Evaluation and Statistical Analysis of HRS-WC Mixture Performance Modified with Tropical Latex

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Abstract. The Marshall characteristics of Hot Rolled Sheet-Wearing Course (HRS-WC) mixed with tropical latex as a substitute of the 60/70 penetration grade asphalt material were studied. The statistical analysis aiming to decide whether the tropical latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% by weight of the asphalt would affect the Marshall performance of HRS-WC was conducted. The suggested content of the tropical latex usage in the HRS-WC mixture was analyzed. The analysis results showed that tropical latex could improve the Marshall characteristics of HRS-WC. However, the extreme percentage of tropical latex could potentially reduce HRS-WC stability. Statistically by analysis of variance (ANOVA), under 5% confidence level, latex utilization as substitution of the 60/70 penetration grade asphalt material with contents of 1%, 3%, 5%, and 7% only affected the flow parameter of HRS-WC mixture, among others Marshall characteristics (density, VMA, VFA, VIM, stability, and Marshall Quotient). Moreover, it is suggested to consider the usage of latex content in the HRS-WC mixture between 1% to 3%, in terms of the 60/70 penetration grade asphalt material substitution.

1. Introduction
The utilization of natural rubber in asphalt mixture was initially expected to increase the asphalt stability value. However, latex properties in asphalt mixture do not have precise specifications because they are influenced by various factors during the asphalt mixing process [1]. Biopolymer natural rubber latex had been used by Prastanto et al. [2] as an additive in rubberized asphalt production to study the influence of various types and dosages of three different natural rubber latex consisting of pure, cationic, and prevulcanized, to physical properties of rubberized asphalt. Siswanto [3] conducted a study to examine the role of natural rubber 0%, 2%, 4%, and 6% of the asphalt binder weight using a wet mixture blending process in avoiding the deformation on the asphalt concrete wearing course (AC-WC).

A study to evaluate the influence of various percentages of natural rubber latex on the morphology and the basic and rheological properties of asphalt binders at various temperatures had been conducted by Sani et al. [4]. To improve the ability in anti-rutting of grouted open-graded asphalt concrete (GOAC), Luo at al. [5] have introduced latex modified cement mortar for semi-flexible pavement. In the study conducted by Qu et al. [6], powder and latex styrene-butadiene-rubber or SBR (0%, 2%, 4%, 6%, and 8%) were used and mixed with the 15% Buton-asphalt rock to choose an optimum binder producing excellent performance in terms of rheological properties and short-term aging performance.
Abd El Rahman et al. [7] prepared a mixture between asphalt 60/70 and epoxidized natural rubber in three different percentages, 5%, 10%, 15%, using aqueous solution 59% at 60-80% to evaluate the asphalt mixture performance through Marshall test [7]. There are many studies conducted to evaluate the effect of latex material on the asphalt mixture with dense-graded aggregate. However, there are lack of study that concern on the influence of the tropical latex on the HRS-WC mixture with gap-graded aggregate.

This research aimed to evaluate HRS-WC performance with gap-graded aggregate consisting of the 60/70 grade penetration asphalt mixed with tropical latex through the Marshall test [8] and to determine the optimum percentage of latex that can meet the required Marshall test specifications. There are five treatments, the HRS-WC asphalt mixture without latex, and the HRS-WC asphalt mixtures with the latex of 1%, 3%, 5%, and 7%, respectively, as a substitute of the 60/70 penetration grade asphalt material. The statistical analysis of variance (ANOVA) in this research was intended to show the evidence on the improvement or reduction in Marshall characteristics of HRS-WC mixture and to confirm whether the tropical latex as a substitute of the 60/70 penetration grade asphalt material could affect the Marshall characteristics of HRS-WC mixture with 5% confidence level.

2. Research method

2.1. Latex, asphalt, and aggregates
In this research, the latex was used as a substitute for the 60/70 penetration grade asphalt material as presented in Figure 1(a). The asphalt used in this research was produced by Pertamina and classified as the 60/70 penetration grade asphalt (Figure 1(b)). Aggregate was obtained from Clereng, Kulon Progo, Indonesia, as shown in Figure 1(c) to (h).

![Figure 1. (a) Latex, (b) 60/70 Penetration Grade Asphalt, (c) Aggregate ½, (d) Aggregate 3/8, (e) Aggregate #8, (f) Aggregate #30, (g) Aggregate #200, (h) Aggregate Pan.](image)

2.2. Samples, treatments and marshall test
This research encompassed five treatments, HRS-WC without latex and HRS-WC with 1%, 3%, 5%, and 7% latex by weight of the asphalt, respectively. Each treatment had three samples, as depicted in Figure 2(a), and each sample was tested by the Marshall [8] procedure as presented in Figure 2(b).

2.3. Statistical analysis
The analysis of variance (ANOVA) and overall treatment effects (Type III Fixed Effect) was conducted to test the null hypothesis; thus, the density, VMA, VFA, VIM, stability, flow, and Marshall Quotient parameters were the same for all treatments. The multiple comparison procedures using Fisher’s Least Square Differences methods have been conducted to test the difference in density, VMA, VFA, VIM, stability, flow, and Marshall Quotient means between the treatments. There were 15 observations from five different treatments, and three samples for each treatment.
Figure 2. (a) Samples and (b) Marshall testing.

3. Results and discussion

3.1. Asphalt material and mixture testing results

Marshall testing results for optimum asphalt content of 7% are presented in Table 1. The next step was to test the HRS-WC mixture consisting of the 60/70 penetration grade asphalt material with the latex material. The recapitulation of the HRS-WC characteristics was presented in Table 2.

| Characteristics | Specification | Asphalt Content |
|-----------------|---------------|-----------------|
| Density         | -             | 5.5% 6% 6.5% 7% |
| VMA             | Min 18%       | ✓ ✓ ✓ ✓        |
| VFA             | Min 68%       | - - - ✓        |
| VIM             | 4% to 6%      | - - - ✓        |
| Stability       | Min. 800 Kg   | ✓ ✓ ✓ ✓        |
| Flow            | Min. 3 mm     | ✓ - ✓ ✓       |
| MQ              | Min. 250 kg/mm | - ✓ ✓ ✓       |

Table 2 implied that the HRS-WC mixture with the use of five different percentages of latex met the specifications of the Indonesian National Standard [8]. In general, the use of latex increased the values of specific gravity, softening point, oil losses, and ductility, and decreased the penetration
value. Overall, these results were consistent with the output of previous research conducted by Prastanto et al. [2], stating that the use of latex could affect the physical properties of asphalt.

3.2. Density characteristics
As seen in Table 2, only the HRS mixture with latex content of 5% and 7% had a specific gravity of > 1.04 gr/cm³, while the HRS mixture with latex content 1% and 3% had a specific gravity of 1.03 gr/cm³, lower than 1.04 gr/cm³ (without latex). According to Wen et al. [9], the specific gravity of natural rubber was > 0.94 gr/cm³ at 25°C. As shown in Figure 3(a), in general, the use of latex increased the density characteristics of the HRS-WC mixture. It was because the use of latex and asphalt material could enhance the ability to fill the cavity in the mixture and increase the softening point (see Table 2). The higher density ranged between 2.24 gr/cc to 2.27 gr/cc, compared with the density of HRS-WC mixture without latex, 2.17 gr/cc.

**Figure 3.** Marshall characteristics of HRS-WC and percentage of latex: (a)Density; (b) VMA; (c) VFA; (d) VIM; (e) Stability; (f) Flow and (g) Marshall Quotient (MQ)
Figure 3. Marshall characteristics of HRS-WC and percentage of latex: (a) Density; (b) VMA; (c) VFA; (d) VIM; (e) Stability; (f) Flow and (g) Marshall Quotient (MQ) (Cont…)

Figure 4. Analysis of variance, covariance and type III tests of fixed effects for density.

In the statistical analysis, the null hypothesis statement is the Marshall characteristics (density, VMA, VFA, VIM, flow, stability and MQ) of HRS-WC is the same for all treatments. According to the alternative hypothesis in the analysis of variance and overall treatment effects (Type III Fixed Effect), there was a tendency to reject the null hypothesis when F-value was large. Thus, the rejection region was \( \{ F \geq C \} \). C was a constant to be determined by the F-table. Given a significant level \( \alpha \), \( C = F_{\alpha}, a - 1, a (n - 1) \), and therefore \( \{ F \geq F_{\alpha}, a - 1, a (n - 1) \} \). In this problem, given \( \alpha = 0.05 \) as the confidence level, “a” was 5 as the number of treatments, “n” was 3 as the number of samples in each treatment, then \( C = F_{0.05, 5 - 1, 5 (3 - 1)} = F_{0.05, 4, 10} = 3.48 \) (from F-table), and hence the rejection region was \( \{ F \geq 3.48 \} \).

As shown in Figure 4, the results from SAS analysis produced the observed F statistic (\( F_{\text{obs}} \)) of 2.72. Since 2.72 < 3.48 and P-value > 0.05 (0.0910), the observed F (\( F_{\text{obs}} \)) statistic was outside the rejection region. In short, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show an improvement in the density characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the density characteristics of HRS-WC.

As shown in Figure 4, the results from SAS analysis produced the observed F statistic (\( F_{\text{obs}} \)) of 2.72. Since 2.72 < 3.48 and P-value > 0.05 (0.0910), the observed F (\( F_{\text{obs}} \)) statistic was outside the rejection region. In short, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show an improvement in the density characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the density characteristics of HRS-WC.

Figure 5 shows the recapitulation of the F-Observed and P-Value from Type III Tests of Fixed Effects statistical analysis for all Marshall Characteristics.

3.3. VMA characteristics

The relationship between the VMA characteristics of HRS-WC and the percentages of latex as a substitute of the 60/70 penetration grade asphalt material is presented in Figure 3(b). Rahmawati [10] showed that the VMA value of asphalt concrete-wearing course (ACWC) tended to decrease along with increasing polyethylene and high-density polyethylene percentages. In this research, the use of latex could also decrease the characteristics of VMA in the HRS-WC mixture (see Figure 3(b)). The VMA values have met the requirements of Bina Marga (2010), higher than 18%. The decrease in VMA value was due to latex as a substitute for the 60/70 penetration grade asphalt material capable of filling cavities in mixed aggregates. Although there were decreases in the VMA values due to latex usage 1%, 3%, 5%, and 7%, the values only ranged from 18.93% to 19.73%.
As shown in Figure 5, the results from SAS analysis produced the observed F statistic \((F_{\text{obs}})\) of 2.82. Since 2.82 < 3.48 and P-value > 0.05 (0.0837), the observed F \((F_{\text{obs}})\) statistic was outside the rejection region. Therefore, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show a reduction in the VMA characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the VMA characteristics of HRS-WC.

![Figure 5](image)

**Figure 5.** Recapitulation of f-observed and p-value for all characteristics.

### 3.4. VFA characteristics

The relationship between the VFA characteristics of HRS-WC and the percentages of latex as a substitute of the 60/70 penetration grade asphalt material is depicted in Figure 3(c). The increase in VFA values was caused by asphalt and latex as a binding material not only could fill the cavity but also bind and wrap the aggregate granules contained in the HRS-WC mixture. In short, the VFA values caused by the use of latex in the HRS-WC mixture have met the minimum requirements set by [8]. Although there was an increase in VFA values due to the use of latex 1%, 3%, 5%, and 7% as a partial replacement for asphalt material in the HRS-WC mixture, the VFA values only ranged from 76.57% to 80.68%.

As shown in Figure 5, the results from SAS analysis produced the observed F statistic \((F_{\text{obs}})\) of 2.94. Since 2.94 < 3.48 and P-value > 0.05 (0.0756), the observed F \((F_{\text{obs}})\) statistic was outside the rejection region. Therefore, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show an improvement in the VFA characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the HRS VFA.

### 3.5. VIM characteristics

The relationship between the VIM characteristics of HRS-WC and the percentages of latex as a substitute of the 60/70 penetration grade asphalt material is presented in Figure 3(d). The use of latex caused a decrease in VIM characteristics in the HRS-WC mixture. Suarayana and Sofyan [11] also discovered that the use of concentrated rubber compound and synthetics polymer as asphalt modifier could decrease the VIM of hot asphalt (pen 60) mixture, from 4.8% (VIM of the mixture without asphalt modifier) to 4.59%, 4.47%, and 4.6%, respectively. A low VIM value, especially under 4% in Figure 3(d), indicated that the presence of cavities in the mixture was relatively small, and there was not enough space for the asphalt to adhere, making the asphalt to rise to the surface (bleeding) when under heavy traffic loads and high road surface temperatures. Conversely, a high VIM value, especially above 6%, indicated relatively large cavities in the mixture, and the mixture was less
impermeable to water and air, causing a decrease in the durability of the asphalt mixture, making the hot asphalt mixture structure became prone to cracking. Although there was a decrease in VIM values due to the use of latex 1%, 3%, 5%, and 7% as a partial replacement for asphalt material in the HRS-WC mixture, VIM values only ranged from 3.68% to 4.62%.

As shown in Figure 5, the results from SAS analysis produced the observed F statistic (F_{obs}) of 2.62. Since 2.62 < 3.48 and P-value > 0.05 (0.0987), the observed F (F_{obs}) statistic was outside the rejection region. Therefore, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show a reduction in the VIM characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the VIM characteristics of HRS-WC.

3.6. Stability characteristics

The relationship between the stability characteristics of HRS-WC and the percentages of latex as a substitute of the 60/70 penetration grade asphalt material is presented in Figure 3(e). It can be concluded that the stability values increased quite significantly due to the use of 1% latex and then consistently decreased until it approached the stability value of the HRS-WC mixture without latex content. These results indicated that latex 1%, 3%, and 5% could increase the stability values of the asphalt mixture because it could provide additional strength. Thereby the bond between materials in the asphalt mixture became more stable. However, the stability value of the HRS-WC mixture with 7% latex content was slightly lower than the HRS-WC mixture without latex. These results indicated that the use of excessive levels of latex as a substitute for some asphalt material could weaken the bonds between the aggregates. In a nutshell, asphalt had a better role than latex as a binding agent between aggregates in asphalt mixture. Even so, the stability values resulting from the addition of latex to the HRS-WC mixture have met the specifications. Although there was an increase in stability values due to the use of latex 1%, 3%, 5%, and 7% as a partial replacement for asphalt material in the HRS-WC mixture, stability values only ranged from 1466.38 kg to 1766.44 kg.

As shown in Figure 5, the results from SAS analysis produced the observed F statistic (F_{obs}) of 1.57. Since 1.57 < 3.48 and P-value > 0.05 (0.2555), the observed F (F_{obs}) statistic was outside the rejection region. Therefore, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show an improvement in the stability characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the stability characteristics of HRS-WC.

3.7. Flow characteristics

The relationship between the flow characteristics of HRS-WC and the percentages of latex as a substitute of the 60/70 penetration grade asphalt material can be seen in Figure 3(f). Ren et al. [12] indicated that adding styrene-butadiene-styrene latex could dramatically enhance the flow resistance of asphalt. However, Figure 3(f) presents the flow values of the HRS-WC mixture, which tended to decrease along with the increase of latex content. It was because latex material made the asphalt mixture denser, thus reduced the chance of deformation, and the asphalt mixture became stiffer. Flow values were also influenced by asphalt viscosity, aggregate gradation, and temperature during the compaction process. By referring to Bina Marga [8], only HRS-WC mixtures with 1% and 3% latex content met the minimum flow value requirements.

As shown in Figure 5, the results from SAS analysis produced the observed F statistic (F_{obs}) of 5.33. Since 5.33 > 3.48 and P-value < 0.05 (0.0146), the observed F (F_{obs}) statistic was inside the rejection region. Therefore, the null hypothesis was rejected, meaning that statistically, with a 5% confidence level, there was much evidence to show a reduction in HRS-WC flow characteristics. In other words, the use of latex as a substitute for the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would affect the HRS flow.

3.8. Marshall characteristics

The relationship between the Marshall Quotient characteristics of HRS-WC and the percentage of latex as a substitute of the 60/70 penetration grade asphalt material can be seen in Figure 3(g). For
porous asphalt mixture, the utilization of styrofoam as an asphalt substitution material could enhance the Marshall Quotient (MQ) value since the styrofoam could improve the stability and reduce the flow of asphalt [13]. As seen in Figure 3(g), the MQ values in the HRS-WC mixture tended to get higher along with the increasing content of latex. The higher the level of latex was, the lower the flow value would be; thus, the dividing factor in the MQ formula was getting smaller and therefore produced the higher MQ. Moreover, MQ values in all HRS-WC mixture met the minimum MQ requirements (≥ 250 kg/mm). Although there was an increase in MQ value due to the use of latex 1%, 3%, 5%, and 7% as a partial replacement for asphalt material in the HRS-WC mixture, the MQ value only ranged from 448.89 kg/mm to 624.18 kg/mm.

As shown in Figure 5, the results from SAS analysis produced the observed F statistic (F_{obs}) of 2.82. Since 2.82 < 3.48 and P-value > 0.05 (0.0839), the observed F (F_{obs}) statistic was outside the rejection region. Therefore, it failed to reject the null hypothesis, meaning that statistically, with a 5% confidence level, there was not much evidence to show an improvement in the MQ characteristics of HRS-WC. In other words, the use of latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would not affect the MQ characteristics of HRS-WC.

4. Conclusions
The Marshall characteristics of HRS-WC mixed with tropical latex as a substitute for the 60/70 penetration grade asphalt material were studied. The analysis of variance and overall treatment effects (Type III Fixed Effect) to decide whether the tropical latex as a substitute of the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% would affect Marshall performance of HRS-WC was conducted. The suggested level of latex usage in the HRS-WC mixture was analyzed. The following conclusions were drawn based on the research results:

- The utilization of 1%, 3%, 5%, and 7% of latex caused an increase in density, VFA, and MQ characteristics and a decrease in VMA, VIM, and flow characteristics of the HRS-WC mixture.
- An extreme percentage of tropical latex could potentially reduce HRS-WC stability to lower than the conventional HRS-WC.
- Statistically, with a 5% confidence level, the use of latex as a substitute for the 60/70 penetration grade asphalt material with levels of 1%, 3%, 5%, and 7% did not affect the density, VMA, VFA, VIM, stability and MQ characteristics of HRS-WC. However, statistically, there was much evidence to show a reduction in the flow characteristics of HRS-WC.
- The suggested content of tropical latex as a partial replacement of asphalt material in the HRS-WC mixture with gap-graded aggregates is between 1% and 3%.

5. References

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