Temperature sensitivity effect in asphalt modification with natural rubber sir20

R Utami* and Suherman

Civil Engineering Department, Politeknik Negeri Bandung, Jl. Gegerkalong Hilir, Ds. Ciwaruga Kotak Pos 1234 Bandung 40012, Indonesia.

E-mail: *retnoutami@polban.ac.id

Abstract. The use of asphalt material is needed so that surface layer could be water-resistant. Asphalt material also improves tensile stress which means enhancing support capacity for traffic load. Asphalt modification can be done by adding certain materials, such as natural rubber, to improve asphalt performance. Experimental methods were taken in this study. Asphalt tests which carried out are specific gravity, softening point and penetration with natural rubber variation 2%, 4%, 6%, 7%, 8%, 9%, 11% and 13%. Results were shown that the higher addition of natural rubber SIR20, asphalt more hardened and more insensitive to changes in temperature. This hardness characteristic of asphalt could be the initial parameter for making asphalt mixtures that more resistant to rutting and permanent deformation.

1. Introduction

According to SNI 6749:2008, natural rubber asphalt is hard asphalt modified with elastomeric type of polymers. In Indonesia, the use of synthetic polymers to improve the quality of asphalt has been carried out, but the synthetic polymer is still imported so that the use of natural rubber as asphalt added material is expected to enhance the use of local product. SIR20 is an acronym for Standard Indonesian Rubber which originated from latex coagulant and one of Indonesia’s export commodities.

The use of oil based asphalt in Indonesia is widely spread across the nation. Most common mixture in Indonesia is Asphalt Concrete Wearing Course (AC-WC). There are many types of AC-WC modification to improve its performance. Modification of AC-WC with rubber material addition is a system to improve AC-WC performance in reducing deformation, increasing crack resistance and increasing asphalt attachment to aggregates [1]. However, the use of raw rubber in solid form as asphalt additive will require longer mixing time and higher temperature than without rubber, because the rubber still has long molecular chain so it is less desirable [2].

The problem of using solid natural rubber as asphalt additives can be handled by carrying out depolymerisation techniques on natural rubber [3]. Depolymerisation is the process of terminating a long chain of polymer molecules into shorter molecular chain, known as mastication stage or grinding process of natural rubber in an Open Mill machine.

In this study, the selection of SIR 20 natural rubber content variations was 2%, 4%, 6%, 7%, 8%, 9%, 11% and 13% determined based on variations that had not been done by previous researchers. With the addition of SIR 20 it is expected to obtain asphalt mixture with higher hardness characteristic. Therefore, this study will be carried out experimentally by doing tests on penetration, softening point and specific gravity from modified bitumen. This study aims to learn how much the
effect of SIR20 solid natural rubber on temperature sensitivity in asphalt 60/70 from the Penetration Index value.

2. Literature Review

Natural rubber as elastomer properties, acted as polymer modification which can change the performance of current conventional asphalt paving roads against temperature changes and traffic loading. Numerous studies have been carried out on natural rubber based on different aspects of compatibility and interactions between the polymers and the asphalt aiming to improve the performances of the modified materials. From the review, the natural rubber used in a form of latex concentrated, Ribbed Smoked Sheet (RSS) and Liquid Natural Rubber (LNR) show promise in improving the asphalt mixes. Therefore, further study is needed to make them applicable as rubberized asphalt binder, thus provide better performance and services on the asphalt pavement [4].

Research on mechanical depolymerization of natural rubber for asphalt mixture additives has been carried out by doing tests as follows [5]:
- Rubber asphalt quality test: penetration, softening point, flash point, viscosity and ductility.
- Aggregate and filler quality tests: gradation, specific gravity, abrasion, sand equivalent and stickiness.
- Marshall Test: Marshall stability, flow, and Marshall Quotien.

Another study on Mechanized Depolymerization of Natural Rubber for Asphalt Additives. This study wanted to know the effect of SIR 20 natural rubber depolymerisation on the mixing process, softening point and asphalt penetration. Besides that, the study also wanted to know the chemical properties of rubber after it was depolymerized and the quality of the mixture of rubber asphalt. The method used in this study is SIR 20 natural rubber mechanically depolymerized using open mill and chemical tools with the addition of 2% peptizer and 1% HNS. Rubber depolymerization results are stored for a certain period of time and then mixed with bitumen and measured the chemical properties of the rubber, such as Mooney viscosity, initial plasticity (Po) and plasticity. The results obtained are mechanical depolymerization of natural rubber can accelerate rubber solubility to bitumen, and accelerate the mixing process from 660 minutes to only 50 minutes and the concentration of rubber to bitumen which meets the requirements of softening point and penetration of polymer asphalt is 5% and 7%. However, to be widely applied, further research is needed on the testing of rubber asphalt as a whole as well as the calculation of its economic technology [3].

Another study with natural rubber mix with bitumen was conducted in Malaysia. It used Natural Rubber Latex on asphalt pen 60/70. It resulted that percentages of 7% Natural Rubber Latex or higher are considered for the optimum content as the softening point at 7, 9 and 12% are all higher than unmodified bitumen [6].

Adding natural rubber into bitumen was also conducted in India. The binders used in the study were PB 80/100 and Natural Rubber Modified Bitumen (NRMB) 60/70. Natural Rubber Modified Bitumen was mostly in situ mixing of natural rubber latex with bitumen. Mixing process of bitumen and natural rubber latex was using wet process in which natural rubber latex was added into hot boiling bitumen in 140°C with kerosene as viscosity modifier. Natural rubber latex was added at about 2% by weight of bitumen. From the study it was known that by adding natural rubber latex, penetration value is decreasing and softening point is increasing [7].
3. Test Methodology

3.1. Materials

Materials for this study were as follows:
- Natural rubber SIR20 with catalyzer Peptizerdi-(o-bezamidephenyl) disulfide and Hidroxilamin neutral sulphate.
- Asphalt Pen 60/70 from Pertamina.

3.2. Equipment

There were two main equipment involved in this study, to depolymerize natural rubber SIR20 and to test asphalt modification characteristics. An open mill and mixer were used for the former process, as shown in Figure 1 and 2. Meanwhile, a softening point and penetration test equipment was used for testing asphalt modification due to its sensitivity on temperature, as shown in Figure 3 and 4.

3.3. Methodology

First stage was depolymerisation process of natural rubber SIR20 with its catalyser. As natural rubber depolymerized, mixing process were taken. Asphalt Pen 60/70 were heated at certain temperature and liquid natural rubber were added accordingly based on planned variations, which were 2%, 4%, 6%, 7%, 8%, 9%, 11% and 13%. Once asphalt and natural rubber SIR20 became one liquid solution, first stage was completed.

Second stage was testing asphalt modification characteristic. Due to its purpose to ensure asphalt modification’s temperature sensitivity, two main tests were taken, penetration test (ASTM D5-97) [8] and softening point test (ASTM D36 – 95) [9]. Meanwhile, specific gravity test were taken to define asphalt modification purity against organic content. Once those tests were done, there were left analysing stage to calculate asphalt modification Penetration Index.
4. Results and Discussion

In addition to the 60/70 pen asphalt material, modified asphalt with elastomeric natural rubber was used as a mixture. The characteristics of mixing pen 60/70 asphalt and natural rubber are presented in Table 1.

**Table 1. Asphalt Modification Characteristic**

| Characteristic          | SIR20 Content |
|-------------------------|---------------|
|                         | 0% | 2%  | 4%  | 6%  | 7%  | 8%  | 9%  | 11% | 13% |
| Penetration             | 65 | 64  | 62  | 60  | 57  | 58  | 55  | 52  | 48  |
| Softening Point         | 50.9| 51  | 53  | 54.3| 54.2| 54.9| 55.4| 56.6| 57.7|
| Spec. Gravity           | 1.037| 1.033| 1.034| 1.035| 1.0356| 1.036| 1.036| 1.0363| 1.0367|

Based on the results as seen on Table 1, from the penetration value it can be concluded that the higher the level of rubber on the asphalt, the smaller the penetration value of the asphalt. The small penetration value indicates that the asphalt properties are getting harder. This shows that asphalt with a greater percentage of rubber will show a smaller penetration value, which means that the bitumen becomes hard.

After testing the softening point and obtaining the results, it can be seen that the greater the rubber content on the asphalt, the softening point that affects the asphalt hardness will be higher. In this study, 60/70 pen bitumen has a softening point temperature of 50.9°C. This temperature meets the hard asphalt point temperature specifications of ≥ 48 °C, based on the General Specifications of Bina Marga 2010 revision 3 [10].

Modified asphalt with natural rubber has a minimum softening point temperature requirement of 54°C. Thus, asphalt with a rubber mixture of 2% and 4% does not meet specifications with a softening point of 51°C and 53°C. However, on asphalt with a minimum rubber mixture of 6% - 13% the softening point temperature has met the specifications of 54.3 - 57.7 °C.

Specific gravity of asphalt as well as on asphalt modification was supposedly minimum 1.00. On table 1, it can be concluded that all asphalt modification is pure against organic content. Furthermore, the more natural rubber content on asphalt modification, specific gravity value gets closer value to original asphalt specific gravity (0% natural rubber content). It can be inferred that the more natural rubber addition could have more similar behaviour with natural asphalt.
Figure 5 combined two main characteristics in defining temperature sensitivity, which are penetration and softening point. As we can see, penetration and softening point have different trends of curve; penetration value tends to get lower as adding the natural rubber content. Meanwhile, softening value tends to get higher as adding the natural rubber content. But, at 9% of natural rubber content, softening point was on higher value than penetration. This showed that at 9% asphalt modification condition reached its optimum hardness.

A study states that the addition of natural rubber into the asphalt can change the nature of the asphalt mixture especially in penetration and softening points so that it can reduce the sensitivity of bitumen to temperature [11]. To determine the sensitivity of asphalt to temperature, a certain parameter is needed, namely by calculating the penetration index. The penetration index (Penetration Index, PI) can be obtained by the following equation:

\[
PI = \frac{(20-500A)}{(1+50A)} \\
A = \frac{(\log 500-\log \text{pen})}{(\text{TL}-25)}
\]

Whereas,
- \(\text{TL}\) = Softening point value
- \(\text{pen}\) = penetration value
- \(\log \text{pen}\) = logarithmic value of penetration

| Characteristic | SIR20 Content |
|---------------|---------------|
|               | 0%  | 2%  | 4%  | 6%  | 7%  | 8%  | 9%  | 11% | 13% |
| PI            | -0.337 | -0.352 | 0.056 | 0.275 | 0.12 | 0.324 | 0.301 | 0.423 | 0.459 |

Based on Table 2, it can be seen that the more rubber content in the asphalt, the penetration index obtained is closer to +1, which is 0.459. The penetration index that is getting closer to +1 indicates that the asphalt properties are getting harder and more insensitive to temperature. The nature of this asphalt is the desired properties of the asphalt mixture with rubber, because with decreasing sensitivity to temperature, the asphalt mixture will further increase the resistance of the asphalt mixture to permanent deformation due to the addition of the load.
5. Conclusion

Addition of rubber to solid SIR 20 on asphalt pen 60/70 adds hardness to the asphalt. This added value of hardness can be seen in the decrease in the penetration value to 48, the increase in the softening point value to 57.7°C and the Penetration Index value to 0.459. The nature of this asphalt is the desired nature of the asphalt mixture with rubber, because with decreasing sensitivity to temperature, the asphalt mixture will further increase the resistance of the asphalt mixture to permanent deformation due to the addition of load.

This increase in asphalt hardness can be used as an initial parameter to make asphalt mixtures that are more resistant to rutting and permanent deformation. However, further testing of asphalt mixes is needed to prove such resilience such as testing asphalt mixes with the refusal density method and Wheel Tracking Machine.

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