluene was mixed with virgin bitumen to observe the effect of the Toluene on the physical properties of the bitumen. It was observed that the LSMP did not cause a significant difference in the rheological properties between the virgin bitumen and bitumen modified with Toluene, with using LSMP. This means that adding of ENR with Toluene to the virgin bitumen and then mixing it for 1 hour under 160˚C will not significantly affect on the physical properties for the bitumen due to the volatility of the Toluene for both short and long term aging.

Table 2: Bitumen properties

Material	Penetration at 25˚C	Softening point (˚C)	Ductility (cm) at 25˚C
Virgin Bitumen	86	49	>100
Bitumen+ 5% ENR with HSMP	63	55	>100
Bitumen+ 5% ENR with LSMP	57	58	>100
Bitumen+ Toluene	84	49	>100

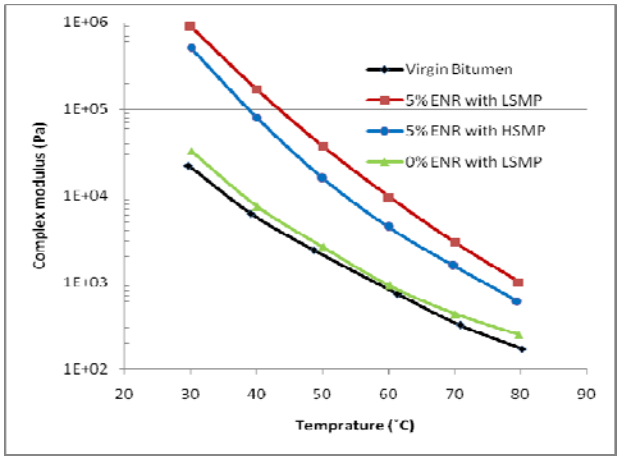


Fig. 1: Isochronal plot of complex modulus for unaged binders.

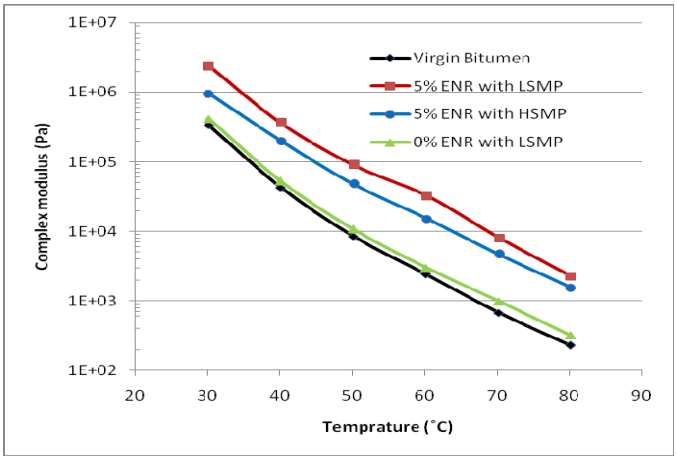


Fig. 2: Isochronal plot of complex modulus for short term aged binders.

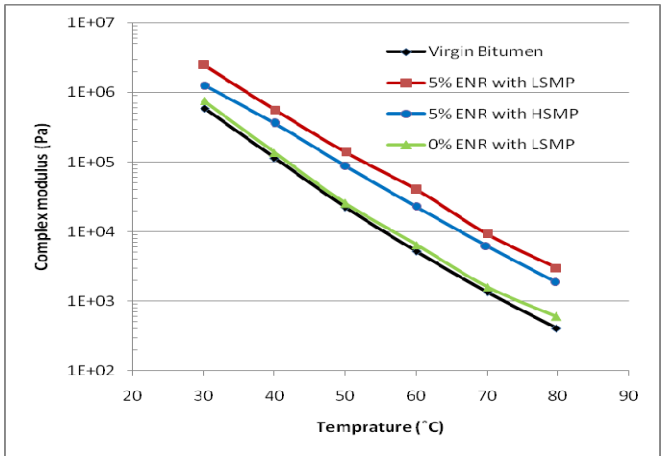


Fig. 3: Isochronal plot of complex modulus for long term aged binders.

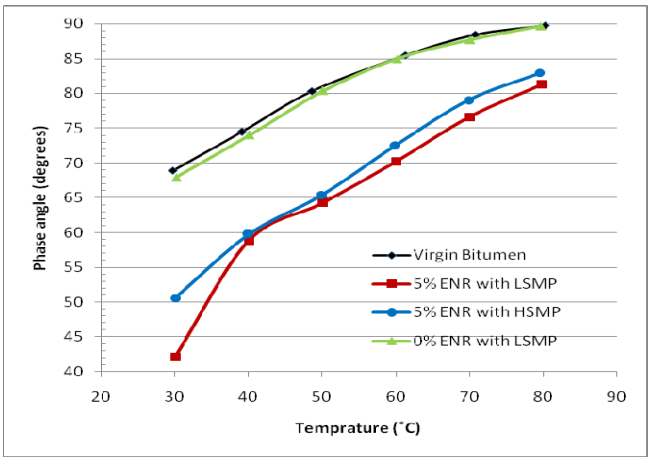


Fig. 4: Isochronal plot of phase angle for unaged binders.

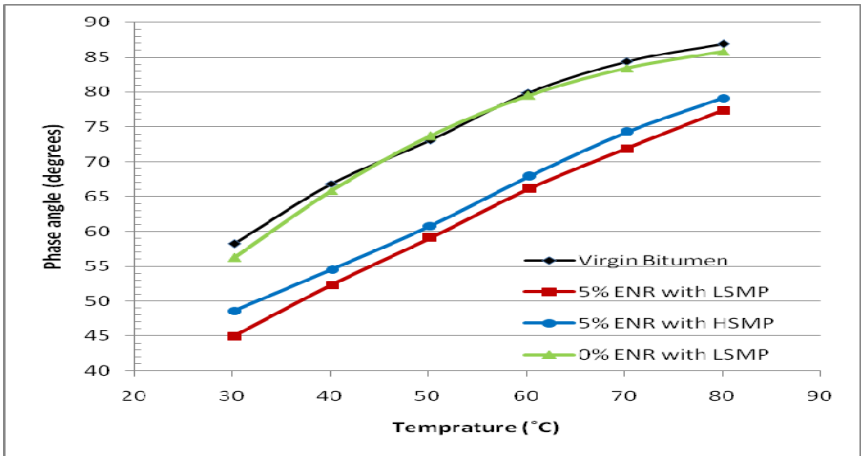


Fig. 5: Isochronal plot of phase angle for short aged binders.

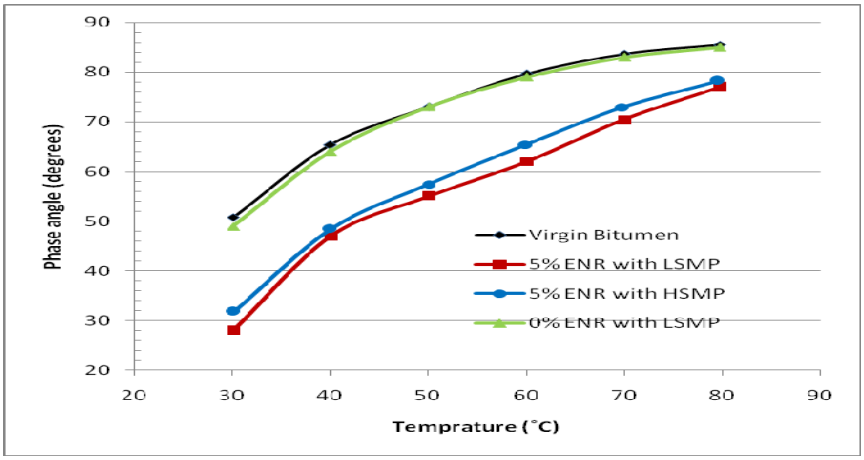


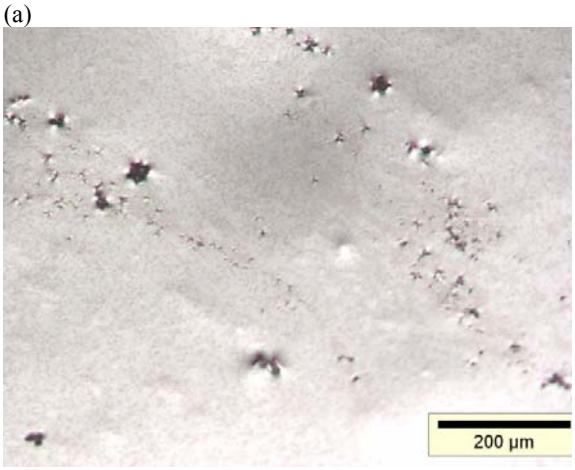
Fig. 6: Isochronal plot of phase angle for long term aged binders.

Morphology Analysis:

The dispersion of polymers in bitumen is critical to the properties of the modifier. The morphology of the binder was investigated with using of Fluorescence Microscopy- Olympus ColorView III. As shown in Figure

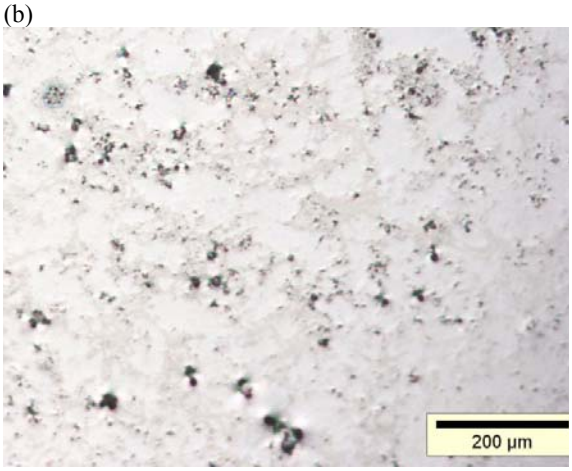
7(a&b), using of LSMP made a significant effect on the dispersion of the ENR in bitumen comparing with the HSMP. Particle size in the LSMP are really smaller than in HSMP which means that the compatibility of ENR modified binder has been improved with using of the Toluene as a solvent.

(a)



Bitumen modified with 5% ENR with using LSMP

(b)



Bitumen modified with 5% ENR with using HSMP

Fig. 7: Fluorescent images of ENR modified Bitumen.

Conclusion:

In this study ENR was mixed with bitumen with using two methods of processes. The first process was done by using high shear mixer (HSMP) without any additives. The second process was done by using normal stirrer but after solving the ENR in Toluene. This study was done to investigate the effectiveness of using solvents to facilitate the dispersion of ENR in bitumen.

DSR and Fluorescence Microscopy are excellent instruments for determining the formation of physical network.

Solving the ENR by Toluene increased the dispersion in bitumen and increased complex modulus G* and decreased the phase angle δ which indicates a rheological properties improvement for the modified binder and without significant negative effects of Toluene on the bitumen physical properties.

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