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Effect of emulsifier on physical properties of cup lump modified emulsified bitumen residues

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Abstract. The improvement of physical properties of emulsified bitumen residues is the prime concern for researchers to improve the performance of cold mix asphalt and different types of polymers are incorporated in emulsified bitumen for this purpose. However, the bitumen emulsion is usually prepared with the help of emulsifier and the function of emulsifier in the emulsions is to reduce the interfacial tension on the surfaces of bitumen and water droplets which results in a stable droplets suspension system for a sufficient period of time. Despite using it as an emulsifying agent, the impact of emulsifier on physical and rheological properties of bitumen emulsion's residues is never studied before. In this study, different types of bitumen with pen 80/100, 60/70 and Cup lump rubber (CLR) modified bitumen were emulsified at 0.5%, 1% and 6.5% emulsifier (Redicote-EM44) content respectively. Physical tests such as penetration, softening point and viscosity were carried out on bitumen residues to investigate the effect of emulsifier. The results indicate that the emulsifier enhances the physical properties of bitumen emulsion residues. The resistance to penetration was improved up to 20% and 16% for the bitumen emulsion residues of 80/100 and 60/70 respectively while it had adverse effect on penetration value of CLR residue resulting in a decreased performance up to 19%. The effect of emulsifier on softening point was not remarkable but has improved SPV of 80/100 and 60/70 bitumen residues whereas the values decreased for CLR bitumen residue. The viscosity results were with better agreement of penetration and softening point results.

1. Introduction

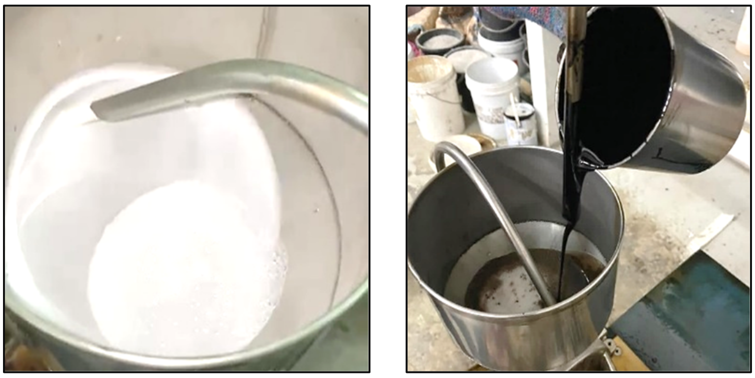
Environment sustainability remains the prime concern in modern development goals of road construction and these demands can somehow be achieved through construction of road at ambient temperatures such as cold mix asphalt [1-2]. Cold mix asphalt mixture is produced using emulsified bitumen and its application is limited to road maintenance work due to numerous problems in its performance when compared to conventional hot mix asphalt [3]. However, efforts have been made by different researchers to enhance the performance of cold mix asphalt mixture that include addition of polymers, additives, cement and also improving the design techniques [4]. The formulation of bitumen emulsions for cold mix is itself difficult task rather than using polymers and other additives which has a lot of compatibility issues during emulsification [5-7].

Bitumen emulsions are two immiscible liquids comprised of bitumen and water droplets suspended in one another. The source of suspension is usually provided by emulsifier thus produces strong electrical charges of identical ions on the surface of droplets which reduces the interfacial tension and remain in suspension for longer period of time. Although, there are number of dependency variables on droplet suspension system such as mixing speed, droplet size & distribution, pH values and bitumen/water concentration etc, which are beyond the scope of this study [8–10]. The fundamental physical properties of bitumen emulsion such as storage stability and viscosity have nothing to do with final performance imparted by emulsions residues, however these properties of bitumen emulsions dictate its utility in road construction. In addition, the emulsifier applied in bitumen emulsion for reducing the interface tension is also believed to enhance the physical properties of bitumen emulsion residues and this may be due to the development of new structure due to emulsifier. But very few studies are available on the effect emulsifier on bitumen emulsion residues since emulsifier tends to improve the physical properties of binder residues [11–13]. This study includes three different types of bitumen to emulsify in order to investigate the effect of emulsifier on the physical properties of its emulsion residues.

2. Experimental procedure

2.1. Materials

Three different types of bitumen 80/100, 60/70 and 80/100 modified with cup lump rubber (CLR) were used to prepare bitumen emulsions. The 60/70 grade bitumen was used only for comparison purposes. The cup lump rubber (CLR) which is a natural rubber in the form of cup lump was received from Ching Hong rubber factory in Johor, Malaysia. The Redicote EM44 cationic type of emulsifier was used to emulsify the different types of bitumen provided by Nouryon. The hydrochloric (HCL) acid was used to manage the pH of aqueous solution and pH was measured by litmus paper. The deionized water was used for preparing the soap solution. The colloid mill as shown in the figure 1(a) & (b) with a shearing speed of 2840rpm was used to emulsify the three different types of bitumen.



(a) Soap solution in the mill (b) Pouring bitumen in the mill

Figure 1. The pouring process of soap solution followed by bitumen in a colloid mill

2.2. Preparation of polymer modified bitumen

The base bitumen 80/100 was selected to prepare cup lump modified bitumen. The physical properties of base bitumen are enlisted in table 1. The cup lump rubber blending with base bitumen was performed according to previous studies [14-16]. The cup lump rubber (CLR) was mixed with base bitumen using high shear mixer at 170℃ for 2 hours with a shearing speed of 4800 rpm as shown in figure 2 (d). The CLR was cut into pieces of 10mm and treated with toluene for 24 hours before mixing with base bitumen as shown in figure 2 (a-d). The toluene to CLR ratio was kept to 2:1. The addition of CLR was limited to 3% only due to compatibility issues in emulsification of bitumen.

Table 1. Physical properties of bitumen binder.

Penetration @ 25°C,100g, 5 Sec	Softening Point °C	Flash Point °C	Ductility @ 25°C 5 cm / min	Specific Gravity @25°C
80-100	43-54	232	100	1.01-1.06

(a) CLR Rubber pieces

(b) Pre-treatment with toluene

(c) Pre-treated CLR rubber

(d) Blending with bitumen using high shear

Figure 2. Pre-treatment and blending process of natural rubber with bitumen

2.3. Preparation of emulsified bitumen

The soap solution prepared at temperature 60°C by introducing dosage of 0.5%, 1% and 5% of emulsifier by weight for 80/100, 60/70 and CLR modified bitumen respectively, at constant pH value of 2-3. The emulsifier dosage was based on achieving sufficient value of storage stability for particular type of bitumen. The soap solution was poured in colloid mill followed by heated bitumen up to 150°C preparing bitumen/water 60:40 emulsions and mixed for 9 minutes as shown in the Figure 1(a) & (b). The mixing time was also identified while achieving optimum storage stability. The emulsions were then tested for particle charge test according to ASTM D7402 [17]. The storage stability was measured according to ASTM D6930 [12] which is determined by the difference in percent of bitumen residue by evaporation of bitumen emulsions samples collected from the top and bottom from undisturbed samples placed in the cylinder for 24 hours. The 50g samples from top and bottom each were collected in beakers and placed in an oven at temperature 163°C for 2 hours. Then the samples were stirred and kept for another 1 hour in the oven in order to get bitumen residues. The results for storage stability should be ≤ 1 and least value gives favourable storage stability.

2.4. Residue by evaporation of bitumen emulsions
The residues of bitumen emulsions for investigation of physical properties were achieved through residue by evaporation of emulsified bitumen tests as per ASTM D6934 [18]**.** The required sample of bitumen emulsions in an open top beaker was kept in an oven at temperature 163℃ for 2 hours. Then the sample was stirred and kept for another 1 hour in the oven in order to get bitumen emulsion residues.

2.5. Penetration and Softening point tests
A series of penetration and softening point tests were conducted on different types of binder and their emulsion residues according to ASTM D5 and ASTM D36. The penetration test is used to measure the consistency in order to specify the penetration grade, while softening test is used to measure the temperature at which bitumen exhibits the flowing characteristics. In addition, these tests can also be used to investigate the temperature susceptibility in terms of penetration index (P.I).

2.6. Measurement of dynamic viscosity
The viscosity is measured in order to investigate the resistance to flow and workability of bitumen. This test is usually performed at elevated temperature 135℃ by Brook field rotational viscometer as per ASTM D4402. However, in this study different temperatures such as 60℃, 100℃ and 135℃ were selected for viscosity measure using spindle # 27 with 50rpm speed. The reason behind choosing these temperatures is to conduct a suitable corelation among the results of viscosity values.

3. Results and Discussions

3.1. Effect of emulsifier on consistency
Figure 3. illustrates the results for consistency of different types of bitumen and their emulsion residues in terms of penetration. The results clearly indicate the difference between penetration values for 80/100, 60/70 and CLR modified bitumen and their residues. The penetration values decrease from bitumen to residues up to 20% and 16% for 80/100 and 60/70 respectively. However, this significant change in values is opposite for CLR modified bitumen and its residue. The penetration value increases significantly up to 19% for CLR modified bitumen. The results probably demonstrate that the new structure is developed by inclusion of emulsifier which resulted a positive impact such as improving the resistance to penetration for 80/100 and 60/70. On contrary, this is a negative impact on CLR bitumen residues, resulting in decreased penetration values. These results are also conform with the findings in studies [11] and [12], where the consistency of bitumen has been improved for its emulsion residues due the existence of emulsifier.

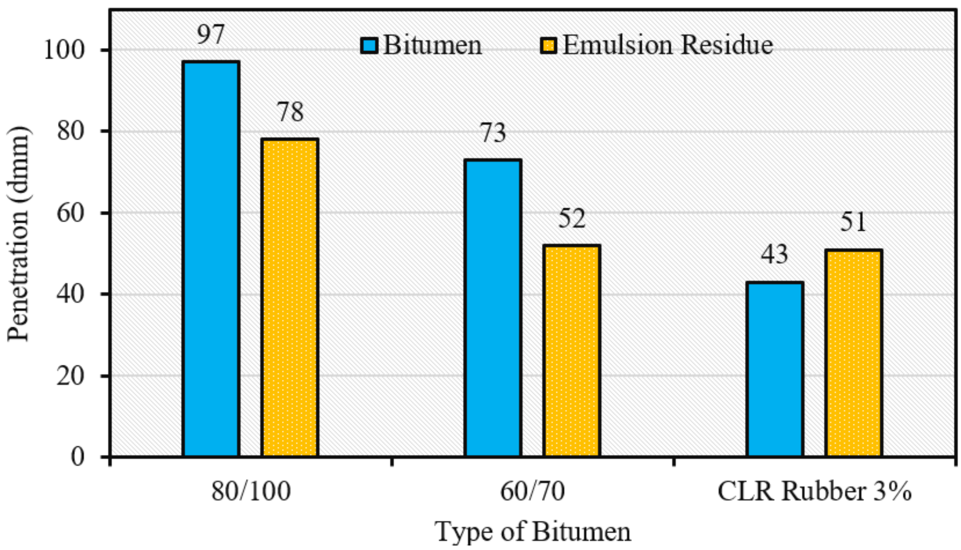


Figure 3. Effect of emulsifier on penetration of bitumen emulsion residues

3.2. Effect of emulsifier on softening point values

Figure 4. illustrates the results of softening point values for different types of bitumen and their emulsion residues. The results indicate that the effect of emulsifier on softening point values is significant but not remarkable as indicated in penetration tests results. The softening point values slightly increase up to one point for 80/100 and 60/70 from bitumen to residues, and this is opposite for CLR modified bitumen that decreased from bitumen to residues. These results are also conform with the findings in studies [11] and [12], where the results for softening point didn't improved remarkably as the results of penetration tests. These results further conform with agreement that of viscosity as a function of temperature.

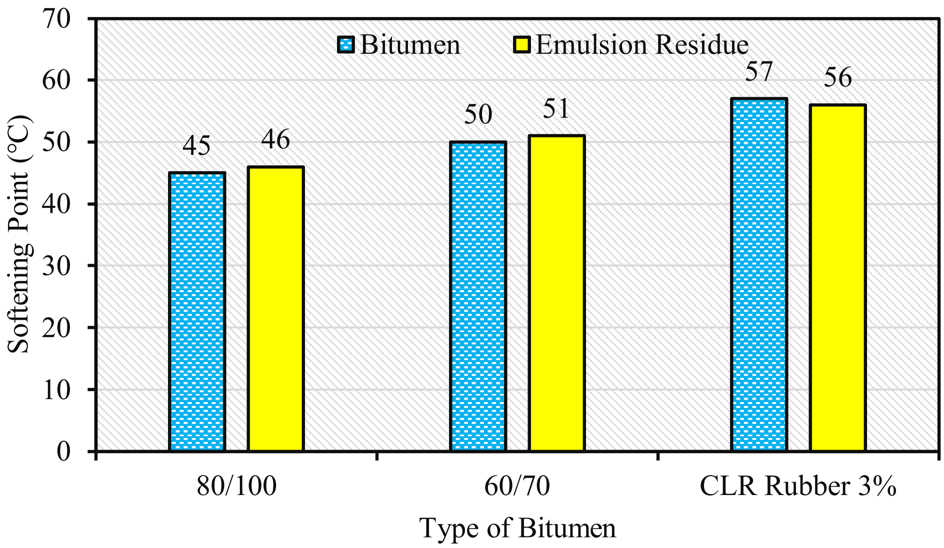


Figure 4. Effect of emulsifier on softening point of bitumen emulsion residues.

3.3. Effect of emulsifier on dynamic viscosity

The effect of emulsifier on viscosity was measured at three different temperatures such as 60°C, 100°C and 135°C for 80/100, 60/70 and CLR modified bitumen and their emulsions residues respectively. The figure 5. illustrates the viscosity results for 100°C and 135°C temperatures, whereas figure 6 exhibit the results for 60°C only. The emulsifier significantly improves the viscosity of all three types of bitumen residues except for CLR modified emulsion residues. The results of viscosity tests for all type bitumen and their residues are in a good agreement with findings for penetration and softening point tests. These results also conform with findings in studies [13] and [12].

4. Conclusions

The objective of this study was to evaluate the impact of emulsifier on the physical properties of bitumen emulsion residues. The results indicate that the emulsifier has significant effect on physical properties of bitumen emulsions residues since the performance was enhanced in terms of consistency except for the residues of CLR modified bitumen emulsions. The penetration results showed that emulsifier has decreased the resistance to penetration for the residues of CLR modified bitumen emulsions up to 19% whereas it has enhanced the resistance to penetration of 80/100 and 60/70 bitumen emulsion residues up to 20% and 16% respectively. Moreover, the effect of emulsifier on softening point was with agreement of consistency results. The addition of emulsifier enhanced the SFV for 80/100 and 60/70 residues up to 1°C whereas it decreased for CLR modified residues. The results penetration and softening point also conform with enhanced performance of viscosity values of different types of bitumen used. Hence, the emulsifier significantly improved the viscosities of 80/100 and 60/70 bitumen emulsion residues. But the viscosity of CLR modified emulsion residue was reduced by the addition of emulsifier.

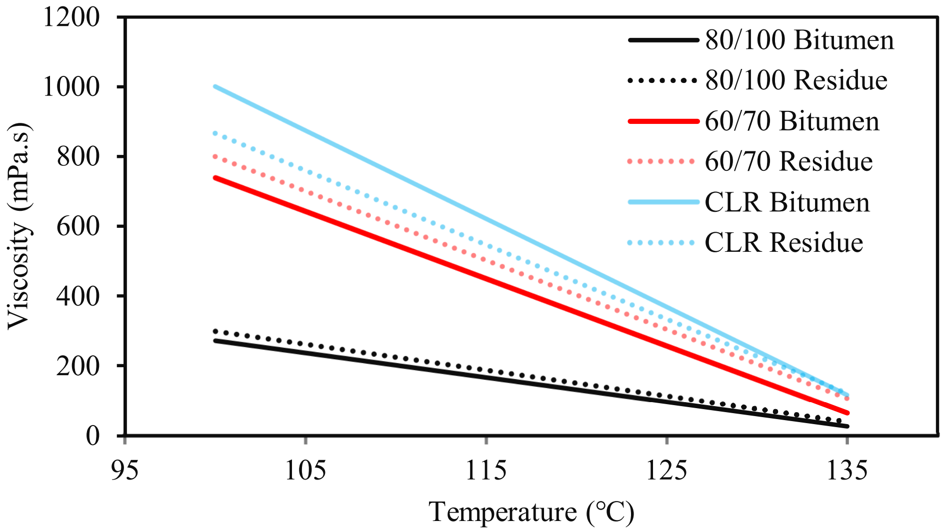


Figure 5. Effect of emulsifier on viscosity of bitumen emulsion residues at 100°C & 135°C

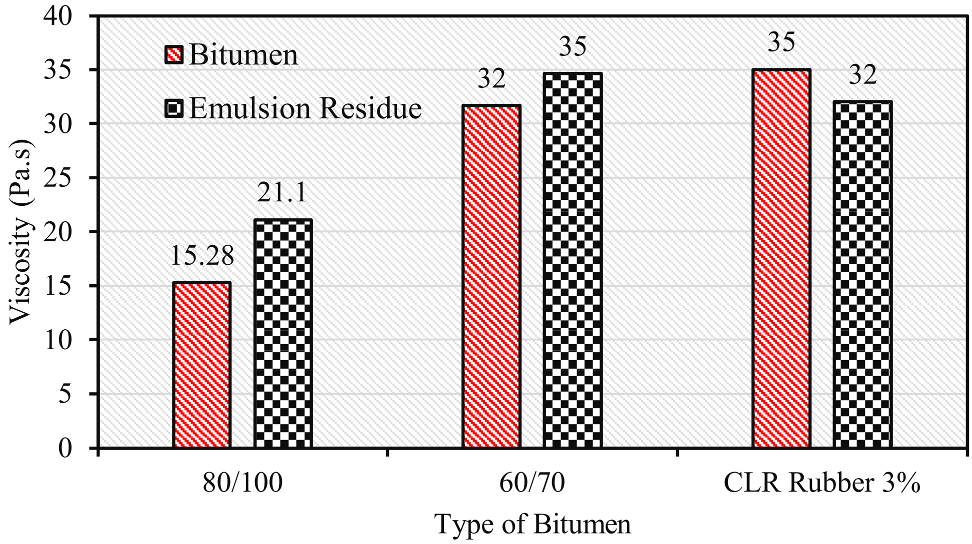


Figure 6. Effect of emulsifier on viscosity of bitumen emulsion residues 60°C.

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