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Properties of bitumen modified with latex

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Abstract. A lot of effort has been made to improve the base bitumen properties by adding different types of modifier. The current issue of pavement failure has raised a concern that high specification of bitumen is essential to counter the asphalt pavement challenges. This is to ensure that the bitumen could perform better as a road material. Natural rubber, particularly latex, has potential to be used as a modifier in bitumen compared to other types of rubber as it is cheaper, accessible and easily dispersed in the liquid bitumen when heated. This study evaluates the physical and rheological properties of the bitumen when added with latex rubber. Difference percentages of latex i.e. 2.5%, 5.0%, 7.5% and 10% were added to the 60/70 PEN bitumen and tested for penetration, softening point, viscosity, ductility, loss on heating and dynamic shear rheometer tests. As a result of the modification, it was found that latex hardened the control bitumen, increases the viscosity and provides better resistance against rutting.

1. Introduction

Bitumen modification is currently significant as base bitumen cannot accommodate the increase in traffic volume and weather effect. Some problems have occurred due to these effects such as permanent deformation, bleeding, cracking and rutting [1]. According to Public Works Department (PWD) specification, the standard design or life span for all highways and urban roads is between 10 and 20 years [2]. Unfortunately, before reaching the maximum period of the designed road serviceability, some damage or distress on the pavement can be observed. According to the previous studies, lifetime of roads can be improved by improving the quality of bitumen for pavement construction [3-5]. For instance, research has been conducted to evaluate the feasibility of using polymer to partially replace base bitumen [6]. Among the polymers used, the renewable natural source polymers such as natural rubber has led to a continuously growing interest in this material, particularly in modification with bitumen for better road pavement [7].

Natural rubber such latex is extracted from rubber tree by tapping containing high water content. The raw natural rubber latex usually undergoes chemical preservation process to prevent natural rubber from bacterial attack, while centrifugation of latex is widely applied to achieve high concentration of solid rubber [8,9]. The preserved and centrifuged latex were then ready to be sold in the international market, where the demand has markedly increased over the years. However, recently, rubber price has fallen dramatically and expected to continue to decline. The increase in natural rubber production and falling price create huge pressure on finding an alternative use of natural rubber [10]. Therefore, the use of natural rubber as an asphalt modifier may provide an alternative way, thus relieving the economic



pressure on rubber industry and at the same time improving road infrastructure. Research program on rubberized road has conclusively established the advantages of using natural rubber [11].

Studies found that using natural rubber as a modifier in bitumen modification produces better binder performance compared to control bitumen in terms of rutting resistance and fatigue cracking [12-14]. Early use of natural rubber was mostly in powder form (vulcanized or lightly vulcanized) since the fine rubber particles improves dispersion during blending with bitumen. However, it is found that high mixing temperature and long mixing time give some drawbacks on the rubberized bitumen quality [15]. On the other hand, the addition of latex into bitumen potentially overcome such problems due to rubber particles in latex that are well dispersed when blended together with bitumen compared to vulcanized rubber. Fernando and Nadarajah [10] used concentrated latex, centrifuged latex and skim latex despite rubber powder into modification with bitumen to provide in-depth understanding on using different types of natural rubber. In a study conducted by Tuntiworawit *et al.* [16], using latex as a modifier in bitumen helps to reduce bleeding on road pavement based on high softening point value and reduce the binder sensitivity when subjected to temperature changes. This was supported by Wen *et al.* [12], where the rubberized bitumen shows improved performance on temperature susceptibility as the latex content increased. In addition, from the multiple stress creep recovery test, it was found that natural rubber modified bitumen may effectively improve the rutting resistance and the recovery capacity of the rubberized mixture [12]. The stability of asphalt mixture incorporating latex as modifier increased, thus making it more durable compared to control mixture [17]. Shaffie *et al.* [18] stated that the addition of rubber, particularly latex, overcomes the stripping problem that occurs on normal mixture. This is due to the elasticity of rubber that enhanced the adhesion of bitumen with aggregates [19].

The improvement of bitumen by the addition of rubber was attempted a century ago, but only recently has it become possible on a large scale for commercial interest. Nevertheless, there is limited study on latex modified bitumen due to the modification that focuses on using synthetic polymers and crumb rubber as a modifier. Therefore, this study provides more information related to the bitumen modification using natural rubber, particularly the latex rubber. The latex was added at various percentages i.e. 2.5%, 5.0%, 7.5% and 10% from the total weight of bitumen and compared to the base bitumen in terms of physical and rheological properties.

2. Materials and method

2.1. Materials

Base bitumen of 60/70 PEN was used for the sample preparation and the binder tests were prepared according to the MS 124 (Standard and Industrial Research Institute of Malaysia, 1996) specification [20]. Table 1 shows the physical properties of the base bitumen. On the other hand, the concentrated field latex was collected from rubber plantation at Muar, Johor and preserved with ammonia (0.5% by weight of latex) in order to control the pH and keep the latex in a liquid state. The liquid latex was then filtered using filter cloth to remove contaminants and unwanted particles prior to mixing with bitumen. Field NR latex (NRL) contains hydrocarbon (1,4-cis polyisoprene) and non-rubber component constituting mainly carbohydrates, proteins and lipids in an aqueous serum phase. Table 2 shows the basic composition of field latex.

Table 1. Properties of 60/70 PEN bitumen.

Properties	Test Standard	Requirement [19]	Result
Penetration at 25 °C (dmm)	ASTM D5	60-70	65.0
Softening point (°C)	ASTM D36	49-52	42
Viscosity at 135 °C (Pa·s)	ASTM D4402	3.0 (Max)	0.5
Ductility at 25 °C (cm)	ASTM D113	100 (Min)	110
Loss on Heating (%)	ASTM D6	0.20 (Max)	0.20

Table 2. Composition of field latex.

Constituents	Water	Rubber	Resins	Protein	Ash
Percentage (%)	55-70	30-40	1.5-2	1.5-3	0.5-1

2.2. *Mixing and sample preparation*

Initially, bitumen 60/70 PEN was heated at 160 °C for 1 hour. Then, various percentages of 2.5%, 5%, 7.5% and 10% concentrated latex by weight of bitumen were gradually mixed with the bitumen. The high shear mixer was used to blend the concentrated latex with bitumen at the temperature of 160 °C for 1 hour with 5000 RPM [21]. During blending, care must be taken against excessive and potentially dangerous foaming and frothing of water in latex that evaporates uncontrollably [16]. The rubberized bitumen samples were then prepared for the binder tests and compared to the control bitumen.

2.3. *Penetration and softening point tests*

Penetration test was conducted for the control and modified bitumen samples. In accordance with ASTM D5, melted sample was poured into flat bottomed cylindrical metallic dish of the penetration cup (55 mm diameter and 35 mm in depth) and was allowed to penetrate using a vertical penetrometer needle for about 5s with 100g load at 25 °C. The softening point was also performed for the control and modified bitumen based on ASTM D36 specification. This is to determine the temperature at which the bitumen starts to become soft and flow by placing the steel ball on the sample in steel ring brass. Using both values, the Penetration Index, PI, was determined for temperature susceptibility.

2.4. *Viscosity test*

Viscosity test was performed for control and modified bitumen in accordance to ASTM D4402 at the temperature of 135 °C and 165 °C. The viscosity was performed to obtain the viscosity of the binder under high temperature range of manufacturing and construction. This test helps to ensure that the bitumen is sufficiently fluid for replicating the pumping and mixing activities.

2.5. *Ductility test*

The ductility test measures the adhesive property of bitumen and its ability to stretch. Ductility of a bituminous material is measured by the distance in centimeters to which it will elongate before breaking when two ends of standard briquette specimen of material are pulled apart at a specified speed and temperature. This test was performed according to ASTM D 113-07.

2.6. *Loss on heating test*

In this study, loss on heating test was performed to determine the loss in weight of the control and modified bitumen samples conditioned at the temperature of 163 °C for 5 hours. This test was performed according to ASTM D6M.

2.7. *Dynamic shear rheometer (DSR) test*

The DSR was conducted in accordance to ASTM D7175. The rheological properties were characterized by the G^* and δ across a range of temperatures. The rutting resistance factor, $G^*/\sin \delta$ was used to determine the high temperature performance grade. The highest temperature at which the bitumen can be used is that where the $G^*/\sin \delta$ value of the sample is higher than 1.0 kPa.

3. Results and discussion

3.1. *Penetration, softening point and penetration index*

The penetration, softening point and penetration index (PI) tests result is given in Figure 1. From the results, it can be seen that the control sample shows a higher penetration of 65 dmm with softening point value of 42 °C. Addition of 2.5% latex reduces the penetration value to 62 dmm but no significant increment is detected on the softening point. Meanwhile, the latex started to influence the softening point

of the modified bitumen at the percentage of 5% where the bitumen can sustain temperature up to 45 °C with penetration value of 55 dmm. The lowest penetration value is obtained at 10% latex content, where the value is 43 dmm with highest softening point of 49 dmm. This shows that the addition of latex hardens and stiffens the bitumen, thus affecting the corresponding softening point by increasing the value. The results from penetration and softening point indicate that the rubberized bitumen could potentially prevent the occurrence of bleeding at service temperature. Additionally, the use of latex in bitumen modification reduces the penetration index, where it decreases from -2.87 to -1.77 PI value. The decrement on the PI value can be correlated with low temperature susceptibility of bitumen.

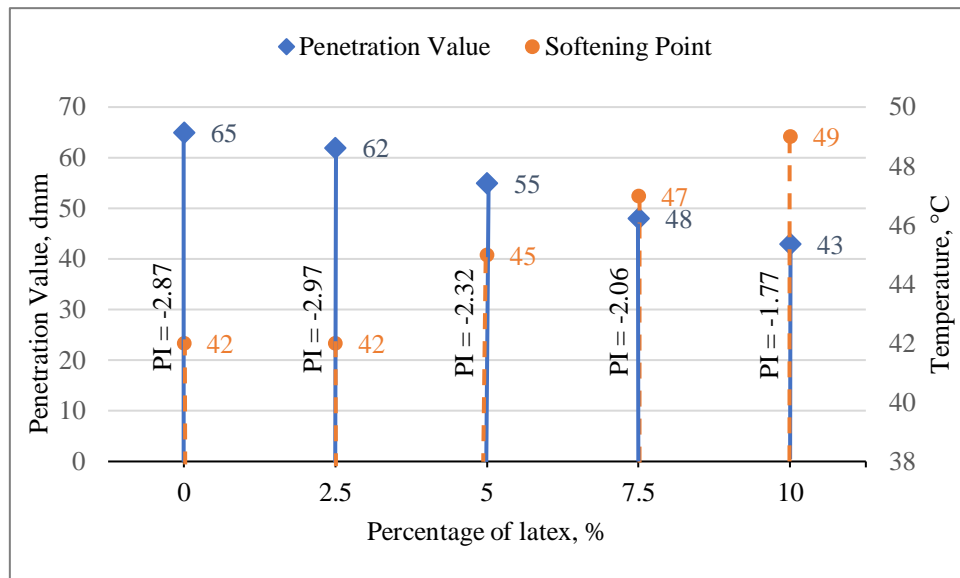


Figure 1. Softening point result.

3.2. Viscosity

Figure 2 shows the viscosity result of the control and modified bitumen. Based on the figure, it can be seen that the viscosity increases with the increase of latex content at both 135 °C and 165 °C. The highest viscosity was found at 10% latex, with the viscosity value of 2 Pa·s. As temperature increases to 165 °C, the viscosity of the modified bitumen decreases but is still higher than control bitumen. This finding supports the aforementioned results for penetration and softening point.

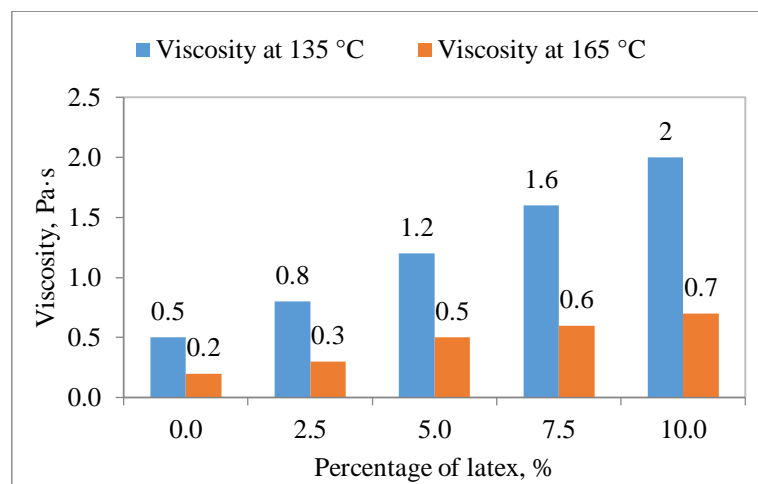


Figure 2. Viscosity result.

3.3. Ductility

Table 3 shows the ductility result of the control and rubberized bitumen. Increasing trends can be observed with the increase in latex content for the ductility. The ultimate elongation for control and 2.5% latex content is 110 and 137 cm, respectively. As the latex increases from 5% to 10%, the rubberized bitumen performs better ductility where the value is higher than 150 cm. The result shows that all specimens pass the requirement of minimum 100 mm, thus indicating that the addition of latex in the bitumen has improved cracking resistance at intermediate temperature. The flexibility provided by the latex structure has caused the bitumen to elongate greater than the limit and prevent cracking potential.

Table 3. Ductility test result.

Latex content (% of bitumen weight)	0%	2.5%	5.0%	7.5%	10.0%
Ductility at 25 °C (cm)	110	137	>150	>150	>150

3.4. Loss on heating

The results of loss on heating for both control and modified bitumen are given in Figure 3. From the figure, it can be seen that the percentage loss on heating increases with the latex content. According to MS 124 requirement, the percentage loss should be less than 0.2% for the control bitumen. The addition of latex increases the volatile loss up to 0.4% for 2.5% and 5% latex content. Further latex addition i.e. 7.5% and 10% increases the percentage loss to 1.6% and 2.4%, respectively. The results show that high amount of latex increases the volatile loss, where this can be due to the high water content (two-thirds) in the liquid latex that evaporates at high temperature under exposure.

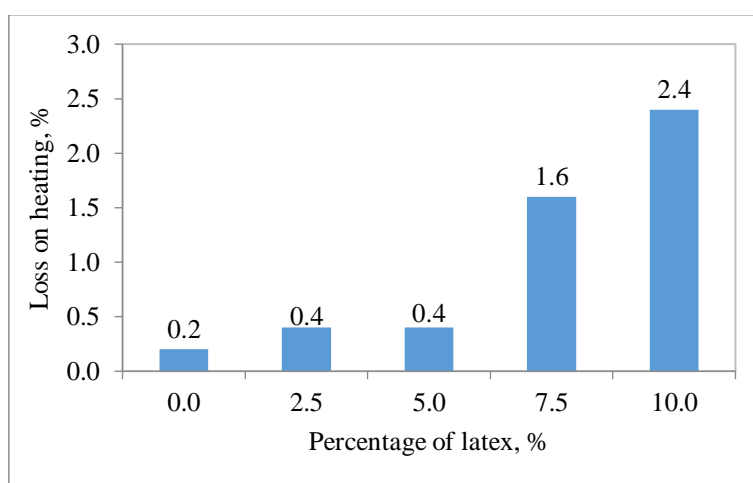


Figure 3. Loss on heating.

3.5. Rutting resistance

The rheological properties of the control and latex modified bitumen were evaluated using DSR. Figure 4 shows the plot of rutting resistance ($G^*/\sin \delta$) against temperature, while Figure 5 gives the exact failure temperature estimated at the minimum requirement of 1.0 kPa rutting resistance based on AASHTO T 315 [22]. It can be seen that the control bitumen can resist rutting phenomenon up to 70 °C before failure. By adding different latex contents in the bitumen i.e. 2.5%, 5%, 7.5% and 10%, the modification improves the rutting resistance, where the latex modified bitumen can sustain rutting potential up to the failure temperature of 75 °C, 77 °C, 80 °C and 85 °C, respectively. Therefore, based on the performance grade, PG requirement, both control and modified bitumen (i.e. 2.5%, 5%, 7.5% and 10%) can be graded as PG (70, 70, 76, 76 and 82), respectively. This clearly indicates that adding natural rubber latex into the bitumen provides better rutting resistance over a wide range of high temperature

compared to the control bitumen. The increase in the viscosity at high temperature has stiffened the binder to provide better resistance against permanent deformation. In addition, this indicates that the natural rubber also has a potential to provide greater elastic recovery and excellent physical strength as specified in Azahar *et al.* [9].

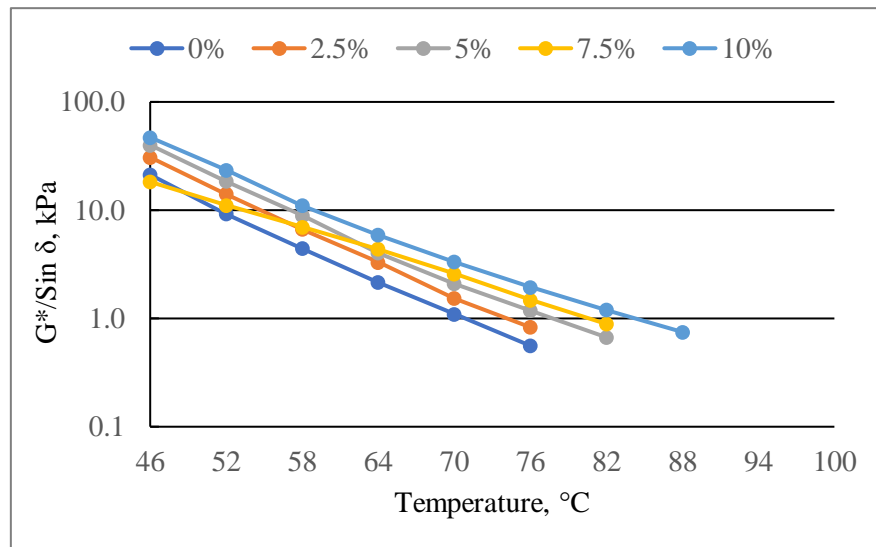


Figure 4. Rutting resistance against temperature.

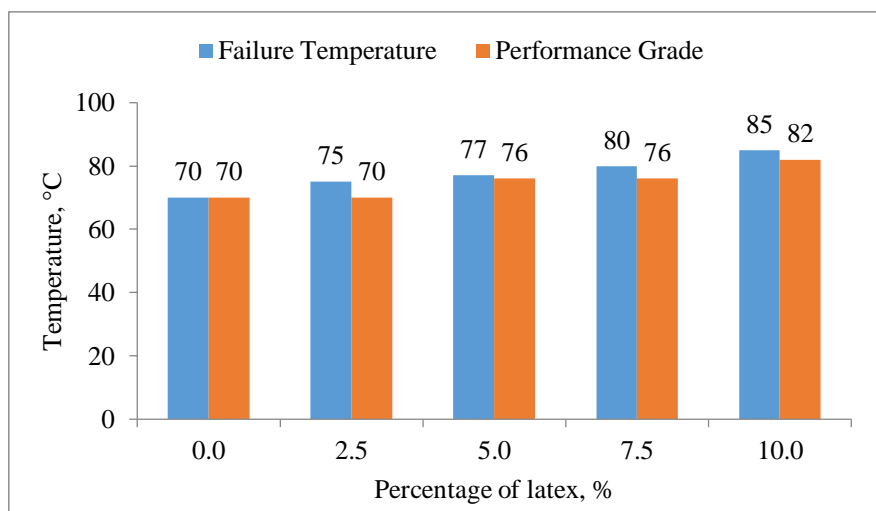


Figure 5. Estimated failure temperature and PG grade based on rutting resistance.

4. Conclusion

Based on the results, it can be concluded that the addition of natural rubber latex in the 60/70 PEN bitumen improves the physical and rheological properties of the binder. The increase in the amount of latex has stiffened the mix with the increase in viscosity and penetration. On the other hand, the rutting resistance of the bitumen also increases with the latex content, which shows that the latex modified bitumen has better resistance against permanent deformation particularly at high pavement temperature.

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