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IMPROVING ASPHALT RESISTANCE TO AGING BY USING WASTE TYRE RUBBER

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Abstract
In recent times, a serious problem that leads to environmental pollution is the abundance and increase of waste tyre disposal. Large amount of rubber is used as tyres for cars and trucks etc. Despite the long run in service, these tyres are not discarded. The major approach to solve this issue is the recycle and reuse of waste tyre rubber, and the reclaimation of rubber raw materials. This research aims to investigate the effects of crumb rubber modifier concentration on the rheological and physical properties of rubberised bitumen after aging. In order to evaluate the durability performance of rubberised bitumen, aging tests have been conducted using short-term aging (i.e., rolling thin film oven test or RTFOT) and long-term aging (i.e., pressure aging vessel or PAV). The results showed that the use of rubberised bitumen binder reduced the aging effect on physical and rheological properties of the bitumen binder as illustrated through lower aging index of viscosity.

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

1. Introduction

In recent times, a serious problem that leads to environment pollution is the abundance and increase of waste tyre disposal. Large amounts of rubbers are used as tyres for cars and trucks etc. Despite the long run in service, these tyres are not discarded. The major approach to solve this issue is the recycle and reuse of waste tyre rubber, and the reclaim of rubber raw materials.

The factor influencing the performance and characteristics of bitumen binder is the phenomenon known as aging. Many factors might contribute to this hardening of the bitumen such as oxidation, volatilisation, polymerisation and thixotropy. This is because bitumen is an organic compound, capable of reacting with oxygen found in the environment. The bitumen composite changes with the reaction of oxidation developing a rather brittle structure. This reaction is referred to as age hardening or oxidative hardening (Peterson, 1984).

The physical hardening can be explained using the free volume theory which introduced the relationship between temperature and molecular mobility. The free volume theory includes the molecular mobility dependent on the equivalent volume of molecules present per unit of free space or free volume. Based on the free volume theory, when amorphous material is cooled from a temperature above its glass transition temperature, molecular adjustments and the collapse of free volume rapidly show a drop in temperature. At that temperature, the structural state of the material is frozen-in and deviates from thermal equilibrium due to the continuous drop in kinetic energy. Hence, it has been postulated in order for physical hardening to happen in binders, temperatures must be higher than the glass transition temperature (Marasteanu and Anderson, 1999; Doolittle 1951). The main purpose of this research is to determine the effect of incorporating waste tyre rubber on the physical and rheological properties of rubberised bitumen after short and long term aging.

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. Three different concentrations of crumb rubber (0%, 8% and 12%) were prepared by first heating the bitumen to

160°C and blending it for 30 minutes. In order to evaluate the durability performance of rubberised bitumen, aging tests have been conducted using short-term aging (i.e., rolling thin film oven test or RTFOT) and long-term aging (i.e., pressure aging vessel or PAV). Three different binder tests have been conducted. Namely (penetration test, Brookfield viscosity test and dynamic shear rheometer test (DSR).

Table 2 Properties of Base Binder Grade 80/100 Penetration

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

3. Results and Discussion

Figures 1 shows the effect of crumb rubber content on G* at76 °C. As rubber content increased from 8 to 16%, complex shear modulus (G*) value showed an increase by about 1.5 to 2 times for aged binder than unaged binder. In addition, the modified binder was also of a higher value in G* than the unmodified by about 1.5–2.5 times for samples with 8 and 16% rubber content. Thus, the increase in crumb rubber content had an obvious effect on aged rubberised bitumen compared to aged unmodified bitumen. Oxidative aging might have increased or decreased the temperature susceptibility of the stiffness of the modified binder, which could have led to the increase in asphaltene.

Figure 2 shows the effect of crumb rubber content on δ at76 °C. As rubber content increased from 8 to 16%, δ value showed dramatic decrease by about 1.0 to 1.5 times for aged binder than unaged binder. In general, as crumb rubber content increased, phase angle δ decreased for the various aging methods. Increases in crumb rubber percentage led to varying degrees in phase angles, indicating increase in elastic behaviour of the binder.

Figures 3 shows the viscosity results at 135 °C for CRM binders with various rubber contents under different aging conditions. A general trend was found, as expected, which indicated that higher crumb rubber content would lead to higher viscosity for the CRM binders. Additionally, the increased viscosity of aged rubberised bitumen were about 36% and 44% for rubber contents of 8 % and 16% under RTFOT aging conditions, while the increase in the viscosity under PAV aging values were about 78% and 82% for rubber content of 8% and 16% respectively. Thus, the increase in crumb rubber content had an obvious effect on aged rubberised bitumen viscosity compared to aged unmodified bitumen with correlation coefficient $R^2 = 0.992$, 0.990 and 0.997 for unaged , RTFOT and PAV aging conditions respectively. This increased viscosity can be explained by the hardening of the bitumen binder due to evaporation of low molecular weight friction oil through aging (Mahrez, 1999).

Figures 4 shows the penetration results of modified and unmodified binder after aging. Based on the results, penetration decreased as crumb rubber content increased as shown in Figures 4. The penetration of the bitumen binder appears to dramatically decrease as the crumb rubber content increased with correlation coefficient of $R^2 = 0.999$, $R^2 = 0.996$ and $R^2 = 0.975$ for unaged, rolling thin file aging test (RTFOT) and pressure aging vessel aging (PAV) , respectively. In addition, the higher rubber content, the lower penetration aging ratio led to reducing the degree of aging of rubberised bitumen binder. Meaning, the crumb rubber addition led to improving the binder resistance to oxidative aging.

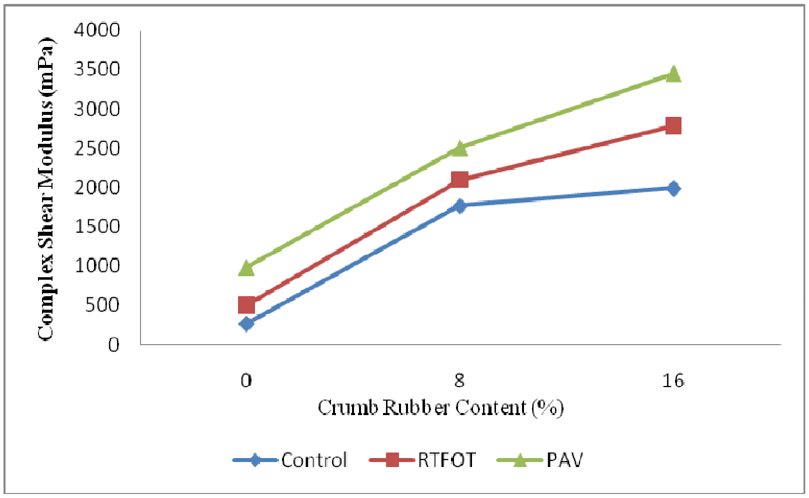

Figure 1 Complex Shear Modulus Results vs. Crumb Rubber Content at 76˚C

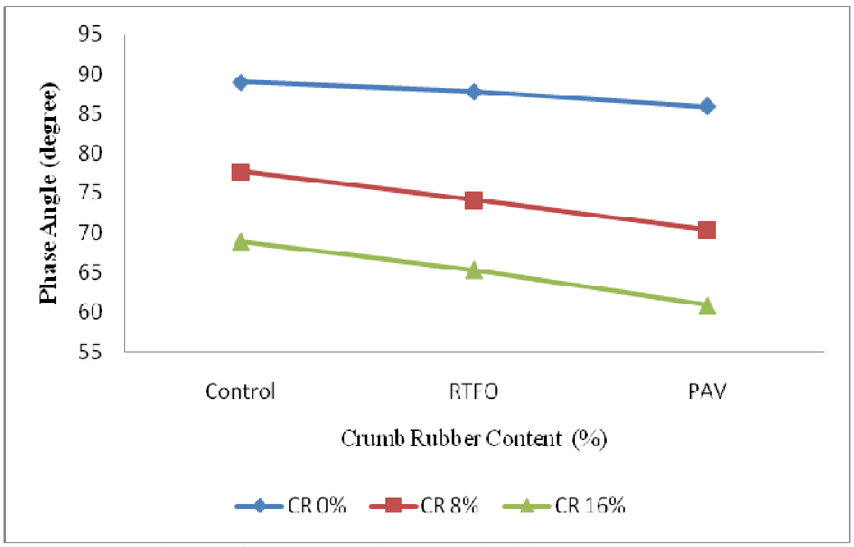

Figure 2 Phase Angle Results vs. Crumb Rubber Content at 76 □C

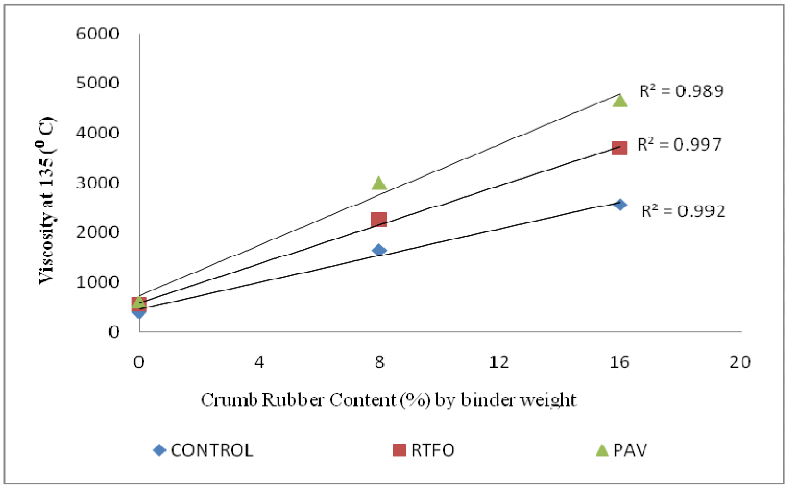

Figure 3 Brookfield Viscosity vs. Crumb Rubber Content at 135˚

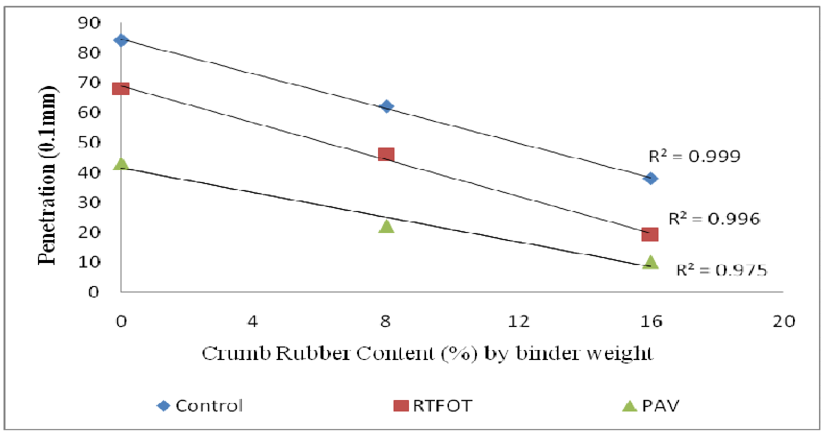

Figure 4 Penetration vs. CRM Content of Specimens at 25˚C

4. Conclusion

Based on the results showed that the use of rubberised bitumen binder reduced the aging effect on physical and rheological properties of the bitumen binder as illustrated through an increase in viscosity, an increase in G*/at 76 □C, a decrease in phase angle (δ) and decrease in penetration with increased crumb rubber modifier content, indicating that the crumb rubber might improve the oxidative aging resistance of rubberised bitumen 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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