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Full Length Research Paper

Effect of blending time and crumb rubber content on properties of crumb rubber modified asphalt binder

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The increasing use of crumb rubber modifier in flexible pavements justifies the necessity for a better understanding of its physical and rheological properties as well as its elasticity behaviour. Basically the performance and properties of rubberised asphalt binder are influenced by the blending conditions and crumb rubber content. In this study, the laboratory investigation was conducted on crumb rubber modified asphalt binder properties as a function of two blending times (30 minutes and 60 minutes) and five crumb rubber contents (4, 8, 12, 16 and 20% by weight of asphalt binder) at mixing temperature of 180˚C. Statistical analysis using two-way ANOVA was conducted on the results to evaluate the significance of rubber contents and blending times. The rubberised asphalt binder was evaluated in terms of binder elasticity and rutting resistance at high temperature. The results indicate that the crumb rubber content had a significant effect on G*/ sin (δ) at 76˚C. The higher crumb rubber content appears to dramatically increase the elastic recovery and ductility. Statistical analysis showed significant effect of crumb rubber content in influencing the ductility, elastic recovery and G*/ sin (δ) values. Whereas the blending time do not appears to significantly affect the ductility, elastic recovery and rutting factor (G*/ sin (δ)) of the CRM asphalt binder. The asphalt binder with higher crumb rubber content and longer blending time of 60 minutes exhibited a higher value of elastic recovery. This indicates that crumb rubber modified asphalt binder has better resistance to rutting as compared to conventional asphalt binder.

Key words: Crumb rubber modified (CRM) asphalt, rubberised asphalt, elastic recovery, rutting resistance, asphalt pavement.

INTRODUCTION

The researches and applications of CRM asphalt binders in various countries have reported that the CRM asphalt binder has many advantages such as improved resistance to rutting due to high viscosity, high softening point and better resilience (Katman et al., 2009; Abdelaziz and Karim, 2003; Fontes et al., 2010; Wong and Wong, 2007; Thodesen et al., 2009). It also improves resistance to surface initiated cracks, reduce fatigue/ reflection cracking, reduce temperature susceptibility, improves durability and lower pavement maintenance costs, and saving in energy and natural resource by using waste products (Liu et al., 2009).

According to Ibrahim et al. (2009), Malaysian production of scrap tyres is about 10 million pieces per annum and they are currently being disposed in an environmentally unfriendly manner. A conventional bitumen 80/100 penetration grade is commonly used in Malaysia and it is subjected to both high traffic load and bhigh temperature weather. Use of crumb rubber in asphalt production is considered a sustainable technology which transforms an unwanted residue into a new bituminous mixture highly resistant to rutting and fatigue. Earlier works have indicated that CRM asphalt binders may even be employed in porous mixes (Katman et al., 2005a, b; Ibrahim et al., 2007). Another study has shown the significant effect of CRM concentration on physical and rheological properties of rubberised bitumen binder (Mashaan et al., 2011).

Since bitumen is a visco-elastic material, its rheological

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properties are very sensitive to temperature as well as rate of loading. The improvement of the properties of rubberised bitumen likely depends on the interaction between crumb rubber and asphalt binder where crumb rubber modifier particles swell in the binder to form a viscous gel, resulting in an increase in the viscosity of the CRM binders (Airey et al., 2003; Yildirim, 2007; Jeong et al., 2010; Bahia and Davis, 1994). However, the properties of rubberised asphalt binders at a wide range of temperature largely depend on the chemistry of the asphalt binder, the crumb rubber modifier percentage, particle size and texture; blending interaction temperature and blending time. From previous literature, it was concluded that swelling of the rubber particles is due to the absorption of the light fractions of the bitumen and stiffening of the residual binder phase are the main mechanism of the interaction (Airey et al., 2003; Abdelrahman and Carpenter, 1999; Shen and Amirkhanian, 2005). From an environment and economic stand point, the use of ground tire rubber as bitumen modifying agent may contribute to solving a waste disposal problem and to improving the quality of road pavement in solving the waste disposal problem and to improving the quality of road pavement.

The main objective of this research study is to investigate the performance properties of rubberised asphalt binder as a function of blending time and crumb rubber modifier contents through selected binder tests. The 80/100 penetration grade bitumen was used as the control binder. The ductility, elastic recovery and stiffness indicator G*/ sin (δ) have been used to evaluate the rutting resistance of the resultant CRM asphalt pavement mix.

MATERIALS AND METHODS

Asphalt binder

The 80/100 penetration grade bitumen was used as the base asphalt binder in this study. This asphalt binder is widely used in Malaysia. Table 1 shows the properties of the base binder used in this study.

Table 1. The properties of the base asphalt binder.

Test properties	Results
Viscosity at 135℃ (pas)	0.65
G*/ sin δ at 64℃ (Kpa)	1.35
Ductility at 25℃(cm)	100
Softening point at 25℃	47
Penetration at 25˚C	88

Crumb rubber modifier

The crumb rubber modifier produced by mechanical shredding at ambient temperature was obtained from one source (Rubberplas Sdn. Bhd.) size 30 # (0.6 mm) and used with gradation as shown in Table 2. To ensure that the consistency of the CRM was maintained throughout the study, only one batch of crumb rubber was used. In this study, fine crumb rubber was selected in order to reduce segregation (Liu et al., 2009).

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Table 2. Constituents of crumb rubber used in the study.

Major rubber components (%)	Tire rubber
Acetone extract	11.0
Rubber hydrocarbon	50.5
Carbon black content	32.5
Natural rubber content	34.0
Ash content	6.0

Production of rubberised bitumen binder

The wet mixing process was used in this study, in which the crumb rubber modifier is added to the base asphalt binder before introducing it to the aggregate. The rubberised asphalt binder was prepared in the laboratory using the propeller blade mixer at a blending speed 200 rpm (Abdelaziz, 1999). The crumb rubber was added to the base binder using two interaction blending times of 30 and 60 min as used by Jeong et al. (2010), and the blending temperature of (180℃) as selected by Navarro et al. (2004) and five crumb rubber (4 ,8,12,16 and 20% by binder weight).

Binder tests

The investigation and evaluation of blending time effect on rubberised asphalt was conducted in the laboratory using the ductility test (ASTM D113) and elastic recovery test (ASTM D 6084). The DSR test method was used to obtain the rutting factor G*/ sin (δ) at 76℃. In this test, standard procedures as recommended by Strategic Highway Research Program (SHRP) were followed.

The effects of crumb rubber content and blending time on rubberised asphalt was evaluated using standard laboratory tests namely, the ductility test (ASTM D113) at temperature of 25˚C, elastic recovery test (ASTM D 6084) at temperature of 25˚C and dynamic shear rheometer test DSR (ASTM D-4 proposal P246). The DSR test method was used to obtain the rutting factor G*/ sin (δ) at 76˚C.

RESULTS AND ANALYSIS

Ductility test results

Ductility test was conducted in accordance with ASTM D113. It provides a measure of tensile properties of bituminous materials. The ductility is measured by the distance in centimetres to which standard specimen will elongate before breaking. The ductility results at 25℃ of two different blending time and various crumb rubber contents are illustrated in Figure 1. Binder ductility

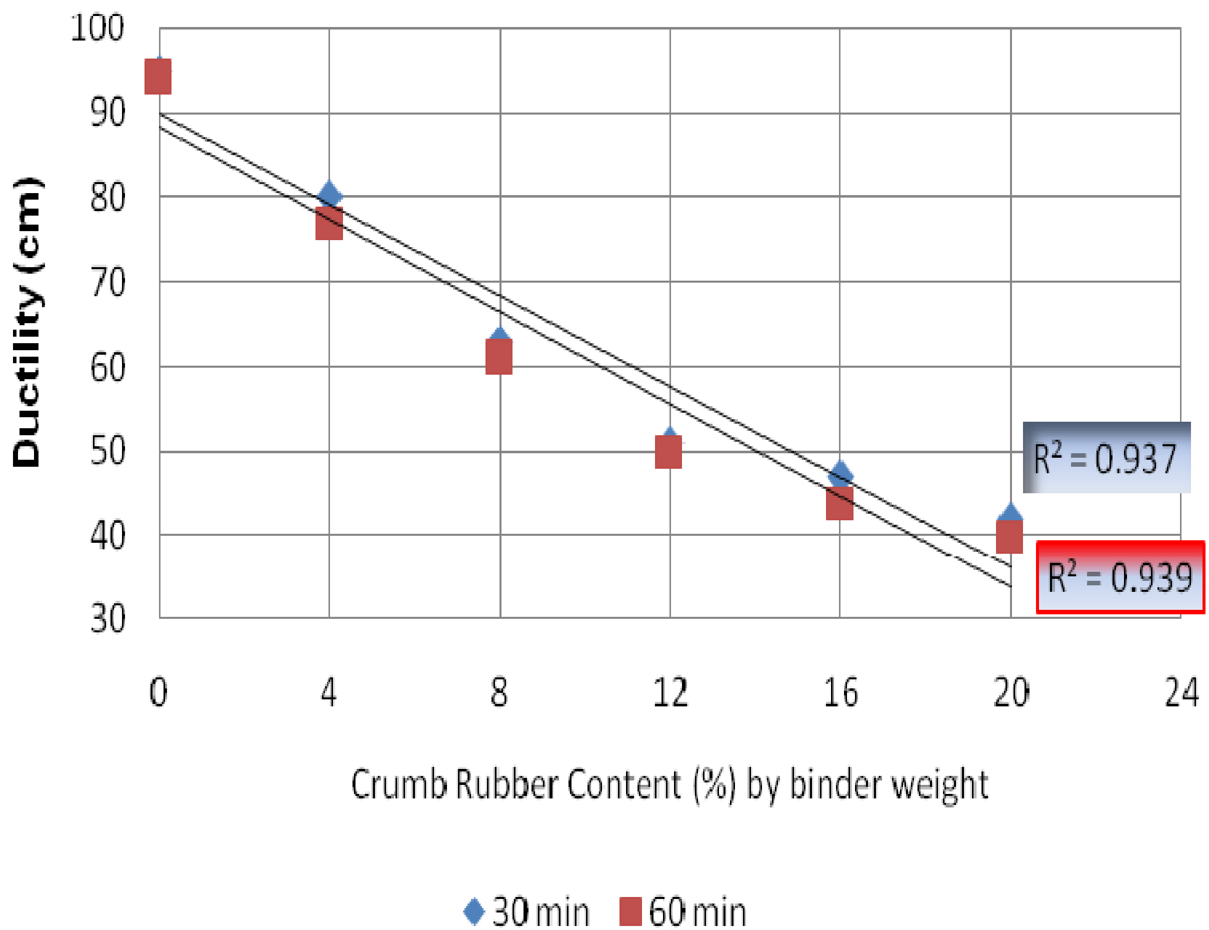

Figure 1. Effect of crumb rubber content and blending time on binder ductility.

Table 3. Output from two–way ANOVA analysis on effect of crumb rubber content and blending time on binder ductility.

Source	S.S	d.f.	M.S.	F value	P -value
Blending time	630.750	1	630.750	27.935	0.60
CRM content	19915.917	5	3983.183	176.410	0.005
Error	903.167	40	22.579		
Total	21739.917	47			

appears to dramatically decrease as the crumb rubber content increases with correlation coefficient R^2 = 0.937 and R^2 = 0.939 for 30 min and 60 min blending time respectively. The blending time, however, do not appear to have any significant effect on binder ductility.

Table 3 shows the statistical analysis of two-way ANOVA (α = 0.05) of ductility test results of different blending time for various crumb rubber content. It is quite apparent that the crumb rubber content have significant influence (p = 0.005) on the ductility of the CRM asphalt binder.

Elastic recovery results

The elastic recovery test was conducted in accordance with ASTM D 6084 at 25°C. Figure 2 shows the effect of crumb rubber content on elastic recovery for two blending times. The increase of blending time does not appear to have any significant effect on the CRM asphalt binder elastic recovery as can be seen for each crumb rubber amount. The elastic recovery of the binder, nevertheless, increases as the crumb rubber content increases with correlation coefficient R^2 = 0.956 and R^2 = 0.946 for

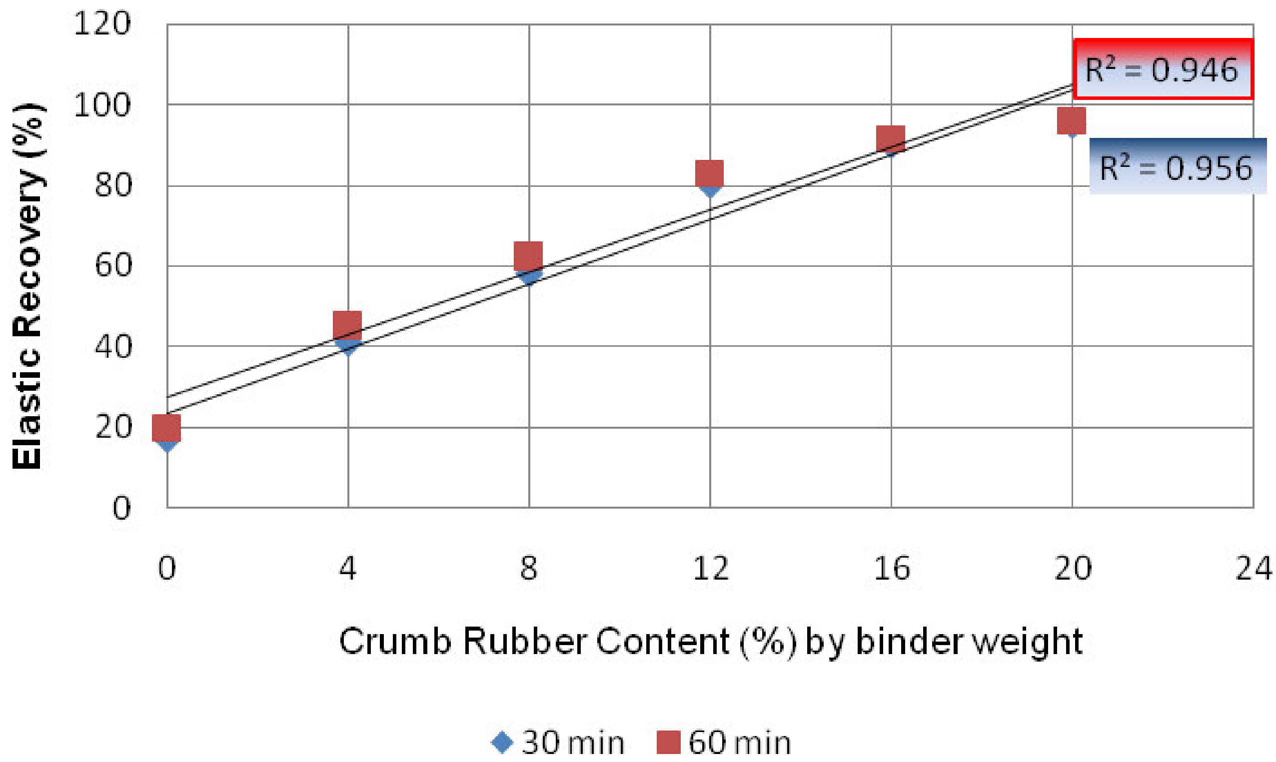

Figure 2. Effect of crumb rubber content and blending time on elastic recovery of binder.

Table 4. Output from two–way ANOVA analysis on effect of crumb rubber content and blending time on elastic recovery of binder.

Source	S.S	d.f	M. S.	F value	p-value
Blending time	64.172	1	64.172	9.510	0.7433
CRM content	32757.401	5	6551.480	970.889	0.0022
Error	269.917	40	6.748		
Total	33409.245	47			

blending time of 30 and 60 min respectively. From ANOVA ($\alpha = 0.05$) analysis results shown in Table 4, it is quite apparent that the crumb rubber content do influence (p-value < 0.05) the elastic recovery property of the CRM asphalt binder.

Dynamic shear rheometer results

Figure 3 shows the results of rutting factor ($G^*/\sin \delta$) at 76°C for the two blending time and various crumb rubber content. The difference in blending time does not appear to have much effect on the rutting resistance, at least between the case of 30 and 60 min. In addition, the blending time of 30 min might not be enough to allow complete reaction between the crumb rubber and asphalt binder (Paulo and Jorge, 2008). Longer blending time, however, has better results on performance properties of modified binder according to findings from studies by Jeong et al. (2010). The amount of crumb rubber in the rubberised asphalt binder, nevertheless, does significantly increase the rutting resistance of the binder. Studies by Bahia et al. (1998) also showed that binder resistance to rutting increases with such binder modification.

Conclusion

The crumb rubber content was found to be the main factor that affects the performance properties of rubberised bitumen as illustrated in Figures 1, 2 and 3. The higher crumb rubber content has resulted in a dramatic increase in both ductility and elastic recovery.

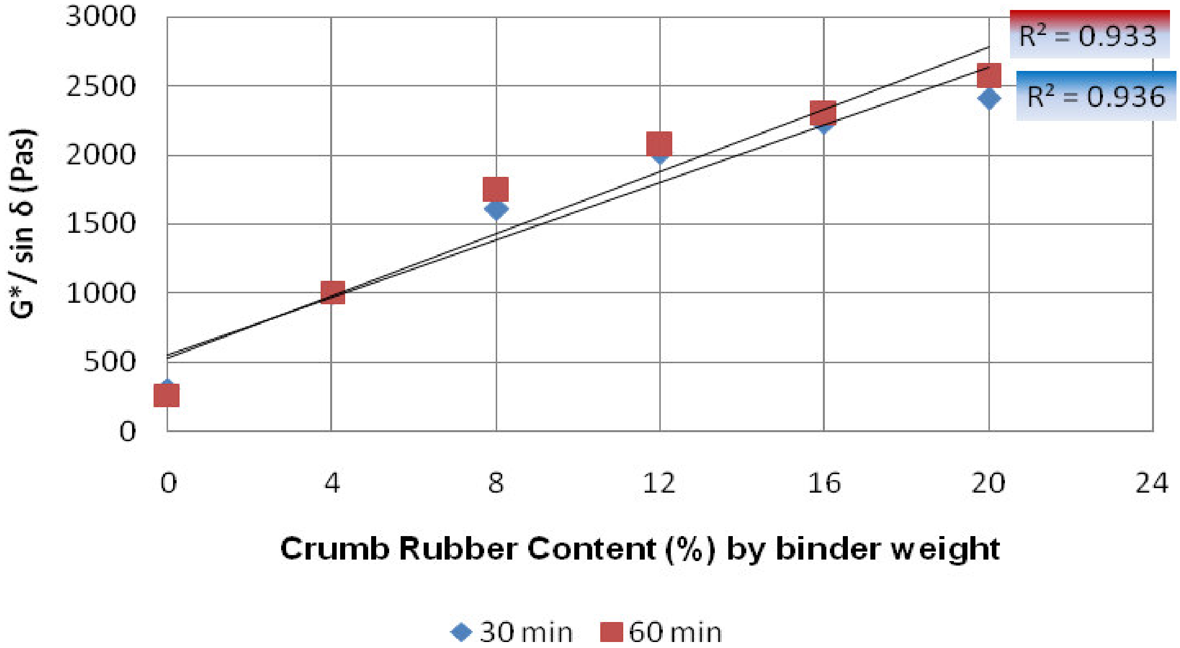

Figure 3. G*/ sin δ results at 76°C vs. blending time.

Also, there was a significant increase in rutting factor G*/sin (δ) values for the five crumb rubber content of the modified asphalt binder. The statistical analysis using ANOVA provide evidence that the crumb rubber content does significantly affect the elastic recovery of rubberised bitumen and improve rutting resistance of the modified asphalt binder. The effect of blending time, however, was found to be not significant for the case between 30 and 60 min blending duration.

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