

Evaluating the Rheological Properties of Waste Natural Rubber Latex Modified Binder

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Abstract. Road surface is designed to be the durable surface material to sustain the traffic loading. However, due to physical and mechanical stress, pavement deterioration is accelerated. Thus, modifying conventional bitumen by improving its properties is seen as the best method to prolong pavement in-service life. The purpose of this paper is to study the effect of waste natural rubber (NR) latex on rheological properties of bitumen. Conventional bitumen PEN 80/100 was modified with different content of waste NR latex using a high shear mixer at temperature of 150°C. The modified binder properties were characterized by conducting physical test (i.e. softening point, penetration and penetration index) and rheological test (i.e. dynamic shear rheometer, DSR). Results showed that, the addition of waste NR latex improved the rheology properties, which indicates by improving of rutting factor ($G^*/\sin \delta$). This properties improvement has also shows a potential to resist deformation on road surface despite of high traffic loading.

1 Introduction

Bitumen is viscoelastic material and its rheological properties are very sensitive to temperature variation as well as rate of loading [1]. The sensitivity of asphalt pavement to temperature and traffic loading cause high temperature permanent deformation, fatigue cracking and low temperature cracking [2–5]. Efforts have been made in improving bitumen properties by selecting the proper starting crude, tailoring the refinery processes and modify the bitumen [4].

Among the existing solutions, modifying bitumen with polymer is seems to compensate the bitumen deficiency. The most common polymers used in bitumen modification are SBR, SBS, EVA, polyethylene and rubber [3,5]. Since polymers are rather expensive, it is necessary to seek cost-effective ways to mitigate and prevent asphalt pavement premature failure [6]. In this sense, using waste rubber is viable alternative to modify bitumen due to economic and environment preservation [4,7].

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Basically, rubber industry waste is disposed of through incineration and landfill disposal [8]. Unfortunately, the abundance and improper handling of waste rubber could cause serious environmental impact [7]. Researches on modifying bitumen with waste rubber were initiated when granular and powder forms of rubber were developed in 1930 [9]. Since then, extensive studies have been conducted on various types of waste rubber: crumb rubber (from waste tires), rubber powder (from rejected gloves) and natural rubber latex [9–14].

One of the most well known, widely used as bitumen modifier is crumb rubber, which is scrapped from waste tires. Basically, crumb rubber contains natural rubber which helps to improve the elasticity behaviour; carbon black and synthetic rubber which are able to improve the thermal stability of the modified binder [15]. Ongoing research and practices demonstrated that crumb rubber can be effectively incorporated into road surfacing [16]. In some cases, crumb rubber is difficult to disperse throughout the bitumen due to the rubbers have been used in a vulcanized state. Ineffective dispersion requires high temperatures and long mixing times and can yield a heterogeneous binder [15]. Rubber dispersion, nevertheless, can be improved by using chemical solvent (e.g. Toluene) to dissolve rubber, without changing the rheological properties of base bitumen [17].

Contrary to crumb rubber, natural rubber latex can provide more homogeneous binder as the rubber particles are dispersed in water phase, which ensure the rubber fuses with bitumen easily. Since the concentrated natural rubber latex contains almost 40 percent of water, mixing natural rubber latex with bitumen resulting in bitumen foaming and frothing due to the water evaporates at high mixing temperature [12-13,18].

Previous research found that modifying bitumen with rubber improves the physical properties of bitumen (i.e. penetration, softening point and viscosity). Moreover, interaction between rubber particles and bitumen helps in increasing elasticity and stiffness behaviour at high temperature which indicates by the increasing of complex shear modulus, G^* and phase angle, δ [1]. The improvement of these rheological properties results in enhancing fatigue and permanent deformation resistance [12,19]. Tuntiworawoit et al. [12] suggested that natural rubber latex as the best alternative as the natural rubber improves the flexibility and stability of asphalt pavement and bringing greater service life expectancy [12].

The main objective of this work is to study the rheological properties of waste latex modified bitumen. To this end, rheological properties of unmodified and modified bitumen are compared.

2 Materials and methods

Bitumen Penetration Grade (PEN) 80/100 was used in this study. In order to ensure the quality of the bitumen, fundamental physical testing as specified in Standard Specification for Road Work (JKR/SPJ/2008-S4) were performed. Since all the values comply with the standard, PEN 80/100 was used as base bitumen and modified with waste NR latex, which was supplied by Malaysian Rubber Board Standard.

2.1 Preparation of modified bitumen

The preparation of waste NR latex modified binder involves wet mixing process by means of high shear mixer. Typical mixing procedure began by heating the base bitumen at 150°C. As soon as the desired temperature was reached, waste NR latex (5-15% by weight) was added gradually into the base bitumen under stirring condition at 1500 rpm for 45 min. Caution should be taken as foam could occur when the waste latex was added.

In order to deal with the rheological behaviour at in-service and handling temperature, the modified bitumen and base bitumen were exposed to high temperature of 163°C for 85 minutes, to artificially aged the bitumen. Ageing process of bitumen was performed as accordance in AASHTO T 240. Meanwhile, rheological properties of the bitumen were determined using dynamic shear rheometer (DSR) as specified in AASHTO T 315. DSR is equipped with parallel plates, one that fixed, and another is oscillating. Rheological parameters: complex shear modulus (G^*) and phase angle (δ) for each modified sample were measured and used to determine the rutting resistance and failure temperature of the modified binder.

3 Results and discussions

3.1 Physical testing

The addition of waste NR latex improves bitumen’s properties by lowering penetration values and increasing the softening point. Softening point and penetration index (PI) are the important physical parameters in enhancing bitumen’s properties. Generally, higher softening point and PI are preferable in tropical countries, as they represent the bitumen response to temperature variation. Basic physical bitumen testing of modified binder is tabulated in Table 1.

Table 1. Physical properties of modified binder.

Properties	80/100	5NR	10NR	15NR
Penetration at 25°C, 100g 5 sec, 0.1mm (AASHTO T 49)	89	76.3	80.2	75.4
Softening Point, °C (AASHTO T 53)	46	47.5	52.4	48.8
Penetration Index (PI)	-0.32	-0.83	-0.33	0.44

3.2 Failure temperature

High service temperature or failure temperature of binders is determined at which $G^*/\sin \delta$ value is greater than 1.0 kPa for unaged and 2.2 kPa for short term aged binder. Generally, bitumen is rated based on its performance at different temperatures which known as Performance Grade system. Typical bitumen Penetration Grade (PEN) 80/100 is equivalent to Performance Grade (PG) 64 [20] which indicate the bitumen meets the high temperature physical properties up to 64°C. Whereas, failure temperature of a binder is obtained through the interpolation of temperatures [21].

Table 2 showed the high failure temperature for both unaged and short term aged condition for waste NR latex modified binder. High failure temperature changes with the addition of waste NR latex content. 15NR recorded the highest failure temperature meanwhile 5NR recorded the lowest failure temperature for both conditions. Difference of failure temperatures between 15NR and base bitumen were 3.72°C for unaged and 3.97°C for short term aged condition. This result revealed that modifying base bitumen with waste NR latex could expand the failure temperature, which later indicates better rutting resistance.

Table 2. Failure temperature of waste latex modified bitumen.

Binder type	Failure temperature (°C)	
	Unaged ($G^*/\sin \delta > 1.0$ kPa)	Short term aged ($G^*/\sin \delta > 2.2$ kPa)
80/100	64.91	64.53
5NR	67.65	65.41
10NR	68.18	67.4
15NR	69.63	68.5

3.3 Rutting resistance

Theoretically, rutting resistance parameter at selected test temperature was measured by $G^*/\sin \delta$. Figure 1 depicted $G^*/\sin \delta$ values of waste NR latex modified binder for each condition: unaged and short term aged. Result showed that, waste NR latex modified binder displayed a good trend as $G^*/\sin \delta$ values increased with the increasing of waste latex content until the maximum value at 15%. The improvement of rutting resistance reaching up to 6% reflected to the addition of waste NR latex when compared to base bitumen. Although modifying bitumen with waste NR latex remained the same performance grade (PG64), rutting resistance recorded slightly well than the base bitumen. Table 3 presented the rutting resistance values for each waste latex content at 64°C.

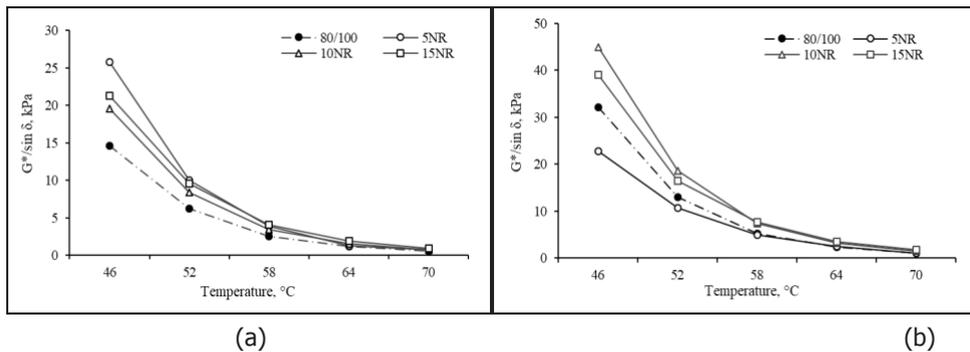


Fig. 1. $G^*/\sin \delta$ of (a) unaged condition, (b) short term aged condition.

Table 3. Rutting resistance measured at 64°C.

Binder type	$G^*/\sin \delta$ (kPa) at 64°C	
	Unaged	Short term aged
Control	1.187	2.301
5NRL	1.319	2.534
10NRL	1.578	3.214
15NRL	1.933	3.575

4 Conclusions

Waste NR latex was successfully used to modify bitumen. Result showed that, waste NR latex slightly changed the bitumen’s physical properties. Furthermore, incorporating waste NR latex into bitumen had positively affected the bitumen response to temperature changes which was represented by the increasing of softening point and penetration index (PI). Further investigation on rheology properties found that modifying waste NR latex into PEN

80/100 improved bitumen's rutting resistance. However, it was noted that the modified bitumen performance grade (PG) remains the same PG with the base bitumen.

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