Analysis of Asphalt Concrete Wearing Course made with Asphalt Polyurethane Modifier

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Abstract. Modified asphalt is one of several solutions to road damage problems. The purpose of this study was to analyze the effect of adding polyurethane to the asphalt concrete wearing course (ACWC). The analysis method used is the Marshall Parameter analysis. Marshall specimens were prepared with modified polyurethane asphalt. The polyurethane content used is 1% to 4% by weight of asphalt with a range of 1%. The results showed that modified asphalt–polyurethane can improve ACWC performance in terms of stability, flow, VIM, VMA, VFA, and MQ. The best performing polyurethane content in this study was 2%, and usage of polyurethane levels above 3% is not recommended due to having MQ which does not meet the specification requirements.

1. Introduction

Based on statistical data from the Ministry of Public Works and Public Housing, the extent of road damage in Indonesia is around 38.34% or along 220,504.19 km of total existing roads [1]. One solution to this problem is to improve the quality of asphalt. Quality improvement can be done by making modified asphalt.

Asphalt modifications have been done for more than 30 years and advancements in the technology are still growing now. Modified asphalt is needed for several reasons, among others: 1) traffic load that continues to rise every year demands high asphalt quality, 2) Superpave technology, which was developed in the 1990s, requires high asphalt specifications, 3) environmental and economic issues.

Several other types of asphalt modifiers have also been used, including natural latex, synthetic latex, fly ash, bagasse ash, reclaimed rubber, recycled tire, polyurethane, glass, lime, etc [2]. Natural latex can improve pavement asphalt performance, and increase resistance to deformation [3], [4]. Meanwhile, research performed by Sabaei et al [5] showed that latex-asphalt modifier improves rheology of asphalt. Several other researchers have developed the use of polymers as asphalt modifiers [6]–[9]. Salas et al [6] discovered that polyurethane foam waste increases the stability of asphalt. Resistance to rutting and cracking was increased with the use of self-healing polyurethane prepolymer (SPP) [7]. The polyurethane modifier reduces the temperature change rate of asphalt mixtures [8]. Another researcher [10] found that the use of Styrene Butane Styrene (SBS) modifier in an asphalt mixture can localize cracking and increase the tensile limit of the mixture. The application of polyurethane to ACWC is deemed necessary because polyurethane
can reduce the risk of cracking and rutting in asphalt mixtures. Resistance to cracking and rutting is required by ACWC because the CWC is positioned at the top layer of the flexible pavement system. ACWC is the part of the construction that is directly subjected to traffic repetition loads and is exposed to environmental influences such as sunlight, rainwater, etc. Thus, this research was conducted with the aim of analyzing the use of polyurethane in asphalt concrete wearing course (ACWC) mixtures.

2. Method

2.1. Materials

The materials used in this research consisted of aggregate, asphalt, and polyurethane. The aggregate is obtained from local quarries, the asphalt used is a product of PT. Pertamina and polyurethane were obtained from the local market. The mixing of asphalt and polyurethane was done using a stirrer with a speed of 2000 rpm at a temperature of 145oC. The ACWC gradation used is the 2018 Indonesian specification standard [11] as presented in Table 1.

| Sieve Size | Weight Passing through the Strainer |
|------------|------------------------------------|
| No (mm)    |                                    |
| 3/4        | 19                                 |
| 1/2        | 12.5                               |
| 3/8        | 9.5                                |
| No. 4      | 4.75                               |
| No. 8      | 2.36                               |
| No. 16     | 1.18                               |
| No. 30     | 0.600                              |
| No. 50     | 0.300                              |
| No. 100    | 0.150                              |
| No. 200    | 0.075                              |

2.2. Testing Procedures

Marshall Specimens were made to obtain optimum asphalt content. The optimum bitumen content was determined through Marshall Parameter analysis. Marshall parameters include stability, flow, Void in the Mixture (VIM), Void in Mineral Aggregate (VMA), Void Filled with Asphalt (VFA), and Marshall question. Each Marshall parameter has a specification. The specifications used in this study are taken from the National Indonesian Standard.

Based on the optimum bitumen content, specimens were made using modified asphalt-polyurethane. The polyurethane content used is 0% to 4% with a range of 1%. The modified asphalt-polyurethane specimens were tested using Marshall testing equipment and the test results were analyzed.

3. Results and Discussions

The results from the asphalt aggregate tests are presented in Table 1 and Table 2. All materials, aggregate, and asphalt must meet specifications. The optimum asphalt content of ACWC asphalt mixture without polyurethane is 6.1%. Based on this optimum asphalt level, polyurethane is added at levels of 0
The test results of ACWC mixtures with various polyurethane contents are presented in Figure 1 to Figure 6. In Figure 1, it can be seen that stability increases with the addition of polyurethane, then it reaches a peak by which stability decreases. The maximum stability value occurs at 2% polyurethane levels, and stability decreases at polyurethane levels above 2%. Research by Salas [6] also found that the addition of polyurethane in an asphalt mixture increased its stability. Asphalt content of 2% shows the most stable combination of all ACWC mixtures, resulting in the highest stability. Interaction between materials is not optimal at polyurethane levels above 2%, this is because the addition of polyurethane increases VIM and decreases VFA, see Figure 3 and Figure 5. According to Jimenez [12], stability is affected by free space in an asphalt mix. On the other hand, the addition of polyurethane also increases the VFA value of the asphalt mix.

In Figure 2, polyurethane content affects the flow value of the ACWC mixture where the higher the polyurethane content, the higher the flow value. The same trend occurs in VIM and VMA, the higher the polyurethane content, the higher the VIM and VMA values. Flow increase is required in asphalt mixtures. Flow describes the flexibility of the asphalt mixture. Increased flow means the mixture has resistance to loads and is not easily damaged, but too high a flow is also not beneficial. High flow has a risk of causing deformations in the asphalt mixture, so the flow must be limited. Flow specifications, according to Indonesian standards, are a minimum of 2 and a maximum of 4.5 [11]. The addition of polyurethane in this study, at 1 to 4%, all met the specifications.

The VIM test results are shown in Figure 3, increasing the addition of polyurethane increases VIM. VIM is useful for accommodating space requirements when the pavement experiences additional compaction, and to accommodate for asphalt expansion when the pavement is heating due to the sun. The VMA test results, shown in Figure 4, shows that the addition of polyurethane increases VMA. All VMAs met Indonesian specification requirements where the minimum VMA is 15% [11].

The VFA test results are presented in Figure 5 and Figure 6. The VFA test results have different trends from the Flow, VIM, and VMA test results. The greater the polyurethane content, the smaller the VFA value. This happens because the VIM in the mixture increased, the adding of polyurethane is frequent, while the amount of asphalt is constant, which consequently cause a decrease in VFA. All VFA test results in this study, polyurethane levels 0% to 4%, met the specification requirements where the minimum VFA is 65.

Marshall Qoetion test results are similar to Marshall stability values whereas polyurethane content is increased, Marshall Qoetion will also increase up to a certain polyurethane content level. This produces the maximum MQ, and further addition of polyurethane will decrease the
MQ value. MQ results have trends such as stability results. Based on Indonesian standards, the minimum MQ is 250 [11], so adding polyurethane above 3% results in MQ that does not meet the requirements as it will cause it to fall below 250.

The results of this study prove that the modified asphalt-polyurethane is suitable for use as the top layer of road pavements. It also supports the findings where the performance of asphalt concrete is strongly influenced by the composition of its constituent materials[13]. In this study, there was compatibility between asphalt-polyurethane, filler, and aggregate.

4. Conclusions
Based on the results of this study, we can conclude that modified asphalt-polyurethane can improve the performance of ACWC mixtures through consideration of the flow, VIM, VMA, VFA, and MQ. The addition of polyurethane up to 2% increases Marshall stability, while the addition of polyurethane above 3% reduces Marshall stability. The addition of polyurethane in ACWC increases flow, VIM, and VMA, while VFA decreases. The best polyurethane content in this study is 2%, while contents above 3% are not recommended for use because the MQ will not meet the minimum specification requirements.

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