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THE USE OF WASTE TYRE RUBBER AS ADDITIVE FOR ASPHALT BINDER

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Abstract
In recent years, polymer modified asphalt is a relatively costly material for paving roads. One way to reduce the cost of such constructions and rendering them more convenient is by using a cost-effective additive, i.e. waste rubber.Scrap tyres lead to serious disposal problems. However, the use of scrap tyres in asphalt pavements in the form of fillers/additives could improve the asphalt mixture performance properties as well as minimise environmental pollution. The main purpose of this research is to determine the effect of incorporating waste tyre rubber on the physical and mechanical properties of asphalt materials. The tests undertaken comprise the penetration test, softening point test, viscosity test and dynamic shear rheometer (DSR). The results showed that the addition of rubber has an effect on the properties of bituminous compound by increasing the viscosity, softening point, shear modulus and a decrease in penetration. Thus, the use of waste tyre rubber could improve the engineering properties of asphalt binder. Additionally, employing waste tyre rubber in sustainable technology could help to reduce some of the current pollution issue of waste tyre disposal.

Keywords: Bitumen, Waste tyre rubber, Rubberised bitumen, Viscosity, stiffness.

1. Introduction

In recent years, polymer modified asphalt is a relatively costly for paving roads. One way to reduce the cost of such constructions and rendering them more convenient is by using cost effective additive, i.e. waste rubber. Scrap tyres lead to serious disposal problems. However, the use of scrap tyres in asphalt pavements in the form of fillers/additives could improve the asphalt mixture performance properties as well as minimise environmental pollution. The main purpose of this research is to determine the effect of incorporating waste tyre rubber on the physical and mechanical properties of asphalt materials.

Several road pavement distresses are related to bitumen properties. Rutting and fatigue cracking are among the major distresses that lead to permanent failure of the pavement surface. The rheological properties and durability of conventional bitumen however, are not sufficient to resist pavement distresses. Since the 1960s, the use of rubberised asphalt in road materials applications has gained increased interest in the paving industry. Hence, the task of current asphalt researchers and engineers is to look for different kinds of modified bitumen with rheological properties that would directly affect the asphalt pavement performance.

However, with the use of alternative materials such as crumb rubber modifier (CRM), it will definitely be environmentally beneficial, and not only it can improve the bituminous properties and durability, but it also has a potential to be cost effective. A conventional bitumen 80/100 penetration grade is commonly used in Malaysia and moreover, it is subjected to high traffic loading and hot weather conditions. Thus, the use of crumb rubber in bitumen modification is considered as a sustainable technology which would transform unwanted residue into a new bituminous mixture highly resistant to rutting and fatigue deformations.

According to a study conducted by Lee et al. (2008), the higher crumb rubber content produced increased viscosity at 135˚C and improved the rutting properties. It was also observed that the increased crumb rubber amount (fine crumb rubber) produced rubberised bitumen with higher viscosity and lower resilience (Liu et al., 2009). However, optimum crumb rubber content still needs to be determined for each crumb rubber size and asphalt binder. It is believed that a physicochemical interaction occurs between the bitumen and the crumb rubber alters the effective size and physical properties of the rubber particle, thus influencing pavement performance (Huang, 2008). Moreover, higher crumb rubber content led to improve physical and rheological properties of modified bitumen binder through better rutting resistance as well as increases its elastic recovery (Mashaan et al., 2011a,b).

The main purpose of this research is to determine the effect of incorporating waste tyre rubber on the physical and mechanical properties of asphalt materials.

2. Materials And Methods

Bitumen binder grade 80/100 penetration was used in this study. This binder has wide use in different areas especially in Malaysia, the physical properties of this binder given in Table 1. The crumb rubber modifier (CRM) produced by mechanical shredding at ambient temperature and passing the 30 mesh sieve was used. Five different concentrations of crumb rubber were prepared by first heating the bitumen to 160°C. Upon reaching 160°C, a weighted amount of rubber (6, 12, 16 and 20% by weight of bitumen binder) were slowly added to the original bitumen while mixing at 180°C using the propeller blade mixer at a blending speed of 200 rpm for blending times of 30 minutes. The tests undertaken comprise the penetration test, softening point test, viscosity test and dynamic shear rheometer (DSR) to investigate the influence of incorporation of crumb rubber modifier (obtained from waste tyre vehicles) on physical and stiffness properties of rubberised bitumen.

Table 2 Properties of Base Binder Grade 80/100 Penetration

Test properties	Test result
Viscosity @135 ˚C (pas)	0.65
$G^*/\sin\delta$ @ 64˚C (kpa)	1.35
Ductility @ 25 ˚C	100
Softening point @ 25 ˚C	47
Penetration @ 25 ˚C	88

3. Results and Discussion

In Figure 1, the results showed that the higher crumb rubber content in the mix led to lower penetration values. These results are due to the crumb rubber content exhibiting a strong effect on penetration reduction by increasing the stiffness of crumb rubber modified bitumen binder. This would make the binder more resistant to high temperature susceptibility, thus leading to high resistance to permanent deformation like rutting as mentioned by Liu et al. (2009) and Hung (2008).

Figure 2 show an increase in softening point as the rubber content increased in the bituminous specimens , the increase in softening point of modified binder samples compared with unmodified binder were approximately about 10 to 80 ºC for 6 and 20% rubber content , respectively. The increase of rubber content in the mix might be related to an increase in the asphaltence/ resins ratio which enhance the stiffened property and make the modified binder less susceptible to temperature changes. According to Liu et al. (2009) the main factor in the increase in softening point can be attributed to crumb rubber content, regardless of type and size. The increase in softening point led to a stiff binder that has the ability to enhance its recovery after elastic deformation. Moreover, this increase in softening point might have resulted from the increase in binder molecular weight when the crumb rubber interacted with the bitumen binder.

Results from Brookfield viscosity test at 135 °C for the various crumb rubber contents are shows in Figure.3, an increase in Brookfield viscosity as the rubber content was increased in the bituminous specimens. The increase in viscosity might be due to the amount of asphaltense in the bitumen that enhanced the viscous flow of the modified bitumen sample during the interaction process. In general, higher crumb rubber content was found to lead to an increase in the viscosity at 135 ºC (Jeong et al., 2010).

The test results of G* and phase angle (δ) 76 ºC) for various crumb rubber contents has illustrated in Figure 4 and 5. Rubber mass increased during the swelling process of blend interaction mix, thus, would lead to sufficient softening of the asphalt binder. The results of this study indicate that the crumb rubber-modified binder manifest visco-elastic behaviours, with the binder exhibiting better relaxation upon applied stress on to the asphalt rubber. In summary, the results have confirmed that rubber-modified binders could become less susceptible to temperature changes as rubber content is increased. The results further confirm improvements in asphalt performance properties at high service temperatures.

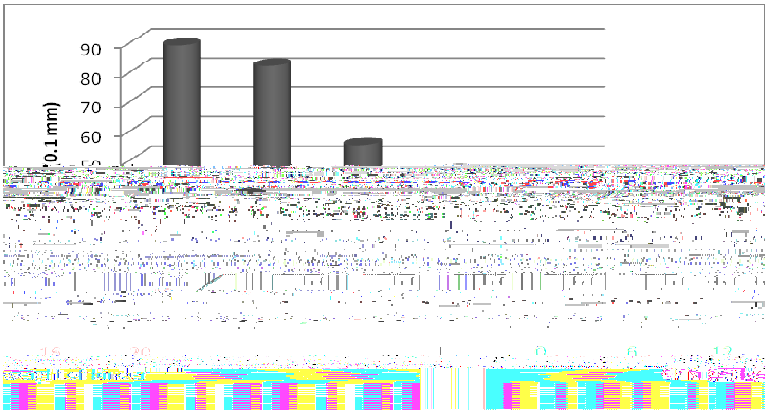

Figure 1 Penetration Results vs. different CRM contents

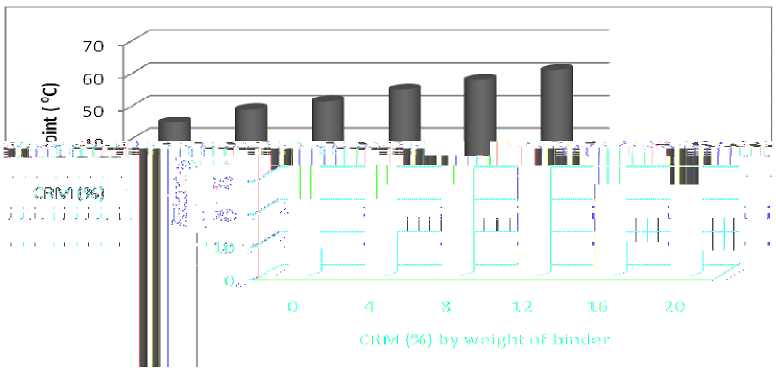

Figure 2 Softening Point Results vs. various CRM contents

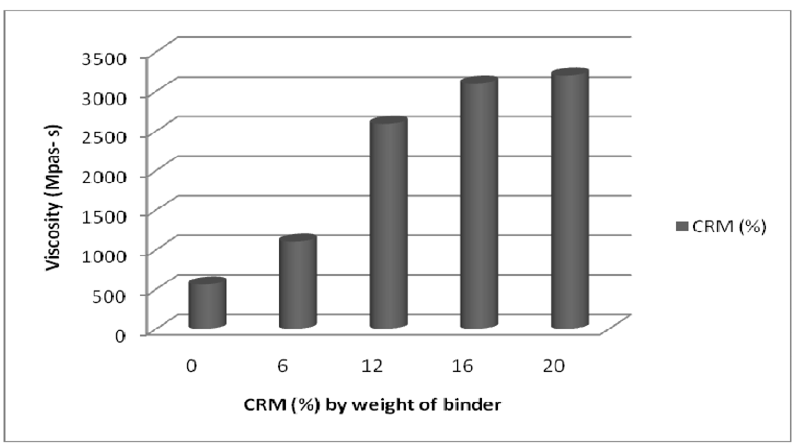

Figure 3 Brookfield Viscosity Results at 135˚C vs. CRM content of bitumen binders

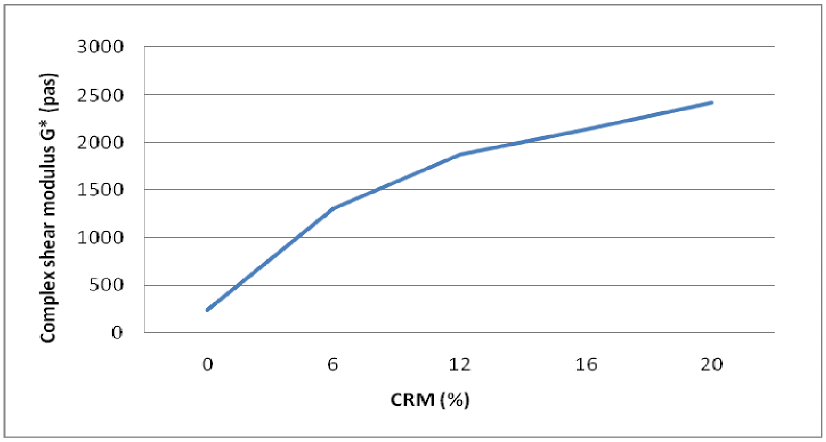

Figure 4 Shear modulus results vs. different CRM contents

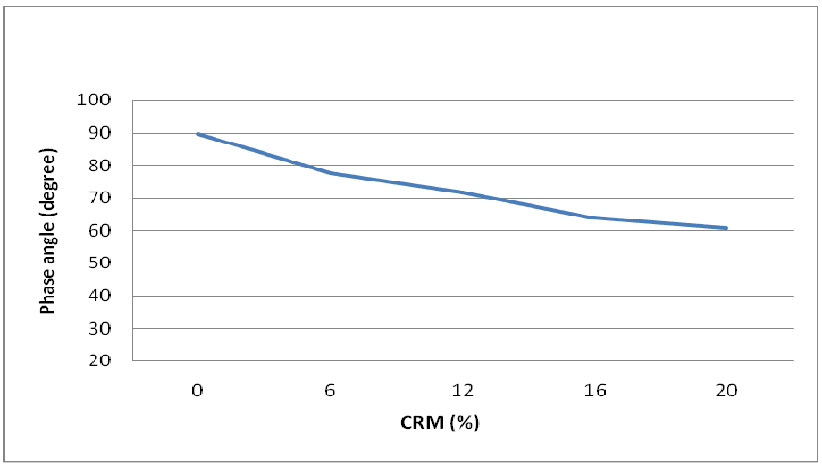

Figure 5 Phase angle results vs. different CRM contents

4. Conclusion

Based on the results of this study, the addition of crumb rubber to the bitumen binder enhance the physical properties of rubberised bitumen binder as indicated by the reduction in penetration value and an increase in the softening point and viscosity at 135 °C, thus enhancing rubberized binder resistance to flow and increase its ability to resist rutting deformation. The higher crumb rubber concentration has an obvious effect on rheological properties of rubberised bitumen with increased complex modulus and decreased phase angle. The addition of crumb rubber in bitumen positively affects the stiffness of modified bitumen, thus, enhancing the rutting resistance of the rubberised pavement mix. Thus, the use of waste tyre rubber could improve the engineering properties of asphalt binder. Also employed waste tyre rubber in sustainable technology could help to reduce some of current pollution issue of waste tyre disposal.

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