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Properties of Bitumen Modified with Latex Under Short-Term Ageing

U Jamaris¹, N A Hassan^{2*}, M Z H Mahmud², C R Ismail², H Yaacob², S A Hassan²

¹Meru Perkasa Sdn. Bhd, Bandar Manjalara, Kuala Lumpur, Malaysia

²Department of Geotechnics and Transportation, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor, Malaysia

*Corresponding author: hnorhidayah@utm.my

Abstract. Short-term ageing is a common issue in bitumen mixing production, and it severely affects the physical, rheological and chemical properties of the bitumen. Polymer modified bitumen is regarded as a preferable paving material to improve the performance of asphalt pavement against binder ageing. One of the additive types used to innovate modified bitumen is natural rubber (latex). This study evaluated the physical properties of bitumen modified with latex under ageing condition. Different percentages of latex (i.e. 2.5%, 5.0%, 7.5% and 10.0%) were added to the control 60/70 penetration grade (PEN) bitumen, which was then tested for penetration, softening point, viscosity, loss on heating and storage stability. The bitumen samples were conditioned under short-term ageing (i.e. rolling thin-film oven) prior to performance tests. Results indicated that modifying bitumen with latex hardens the conventional bitumen 60/70 PEN and potentially improves the bitumen's resistance against temperature susceptibility with a high value of softening point. The addition of latex up to 10% produces a homogenous blend even after short-term ageing condition.

1. Introduction

Ageing is one of the main problems of asphalt pavements, affecting the physical, rheological and chemical properties of the bitumen [1-2]. This problem is mainly due to oxidation, volatilisation and polymerisation [1,3]. The two types of ageing conditions for bituminous mixtures are short-term and long-term ageing. Short-term ageing takes place during the construction phase of asphalt pavements while long-term ageing occurs mainly due to environmental exposure and traffic loading [2-3]. According to Zhang, ageing changes the chemical composition of bitumen, thus increasing the formation of ketones in the mixture and contributing to the increased production of asphaltenes [2]. Subsequently, the rheological properties of the bitumen are also affected. This effect causes the bitumen viscosity to increase progressively, which leads to harder and more brittle bitumen properties [2, 4-5]. Conventional bitumen is not suitable for modern pavements because it undergoes numerous types of failures during service time due to heavy traffic loading. This is one of the main reasons' bitumen modification is needed.

Bitumen modifiers involving natural and synthetic polymers have been used in the paving industry as early as 1843 [6]. The main objective of using a modifier is to improve pavement performance against road failures, including cracking, stripping and rutting [7-11]. On the basis of laboratory and field data, numerous types of materials were used to modify the bitumen properties, including natural rubber. Natural rubber is a thermoplastic elastomer type that can be used to prepare polymer modified bitumen.



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Thermoplastic elastomers are usually better than plastomers for bitumen modification [12]. The most popular thermoplastic elastomers as bitumen modifiers are styrene–butadiene–styrene copolymers and styrene–isoprene–styrene copolymers.

Latex is a type of natural rubber that is considered a thermoplastics elastomer; it helps increase the stiffness and elasticity of the bitumen and reduce its temperature susceptibility [7, 9]. As soon as the latex is recovered from the tree, it contains 70% water and 30% rubber. Based on previous studies, natural rubber used for bitumen modification produces better rutting resistance and higher ductility compared to conventional bitumen [8–11, 13–14]. However, the type of mix is prone to decomposition and oxidation [12]. Therefore, with the numerous benefits of a bituminous mixture containing latex, the effect of short-term ageing on the modified mixture must be explored further due to variability in volumetric properties of latex. This study focused on evaluating the effect of short-term ageing on the properties of modified bitumen containing latex.

2. Materials and methods

This section describes the materials and methods used to determine the properties of bitumen modified with latex for short-term ageing. The study used 60/70 PEN bitumen with various percentages of latex added (i.e. 0.0%, 2.5%, 5.0%, 7.5% and 10.0%) from the total weight of the bitumen. The latex was collected from a rubber plantation in Muar, Johor, Malaysia. Initially, the latex was conditioned in an oven at various temperatures, 115 °C (approximately exceeding the boiling point of water), 140 °C and 165 °C (mixing temperature), to determine the loss in mass, which reflects the loss of water content available in the latex due to evaporation in comparison to the initial mass of the sample. The result is very important to justify the amount of water and rubber content within the latex that could potentially be lost during mixing and handling of the rubberised bitumen. The bitumen was mixed with latex at 160 °C for approximately 30–45 minutes by using a low shear mixer at the speed of 700 rpm until the mix became homogeneous. The physical properties of the modified bitumen were then tested for penetration, softening point, viscosity, loss on heating and storage stability. The bitumen samples were also evaluated under short-term ageing conditioned with rolling thin film oven at 163 °C for 85 minutes. and compared to unaged samples. Table 1 shows the specifications used for the bitumen testing.

Table 1. Specifications of the asphalt testing.

Bitumen tests	Specification
Penetration	ASTM D5
Softening point	ASTM D36
Viscosity	ASTM D4402
Loss on heating	AASHTO T 47-83
Storage stability	ASTM D7131
Rolling Thin Film Oven	ASTM D2872

3. Results and discussion

This section covers the analysis of all the results and the discussion for the experimental work. Different percentages of latex were blended with conventional bitumen. The laboratory tests involved were latex evaporation, penetration test, softening point, viscosity test, loss on heating and storage stability. The data obtained were analysed and compared with the control sample for unaged and short-term ageing condition.

3.1. Measurement of water content

Figure 1 shows the plot of loss in mass for latex after 5 hours in the oven at three different temperatures. The loss in mass reflects the loss of moisture content in the latex during handling. As can be seen in the figure, the loss in mass increased as the samples were heated and reached a consistent mass of 66% loss after 75 minutes and 120 minutes at the temperatures of 165 °C and 140 °C, respectively. However, when a lower temperature was used (115 °C), the loss in mass continued to increase even after 300

minutes. Overall, it can be concluded that the latex collected for this study contains approximately 66% water and 34% rubber. In addition, there is a potential for water evaporation during the mixing process (between bitumen and latex) which requires further study for verification.

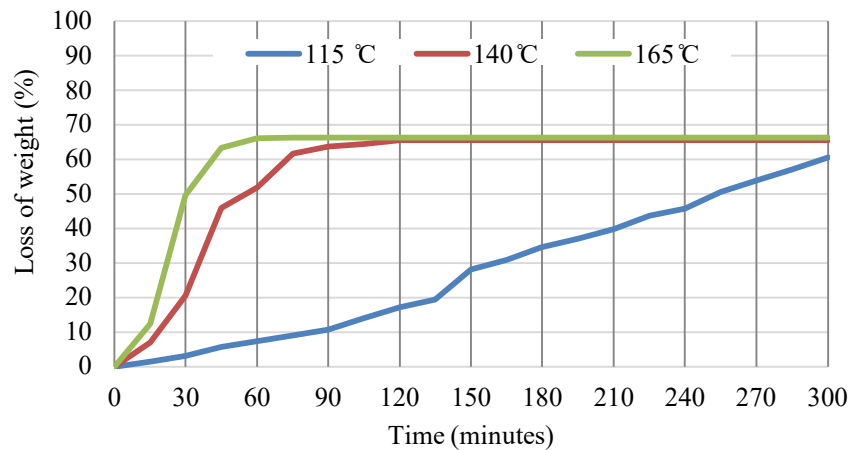


Figure 1. Water evaporation under various temperatures.

3.2. Penetration, softening point and penetration index

The result of the penetration test is shown in Figure 2. The presence of latex is shown to help improve the hardness of bitumen for the unaged sample. The sample with 2.5% of latex shows a slightly higher penetration value, and the lowest penetration value was obtained for the sample with 5.0% latex. Samples with low penetration values show bitumen properties that hardened because the sample is mixed latex. For the short-term ageing sample, the increase in the amount of latex up to 10% softened the bitumen sample compared to the control sample, showing that the latex has the potential to retard the effect of ageing and provide flexibility to the mixture. As shown in Figure 3, the penetration value increases gradually as the amount of latex increases. In other words, the latex can control the hardness of bitumen under ageing condition.

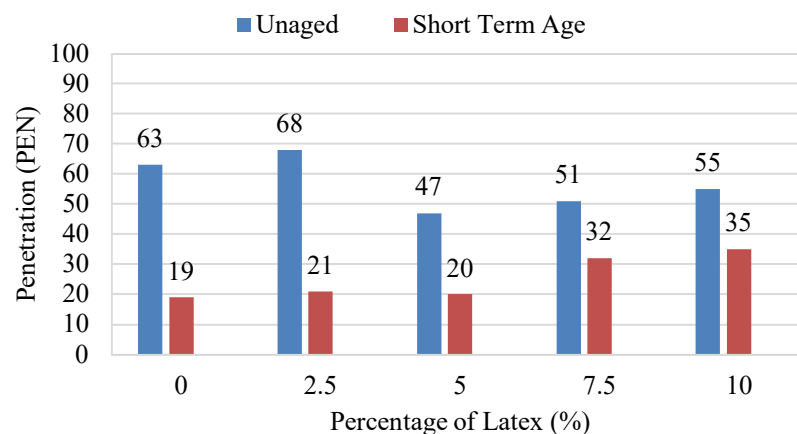


Figure 2. Penetration result.

The result of the softening point is shown in Figure 3. As can be seen for the unaged sample, the presence of latex helps improve the softening point of bitumen. The control bitumen gives the lowest softening point at 50 °C. The softening point increases gradually as the percentage of latex increases. At 10% latex, the bitumen shows the highest softening point at 63 °C. For the short-term ageing sample, the presence of latex increases the softening point value after undergoing the rolling thin-film oven. At 10% latex, the sample shows the softening point value increases to 65 °C. By contrast, the control

bitumen shows the lowest softening point at 53 °C. From the result, it can be concluded that latex enhances the bitumen properties to survive at higher service temperatures compared to conventional bitumen.

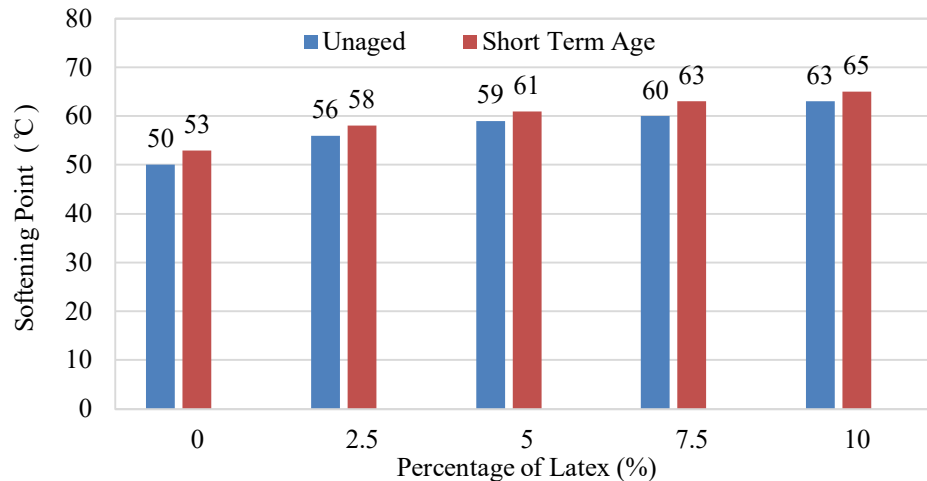


Figure 3. Softening point result.

One of the important indicators for measuring the temperature susceptibility of bitumen is based on the penetration index (PI). The lower the PI, the greater will be the sensitivity of the bitumen. PI is calculated using Equation (1).

$$PI = \frac{1952 - 500 \log P - 20 SP}{50 \log P - SP - 120} \quad (1)$$

where P = penetration at 25 °C (0.1 mm), and SP = softening point (°C). With the use of the penetration and softening point values, the PI was calculated for the unaged and age samples (Table 1). The result in Table 2 indicates that the PI value is within the range of -1 and +1, including those samples modified with latex. As the percentage of latex increases, the PI value decreases but is still within the acceptable range. Therefore, the addition of latex shows the modified bitumen is applicable for paving works.

Table 2. Penetration index for unaged sample and short-term ageing.

Percentage of Latex (%)	Ageing condition	
	Unaged	Short-term Ageing
0.0	+0.07	+0.67
2.5	-0.11	+0.35
5.0	-0.10	+0.67
7.5	-0.15	-0.11
10.0	-0.26	-0.20

3.3. Viscosity

The viscosity results for the unaged samples and samples after short-term ageing condition are shown in Figs. 4 and 5, respectively. As can be seen from the figures, the viscosity measured at 135 °C for both unaged and aged samples increases gradually with the latex content. Similar findings were also found by previous researchers that show an increment in the viscosity for bitumen modified with latex [9]. However, viscosity measured at 165 °C seems to provide comparable values to conventional bitumen but slightly lower for the rubberised sample with 2.5% latex. At higher temperature, the hardening effect caused by the latex component reduces or becomes insignificant until the addition of latex reaches 7.5%–10%, where the increment in viscosity can clearly be observed from the plots compared to the

unmodified sample. This outcome shows that at a certain temperature, the natural rubber cannot retain its properties to cope with higher temperature or provide resistance against heat unless more latex is added to the mix. For the aged sample with 10% latex, the result shows the highest viscosity both at 135 °C and 165 °C (i.e. 2.1 and 0.7 Pa.s, respectively). Meanwhile, for the unaged sample, the viscosity result is slightly lower than those for aged samples, with the highest viscosity also found at 10% latex at both 135 °C and 165 °C (i.e. 1.8 and 0.6 Pa.s, respectively).

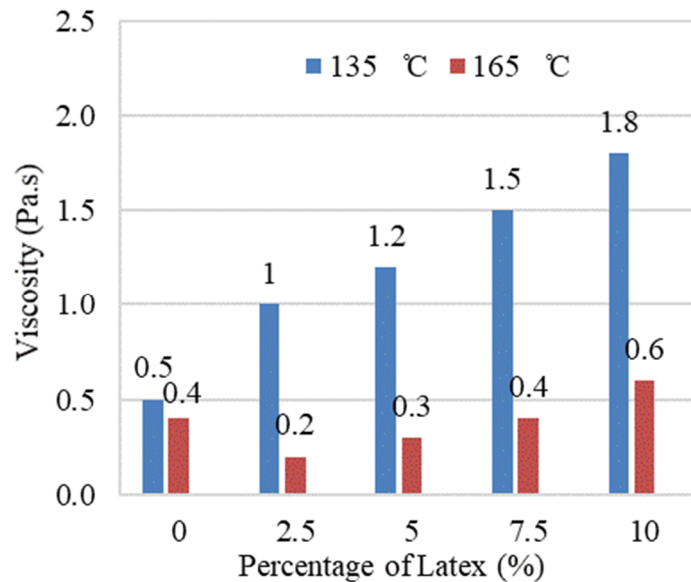


Figure 4. Viscosity result for the unaged sample.

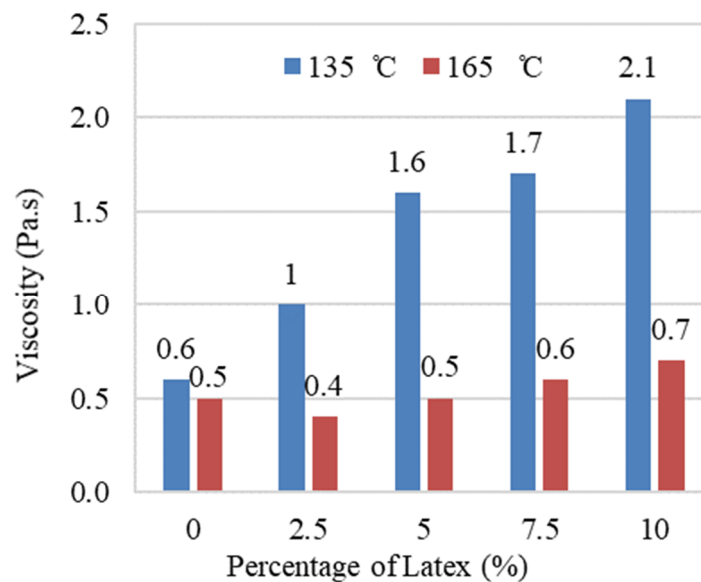


Figure 5. Viscosity result for short-term ageing.

3.4. Loss on heating

The result of loss on heating is shown in Figure 6. The graph shows the plot of loss on heating against percentages of latex. As can be seen for the unaged sample, the addition of latex increases the mass loss due to heating under the temperature of 163 ± 1 °C. At 10% latex, the sample shows the highest percentage of loss at 4.1%. The conventional bitumen has the lowest loss on heating percentage at 0.12%. For the short-term ageing sample, the percentage of loss increases with the latex content but is

lower than those observed for the unaged samples. Bitumen with 10% latex shows the highest percentage of loss at 1.0%. The results support the aforementioned observation on the loss of water content monitored for the latex composed of almost 70% water. This could cause greater loss with the increase in latex content.

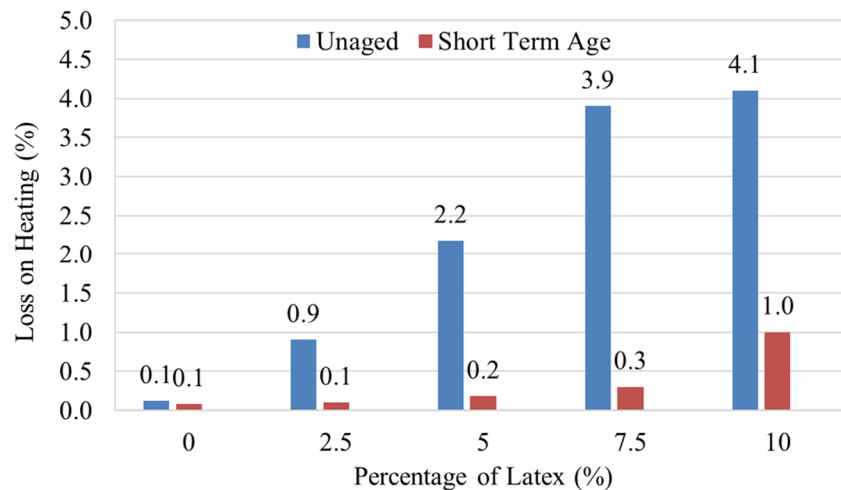


Figure 6. Loss on heating result.

3.5. Storage stability

The result of softening point after storage stability is shown in Table 3. Overall, the results obtained comply with the specification of less than 2.2 °C difference. As can be seen for the unaged sample, the bottom section has a higher softening point than the top section as the percentages of latex increase. At 10% latex, the sample gives the highest softening point which is 54 °C and 55 °C for the top and bottom sections, respectively. For all latex percentages, the difference in softening point between the top and bottom is consistent at 1 °C. On the other hand, for the short-term ageing sample, the bottom surface has a higher softening point than the top surface as the percentages of latex increase. At 10% latex, the modified bitumen has the highest softening points at 64 °C and 66 °C for the top and bottom surfaces, respectively. For all percentages of latex, the difference in softening point between top and bottom is consistent at 2 °C. Therefore, the presence of latex in the bitumen after undergoing storage stability does not seem to have major separation in the modified bitumen component. However, for the aged samples, minor separation could occur at high latex percentage even though the results obtained in this study are considered acceptable.

Table 3. Softening point (storage stability) result for unaged and short-term ageing samples.

Percentage of Latex (%)	Softening point, °C					
	Unaged			Short-term Ageing		
	Top	Bottom	Difference	Top	Bottom	Difference
2.5	48	49	1	56	58	2
5.0	50	51	1	60	62	2
7.5	52	53	1	62	64	2
10.0	54	55	1	64	66	2

4. Conclusion and recommendation

This study found that the presence of latex as a modifier in bitumen improves the properties of bitumen in such a way that it hardens the bitumen and provides good resistance against temperature susceptibility. The amount of latex up to 10% seems to blend well with the bitumen compound and improves the softening point higher than conventional bitumen. High water content in the latex causes reduction in

mass after heating. For further study, it is recommended that higher percentages of latex be used in the bitumen and long-term ageing condition be considered in the evaluation.

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