Influence of gradation using local aggregate on porous asphalt to enhance stormwater absorption

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Abstract. Porous asphalt is one of the pavement technologies that have a large void in the mix and enables water flows through the pavement structure. Due to its porous characteristic, strength and stability of porous asphalt are lower than normal asphalt mix caused by coarse aggregate domination in mixture leads. Selection of aggregate and gradation highly affected desired porous asphalt characteristics, so that research is needed to understand the performance of porous asphalt using local material based on permeability characteristic, cantabro loss and marshall characteristic with several aggregate gradations from several countries. The method of this research would be a laboratory-scaled experiment. Materials for this research were asphalt pen 60/70 and local aggregate from Majalengka (M) with gradation variation from Japan (J), Australia (A), and Indonesian (I), then designed to obtain a porous asphalt namely MJ, MA, and MI. Permeability test showed lower value for every mixture with the highest permeability coefficient is on MI with 4.64 x 10\textsuperscript{-5} cm/s. Cantabro loss gave the lowest value on MI with 20.45%. By permeability and cantabro loss, porous asphalt mixture with aggregate from Majalengka with Indonesian grading is the best one to represent environmentally friendly mixture and enhance stormwater absorption.

1. Introduction
Porous asphalt is a new option for road pavement technology to manage stormwater, where its function is as a rainwater storage and infiltration system, as well as a pavement surface that drains rainwater (rolling surface). As an environmentally friendly technology, porous asphalt can promote infiltration, improve water quality, control peak and total runoff volume, and can refill groundwater reservoirs, depending on the type of management system. Porous asphalt is good for low-traffic pavements and parking lots [1–4]. The application of porous pavements for highways is challenging due to variability in soil conditions, utilities, fills, and slope. However, with diligent engineering, the use of porous asphalt pavements for highways is possible for some situations [5].

The porous asphalt mixture itself is an asphalt mixture that is being developed for the wearing course construction. This layer uses an open-graded which is dominated by coarse aggregates, resulting in a large enough void. Increasing the proportion of coarse aggregate and reducing the fine aggregate (in this case the gradation of aggregate) can increase the value of cavities in the mixture [6]. Thus, the difference in the grading system used on porous asphalt will give a different mixture performance. Also, with the large number of voids formed, the stability of the porous asphalt mixture is lower than the conventional asphalt mixture. Its composition which is dominated by coarse aggregate is one of the factors that causes it to tend to be brittle and stiff. To produce good mixture stability, it is necessary to select the aggregate that comes from its place with its inherent properties, this needs to be emphasized because the split stone crusher products sometimes have fluctuating sizes. Based on this, research is needed to be able to see how the performance of environmentally friendly porous asphalt mixtures using locally available
materials, to determine the permeability and characteristics of Marshall using several standards for porous asphalt which has a different aggregate grading system.

2. Material and methods

2.1. Material

The materials used in this research are

- Aggregates used are local aggregates from Majalengka, West Java, Indonesia
- The asphalt binder used is 60/70 pen asphalt from PT Pertamina
- Porous asphalt mixtures are produced using aggregate grading from Japan standard (J), AAPA Australia (A), and KemenPU Indonesia (I).

2.2. Methods

The method used in this study was to test the properties of the local aggregate of Majalengka (M) and asphalt, which was then used as the base material for the formula of a porous asphalt mixture using various gradations and variations in asphalt content based on the calculation of the estimated asphalt content (Pb), to produce specimen mixture of porous asphalt with aggregate from Majalengka and gradations according to Japanese standards (MJ), a mixture of porous asphalt with Majalengka aggregate and Australian grading (MA), as well as a mixture of porous asphalt with Majalengka aggregate and Indonesian grading (MI), each type of mixture produced 15 specimens (Table 1), to then test the volumetric and stability of the marshall and produce OBC. In the OBC conditions for each type of porous asphalt mixture (3 specimens for each type), the permeability and cantabro loss were then tested based on the Draft Guidelines for the Design and Implementation of Porus Asphalt, Ministry of Public Works. 2012 [7]. The estimated bitumen content (Pb) for each type of mixture is:

- Pb MJ = 5.263 % rounded to 5.5 %
- Pb MA = 5.0825 % rounded to 5 %
- Pb MI = 4.980 % rounded to 5 %

| Aggregate type | Pb (%) | Sample Code | Japan | Australia | Indonesia |
|----------------|--------|-------------|-------|-----------|-----------|
| Majalengka     | 4.0    | -           | MA11  | MA12      | MA13      |
|                 | 4.5    | MJ11        | MJ12  | MJ13      | MA21      |
|                 | 5.0    | MJ12        | MJ13  | MA21      | MA22      |
|                 | 5.5    | MJ21        | MJ22  | MJ23      | MA31      |
|                 | 6.0    | MJ22        | MJ23  | MA31      | MA32      |
|                 | 6.5    | MJ31        | MJ32  | MJ33      | MA41      |
|                 |        | MJ32        | MJ33  | MA41      | MA42      |
|                 |        | MJ33        | MA41  | MA42      | MA43      |
|                 |        | MA41        | MA42  | MA43      | MI11      |
|                 |        | MA42        | MA43  | MI11      | MI12      |
|                 |        | MA43        | MI11  | MI12      | MI13      |
|                 |        | MA51        | MA52  | MA53      | MI51      |
|                 |        | MA52        | MA53  | MI51      | MI52      |
|                 |        | MA53        | MI51  | MI52      | MI53      |
|                 |        | MJ51        | MJ52  | MJ53      | -         |
|                 |        | MJ52        | MJ53  | -         | -         |
|                 |        | MJ53        | -     | -         | -         |

The permeability equation used is based on the equation from Westerman’s research, 1999 [8], as follows:

\[ k = (1.38 \times 10^{-7}) (3.92 V^a) (0.62 T) \]  

where:

- \( k \) = Permeability (cm/s)
- \( V^a \) = Void/porosity (%)
- \( T \) = Thickness (cm)
2.3. Mixture Sample Preparation
The mixing and compaction temperatures were obtained from the relationship between viscosity and temperature, wherein this study the mixing temperature was 155 °C and the compaction was 145 °C. The specimens were made by mixing the hot aggregate with asphalt at mixing temperature with an average stirring time of 30-60 seconds, then placing it into a marshall mold with a diameter of 4 in and a height of 3 in. at compaction temperature beaten on both sides 50 times/side (low traffic). The test object that has been made is then tested by Marshall to obtain the Optimum Binder Content (OBC) value (based on Marshall stability and porosity). In OBC conditions, each type of mixture was tested for permeability using a water permeability test based on ASTM D4491 / D4491M [9] standards and cantabro loss testing using a Los Angeles machine based on ASTM C-131 standards [10]. The gradation design for each type of mixture is shown in Table 2.

| Table 2. Aggregate gradation for Porous Asphalt |
|-----------------------------------------------|
| Sieve Number       | Passing (%) | Japan | AAPA | Indonesia |
| 1"                | 100         | -     | -    | -         |
| 3/4"              | 97.5        | 100   | 100  | -         |
| 1/2"              | -           | 94    | 92.5 | -         |
| 3/8"              | 71          | 57.5  | -    | -         |
| No.4              | 20.5        | 17.5  | 17.5 | -         |
| No.8              | 15.5        | 11    | 7.5  | -         |
| No.30             | 10.5        | 7.5   | -    | -         |
| No.40             | -           | -     | -    | -         |
| No.50             | 7.5         | 6     | -    | -         |
| No.100            | 5.5         | 5     | -    | -         |
| No.200            | 4.5         | 3.5   | 3    | -         |
| pan               | -           | -     | -    | -         |

3. Result and discussion

3.1. Aggregate and binder test result
The results of the local Majalengka aggregate test are presented in Table 3, while the results of the asphalt test are in Table 4. Based on the results of the aggregate and asphalt test, it can be seen that all of their properties meet the specification standards so that they can be used in making porous asphalt mixtures.

| Table 3. Aggregate properties |
|-------------------------------|
| Test                        | Test Method  | Result |
| Coarse aggregate            |              |        |
| Specific gravity            | ASTM C 127-84| 2.59   |
| Los Angeles abrasion (%)     | ASTM C 131-76| 24.93  |
| Water absorption (%)        | ASTM C 127-84| 2.15   |
| Fine aggregate              |              |        |
| Specific gravity            | ASTM C 127-84| 2.50   |
| Water absorption (%)        | ASTM C 127-84| 2.14   |
3.2. Marshall test result

One of the Marshall test results is stability, the function of measuring this stability parameter is to determine the maximum ability of the asphalt mixture specimen to withstand loads until plastic melting occurs which is stated in load units. The results of the Marshall stability test for the three types of mixtures can be seen in Figure 1.

![Figure 1. Marshall stability of porous asphalt](image)

It can be seen that MJ has a trend of decreasing stability values with higher asphalt content and the highest value of stability is 871.22 kg at 4.5% asphalt content. For MA, the trend of the stability value is decreasing along with the increase in asphalt content with the highest stability value of 644.84 kg at 4.0% asphalt content. Whereas in MI, the trend of the stability value was increasing with the increase in asphalt content with the highest stability value of 627.22 kg at 6% asphalt content. Based on its stability,

![Figure 2. Porosity of porous asphalt](image)
when comparing the three types of mixtures, the use of Majalengka aggregate for porous asphalt mixtures is more suitable for mixing porous asphalt using Japanese gradations.

As for porosity (VIM, %), the test results can be seen in Figure 2. Porosity is the presentation of the pores or air cavities contained in a mixture and the main factor in the porous asphalt mixture because these pores are the comparison with other asphalt mixtures. Based on the ministry of public works and public housing of the Republic of Indonesia, (KemenPUPERA, 2012) porous asphalt specifications, the minimum VIM value is 17% and the maximum VIM value is 23%. When compared to the three types of mixtures, it can be seen that MJ and MA will produce porosity according to specifications at an asphalt content that is smaller than the asphalt content required by MI. From the results of the Marshall test, with stability and porosity parameters, the OBC value was obtained. The OBC for each type of mixture is:

- OBC MJ : 4.00 %
- OBC MA : 4.50 %
- OBC MI : 5.25 %

3.3. Cantabro loss test result
The cantabro loss test in this study uses a Los Angeles machine without steel balls, by doing this test it can be seen the amount of weight loss of the test object where the smaller the weight loss that occurs indicates the higher the resistance of the test object. The results of the cantabro loss test in this study can be seen in Table 5. Based on this table, it can be seen that the mixture with the smallest cantabro loss (CL) percentage value is MI mixture. So that if based on the cantabro loss parameter, Majalengka aggregate is more suitable for Indonesian graded porous asphalt mixtures.

### Table 5. Cantabro loss of porous asphalt

| Mixture Type | Sample number | CL (%) |
|--------------|---------------|--------|
| MJ           | 1             | 29.01  |
|              | 2             | 24.93  |
|              | 3             | 22.40  |
| MA           | 1             | 39.04  |
|              | 2             | 43.23  |
|              | 3             | 38.00  |
| MI           | 1             | 28.26  |
|              | 2             | 21.49  |
|              | 3             | 20.45  |

3.4. Permeability
The permeability value calculated in this study is the permeability value of each type of porous asphalt mixture under OBC conditions. The permeability value of the porous asphalt mixture is shown in Table 5. Based on the permeability data of the three types of porous asphalt mixtures, it can be seen that all types of mixtures have low permeability values. The value of the highest permeability coefficient is MI, when viewed from its permeability value, the Majalengka aggregate is better off using Indonesian grading.
Table 6. Permeability of porous asphalt

| Sample | Thickness, T(cm) | Porosity, Va (%) | Permeability Coefficient, K (cm/s) | Notes      |
|--------|------------------|------------------|----------------------------------|------------|
| MJ     | 7.51             | 17.00            | 4.05 x 10^{-5}                   | low permeability |
| MA     | 7.10             | 17.00            | 4.18 x 10^{-5}                   | low permeability |
| MI     | 7.33             | 18.42            | 4.64 x 10^{-5}                   | low permeability |

4. Conclusion

The performance of environmentally friendly porous asphalt mixture showed high stability, high permeability, and low cantabro loss. Locally produced aggregate from Majalengka with Indonesian grading gave the highest permeability and the lowest cantabro loss value than other types of mixtures. Thus, porous asphalt mixture using Majalengka aggregate with Indonesian grading will enhance stormwater absorption and represent an environmentally friendly porous asphalt mixture.

References

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