Comparative study of asphalt concrete characteristic between ideal gradation and laboratory tested gradation with crumb rubber

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Abstract. Modifying asphalt concrete with using Crumb Rubber (CR) can provide environmental benefits. The method used in this study is an experimental laboratory with Marshall machine. The tests used two types of gradation, namely the gradations of Ideal and Laboratory Test. CR used in a mixture with a dry process method to replacement 0%, 5%, 15% and 20% of the weight aggregate at fraction No. 30 (0.6 mm). The results showed that the Ideal gradation mixture has a better characteristic than the mixture of laboratory tested gradations. Ideal gradations can increased stability into 10% from Laboratory Test gradations for mixture without CR. Addition of CR content in AC mixture did not significantly effect for the characteristics. To ensure the effect of CR in mixture, further test must be taken.

1. Introduction

Asphalt concrete (AC) is a construction layer consisting of a mixture of asphalt and continuously graded aggregate, mixed, spread, and compacted at a specific temperature. Layers of asphalt concrete consist of mixture of three types namely Asphalt Concrete-Wearing Course (AC-WC), Asphalt Concrete- Binder Course (AC-BC), and Asphalt Concrete Base (AC-Base) [7].

Modified asphalt concrete wearing course (AC-WC) used for increases the strength of pavement structure with adding some additive such as chemicals, natural ingredients, and residual waste [4]. In many countries, crumb rubber (CR) are used as an addictive for flexible pavement cushion as in US Department of Transportation Federal Highway Administration in America since 1986. The used of CR could reduce damage to flexible pavement due to weather and traffic load factors (AASHTO, 1982) [3]. Whereas in Indonesia the use of CR is quite high and contributes cushion as large waste due to not utilized properly. According to the Indonesian Rubber Council at 2012, tire rubber production in Indonesia reached 15.4 million in 2011. Meanwhile, according to the Association of Tire Companies (2016) the use of tires reached 45 million tires/year.
By adding 50% CR on fraction No. 50 in AC mixtures can improve the resistance to permanent deformation due to ruts and provide better resistance to high temperatures and loads [9]. Further, AC mixture with adding 2% CR on mesh #80 resulted higher stability than mixture normal [3]. Moreover, there are still many of size and mix variations used CR to be researched in AC mixture. Therefore, this research mainly focused on CR content from 5.0%, 10%, 15%, and 20% by replacement weight of aggregate at fraction No. 30 (0.6 mm) on ideal and Laboratory tested gradations in AC mixture.

2. Literature Review
Asphalt mixture is asphalt made by mixing hard asphalt with an added ingredient. The strength of asphalt concrete is influenced by the properties of the mixed material. Modified polymer asphalt used in paved mixtures can improve better resistance to deformation, overcome cracks and increase resistance to aging damage. [4].

Modified asphalt was also developed with the addition of used residual tire rubber. Tire rubber can be used as pavement material with two methods, dry process and wet process method. The first is called dry process, namely the method of adding used tire powder as a substitute for part of the aggregate in concrete asphalt mixture and not part of asphalt binder. Whereas for the wet process is the method of adding used tire powder to the asphalt as a binder where before asphalt is added to the asphalt concrete mixture [6].

The percentage of used CR added in dry processes varies shows that 3%-5% of used tire powder with aggregate weight is commonly used [1]. Research on the effect of mixture that used CR on AC mixture was carried out by Laos. The variation is 1%, 2% and 3% of CR with a mesh size of 40. But it produces uneven linear stability and flow between the addition of CR to the stability value of the mixture [5]. Then it was resumed by Gosali, also on AC mixture with 80 mesh size. The results showed that the addition of 1-2% CR can produce a better value of stability than the standard mixture [3].

3. Methodology
In general, this study consists of several preparations and tests, as follows:

3.1 Material
Materials such as fine aggregates, coarse aggregates, stone ash (filler) used in this study came from Cagak, Subang, West Java. The bitumen from Pertamina asphalt with 60/70 penetration. Then the wasted crumb rubber were ordered from PT Pura Agung, Mojokerto, East Java. Figure 1. shows the materials.
3.2 Specimens
The specimens used in the study are two types of gradation, which are ideal and laboratory tested gradations. Asphalt content used from 5.0% until 7.0%, while the CR content from 5.0%, 10%, 15%, and 20% by replacement weight of aggregate at fraction No. 30 (0.6 mm). It means that the mixture is not modified asphalt because it’s still used standard bitumen with 60/70 penetration.

3.3 Testing Methods
Marshall test was carried out to obtain mixture characteristic, such as Voids Mix Aggregate (VFB), Voids Filled Bitumen (VFB) and Voids in Mixture (VIM), Stability, and Flow by using the machine as shown in Figure 2. The testion is carried out according to RSNI M-01-2003. The results of this test are compared with the specifications of Spesifikasi Umum Bina Marga, 2010 [2][8].

![Figure 2. Marshall test](image)

4. Result and Discussion
4.1 Aggregate Testing Result
The aggregate characteristics which used in Asphalt Concrete (AC) mixture are shown in Table 1. It can be seen that the aggregate used in this study has fulfilled the Specifications [2]
Table 1. Aggregate Characteristic

| No | Testing                                      | Method       | Specification | Result |
|----|----------------------------------------------|--------------|---------------|--------|
| A  | Coarse Aggregate                             |              |               |        |
| 1  | Satured Surface dry Specific Gravity (SSD)    | SNI 1969:2008| -             | 2.65   |
| 2  | Bulk Specific Gravity                         | SNI 1969:2008| Min. 2.5      | 2.58   |
| 3  | Apparent Specific Gravity                     | SNI 1969:2008| -             | 2.78   |
| 4  | Absorption                                   | SNI 1969:2008| Max 3%        | 2.77%  |
| 5  | Los Angeles Abrasion (500 spin)              | SNI 2417:2008| Max 40%       | 14.19% |
| 6  | Materials Finer than 75-μm (No. 200) Sieve    | SNI 03-4142-1996| Max 2%    | 0.46%  |
| 7  | Coating of Bitumen                            | SNI 2439:2011| Min. 95%      | 100%   |
| B  | Fine Aggregate                                |              |               |        |
| 1  | Satured Surface dry Specific Gravity (SSD)    | SNI 1969:2008| -             | 2.64   |
| 2  | Bulk Specific Gravity                         | SNI 1969:2008| Min. 2.5      | 2.55   |
| 3  | Apparent Specific Gravity                     | SNI 1969:2008| -             | 2.79   |
| 4  | Absorption                                   | SNI 1969:2008| Max 3%        | 3.32%  |
| 5  | Materials Finer than 75-μm (No. 200) Sieve    | SNI ASTM C117:2012| Max 10% | 10.95% |
| 6  | Sand Equivalent                               | SNI 03-4428-1997| Min. 60%  | 79.10% |

4.2 Asphalt Test Result
Asphalt test was conducted to determine the characteristics of asphalt in AC mixture. Based on Table 2, it can be seen that the characteristics of the 60/70 penetration asphalt used in this study have fulfilled the Specifications [2]

Table 2. Asphalt Pen 60/70 Characteristic

| No | Test                | Method       | Specification | Result |
|----|---------------------|--------------|---------------|--------|
| 1  | Penetration         | SNI 2456:2011| 60-70         | 63     |
| 2  | Kinematic Viscosity 135°C | SNI 7729:2011| ≥ 300°C   | 500°C |
| 3  | Softening point     | SNI 2434:2011| ≥ 48°C      | 52.1°C |
| 4  | Ductility           | SNI 2432:2011| ≥ 100 cm    | > 140 cm|
| 5  | Density             | SNI 2441:2011| ≥ 1         | 1.04   |

4.3 Gradations
The gradations used in this study are 2 types, Ideal gradation and Laboratory Test gradation. The difference between the two will be seen in the cumulative percentage of passing size for each filter size shown in Table 3 of the following:
Table 3. Aggregate gradation used

| Sieve (mm) | (Inch/No) | Lower limit | Upper limit | Ideal gradation | Laboratory tested Gradation |
|------------|-----------|-------------|-------------|-----------------|-----------------------------|
| 25         | 1         | 100         | 100         | 100             | 100                         |
| 19         | ¾         | 100         | 100         | 100             | 100                         |
| 12.5       | ½         | 90          | 100         | 95              | 100                         |
| 9.5        | 3/8       | 77          | 90          | 81              | 87.4                        |
| 4.75       | No. 4     | 53          | 69          | 53              | 59.1                        |
| 2.36       | No.8      | 33          | 53          | 33.5            | 52.2                        |
| 1.18       | No.16     | 21          | 40          | 22              | 30.9                        |
| 0.6        | No.30     | 14          | 30          | 16              | 17.3                        |
| 0.3        | No.50     | 9           | 22          | 12              | 10                          |
| 0.15       | No.100    | 6           | 15          | 9.5             | 7                           |
| 0.075      | No.200    | 4           | 9           | 7               | 4                           |

Based on Table 3, it shows that laboratory tested gradations have percentage cumulative which tends to approach the low limit value. Laboratory tested gradations have more fine aggregate and less coarse aggregate than ideal gradations. Later in this paper, ideal gradations will be stated as A1 while laboratory tested gradations is A2.

4.4 Comparasion of Marshall Test Result

The test results obtained the compasion of Asphlat Concrete (AC) characteristic between two types of gradations can be seen in Figure 3, until Figure 7.

Figure 3. Comparison of VMA

Figure 3. Shows that the value of Voids Mix Aggregate (VMA). This figure shows the relationship between voids on aggregate for 2 types of gradations. The result shows that the A2 has a quite a lot of voids gap in each addition of CR compared to the normal mixture. While A1 has fewer voids gap.
VMA values are higher in each context of CR in both gradations but different things happen in 15% CR for ideal gradation. This mixture actually has a lower voids than 20% CR.

Figure 4. Comparison of VFB

Figure 4. Shows that the value of VFB, it shows that A1 is better than A2. It is also seen that VFB of A1 value meets specifications which is a minimum of 65%. While A2 for all mixtures that did not meet the specifications. It happened because the voids of A2 are not fully filled with asphalt. A2 has smoother gradation, so that it has more voids. Therefore, asphalt liquid couldn’t fill the gap of void easily.

Figure 5. Comparison of Voids In Mix

Figure 5. shows the value of VIM between A1 and A2. Based on this figure, A1 is better than A2 because it can be seen from the VIM graph in A1 has meet specifications. Meanwhile, none of A2 entered the minimum VIM specifications, even the VIM in A2 reached a double value (21% than 12%). It happened, A2 has more voids due to the effect of more fine aggregate. For the more, the voids can’t be filled with CR and increase the percentage of voids in mixture.
Figure 6. Comparison of Stability

Figure 6. Shows that the value of Stability between A1 and A2. It shows that the A1 is better than A2, except for CR 20% was 700 kg, below minimum specification. Meanwhile for A2, all mixtures containing with CR did not meet any minimum specification. In A2 mixture with CR content, voids were in huge amount so it results lower stability compared to mixture without CR [9].

Figure 7. Comparison of Flow

Figure 7. Shows that the value of Flow. Based on the figure, flow values from both of gradations did not meet specifications. So that the best gradation cannot be taken between the two. It happens because the CR couldn't be able to maximally filled the voids, resulted in large amount of flow.
5. Conclusion and Recommendation
Based on the results of the study it was found that:

- Ideal gradations is better than Laboratory Test gradations based on characteristic of Marshall
  and is recommended for mixture with CR.
- Ideal gradations can increased stability into 10% from Laboratory Test gradations for mixture
  without CR.
- Addition of CR content in AC mixture did not significantly effect for the characteristics. This
  could happen due to the size of CR could be bigger than it should be.
- To ensure the effect of CR in mixture, further test must be taken cush as test with different CR
  variations and sizes.

Acknowledgment
The author acknowledges to UPPM POLBAN that already support the funding for commencement the
research and Bandung Research Center of Roads and Bridges that support the laboratory for the
research.

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