Effect of recycled materials on marshall performance of hot asphalt mixture (HMA – RAP)

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Abstract. Limitations of road construction materials and increasing demand of aggregate and asphalt have resulted in high construction costs and road rehabilitation so that alternative materials such as reclaimed asphalt pavement (RAP) are needed. In this study using RAP variation of 10-30% to the total weight of the mixture. In the HMA-RAP mixture that was heated at a temperature of 150\(^{\circ}\)C then mixed with aggregate at a temperature of 170-180\(^{\circ}\)C and asphalt at a viscosity temperature of 153\(^{\circ}\)C so that the new mixing temperature was obtained in 148-153\(^{\circ}\)C, with a penetrating approach and soft point was obtained optimum reclaimate rejuvenation content of 23% to be mixed into the RAP heat mixture. The test results showed an increase in RAP levels, the optimum value of asphalt level (KAO) decreased so that the asphalt in the RAP material can be activated and mixed well so that it can reduce the amount of used asphalt in the mixture. Furthermore, for the mixed performance with Marshall test, the highest stability value was 1648.09 kg in the RAP30% mixture and the increase in residual Marshall stability was 90.8%, this showed that the mixture stability to the influence of water, changes in temperature and bonds between new materials (pen60 / 70 asphalt and aggregate) with RAP material was still good.

1. Introduction

Road infrastructure development is an important requirement in the development of transportation systems in Indonesia, a good transportation network will have an impact on the development of an area activities, from the construction and maintenance of paved roads in Indonesia, about 1.3 million tons of asphalt per year is needed, if mixed Asphalt has 6% asphalt level of the mixed weight, so that 1.3 million tons of asphalt will produce as much as 21.6 million tons of hot asphalt/ hot mix asphalt\(^1\). For asphalt needs, in addition to increasing prices from year to year, Indonesia is only able to produce 900,000 tons of asphalt per year where Pertamina is only capable to produce 600,000 tons per year and Sarana Karya as much as 300,000 tons per year, while the rest is imported to meet its shortcomings [3] (Pertamina, 2015), based on the requirements mentioned, it is clear there is a large availability of pavement material for development activities and road preservation in the form of aggregate and asphalt [5].
Reclaimed asphalt pavement (RAP) technology is an ingredient resulting from pavement scratching process that contains asphalt and aggregate. This material is produced when the asphalt layer is removed for reconstruction, returning the surface layer or dismantling the pavement due to utility installation. This method was tested in the field in Indonesia in 2007 by the research and development agency for public works on the Palimanan - Jatibarang road with a length of approximately 3.5 km, while in 1989 the asphalt institute used hot asphalt mixed RAP [4].

Based on the above issues, it is necessary to develop pavement technology, one of the technologies that has been developed is the use of old reclaimed asphalt pavement (RAP) as a pavement material. Reclaimed asphalt is an alternative technology that is useful for pavement materials because it reduces the need for natural aggregate use and materials of the new asphalt binder that needed in the asphalt mixture so that it can save construction costs and reduce waste material which has an effect on the environment. Based on studies that was conducted by the American asphalt association the average percentage of RAP used in asphalt mixes increased in 2009 by 15.6%, increasing to 20.4% in 2014, with an estimated number of RAPs used in asphalt mixtures at 71.900,000 tons. Assuming 5% asphalt level on RAP, it is equal to 3.6 million tons of asphalt savings and 68 million tons of natural aggregate [6].

2. Materials and Methods
The material used in this study are pertamina penetration 60/70 asphalt, a new aggregate from PT Kadi, RAP material from raking on the national road of Karawang city and reclamite rejuvenation material, while the testing equipment uses Marshall. The design of hot paved mix design starts from testing the characteristics of asphalt material with 60/70 penetration, new aggregate, RAP and slag with the gradation that used as reference is the intermediate Laston gradation (AC-BC) specified in the General Specifications of Roads and Bridges, Bina Marga Year 2010 Revision 3.

In testing of the mixture there are 3 variations of RAP material level to the total weight of the mixture, namely 10%, 20% and 30% of RAP material. This mixture test is carried out in accordance with the test standard for hot paved mixtures. To get the value of Optimum Asphalt Level (KAO), planning with the Marshall Method with the Absolute Density Approach is used. In Figure 1 a structured methodology is explained in this study.

![Figure 1. Research Methodology Using Hot Asphalt Mixed RAP Materials](image)

3. Result and Discussion
3.1. Material Test RAP
Testing the characteristics of RAP material consists of testing the levels of asphalt (residual) in RAP, aggregation of RAP, characteristics of RAP Asphalt, percentage of the RAP amount that used in asphalt mixture. The percentage content of RAP asphalt content can be identified using Trichloor Etyleen (TCE) liquid, while to separate the asphalt with TCE liquid using an evaporator. Testing of RAP asphalt from the extraction results can be seen in Table 1. Based on the test results it is known that the asphalt level is 5.15% where the asphalt level will affect the new 60/70 pen asphalt which will be added to the hot asphalt mixture, whereas when viewed from the Asphalt property test decreased the penetration value.
Table 1. Characteristic of RAP Asphalt

| No | Type of Test        | Test Result | Test Method     | Unit |
|----|---------------------|-------------|-----------------|------|
| 1  | Asphalt Level       | 5.15%       | SNI 03-3460-1994 | %    |
| 2  | Penetrate 25°C,100gr, 5second; 0.1 mm | 10          | SNI 06-2456-1991 | 0.1 mm |
| 3  | Softening Point 0°C | 80          | SNI 06-2434-1991 | °C   |
| 4  | Ductility, 25°C, cm | 38          | SNI 06-2432-1991 | cm   |

From the results of rap aggregate testing, the hardness of RAP aggregate is 32.30%, this shows that the RAP aggregate meets the general specifications of the Bina Marga road and bridge 2010, which is a maximum of 40%. Whereas for aggregate specific gravity under 2.5 this is because the strength of the aggregate has been reduced in line with the decreasing strength of abrasion, while for RAP gradation testing can be seen in Figure 2, the results of sieve analysis obtained the RAP gradation inside the upper and lower limits of the intermediate tier gradation (AC-BC) so that based on theoretical calculations in obtaining a combination of new aggregate with RAP aggregates there is no percentage limit that can be added to the mixture, but in this study the use of RAP is limited to 30% in the hot mixed asphalt (HMA-RAP).

Figure 2. Gradation of RAP Aggregate

3.2. Addition of Rejuvenating Ingredients to the Penetration and Softening Point Values

The adolescent material used in this study is reclamite, where to determine the levels added to the mixture is used the approach to softening point values and their penetration so that in accordance with the General Specifications of Bina Marga Road and Bridge 2010, can be seen in Table 2 with the addition of rejuvenating ingredients reclamite to RAP asphalt will increase the penetration value and reduce the softening point value, the optimum reclamite level is 20-25% to be mixed into the RAP heat mixture.

Table 2. Reclamite Relationship to the RAP Asphalt Penetration and Softening Points

| Rejuvenating Reclamite® (%) | Average Penetration (dmm) | Average Softening Point (°C) |
|------------------------------|---------------------------|-------------------------------|
| 2                            | 19.6                      | 67.25                         |
| 5                            | 26.8                      | 65.5                          |
| 9                            | 33.2                      | 62                            |
| 15                           | 41.6                      | 58.5                          |
| 20                           | 58.2                      | 54                            |
| 25                           | 64.6                      | 52.25                         |
3.3. Combined temperature based on the number of RAP
Determination of the combined temperature needs to be done because there are differences in the mixing method, RAP aggregates are mixed with heat conditions due to the availability of tools and applicability in the field, the maximum temperature is 150°C, while for new aggregates mixed at ± 21°C asphalt viscosity temperature. The test was carried out with the addition of RAP 10 - 30%.
Based on the test results obtained by mixing new aggregates with RAP will produce a lower combined temperature than the new aggregate temperature, the more the percentage of RAP, the lower the combined temperature obtained by the combined mixing temperature of 148-53°C, while for the combined compaction temperature is 138 -153°C (this temperature is taken from the temperature difference of mixing and compaction on 60/70 penetration oil asphalt).

3.4. Calculation of RAP Weight in mixture
Marshall testing is carried out on asphalt level of 4.5% - 6.5% with a range of 0.5%, the calculation of weight in the mixture for new aggregates and RAP is carried out at each asphalt level because it will affect the amount of added RAP. In this study the asphalt density used was 60/70 asphalt pen as a control, while the aggregate specific gravity used was combined aggregate specific gravity.

The method of mixing and compacting the RAP heat mixture (HMA RAP) is by gradation and temperature adjusted by the number of RAP added to the mixture, in outline are as follows:
- New Aggregates are heated in an oven with a viscosity ± 28°C asphalt temperature.
- RAP is heated to reach 150°C, after that it is evenly mixed with the new aggregate that has been oven.
- After the aggregate is mixed evenly add 60/70 asphalt pen with a constant temperature of 153°C, then the rejuvenating ingredients are added with a percentage of 23% of the weight of the RAP asphalt.

Prepare the mixture at the compaction temperature in accordance with the addition of the RAP after the temperature has been reached by pulverizing with Marshall.

3.5. Testing of Mixed AC-BC Marshall with RAP
Marshall testing was carried out in AC-BC mixture using RAP addition from 10-30%, after obtaining the value of Optimum Asphalt Level (KAO) absolute density testing was carried out with a percentage range of 0.5 from the KAO value, for immersion testing, the following can be seen in Table 3.

| No | Mixed Properties         | Unit | Test Result of HMA-RAP | Specifications |
|----|--------------------------|------|------------------------|----------------|
|    |                          |      | 10% RAP | 20% RAP | 30% RAP |                      |
| 1  | Optimum Asphalt Level    | %    | 5.95     | 5.73    | 5.55    |                      |
| 2  | Effective Asphalt Content| %    | 5.31     | 4.93    | 4.50    |                      |
| 3  | Absorption Of Asphalt    | %    | 0.68     | 0.85    | 1.12    |                      |
| 4  | Density                  | Gr/mm³| 2.34     | 2.32    | 2.32    |                      |
| 5  | Void In Mix (VIM)        | %    | 3.60     | 4.51    | 4.56    |                      |
| 6  | Void In Mineral Aggregate(VMA) | % | 15.74   | 15.67   | 14.75   |                      |
| 7  | Void Filled With Asphalt (VFA) | % | 77.14   | 71.32   | 69.22   |                      |
| 8  | Stability                | Kg   | 1432.55  | 1526.49 | 1648.09 |                      |
| 9  | Flow                     | mm   | 3.32     | 3.08    | 3.60    |                      |
| 10 | Marshall Quotient        | kg/mm| 436.01   | 496.34  | 460.04  |                      |
| 11 | Marshall Imersion        | %    | 90.1%    | 90.9%   | 90.8%   |                      |

From the Marshall test results can be seen the value of Marshall stability increases with increasing RAP content in the mixture, this is influenced by the value of rigidity in RAP which ultimately increases the value of Marshall stability.
The volumetric test results of the HMARAP mixture with increasing RAP decreases the VIM value, this can be said that the asphalt contained in the RAP material can be activated properly due to RAP material when mixed through a heating process up to 150°C so that the asphalt contained in the RAP can mix with the new asphalt. The effect of using RAP also increases the VMA value, the RAP percentage increases, the reduced VMA value is estimated due to the decreasing mixing and compaction temperatures, even though when mixing the RAP material is heated first but still decreases the temperature, so that a new gradation is different from the gradation used, namely become more rough.

Based on marshall analysis with absolute density method, the optimum asphalt content (KAO) is obtained with increasing RAP percentage, for RAP 10% which is 5.95, RAP 20% KAO is 5.73% and for RAP content 30% to 5, 55% of this shows that the asphalt in the RAP material can be activated properly so that it can reduce the amount of asphalt used in the mixture. The influence of the use of RAP is also seen in the density value, where with the increase in the RAP value in the mixture the density value will be decrease, this is due to the decrease in temperature during the mixing and compaction process. The mixing process was done by RAP method heated at 150°C temperature mixed with new aggregate at a temperature of 170°C – 180°C then mixed with 60/70 pen oil asphalt at a temperature of 153°C so that the mixing temperature was reduced as well as the compaction temperature this caused the mixture density to be smaller with RAP value increases in the mixture.

The test results show that the stability value of marshall immersion after 24 hours immersion at a temperature of 60°C with increasing RAP in the mixture then the Marshall immersion values also increases, this shows that the stability of the mixture to the influence of water, changes in temperature and bonds that occur between new materials (pen60 / 70 asphalt and aggregate) with RAP material is still good.

4. Conclusion
Based on the analysis and discussion of the effect of RAP material on the performance of the heat mixture, the following conclusions are obtained:

1. The used RAP asphalt has experienced aging, this can be seen from the hard penetration value, its increased softening point and decreasing ductility, this causes the need for rejuvenating materials to be used in hot asphalt mixture (HMACRAP).
2. The rejuvenating materials added to HMACRAP use an approach to the penetration value and softening point so that it is obtained at levels of 23%.
3. RAP aggregate gradation determines the number of RAP that can be used in this study, but because the RAP gradation is still in the upper and lower boundary area, there is no definite limit on how much RAP can be used in the heat mixture (HMACRAP) but this study is limited 30% of RAP material.
4. The method used in the process of mixing and compaction namely RAP material is heated first to 150°C then mixed with new aggregate temperature of 170 – 180°C so that the mixing temperature drops to 138°C – 141°C (below the mixing temperature at 60 / 70 asphalt penetration viscosity). This causes the density of the mixture to be smaller by increasing the RAP value in the mixture.
5. HMARAP mixing process of RAP asphalt activation can be occurred. This is indicated by an increase in KAO value of 0.2% for each addition of RAP in the mixture, in addition to changes in volumetric value also shows that RAP asphalt can be activated and mix well with the new asphalt in meeting Asphalt requirements in the mixture are also seen from the VIM value.
6. Marshall test gives results that the increasing RAP in the mixture can increase its stability value, as well as the remaining Marshall stability on RAP30% giving good results.
5. References

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