Warm Mix Asphalt Additive in Natural Rubber Modified Bitumen

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Abstract. The growing concern over the reduction of emissions and energy savings has led to the development of new paving technologies that are environmentally friendly. As a result, a warm mix asphalt technologies have been introduced to reduce the mixing and compaction temperature for asphalt mixture. The influence of additive with variation loading on the performance of Natural Rubber Modified Bitumen was acquired. In this work, Brookfield rotational viscometer test and Dynamic Shear Rheometer (DSR) mechanical analysis method and typical bitumen tests were employed. Results indicated that viscosity and the penetration of the Natural Rubber Modified Bitumen decreased, while the softening point increased with addition of additive. This in return would possible to reduce mixing and compaction temperature of the Natural Rubber Modified Mixture. Findings of the study also showed that the additive resulted in increase in complex shear modulus value and the rutting parameter modulus.

1 Introduction

In general, hot mix asphalt mixing contributes to high mixing temperature from drum mixer or batch mixer at a temperature ranges from 160^o c to 180^o c. Hence, a few technologies are introduced in order to reduce bitumen viscosity which in turns lower mixing temperature and emission from the asphalt plant without affecting the pavement quality. The new technology has also been reported in reduction in compaction temperature and several other advantages.

One of these processes utilizes a synthetic long chain Fischer-Tropsch wax which can be blended in the contractor's tank, [1].

Several studies have been performed on the incorporation of wax additives into neat and modified binder [2, 3]. It was reported that, the binder viscosity of Crumb Rubber Modified Bitumen (CRM) at 60°C and the complex modulus at low temperatures and high frequencies increased as, compared to asphalt binders modified with any Fischer-Tropsch wax loading [4]. Besides, other experimental results indicated that asphalt binders of Warm Mix Asphalt (WMA) had lower $G^*/\sin \delta$ values than binder of conventional Hot Mix Asphalt [5]. Due to that, several WMA techniques are available, namely the double-coating or two-phase mixing method the application of the double-barrel green process (with reductions of 10 to 30°C) and the half-warm mix asphalt technologies that use water or vapor, being produced at 90-100°C with foamed bitumen or at 70-115°C with emulsions, [6,7,8,9].

Thus, the aim is of the study is mainly to reduce bitumen viscosity, which in turn improves mix workability, and other binder performances.

2 Experimental

2.1. Materials

Performance grade (PG) 60-70 bitumen binder and Natural Rubber modified bitumen binder containing 1-10% of warm mix additive based on hydrocarbon were used in the study. Table 1 shows the properties of base binder and Natural Rubber modified binder used in the experiment.

2.2 Penetration and Softening Point

The penetration grade of modified bitumen with and without warm mix additive was investigated using the penetrometer in accordance with ASTM D5-86 specification, while the softening point was determined accordance to ASTM D36-95.

2.3 Viscosity

The viscosity of the binder was determined using Brookfield viscometer at a shear rate of 6.8/s. A rotational of 20rpm with the Brookfield Spindle of 27 at a temperature of 120°C and 135°C was used in the experiment.

2.4 Dynamic Shear Rheometer:

The rheological characteristics of unaged and aged Natural Rubber Modified Bitumen at intermediate temperature were investigated in terms of G^* and the phase angle (δ) determined from Dynamic Shear Rheometer (DSR). Temperature sweeps were applied

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from 46°C to 82°C in accordance with Superpave requirements.

Table 1. Properties of Base Binder PG 60-70 and Natural Rubber Modified Bitumen

TEST	Unaged Binder		Rolling Thin Film Oven (RTFO) Aged Binder	
	Performance Grade (PG) 60-70	Natural Rubber Modified Bitumen	Performance Grade (PG) 60-70	Natural Rubber Modified Bitumen
Viscosity at 135 °C (Pa.s)	0.6-0.8	1.5-2.5	-	-
G*/sin δ (64 °C)	3141.00	6863.00	3622.00	7295.00
Failure temperature (°C)	76	82	76	82

3 Results and Discussion

Penetration value is an indication of stiffness and hardness bitumen. In general, asphalt mixtures containing bitumen with high penetration is more resistant to low temperature cracking as well as permanent deformation [10]. The effect of additive on NR based cup lump modified binder on the conventional binder properties on the softening and penetration properties can be seen in Figure 2 and 3. Figure 2 and 3 shows that, increasing the content of wax additive leads to a decrease in the penetration grade and an increase in softening point of modified bitumen. The decrease in penetration and increase in softening as indication of increase in stiffness and decrease in thermal sensitivity of binder which suitable to be employed in warmer climates

Fig.1. Effect of additive loading on penetration of Natural Rubber Modified Bitumen

Fig.2. Effect of additive loading on softening of Natural Rubber Modified Bitumen

On the other hand, the flow behaviour of the binders was determined by the Brookfield viscometry over the temperature range of 90°C to 180°C. In general, the viscosity of bitumen binders at high temperatures is an important property as it is a good indicator of the binder's ability of pumping through bitumen plant. Figure 1 shows the experimental values of the viscosities of asphalt binder containing additive at different setting temperatures. The results clearly showed that the addition of additive decreased the binder's viscosity with temperatures.

Table 2 demonstrates effect of additive loading on the modified bitumen at temperature of 120°C and 135°C. The viscosity of modified bitumen reduced approximately by 50% with 1% loading of additive. Although at 135°C the modified binder shows the higher value, the modified binder with additive satisfies the Superpave requirement.

In kind, the WMA technologies used enabled to reduce viscosity at lower temperature. The WMA however seems not suitable to be applied in this Modified Bitumen. The viscosity of the modified binder with additional additive at 120°C could not satisfy the requirement set by Superpave (I.e., 3000cP), Table 2. Overall, there were significant differences in viscosity between modified binder containing additive and one without additive.

Fig.3. Variation of viscosity on the Natural Rubber Modified Bitumen with addition of additive.

Table 2. Effect of additive on viscosity of modified bitumen at temperature of 120°C and 135°C

Additive %	Viscosity CPs	
	120°C	135°C
0	9300	4400
1	4800	2200
3	4100	1900
5	4300	2100
10	3100	1500

Rheology performance is very important in order to study the influence of mixing process and condition to the non solid material characteristic [11]. The effect of warm mix additive on Natural Rubber Modified Bitumen on the complex modulus (G^*) which is related to the viscoelasticity property is illustrated in Figure 4.

The addition of additive on the natural modified bitumen on the rheological properties at different condition (aged and unaged) was studied. The determination of complex modulus(G^*),rutting properties, and elastic recovery subject to the phase angle characteristic is provided by Dynamic Shear Rheometer Analysis. Figure 4 shows that complex modulus increased with the increasing additive content compared to the one without any. The increased of complex modulus is due to the stiff structure formed effecting the temperature sensitivity thus increase the binder elasticity [12]. Likely, the greater the G^* value of the modified bitumen, the stiffer the asphalt binder is able to resist deformation.

In contrast, the value of complex modulus decreases with increasing of temperature test. This shows that the elasticity of the modified bitumen decreases at higher temperature. At higher temperature above the melting point, the binder and additive polymer structure failed to form lattice crystalline stucture thus affected the complex modulus value. In other word, the temperature processing of the modified bitumen must not more than additive melting point. Similar trend was observed on the addition of Sasobit in the bitumen 60/70, PG 70 and PG 76 bitumen grade [13].

Fig.4. Additive effect on the complex modulus G^* of Natural Rubber Modified Bitumen.

Rutting properties by Superpave specification parameter is defined by the $G^*/\sin \delta$ ratio at elevated temperature. The value of unaged binder and aged binder should be greater than 1.0 kPa and 2.2kPa for short term ageing condition. The effect of additive on the rutting properties is shown in Table 3. The addition of additive decreased the value of $G^*/\sin \delta$ for unaged condition and increased the value at aged condition for 3% addition and above. The change in chemical structure was expected occurred during ageing condition thus increased the $G^*/\sin \delta$ value.

Table 3. $G^*/\sin \delta$ for different additive content at unaged and aged condition

$G^*/\sin \delta$	Temperature(°C)						
	52	58	64	70	76	82	88
0%	29730	12280	7327	4572	2391	1414	772.8
Aged	33980	20070	11430	5981	3028	1812	-
1%	19300	10730	6174	3709	1671	1015	625.3
Aged	27760	12770	9724	5235	2095	2021	-
3%	33590	10490	6424	3172	2054	1228	642
Aged	42450	26730	13970	7773	3176	2605	1357
5%	33590	10490	6424	3172	2054	1228	642
Aged	74980	34630	23120	11680	6412	3523	1334
10%	30990	17310	11730	5606	2708	826.7	-
Aged	87230	40100	20450	12360	6470	3741	1563

4 Conclusion

1. The addition of warm mix additive reduced penetration and increased softening point of Natural Modified Bitumen.
2. The viscosity of Natural Rubber Modified bitumen decreased significantly with addition of warm mix additive.
3. The addition of warm mix additive improved the elasticity and stiffness of the Natural Rubber Modified bitumen thus improves the complex modulus and rutting properties (aged condition)

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