Effect of Variation in Blending Variables on the Properties of CRMB

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ABSTRACT

The enhancement in the properties of the modified blends largely depends on the proper understanding of the interaction between CR (Crumb Rubber) and bitumen, where the CR particles swell after absorbing lighter fraction from the bitumen phase. However, the properties of CRMB (Crumb Rubber Modified Bitumen) blends at a wide range of temperatures are considered to be somewhat unclear due to the various interaction effects of CR and base bitumen. This largely depends on the interaction conditions such as blending time, temperature, speed and device, which may alter the properties of the blend to great extent. In this study, influence of the interaction condition was investigated by looking at the viscosity with a Brookfield viscometer. For this, CR and bitumen proportions along with other material characteristics were kept constant to understand the effect of interaction parameters of the properties of the CRMB blend. A total of 12 CRMB blends were produced with unvarying combinations of material constituents. However, selected variation in the blending parameters were; blending device, duration, speed and temperature. Observations from this laboratory study indicated: (1) blending performed with the high shear mixer resulted in higher viscosity values compared to the blends produced with the low shear mixer; (2) reduced blending time was required to achieve peak and ultimate stable viscosities, when blends were produced with the high shear mixer; (3) blending temperature of 180°C has resulted in the blends with consistent properties for longer blending durations compared to the blends produced at higher temperature. As a result, results with high shear mixer were always promising, which required comparatively lower interaction temperature, time and speed.

Key Words: **Crumb Rubber, Crumb Rubber Modified Bitumen, High Shear Mixer, Mechanical Stirrer, Blending Speed, Blending Temperature, Blending Device, Blending Speed.**

1. INTRODUCTION

The increasing usage of CR obtained from waste tyres requires a better understanding of its effects on the physical, chemical, and performance properties of the bitumen. In general, the introduction of CR as a modifier is proposed to improve the properties of bitumen such as reducing the inherent temperature susceptibility of the binder.

In addition, the optimised enhancement in the properties of the modified blends largely depends on the proper understanding of the interaction between CR and bitumen, where the CR particles swell after absorbing lighter fraction from the bitumen phase. This results in a form of a viscous gel and leads to a significant increase in the viscosity of the blend [1-5]. However, the properties of CRMB blends

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at a wide range of temperatures are considered to be somewhat unclear due to the various interaction effects of CR and base bitumen. This largely depends on the base bitumen grade as a function of chemical composition and CR characteristics as a function of content, size and texture. The interaction conditions are also said to play an important role in governing the properties of the blend [3,6].

After blending, interaction between bitumen and CR is generally evaluated based on stable viscosity, which is obtained at an equilibrium stage of reaction. Proper understanding of the variables involved during the production of CRMB blend under the wet process is of most importance to obtain a better and stable product. In other words, optimum selection of basic material components and blending conditions leads to a product with the best possible enhanced properties. In this regard, to address these issues researchers have done a fair amount of research and have presented solutions in the following manner.

2. IMPORTANCE OF INTERACTION PARAMETERS IN BITUMEN-CR INTERACTION

During the reaction phase of basic constituents, swelling of CR particles mainly depends on interaction time and temperature. The two blending parameters may affect the rate and extent of CR swelling at a significant level and results in varied increase in CR volume. The increased volume of CR particles reduces the inter particle distance and thus reduces the mobility. This reduced mobility results in viscous material. Once the swelling equilibrium stage is achieved, the swollen CR particles may start disintegrating in the bitumen matrix if elevated temperature is maintained for a longer period. At this stage depolymerisation of CR particles comes into play and causes a significant reduction in viscosity.

It is also reported that the reaction does not result from melting of the CR into the bitumen phase. Rather, rubber particles are swollen by the absorption of light fractions at elevated temperatures. In addition, two different temperature effects on the interaction process are observed, the first being the rate and the second being the extent of swelling of CR particles. However, with increase in temperature, the rate of swelling increases and the extent is decreased [5,7]. Therefore, increase in blending temperature decreases the extent of swelling and the rubber network becomes stiffer. In addition, increasing the reaction time, allows the lighter fraction of bitumen to penetrate into the CR and swelling occurs [3,6].

3. LABORATORY BLENDING PARAMETERS

Besides the selection of the basic constituents in the previous section, it was also of significant importance to investigate and optimise the laboratory blending parameters. These parameters are, blending device, blending duration, blending temperature and blending speed.

3.1 Laboratory Blending Device

Traditionally, two types of laboratory mixing devices have been used for blending purposes during the modification of bitumen with polymers. The laboratory mixers are the low shear and high shear mixers. In general, low shear mixers are known to be operated and controlled easily compared to high shear mixers. On the other hand, modified binders produced using high shear mixers appear to have superior properties compared to those produced using low shear mixers [7].

To verify the limited findings and the lack of comparative literature for the two laboratory mixers, a Silverson L4RT high shear mixer and a laboratory mechanical stirrer as a low shear mixer were used to blend bitumen and CR. Illustrations of the high shear mixer and mechanical stirrer along with schematics of their functions are presented in Figs. 1 and 2 respectively.

3.2 Blending (Time, Temperature and Speed)

Consistency of CRMB blends mainly depends on the optimisation of factors such as blending time, temperature and speed during the production stage. Researchers have carried out different laboratory studies to optimise these laboratory parameters. As a result, these factors have been reported to have a considerable effect on the performance of the modified binder. Available literature reveals the usage of blending times of 30-300 minutes, temperatures ranging from 160-220°C and blending speeds of 1000-10000rpm to produce CRMB in the laboratory [8-13]. Therefore, to gain full understanding of the effect of blending parameters on the properties of CRMB blends, a comparison was necessary to reveal the optimum preparation of the product with best possible properties.

4. OPTIMISATION OF LABORATORY BLENDING PARAMETERS

With all these factors contributing to the performance of the CRMB blend, there is a definite need for the formulation of a protocol for the production of CRMB. Therefore, the effect of laboratory blending as a function of blending (device, speed, time and temperature) was studied by different variations. The range of selected blending parameters is as follows.

- Blending Device: High shear mixer and Mechanical stirrer.
- Blending times: 30, 60, 90, 120 and 180 minutes.
- Blending speeds: 1000, 2000 and 3000 (rpm).
- Blending temperature: 180 and 200°C.

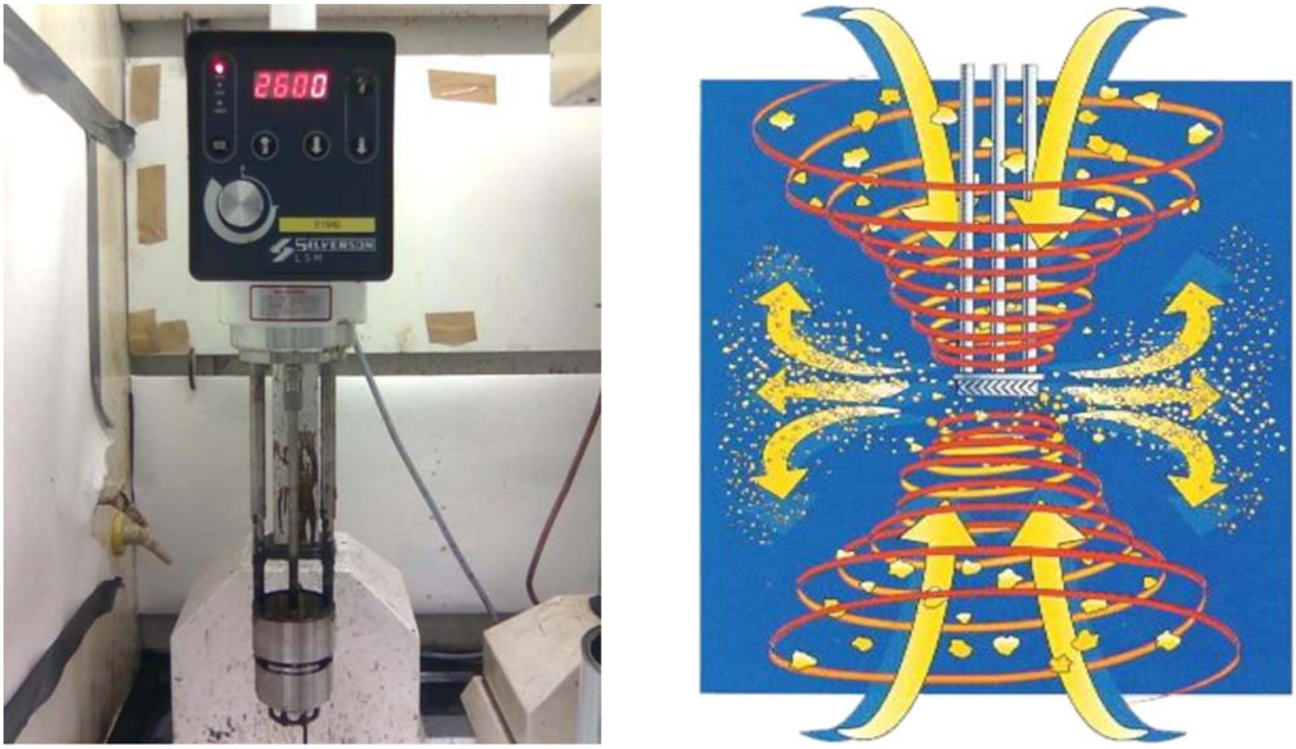

FIG. 1. HIGH SHEAR MIXER (LEFT) AND FUNCTIONAL SCHEMATIC OF THE MIXER (RIGHT)

In total, 12 CRMB blends were produced in the laboratory to understand the laboratory blending phenomenon. Besides the variation in blending parameters, base bitumen 40/60 and CR from ambient source and Size No. 40 mesh with proportions of 85 (bitumen): 15 (CR) by mass of the total blend were kept constant for all above combinations. The main objective was to record the effects of the blending conditions on the properties of the modified binder at different stages. In addition to the examined blending parameters, a blending speed of 4000 rpm was used to allow smooth feeding of CR into the bitumen and faster interaction between material constituents for the first 10 minutes. The selection of increased blending speed during CR feeding was based on laboratory experience, where problems were observed in CR feeding in hot bitumen during blending. This resulted in considerable reduction in bitumen's temperature and increased blending time along with increased blending effort was also recorded.

Moreover, selection of ambiently ground rubber was based on the easy availability of the material within the local area. Also, similar type of material with moderate size such as No. 40 mesh has been used in the past by number of researchers [6-7,10]. Therefore, to optimise blending variables, a known material was used to prepare CRMB blends. An illustration of the methodology carried out to accomplish this laboratory exercise is presented in Fig. 3.

5. RESULTS AND DISCUSSION

Evaluation of the CRMB blends for the optimisation of the blending parameters was performed by means of the

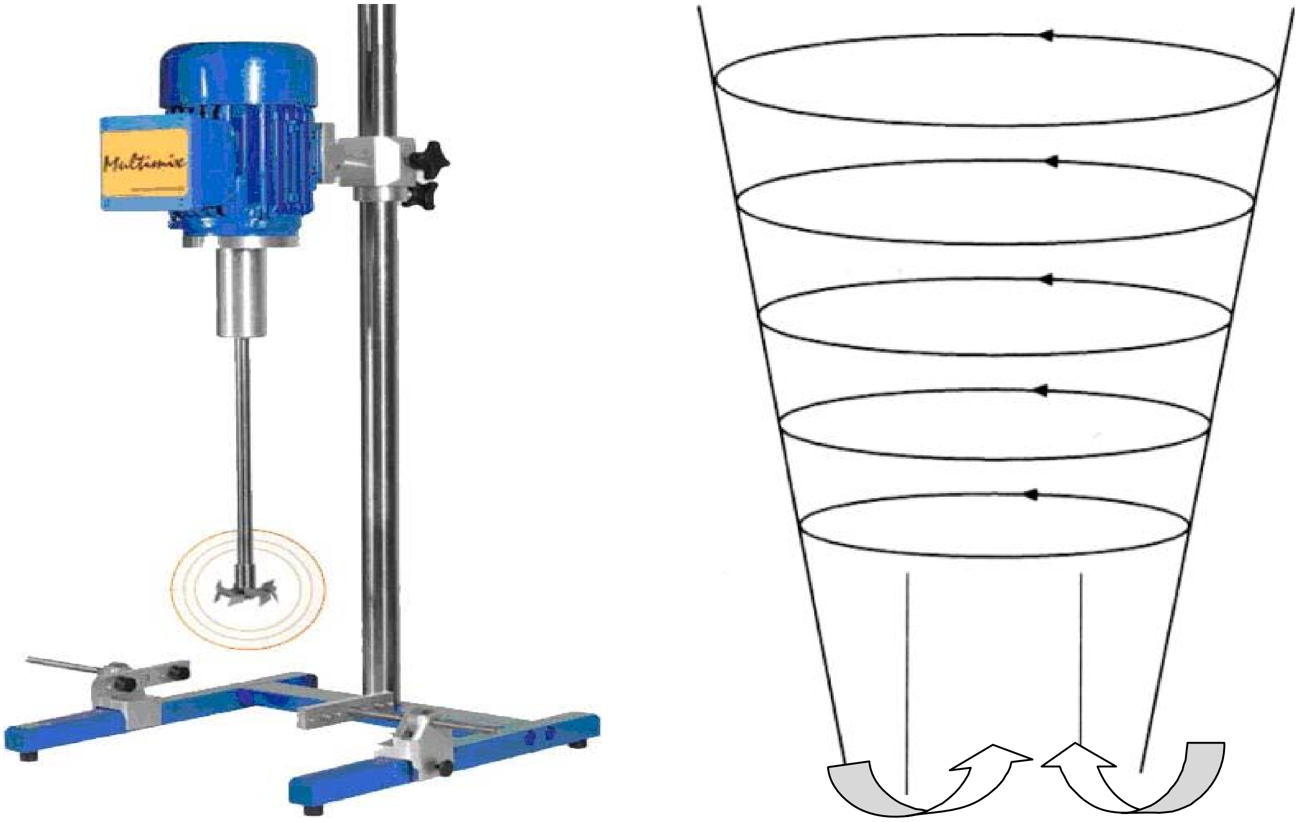

FIG. 2. MECHANICAL STIRRER (LEFT) AND FUNCTIONAL SCHEMATIC OF THE MIXER (RIGHT))

resultant viscosity at the equilibrium state. The equilibrium states in this study are referred to the blending stages, where measured values were more consistent and did not go through further changes over a period of time. To carry this out, the samples collected after 30, 60, 90, 120 and 180 minutes of blending duration from the 12 blends were used for the viscosity observations.

Figs 4-7 present the correlation between the blending parameters and the viscosity measured at 177°C. This relationship explains the effect of the laboratory blending device as a function of blending time, blending duration and blending speed at specific interaction temperatures of 180 and 200°C on the properties of CRMB blends.

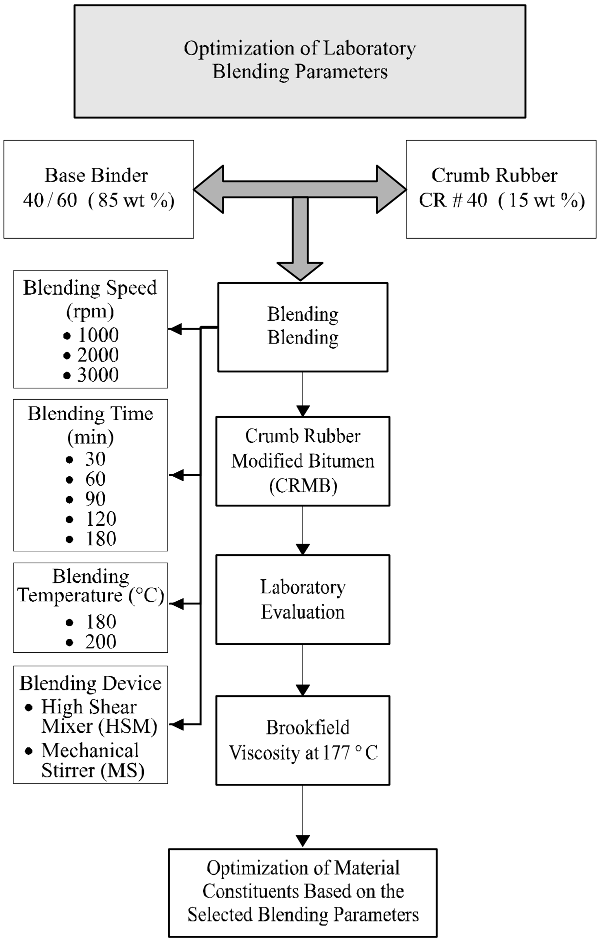

FIG. 3. METHODOLOGY ADOPTED TO OPTIMISE LABORATORY BLENDING PARAMETERS

To get a further understanding, a detailed comparison of the Brookfield viscosities of CRMB samples produced with high and low shear mixers at specified blending times and temperatures are presented in Figs. 8-9.

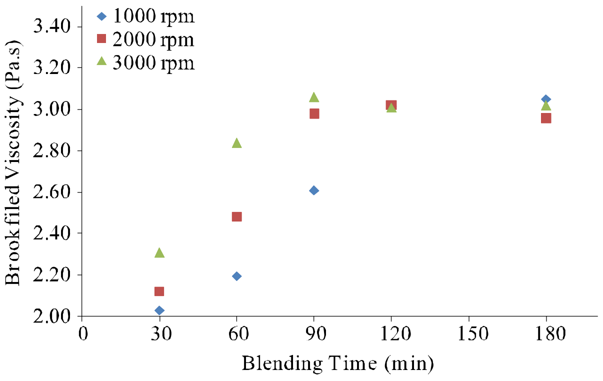

FIG. 4. CRMB BLENDED AT 180°C WITH HIGH SHEAR MIXER

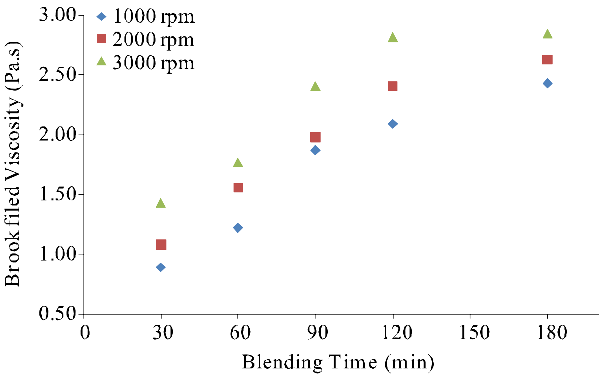

FIG. 5. CRMB BLENDED AT 180°C WITH MECHANICAL STIRRER

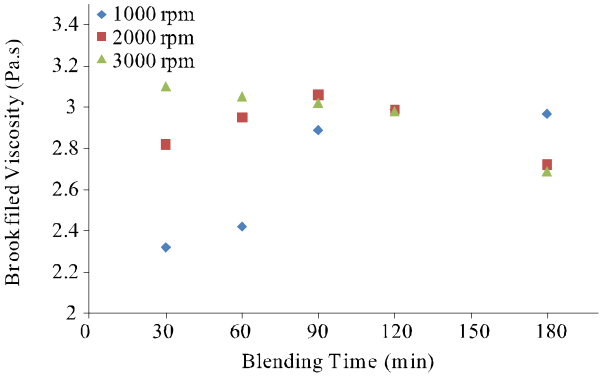

FIG. 6. CRMB BLENDED AT 200°C WITH HIGH SHEAR MIXER

In general, the properties of the CRMB blends were found to be significantly changed based on the variation of blending effort applied. The laboratory observations by means of the viscosity measurements and further comparison with varied blending parameters are displayed in Figs. 4-7.

Fig. 4 presents the variations in the viscosity observations, when assessed in terms of different blending times and speeds with high shear mixer at 180°C. From the observations, the peak and stable viscosity values were achieved after 90 minutes of blending duration with a minimum of 2000-3000 rpm high shear mixing. However, the required blending time was increased to 120 minutes at the same blending temperature, when mixing speeds were reduced to 1000 rpm. The viscosities of the blends did not go through any further significant changes for the extended blending durations to 180 minutes in both conditions.

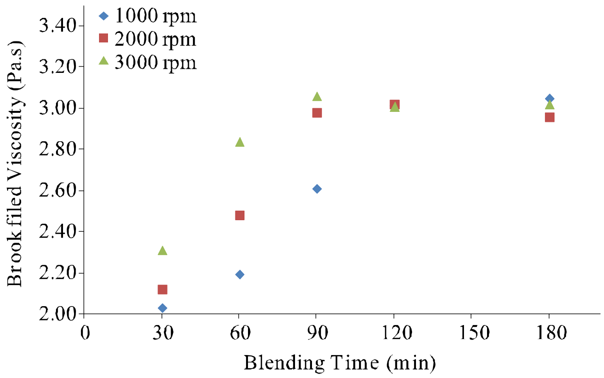

FIG. 7. CRMB BLENDED AT 200°C WITH MECHANICAL STIRRER

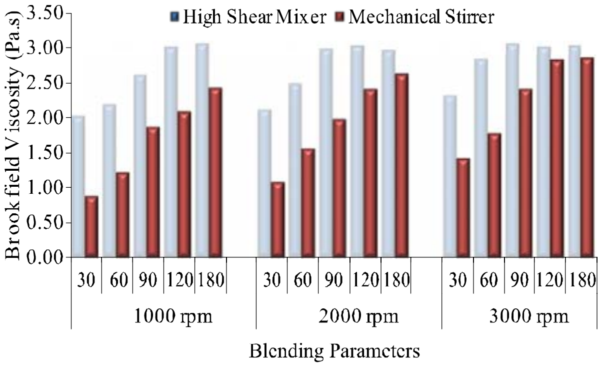

FIG. 8. COMPARISON OF BLEND VISCOSITIES PRODUCED WITH HIGH AND LOW SHEAR MIXERS AT 180°C

Blending performed by mechanical stirring at 180°C required additional blending effort compared to the high shear mixing. The results are presented in Fig 5. In this case, a minimum of 180 minutes of blending time was needed at blending speeds of 1000 and 2000 rpm to obtain stable viscosities. However, the blending time reduced to 120 minutes with the increase in blending speed to 3000 rpm to achieve the highest possible viscosity values. The viscosity of the blends remained stable during further blending.

Brookfield viscosity observations of the CRMB blends prepared at 200°C presented in Fig 6 also revealed significant variations in the parameters required to achieve the equilibrium stage of viscosities. Blends prepared with high shear mixer at blending speeds of 2000 and 3000 rpm demonstrated a decrease in processing time to 60 minutes.

However, at a blending speed of 1000 rpm, the peak viscosity values were obtained after 120 minutes of blending. For all combinations, the observed values continued to be stable until 120 minutes of blending.

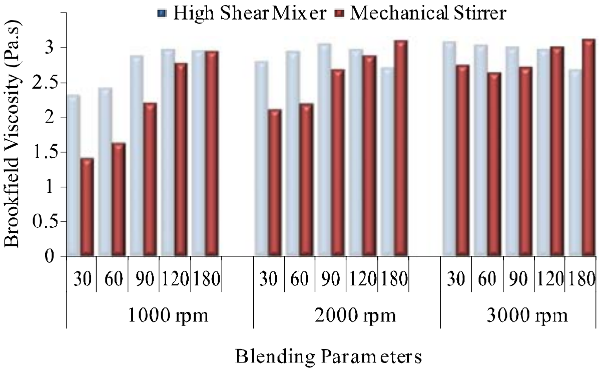

FIG. 9. COMPARISON OF BLEND VISCOSITIES PRODUCED WITH HIGH AND LOW SHEAR MIXERS AT 200°C

However, viscosities of the blends started decreasing with further increases in blending times due to the probable degradation of the CR particles in the blend prepared at 200°C.

In the case of blending performed with a mechanical stirrer at 200°C, peak viscosity values were obtained after 120 minutes of blending and did not significantly change after further processing. Similar trends of viscosity values were observed, when blends were prepared with three different blending speeds of 1000, 2000 and 3000 rpm. The observations are shown in Fig. 7.

6. CONCLUSIONS

In general, mixing performed with the high shear mixer resulted in higher viscosity values compared to the blends produced with the low shear mixer. The difference may be attributed to the proper interaction between the basic components during high shear mixing. In addition, a reduced blending time was required to achieve peak and ultimate stable viscosities, when blends were produced with the high shear mixer. This also could have reduced the exposure of the blend to the atmosphere and resulted in a reduction in oxidation and volatilisation. Furthermore, the blending temperature of 180°C has resulted in the blends with consistent properties for longer blending durations compared to the blends produced at higher temperature. As a result, results with high shear mixer were always promising, which required comparatively lower interaction temperature, time and speed.

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REFERENCES

[1] Memon, N.A., “Characterisation of Conventional and Chemically Dispersed Crumb Rubber Modified Bitumen and Mixtures”, Ph.D. Thesis, University of Nottingham, UK, 2011.

[2] Airey, G.D., Rahman, M.M., and Collop, A.C., “Absorption of Bitumen into Crumb Rubber Using the Basket Drainage Method”, International Journal of Pavement Engineering, Volume 2, pp. 105-119, 2003.

[3] Bahia, H.U., and Davies, R., “Effect of Crumb Rubber Modifier (CRM) on Performance Related Properties of Asphalt Binders”, Journal of Asphalt Paving Technologies, Volume 63, 1994.

[4] Green, E.L., and Tolonen, W.J., “The Chemical and Physical Properties of Asphalt-Rubber Mixes, Arizona Department of Transport”, Report ADOT-RS-14-162, Arizona, 1977.

[5] Heitzman, M.A., “State of Practice-Design and Construction of Asphalt Paving Materials with Crumb Rubber Modifier”, Fedral Highway Administration (Edition), FHWA-SA-92-022, Wahshington, DC, 1992.

[6] Shen, J.N., et. al., “Influence of Surface Area and Size of Crumb Rubber on High Temperature Properties of Crumb Rubber Modified Binders”, Construction and Building Materials, Volume 1, pp. 304-10, 2009.

[7] Garcia-Morales, M., et. al., “Processing, Rheology, and Storage Stability of Recycled EVA/LDPE Modified Bitumen”, Polymer Engineering and Science, Volume 2, pp. 181-91, 2007.

[8] Amirkhanian, S.N., Xiao, F.P., and Tang, B.M., “Establishment of an Asphalt-Rubber Technology Service (ARTS)”, Asphalt Rubber, Brazil, 2003.

[9] Huang, S.C., and Pauli, A.T., “Particle Size Effect of Crumb Rubber on Rheology and Morphology of Asphalt Binders with Long-Term Aging”, Road Materials and Pavement Design, Volume 1, pp. 73-95, 2008.

[10] Neto, S.A.D., et. al., “Influence of Crumb Rubber and Digestion Time on the Asphalt Rubber Binders”, Road Materials and Pavement Design, Volume 2, pp. 131-48, 2006.

[11] Palit, S.K., Reddy, K.S., and Pandey, B.B., “Laboratory Evaluation of Crumb Rubber Modified Asphalt Mixes”, Journal of Materials in Civil Engineering, Volume 1, pp. 45-53, 2004.

[12] Thodesen, C., Shatanawi, K., and Amirkhanian, S., “Effect of Crumb Rubber Characteristics on Crumb Rubber Modified (CRM) Binder Viscosity”, Construction and Building Materials, Volume 1, pp. 295-303, 2009.

[13] Wang, Q., et al., 'Preparation of high-temperature vulcanized silicone rubber of excellent mechanical and optical properties using hydrophobic nano silica sol as reinforcement', Chinese Journal of Polymer Science, Volume 4, pp. 495-500. 2008.