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Influence of the Variation in Material Constituents on the Properties of the Crumb Rubber Modified Bitumen Blends

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Abstract: The properties of the Crumb Rubber Modified Bitumen (CRMB) are greatly influenced by the amount and type of the material constituents used in the perpetration of the blend. Moreover, characteristics of the crumb rubber (CR) are modifier on the basis of processing mechanism is mainly found to govern the properties of the CRMB. A fair amount of research was observed in the literature on the bitumen modified by CR processed cryogenically and ambiently. However, little or no work has been done on the CR processed by the other methods such as the Aquablast processing technique, which is a relatively a new waste tyre rubber processing technique within the CR industry. In this study, influence of the scrap tyre fracture technique on the properties of CRMB blends was investigated by looking at viscosity with a Brookfield viscometer. The study allowed concluding that the amount of CR significantly influences the behavior of the blend. Based on the allowable limits of the specifications, 15% CR concentration in the blend met all the viscosity requirements irrespective of varied material parameters. On the other side, variation of the CR type did not affect the properties of the blend greatly, when comparing the incorporation of 40 and 50 mesh CR size. However, results revealed some significant differences, with increased CR size to 30 mesh.

Keywords: CR; CRMB; Ambient CR; Aquablast CR; Tyre Fracture Technique

1. INTRODUCTION

Traditionally, the production of CRMB involves bitumen and CR as the major components. Bitumen as a function of penetration grade and source and CR as a function of type, proportion and size have been selected in the past. Therefore, to optimise the selection of the basic material constituents and ultimately to get the production of the best possible blends, the range of selected material properties in the light of available guidelines and specifications are described in the following sections.

Optimisation of the basic constituents was mainly based on the preparation of the CRMB blends by varying the material and not the interaction conditions. The blending parameters optimised from previous laboratory investigation were adopted for the preparation of the CRMB blends (Airey, 2003; Bahia 1994). The objective was to optimise material constituents and to acquire the best possible blends within the specified viscosity limits. In addition, the effect of CR processing technique and size on the properties on the CRMB blends was investigated in this section.

For this purpose, CRMB blends with bitumen-CR proportions of 90:10, 85:15, 82.5:17.5 and 80:20 wt % with two CR types and three identical CR sizes were produced in the laboratory. The blending parameters used were high shear mixing at 2000 rpm, blending temperature of 180°C and 120 minutes of maximum blending time. The selection of the base binders was based on the increasing penetration grades from the same source. The three grades of base binder selected for this study were 40/60, 70/100 and 100/150. However, the selection of the CR as a bitumen modifier was based on several variables. These variables included CR type (Ambient and Aquablast), CR size (30, 40 and 50 mesh) and CR content (10, 15, 17.5 and 20 percent by mass of the total blend). For the optimisation of the proportions of the material constituents such as bitumen and CR based on the above

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parameters, 72 RMB blends were produced in the laboratory by varying their parameters.

2. MATERIAL AND METHODS

Investigation of the CRMB blends for the Optimisation of Basic Material

The task was mainly carried out to find out the optimum proportions of the CRMB blends within the viscosity ranges specified in different specifications and guidelines. Brookfield viscosities obtained at equilibrium state by varying material proportions and parameters are illustrated in **(Fig. 1 to 6).**

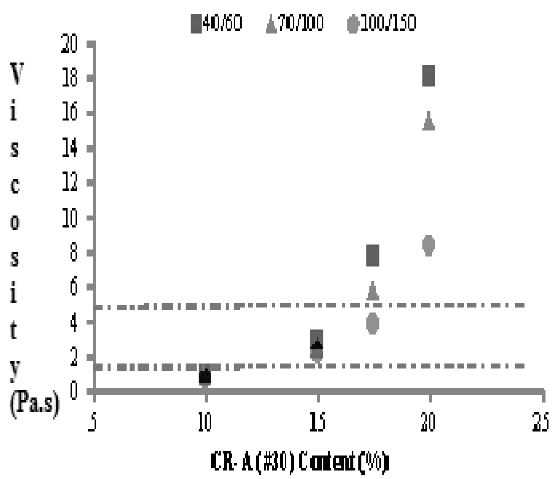

Fig. 1 Screening of CRMB blends produced with CR-A#30 for target viscosities

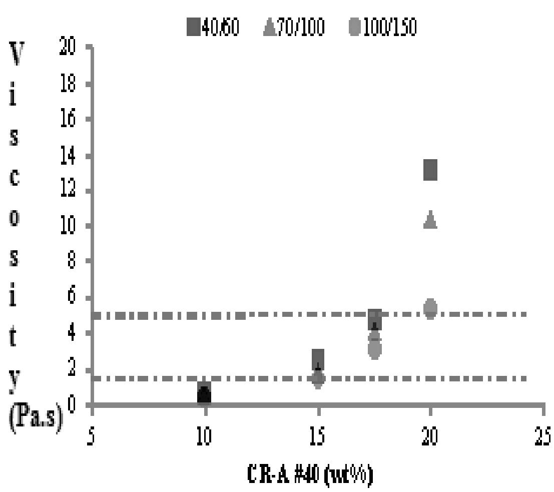

Fig. 2 Screening of CRMB blends produced with CR-A#40 for target viscosities

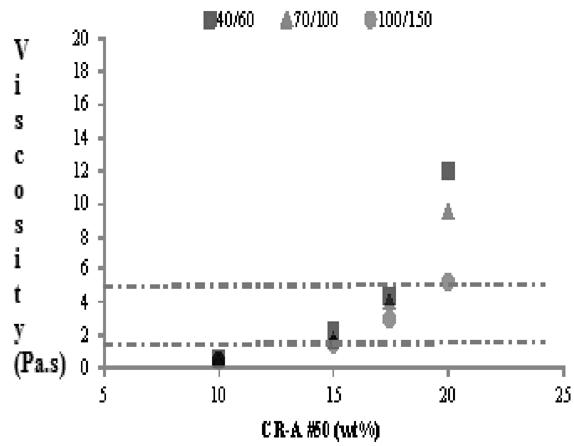

Fig. 3 Screening of CRMB blends produced with CR-A#50 for target viscosities

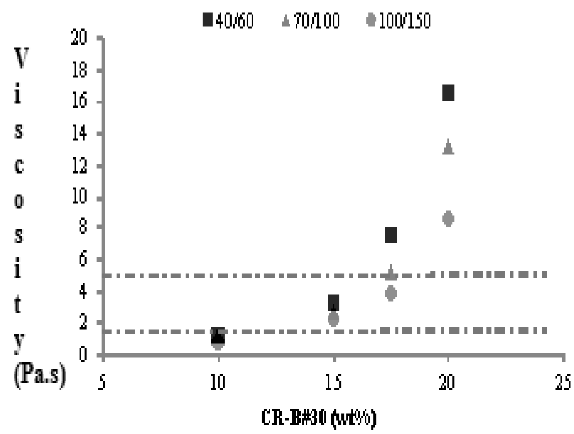

Fig. 4 Screening of CRMB blends produced with CR-B#30 for target viscosities

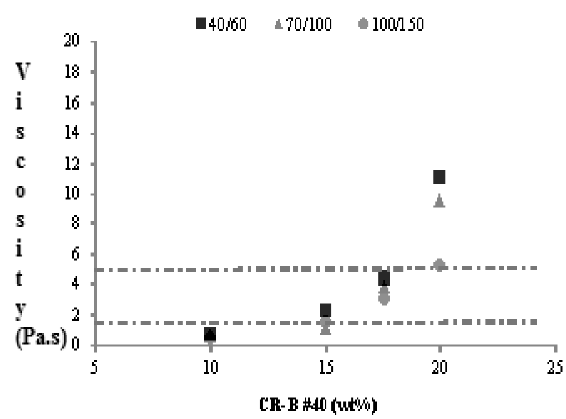

Fig. 5 Screening of CRMB blends produced with CR-B#40 for target viscosities

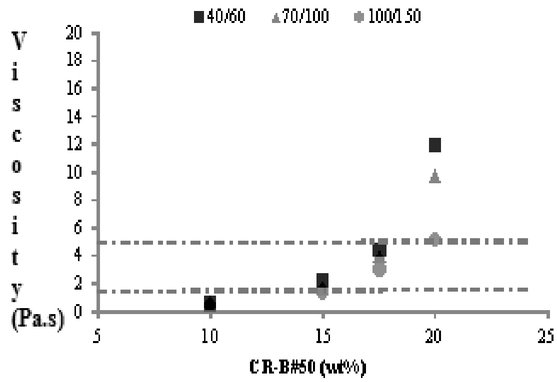

Fig. 6 Screening of CRMB blends produced with CR-B#50 for target viscosities

The properties of the CRMB blends largely depend on the proper interaction between the primary components, where the CR particles swell to form a viscous gel. This results in a significant increase in the viscosity of the blend ([Memon 2011, Haung 2008). However, the properties of the blend are always varied and inconsistent due to the varied properties of the material constituents and various interaction effects. In general, the properties of the blend are largely dependent on the chemistry of the base binder, CR source, percentage and size (Airey 2003; Thodeson, 2009).

2.1 Viscosity as a Function of Base Bitumen Type

When comparing base bitumen grades as a function of peak viscosity of the CRMB blend in Figures 1 to 6, viscous behaviour of the modified blends was found to be greatly affected by the penetration grade of the base bitumen. The softer base binders in general were found more compatible with CR by accommodating increased CR concentration. Among the three base bitumen grades used for the preparation of CRMB blends at different proportions, blends produced with the 40/60 bitumen resulted in the highest viscosity values followed by the 70/100 and 100/150 base bitumens. This was mainly due to the higher amount of lighter fraction available in the softer base bitumens compared to stiffer ones, which allowed proper interaction of the two phases. The observed trend is also thought to be attributed to the initial viscosities of the base bitumens, where base bitumen 40/60 has higher viscosity compared to the 70/100 and 100/150.

2.2 Viscosity as a Function of CR Source

When the scrap tyre grinding procedures were compared for their effects on the properties of CRMB blends with different variations in material constituents, varied observation were recorded for different blend combinations. The scrap tyre processing method used to manufacture CR was found to have a relatively significant effect on the viscosity of the blends. The results revealed that the CR produced by Aquablast grinding yielded relatively higher viscosities compared to the ambient source at lower CR concentrations. These observations were true, when CRMB blends were produced with 90:10 bitumen-CR proportions. However, the trend was reversed, when blends were produced with higher concentrations of CR in the blend such as 15, 17.5 and 20 wt%, where CRMB blends produced with ambiently ground rubber resulted in higher values of viscosity compared to the Aquablast blend. The differences in results were also influenced by the initial differences in the properties of the CR obtained from the two sources, where ambiently ground rubber showed higher densities compared to Aquablast CR.

2.3 Viscosity as a Function of CR Size

CR size had a significant effect on the viscosity of the CRMB blends at equilibrium state. It is generally understood that the finer CR particles compared to the larger CR particles would produce blends with higher viscosities (Aiery, 2002). This has not necessarily been the case in recent research (Memon, 2011, Bahia 1994), where studies have found a reversed trend. As a result, contradictory observations have been reported by previous researchers with increasing trend of viscosity with decreasing CR size in the blend but a reversed trend on some occasions. It is also assumed that an additional blending effort is required with an increase in CR size to achieve stable viscosity and ultimate equilibrium state (Neto, 2006; Palit, 2004). Therefore, the equilibrium state of the CRMB blends may differ based on the CR size used in the blend as coarse CR particles in the blend would require more reaction compared to the fines.

When results were analyzed for the effect of particle size on the viscosity of the CRMB blend in this study, a clear decreasing trend of the viscosity was observed with decreasing CR size. As a result, 30 mesh produced the highest viscosity values at equilibrium state for all blend combinations. The decreasing trend of the blend viscosity was followed by decreasing CR size to 40 mesh in the blend. However, with a further decrease in CR size to 50 mesh, no significant decrease in the viscosities of the CRMB blends was observed. The changes may be attributed to the increased blending effort from the blending device and extended blending duration. This could have achieved the highest possible viscosity values of the blends produced with larger CR particles. In addition, when larger particles attained maximum possible swelling after absorbing lighter fractions from the bitumen phase, the swollen CR particles were less prone to free movement within the bitumen matrix and have resulted in increased viscosity. On the other hand, finer CR particles were free to move into the bitumen matrix due to their size even after swelling.

Moreover, finer CR particles were found to be easily dispersed in the binder compared to coarse CR particles. The homogeneous dispersion of the finer CR particles in the bitumen phase could have also led to the lower viscosities of these blends compared to the blends with heterogeneous dispersing of larger CR particles, which resulted in higher viscosity values.

2.4 Viscosity as a Function of CR Content

Previous research has shown that the viscosity of CRMB blend increases with increase in CR concentration in the blend. This is irrespective of rubber type and size (Shen, 2009). A general trend was found, as expected, indicating that the higher CR percentages led to higher viscosity of the CRMB blends. From an analysis of the viscosity results presented in Figures 1-6, it is evident that the CR percentage had a major effect on the viscosity of the CRMB blends. Available specifications and guidelines include a maximum and minimum viscosity range of 1.5 to 5.0 Pa.s viscosity requirements. Based on these limit, the selection of the blends based on the minimum and maximum Brookfield viscosity limits suggested by different specifications, produced results that have led to following observations; CRMB blends prepared with 90:10 proportions were found to be below the minimum viscosity requirement. On the other hand, blends produced with 20% CR concentration, have resulted in viscosity values above the limit. The observations were true for all the blend combinations with these CR proportions, at different sizes and types. In addition, variations in base binder could not affect the results significantly. CRMB blend prepared with 85:15 proportions resulted in viscosity values within the specified limits. The observations were true regardless of the variation in binder type, CR source and size used in the blend combination.

Furthermore, some of the blend prepared with 17.5% CR concentration also met the viscosity requirements. As a result, blends prepared with base bitumen 100/150 and three different CR sizes at 17.5% concentration resulted in viscosity values within the specified limits. In addition, blends produced using base bitumen 70/100 and CR sizes of 40 and 50 mesh from the two sources at the same concentrations, could also meet the viscosity requirements.

3. CONCLUSION

The study accomplished allows the conclusion that the amount of CR significantly influences the behavior of the blend. For the selection of blends with optimised material proportions and properties, the amount of CR in the blend was found to be the most influential factor in controlling the viscosity of the binder. Based on the allowable limits of the specifications, 15% CR concentration in the blend met all the viscosity requirements irrespective of varied material parameters. On the other side, variation of the CR type did not affect the properties of the blend greatly, when comparing the incorporation of 40 and 50 mesh CR size. However, results revealed some significant differences, with increased CR size to 30 mesh.

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