Performance improvement of Asphalt Concrete-Wearing Course with modification of masterbatch SIR20

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Abstract. Asphalt Concrete-Wearing Course is a layer that is located at the top of flexible pavement structure. Types of damage that often occur in the AC-WC layer are rutting and slippery. AC-WC modification with masterbatch SIR20 is a system that improves AC-WC performance in reducing deformation in pavement structure and improving crack and skid resistance. The method that is used in this study is an experimental method that compares and analyzes the performance of the modified AC-WC layer with variations of masterbatch content are 2%, 4%, 6% and 8% and 0% as a control. The 4% of masterbatch content in the AC-WC modification layer is an effective and efficient option to be applied as a surface layer of a pavement structure.

1. Introduction
Nowadays, the use of asphalt penetration 60/70 in Indonesia as a binder of a flexible pavement structure, generally in Asphalt Concrete-Wearing Course (AC-WC), is capable of causing various types of damage that can affect the structural and functional performance during the service life, for example, there are many roads that is defective before the service life is reached. It is strengthened by the research of Amal which states that the use of asphalt penetration 60/70 in application is less durable where the asphalt easily hardened so the pavement easy to cracked [1]. On the other hand, with the rapid growth of traffic volume and the limited allocation of maintenance funds, it is necessary to develop innovation of AC-WC material and modified AC-WC material mixing technology to minimize the damage of pavement structures.

Asphalt modification with rubber is a system that improves asphalt performance such as reducing deformation in pavement structures and improving crack and skid resistance [2]. However, the solid natural rubber when directly used as an asphalt additive will require a very long mixing time and higher temperature than an asphalt without rubber, because the molecular chains of rubber are still so long so it is less desirable [3].

Furthermore, Yusep suggests an alternative in applying mixing method of modified solid natural rubber from the laboratory scale to the field scale by making the masterbatch [4]. According to Prastanto, the problem of using solid natural rubber as additive of asphalt can be overcome by doing depolymerization technique to natural rubber [5]. Depolymerization is the process of breaking long chains of polymer molecules into shorter molecular chains, otherwise known as the mastication stage of the process of grinding natural rubber in an Open Mill machine with a heat regulated as needed.

Based on the above description, the development research of solid natural rubber as an asphalt mixture modified material of this research will be used a SIR20 solid natural rubber which has been
through the process of vulcanization. The selection of 2%, 4%, 6% and 8% natural rubber content of SIR20 was determined based on variations of natural rubber content that have not been done by previous researchers whom are Prastanto [6] and Yusep [4].

2. Methodology

2.1. Material
The material used in this research consists of SIR20 solid natural rubber as the base material of masterbatch polymer; zinc oxide, stearic acid and TMQ anti-oxidant as activators to accelerate the depolymerization of the SIR 20; sulfur as a solid natural rubber vulkanizator as shown in Fig. 1; Asphalt penetration 60/70 production PT. Pertamina; as well as coarse aggregates, fine aggregates and fillers from Cagak, Subang, West Java.

![Figure 1. Materials: (a) Solid natural rubber; (b) Zinc oxide; (c) Stearic acid; (d) TMQ anti-oxidants; (e) Sulfur.](image)

2.2. Machine and specimen
The tool used in this research consists of a mill machine that serves to mix rubber compounds (SIR20 solid rubber, zinc oxide, TMQ anti-oxidant, stearic acid and sulfur) with asphalt penetration 60/70 as shown in Fig. 2.

![Figure 2. (a) Mill machine; (b) Masterbatch.](image)

Wheel tracking machine serves as a tool of deformation resistance test as shown in Fig. 3a. The test is carried out for 1 hour at 45°C and 60°C temperature. Determination of the temperature of this research is based on the research of Widodo which states that the temperature range of this test from 25°C - 60°C [7]. The specimen in this deformation resistance test is 30 cm x 30 cm x 5 cm as shown in Fig. 3b.
3. Test results

3.1. Structural performance

The parameter of structural performance in this research is rutting through dynamic stability test. The deformation test with the Wheel Tracking Machine is performed to simulate the deformation occurring in a pavement structure due to the vehicle path. The following comparison of the three deformation parameters of Wheel Tracking Machine testing results are dynamic stability or deformation resistance, deformation velocity and total deformation.

![Total deformation graph](image)

**Figure 5.** Total deformation.

British pendulum tester serves as a tool of skid resistance test as shown in Fig. 4a. The specimens in this test are 30 cm x 30 cm x 5 cm as shown in Fig. 4b. Prior to testing, the surface of the specimen shall be cleaned and moistened with sufficient water.

![British pendulum tester](image)

**Figure 4.** (a) British pendulum tester; (b) Deformation resistance specimen.
Based on Fig. 5, it can be concluded that the higher the temperature, the deeper the rutting will occur, this is in accordance with the research of Kurnia [8]. This 60°C temperature describes the extreme pavement temperatures that may occur. At the temperature of 45°C, the lowest total deformation value occurs in the mixture with a 0% masterbatch content. While at a temperature of 60°C, the lowest total deformation value occurs in the mixture with an 8% masterbatch content.

**Figure 6. Deformation velocity.**

Fig. 6 shows that the more rapid deformation, the deeper the rutting that is produced on the specimen. At this deformation velocity parameter, the mixture with 8% masterbatch content has the lowest deformation velocity value, so the rutting is relative small.

**Figure 7. Dynamic stability.**

Fig. 7 shows the comparison of dynamic stability or deformation resistance at each mixture with a certain temperature. The highest dynamic stability value at 60°C is indicated by mixture with 8% masterbatch content. This dynamic stability value is influenced by the density and temperature variation of the test [9].

From all of deformation tests performed, AC-WC with 8% masterbatch content had a lower deformation value than the other masterbatch content. It is happening because the rubber contained in the masterbatch made the mixture denser so that the layer has deformation resistance/ higher dynamic stability, as well as the deformation velocity can be retained, then the rutting will be smaller. In this case the rutting or depth of the vehicle's tread trails is referred to as rutting caused by too much repetitive pressure/loading that impacts damage to the surface layer of a pavement structure.

### 3.2. Functional performance

The parameter of functional performance in this research is skid resistance. According to Mannering et al., friction resistance is strongly influenced by the season that occurs, such as in dry time all roads have great frictional resistance as well as conversely [10]. The skid resistance is influenced by factors such as surface shape variation and tire conditions, road surface texture, weather conditions and driving conditions [11]. From the result test using the British Pendulum Tester (BPT), the value of British Pendulum Number (BPN) is shown in figure 8. The surface temperature for the test is 27°C.
Transportation Road Research Laboratory (TRRL) provides minimum standards of result test with BPT tools on motorway freight >2,000 vehicles per day is greater than or equal to 55 BPN [12]. This is also in line with the requirements issued by the TRRL (1989) which can be seen in figure 9.

From the result that are obtained after the implementation of skid resistance test, the asphalt mixture with all variations of masterbatch content have meet the requirements. The 2%, 4% and 6% of masterbatch content are increasing BPN values, this indicate that the role of masterbatch provides a good contribution in improving the skid resistance as the surface layer of the flexible pavement structure.

Fig. 8 shows that the value of the skid resistance increasing with the increase of the masterbatch content from 2% to 6%. Nevertheless, at 8% masterbatch content, the skid resistance value decreased significantly from 90 BPN to 81 BPN. Thus it can be concluded that with the addition of masterbatch up to 6%, the value of BPN produced increases, in line with the increasing AC-WC layer and AC-WC modification of skid resistance.

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**Figure 8.** Result of skid resistance test.

**Figure 9.** Minimum number of skid resistance using BPT.
From the overall improvement of structural and functional performance of the modified AC-WC layer, it can be seen that the masterbatch content showed the greatest increase at 4% and 8%. In determining the most effective and efficient alternative masterbatch to be applied in Indonesia’s highway, a summary of each test parameter is presented in Table 1.

| Parameter             | Masterbatch level in asphalt pen. 60/70 |
|-----------------------|------------------------------------------|
|                       | 0%         | 4%       | notes | 8%         | notes |
| Rutting (mm)          | 2.23       | 2.18     | increase | 1.86     | increase |
| Skid resistance (BPN) | 83         | 90       | increase | 81       | decrease |

4. Conclusion
From the two parameters that have been tested, it shows that all performance parameters have increased, except for the skid resistance parameter at 8% masterbatch content. Nevertheless, the retaining resistance of 81 BPN still meets the minimum service standard, which is greater than 55 BPN. Therefore, to fulfill the road as one of the strategic National assets, the road should be able to provide the minimum level of service during its service life. This can be accomplished if the performance of the pavement structure can be increased, especially on the surface layer of AC-WC.

Thus, the selection of 4% masterbatch content is an effective alternative of performance improvement and efficient alternative of added cost compared with 8% masterbatch. However, the techno economy needs further research. In general, it can be applied to improve the performance of pavement structures in Indonesia both from structural and functional performance.

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