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EFFECT OF MIXING VARIABLES ON PHYSICAL PROPERTIES OF MODIFIED BITUMEN USING NATURAL RUBBER LATEX

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ABSTRACT

Modification of bitumen using polymers has been used from a long time to solve the roads problem which subjected to several distresses; mostly due to heavy traffic, poor bitumen properties, climatic condition and improper mix design. The application of natural rubber latex (NRL) in asphalt mixtures is intended to improve the physical characteristic of the bitumen. However, the properties of NRL bitumen in hot mix asphalt (HMA) pavement are still unclear due to influence of mixing variables factors of NRL with bitumen. This paper presents the procedure for determining the physical properties of bitumen as a function of various mixing variables (temperature, time and speed) using 80/100 penetration grade bitumen with different percentages of NRL. The bitumen was modified with 2, 4, 6, 8 and 10% by weight of bitumen in order to determine the appropriate proportion of NRL that can achieve the specifications required through penetration, softening point, viscosity and penetration index testing. The results of this investigation indicated that the mixing variable; temperature, time and speed for the NRL bitumen have significant effect on the bitumen properties and 8% by weight of bitumen is the most effective proportion that having potential to improve physical properties of bitumen such as increasing softening point and decreasing the penetration and also increase the penetration index. Therefore, it can be concluded that the NRL polymer is suitable to be used as a modifier to modified bitumen in order to enhance the properties of the bitumen and thus improves the physical properties of bitumen.

Key words: Modified Bitumen, Natural Rubber Latex, Physical Properties, Natural Rubber, Physical Properties.

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1. INTRODUCTION

Bitumen is an organic mixture that plays an important role in determining viscous behaviour of hot mix asphalt (HMA). Bitumen has been widely used as binder in road pavement to provide adhesive and protective coating to aggregates. However, the bitumen has several weaknesses due to various factors that can accelerate premature pavement failures. Bitumen does not have good engineering properties because of its limitation to temperature. The bitumen can soften at high temperature and consequently reduce the stiffness of bituminous mixes. The bitumen stiffens and reduce the flexibility of paving mix at low temperatures, resulting in cracking [1]. Bitumen also exposed to a wide range of load stresses and weather conditions due to several factors such as increasing traffic volume, higher tyre pressures of current traffic and climatic weather condition. These conditions caused the service life of the pavement reduce and the cost of maintenance increased. Thus, the performance of existing pavement should be improved and enhanced by bitumen modifications in order to obtain better pavement performance [2].

The use of polymers as additives in bitumen modification has shown to greatly improve the performance of conventional bitumen. Previously, many researchers have been carried out bitumen modification by using various additives and modifiers as to improve the physical properties as well as the rheological properties of the bitumen. In addition, the utilization of polymer modified bitumen provide many significant advantages such as; obtain stiffer mixtures at high service temperatures to minimize rutting, obtain softer mixtures at low service temperatures to minimize non-load associated thermal cracking, improve fatigue, stripping resistance of HMA mixtures, improve abrasion resistance of mixture to reduce ravelling, minimize tender mix problems during construction, rejuvenate aged asphalt binder and replace asphalt cement as an extender, permit thicker asphalt films on aggregate for increased mix durability, reduce flushing and bleeding and also reduce life cycle costs of HMA pavements and improve overall performance of HMA pavements [3-6].

Polymer modified bitumen also can increase the surface roughness of the aggregate and improved adhesion and degree of cohesion by creates an aggregate coating material thus produces superior asphalt mixtures. Some previous studies had carried out to improve asphalt properties by using several kind of natural rubber latex such as field latex, concentrated latex and skim latex. They found that the natural rubber latex is the best alternative for road making due to flexibility and stability improvement in asphalt pavement and extend service life of the road pavement. It was also found that the roads paving with natural rubber latex shall have more strength and durability than using unmodified bitumen [2, 5-8]. Although there are many other materials that have been used as the modifiers in the bituminous mix such as crumb rubber, SBS, SBR latex, chemical additives and engineered binders but most of them are high cost materials. Furthermore, Vichitcholchai [7] studied the potential of modification of bitumen using natural rubber on the bitumen properties. It was found that the results from experiments show low penetration, high softening point, high penetration index, high torsional recovery, and high toughness – tenacity. These properties can indicate that the roads paving with natural rubber-modified bitumen shall have more strength and durability than using conventional bitumen.

Some initial studies were made to mix the polymers in the essential amounts manually at various temperatures and mixing time. However, this technique could not produce a

homogeneous bitumen. This bitumen properties improvement likely depends on the interaction between polymer and bitumen where polymer particles swell in the bitumen to form a viscous gel; resulting in an increase in the viscosity of the polymer binders [8]. The properties of polymer bitumen at a wide range of temperature are consider to be somewhat unclear due to various mixing variables effects of polymer with bitumen, polymer percentage, particle size, texture service of polymer and the mixing temperature and time. Therefore, there is a need to evaluate the effect of mixing variables on the properties of the polymer modified bitumen. In this study, the effect of mixing variables on the properties of NRL will be studied in details. The application of NRL in modified bitumen is expected to improve engineering properties of asphalt bitumen.

2. MATERIALS AND METHODS

2.1. Materials

Granite aggregates used in this study were obtained from Blacktop Quarry, Rawang located in Klang Valley. The aggregates were processed by washing, oven drying and sieving. All the aggregates were sieved to the appropriate size using sieving machine and then stored in individual bins according to the size of aggregates. The specific gravity of the coarse and fine aggregate was determined according to ASTM standard procedures. The bitumen used in this study was 80/100 penetration grade. The bitumen penetration grade 80/100 were obtained from SHELL. The bitumen physical properties were tested and fulfilled the standard requirements. Table 1 shows the properties of PEN 80/100 grade asphalt binder. Natural Rubber Latex (NRL) modifier was used in this study, which was provided by the ACP-DMT company from Port Klang. Natural rubber latex is defined as an elastic hydrocarbon polymer which naturally occurs in the form of latex. It is a polymer compound that has a high molecular weight and it also has a lot of complex molecular chain that it was polymer chain. Latex, sheet rubber, rubber powder and ground tire-tread are the general types of natural rubber used in bituminous road surfacing. Table 2 shows the properties of the natural rubber latex (NRL).

Table 1 The Properties of PEN 80/100 Grade Bitumen

Test	Test Result	Requirement
Penetration(0.1 mm)	84	80 - 100
Softening Point (°C)	44	45 – 52
Specific Gravity (g/cm³)	1.03	-

Table 2 The Properties of the Natural Rubber Latex

Test	Test Result	Requirement
Total Solid Content	65.5 %	%
PH	4.5	
Brookfield Viscosity	600 max	Cps
MST	1800 min	Secs

2.2. Methods

In this study, modified bitumen was prepared by using a high shear mechanical mixer. Preliminary study was carried out to determine the mixing variables of conventional bitumen with NRL polymer. The NRL was added to the base bitumen at different mixing variables with different percentages (0, 2, 4, 6, 8, 10 and 12% by weight of bitumen) of NRL modifiers. The mixing variables used were; two mixing temperature (140ºC and 160°C), two mixing time (30 minutes and 60 minutes), and four mixing stirring speed (500, 1000, 1500 and 2000 rpm).

Investigation was started with using PEN 80/100 bitumen with 3%NRL with mixing temperature of 160°C, mixing time of 30 minutes, and mixing speed of 500 rpm).

For the preparation of a sample, 500g of base bitumen was prepared by melted at 110˚C and poured into a 500 ml container. Then, the bitumen was heated in the oven at 150˚C until it liquefies. The NRL was then added slowly into the liquid bitumen and sheared using a mechanical stirrer attached with a high shear mixer. Once the mixing temperature of 160°C was reached, the mixing cycle started at an increased speed up to 500 rpm for 30 minutes. Mixing temperature was maintained at 160 ± 5°C when mixing was in progress. Once finished, the NRL polymer modified bitumen was then prepared for the further physical properties tests (Penetration and softening point), to determine its temperature susceptibility through penetration index (PI). PI was used to determine mixing variables of NRL polymer modified bitumen. Mixing NRL polymer modified bitumen was then continued with 1000, 1500 and 2000 rpm mixing speed. Polymer modified bitumen was then used for further physical properties testing in order to determine the effect of the possible changes in temperature, time and stirring speed. The appropriate mixing variables were selected according to the highest PI and were used for further mixing of polymer modified bitumen in the research. The optimum NP polymer content was determined by using obtained mixing variables from previous stage.

3. RESULT AND DISCUSSION

3.1. Effect of mixing speed on Physical Properties of NRL modification

Table 3 and Figure 1 to Figure 3 shows a result of effect of mixing stirring speed on physical properties of NRL modification. The result shows that; the mixing speed have a significant effect on physical properties. When the mixing speed was increased beyond that speed, the softening point value started to increase. However, the blending velocity does not have significant effect on the penetration value and the value is shows downward and upward trend throughout the test. In order to determine the best mixing speed, monograph was used to determine the penetration index value which is obtained based on penetration and softening point results. Based on previous study conducted by Rusbintardjo [9], the blending velocity was selected based on the average PI value. For the purpose of this study, 1270 rpm mixing speed as shown in [10] was selected as the appropriate mixing speed based on 0.2 average PI value.

Table 3 The Properties of PEN 80/100 Grade Bitumen

Mixing Speed	Penetration@ 25°C (dmm)	Softening Point (°C)	Penetration Index (PI)	Average Penetration Index (PI)
500	55.0	50.8	-0.8	0.2
1000	46.6	55.0	-0.2	
1500	51.1	57.5	-0.6	
2000	45.7	61.0	1.1	

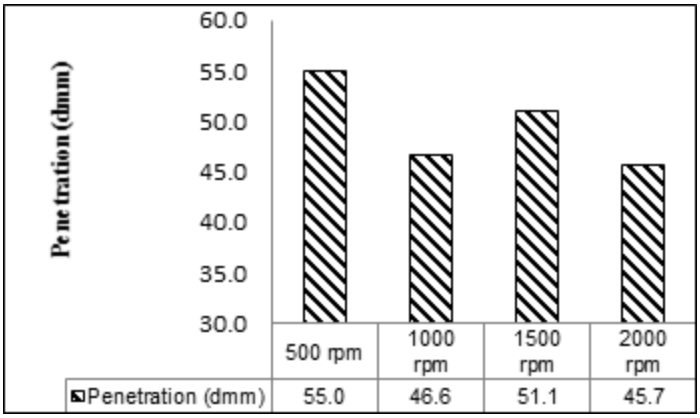

Figure 1 Effect of Mixing Speed on Physical Properties of Bitumen

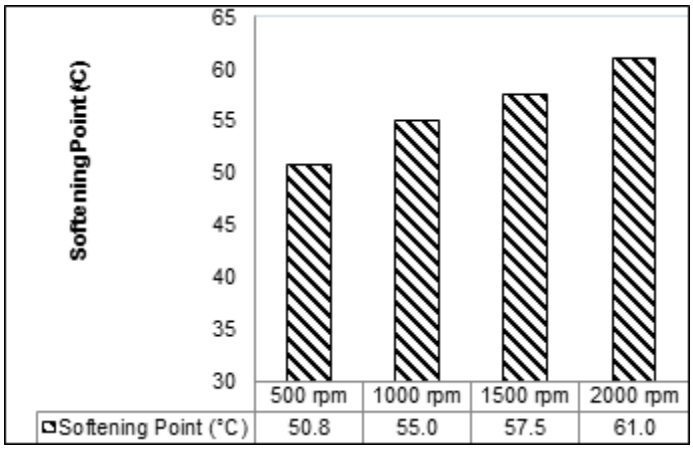

Figure 2 Effect of Mixing Speed on Physical Properties of Bitumen

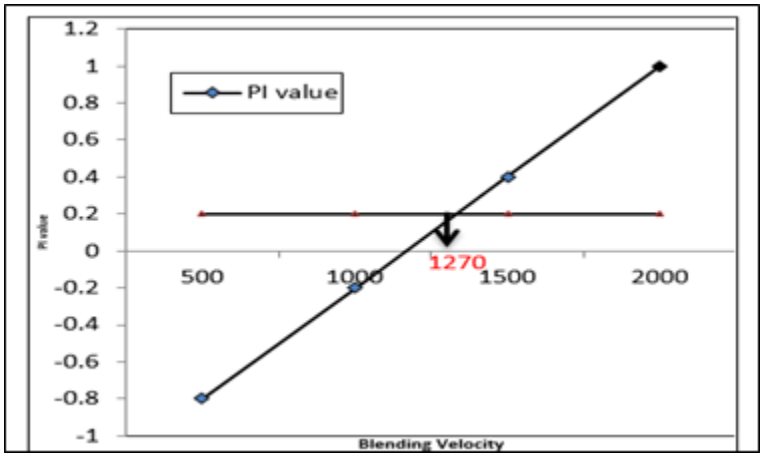

Figure 3 Effect of Mixing Speed on Physical Properties of Bitumen

3.2. Effect of mixing time on physical properties of bitumen at different temperature

Further evaluation to determine the mixing time was obtained using the appropriate mixing speed of 1270 rpm. The appropriate mixing variables for mixing time was carried out at 140°C/30 minutes, 140°C/60 minutes, 160°C/30 minutes, and 160°C/60 minutes respectively. Physical properties (softening point, penetration and penetration index (PI) of the bitumen were considered to determine the best mixing time. The result in Figure 4 and Figure 5 show that, at

140°C temperature tested, the blending time shows a significant effect on the penetration value and the penetration value increased with the increasing blending time from 53.2 to 55.3 for 30 minutes and 60 minutes respectively. Results also showed that an increase in mixing time at 140°C also increases the softening point from 51.1 to 54.3 and its penetration index (PI) value. A similar trend could be seen at 160°C mix temperature whereby an increase in the mixing from 30 to 60 minutes also increases the softening point temperature from 58.3 to 59.3. A possible explanation for this phenomenon may be the dispersion of NRL in bitumen which shows that longer blending time is given better dispersion of NRL in bitumen which also resulted in stiffer bitumen, hence increasing the softening point value [2]. Meanwhile, the mixing time appears similar significant effect on the penetration value for both at 140°C and at 160°C of the mixing time.

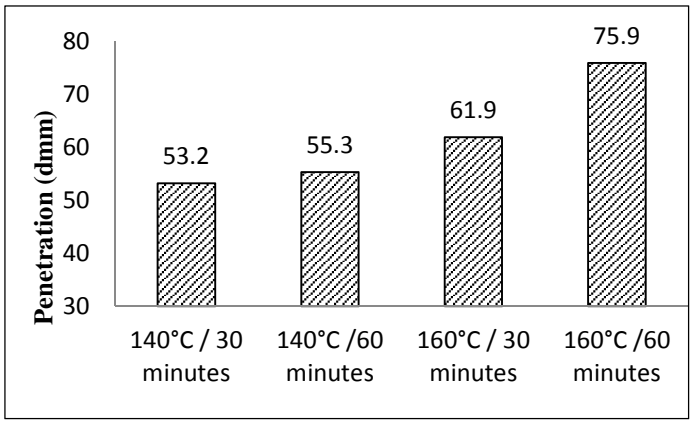

Figure 4 Penetration of Bitumen at Different Mixing Time

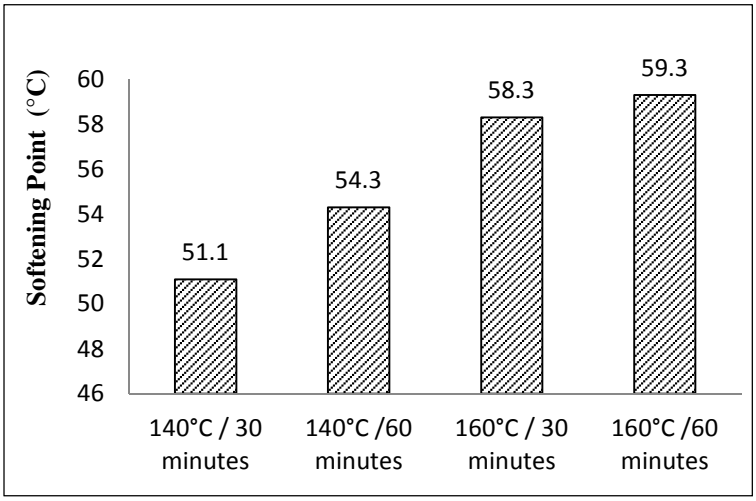

Figure 5 Softening Point of Bitumen at Different Mixing Time

3.3. Effect of mixing temperature on physical properties at different time

In order to determine the mixing temperature, the temperature was varied into two temperatures (140° and 160°C) and tested according to physical properties (penetration, softening point and penetration index) at different mixing times (30 and 60 minutes). Figure 6 to Figure 7 shows that increase in mixing temperature at 30 minutes blending time also increases the penetration and softening point values. The similar trend was shown at 60 minutes mixing time which is penetration values increase from 55.3 to 75.9 dmm for 140 °C and 160 °C respectively. Table 4 also shows that the penetration index (PI) value also increase when the blending temperature increase. It means that the NRL polymer helps to reduce the temperature susceptibility due to

an increasing in PI value when blending time and temperature was increased. The highest value of PI should be selected as the best blending time and temperature for the mixing condition of NRL polymer, or on the other word, they have higher resistance to temperature susceptibility compare to the other mixing temperature and mixing time combination. As a result, combination of blending temperature and blending time of 160°C/60 minute produced the higher PI which the bitumen has higher resistance to temperature susceptibility compared to the other three mixing time and mixing temperature combinations. This reason was agreeing by study conducted by Rusbintardjo G which is stated that bitumen with high PI value will have the higher resistance to temperature susceptibility [9]. Therefore, for the purpose of this study, the combination blending temperature/time of 160°C/60 minute was selected as the best blending temperature.

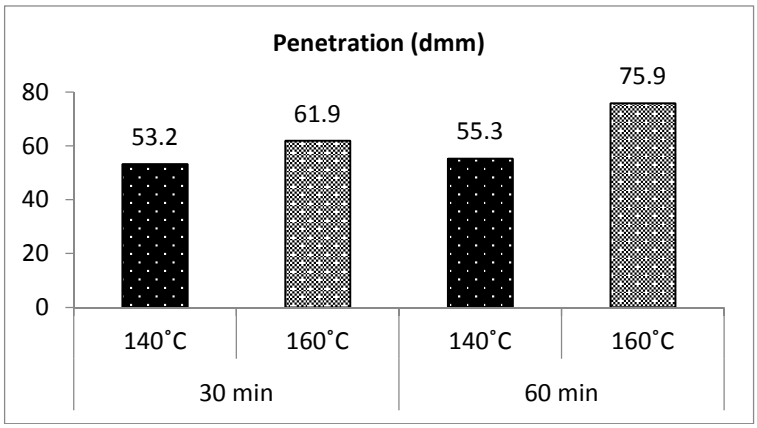

Figure 6 Penetration of Bitumen at Different Mixing Temperature

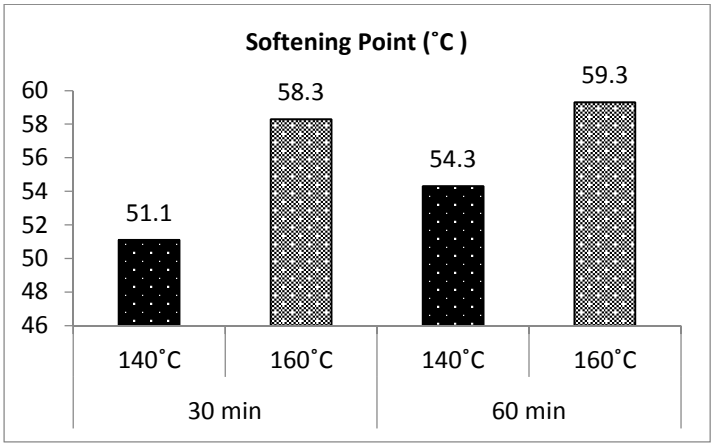

Figure 7 Softening Point of Bitumen at Different Mixing Temperature

Table 4 Penetration Index of Modified Bitumen using Different Mixing Temperature

Blending Time (minute) & Blending Temperature (°C)	**Penetration Index**
140°C / 30 minutes	-0.9
140°C /60 minutes	0
160°C / 30 minutes	+1.2
160°C /60 minutes	+1.9

3.4. Effect of NRL Polymer content

The effect of NRL polymer content was determined according to selected mixing variables that had been carried out at early stage of this study. The amount of NRL used in this study varies from 0 to 12 percent by weight of bitumen with an increment of two percent for each blend. The mixing speed of 1270 rpm at mixing temperature of 160°C with mixing time of 60 minutes were selected and used as mixing variables. Further evaluation using physical properties testing (Penetration, softening point and penetration index (PI) were conducted to determine the optimum NRL polymer content. As shown in Figure 8 and Figure 9, it could be seen that, the penetration value decreased with the increasing in NRL content which shows the tendency of strength. It shows that NRL will make the bitumen more harden and stiffen. In term of softening point result as shown, it can be seen that the softening point is increasing with the increasing of NRL content. The effect of bitumen modification for the different NRL polymer content can be seen as a decrease and increase in penetration and softening point that demonstrate the increased hardness and stiffness of the modified bitumen. It is also can be seen that the addition of NRL polymer to bitumen improves the physical properties of bitumen.

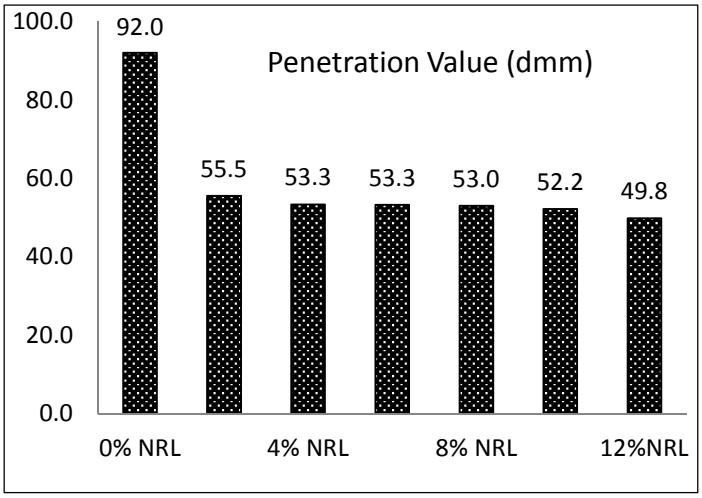

Figure 8 Penetration Value at Different Content

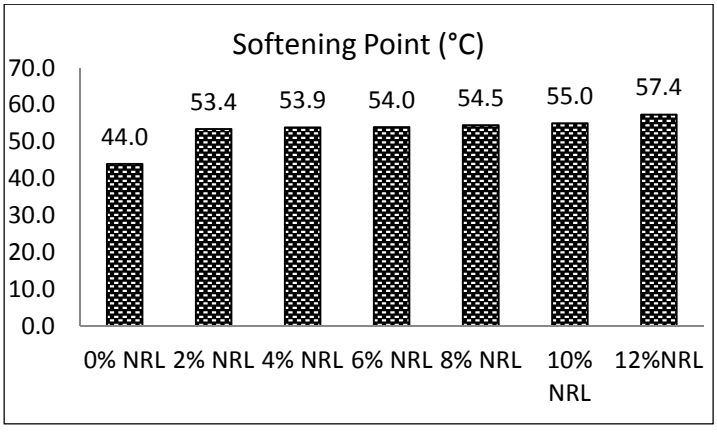

Figure 9 Softening Point at Different Content

Table 5 also shows the penetration index (PI) value of the modified bitumen. PI indicates temperature susceptibility which is shows the sensitivity of bitumen to temperature change. Higher PI values indicate lower thermal susceptibility which is that the roads have sensitivity to the temperature changing and can be indicated the trend on durability of the roads. Based on this result, it shows that adding more NRL polymer could increase PI value. Based on the results

of PI value obtained, it is shown that the values of penetration index are increasing with the content of NRL added. It shows that, due to all the results obtained, the NRL will enhance the temperature susceptibility of the bitumen. Based on those results, the best percentage of NRL is 12% to be use to modify the binder. However, the range of the PI value for conventional bitumen is between -1 to 1 penetration index. Hence, 8% of NRL content had been chosen as the optimum percentage as it has the PI value within the range and the results obtained might also acceptable. Furthermore, 12% of NRL content may be seen as too much and it will have problems due to costing if it will be use in road construction in the future.

Table 5 Penetration Index of Modified Bitumen at Different NRL Content

%NRL	Penetration Index
0	-1.4
2	-0.5
4	-0.4
6	-0.2
8	0
10	+0.2
12	+0.5

4. CONCLUSION

Based on the result, it can be concluded that:

- The mixing variables results with mixing speed of 1270 rpm at mixing temperature of 160°C and mixing time of 60 minutes show positive effect on the physical properties of NRL modified bitumen
- 8 percent of NRL content was the optimum useful content that could be added to the bitumen
- Based on the PI value, the presence of NRL polymer improves the temperature susceptibility of the asphalt. The asphalt mixtures containing bitumen with higher PI are more resistance to low temperature cracking as well as permanent deformation (rutting).
- The overall conclusion was NRL is feasible to be used as bitumen modifier in order to enhance the properties of the bitumen in terms of temperature susceptibility and physical properties and thus could performed better performance in terms of strength and durability of pavement compared than unmodified bitumen mixes.

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