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EVALUATION OF POROUS HOTMIX ASPHALT PERFORMANCE UNDER ACCELERATED LOADING

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ABSTRACT: The purpose of the study is to evaluate the performance of porous hot mix asphalt under accelerated loading. The parameters measured were stresses and deformation (rutting) occurred in the test section. To achieve the objective, a test section was constructed and tested with a loading device, simulating truck loading. Subbase and base layers were constructed using similar materials. The variable is on the surface layers, which consist of two conventional and two porous hotmix asphalt. The pavement material conforms to the Indonesian Directorate General of Highway for the conventional HMA and Australian standard for Porous HMA. The thickness of the test section was prepared to simulate the real condition of the pavement structure. The simulated load applied to the pavement test section was equivalent to the 9,600 kg, which was more than the standard 8,160 kg axle load, and applied for more than 1,500 passes. For every 100 passes, stresses and deformation were recorded. The result shows porous HMA relatively has a comparable performance when compared to the conventional one. Hence, the application of porous HMA needs to be pushed particularly in the area where rain intensity is high.

Keywords: Porous HMA, Hotmix Asphalt, Accelerated loading, Gilsonite

1. INTRODUCTION

The development of urban areas in Indonesia in recent years has shown a significant increase. By some estimates, in 2050 there will be about 160 million people living in urban areas [1]. This rapid increase has led to changes in the land use. Many farmlands and open areas have been converted to residential and business areas. The real consequence of this condition is a reduction of open land and its ability to infiltrate water into the ground, particularly during rainy season. In addition to the flooding during the rainy seasons, this condition has also caused depletion of the underground water reservoir. This phenomenon has become common in some large and medium cities in Indonesia.

Meanwhile, the importance of a sound infrastructure condition in supporting the economic development is undisputable. Countries investing more for betterment of infrastructure, particularly highway infrastructure, usually become more competitive and provide multiplier effect for their economic development. However, inability to truly understand the behavior of pavement, overloading, and climate condition also have a role in road deterioration. As a country positioned in the equatorial lines, Indonesia experiences heavy rain almost 6 months in a year. As such, the most factors causing deterioration is due to water. Therefore, in order for the road construction to contribute to the water conservation program, it is necessary to modify the design, i.e, it should allow water to enter the road structure without damaging it. One may use the porous pavement.

Porous pavement allows to penetrate the structure [2]. The use of porous pavement has actually been practiced since the 1960s in Europe for the construction of airport runway [3]. Currently about 90% of the construction of new road network in the Netherlands have adopted porous pavement [4]. The road rehabilitation policy in Japan is directed toward the use of porous pavement [5]. Studies by Collins, et al found that the use of porous pavement reduces peak flow rate of runoff (peak flow rate) from 52% to 81% [6]. In addition, the use of porous pavement has also reduced the volume of tracks that vary from 38% to 78%. Djakfar, et al, studied the base course gradation that provides the best infiltrating performance without significantly reducing its structural performance [7]. However, until recently the use of porous pavement is still mostly under testing condition, in which its performance still needs to be investigated.

Another challenge for the pavement evaluation is its ability to evaluate the pavement performance before being constructed in the field. Previous efforts have been made on pavement works as well as composite materials. [8,9]. Louisiana Transportation Research Center has constructed an Accelerate Loading Facilities (ALF) in order to evaluate the performance of several types of pavement materials [10]. Bonaquist et al. [11] used the ALF to evaluate the effects of tire pressure on flexible pavement response and performance. Sebaaly et al. [12] used data from previous ALF research to evaluate relationships between surface cracking and the structural capacity of both thin and thick pavements. Kadar [13] used the ALF test results to assess the relative performance of a variety of asphalt surface types for pavement rehabilitation. Johnson-Clark et al. [14] employed the ALF to investigate the effectiveness of a geotextile reinforced seal between the subgrade and gravel layers to rehabilitate low volume roads.

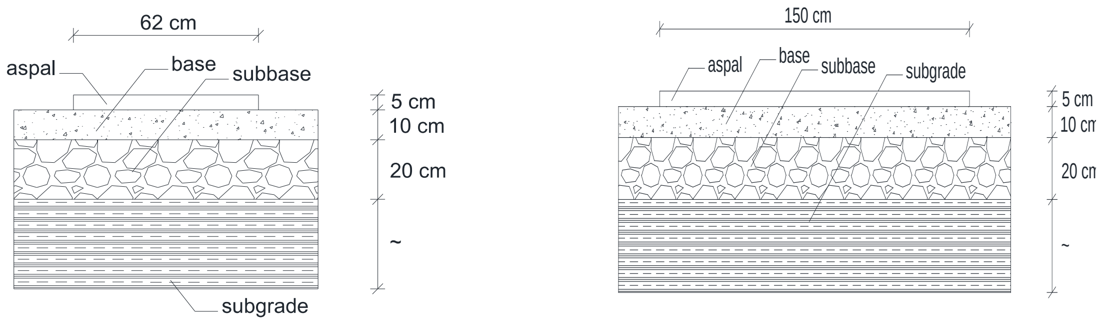
Several researchers have also developed and utilized accelerated pavement testing to investigate the performance of some pavement materials. Tang et al [15] used Model Mobile Load Simulator (MMLS3) to investigate the use of geogrids for subgrade stabilization in flexible pavements. Al Qadi et al. [16] investigated the effect of various tire configurations on Geogrid-reinforced low-volume flexible pavement using the mobile Accelerated Testing Loading Assembly (ATLAS) housed at University of Illinois at Urbana-Champaign.

Although accelerated loading equipment has been developed in many institutions, however, not many highway departments particularly in developing countries have used it, due to cost consideration. Therefore, simpler and modest equipment need to be developed. Djakfar et al [8] has developed such equipment, although until recently it is still under development and improvement. This equipment can be used to evaluate the performance of pavement under accelerated loading.

In this research, the researchers would like to compare the performance of conventional hotmix asphalt and porous hotmix asphalt under accelerated loading. The objective of the study is to evaluate the performance of conventional and porous asphalt when subjected to accelerated loading.

2. METHODS

To achieve the objective, a test section was constructed with configuration as shown in Figure 1. Since the focus of the research was on the surface layer, the base and subbase layer were kept constant. Therefore, only one section was constructed for the subbase and base, while fours surface layers consisting of two conventional HMA and two porous HMA were prepared. Figure 2 presents the subbase and base construction, while Figure 3 presents the preparation process of surface layers.



(a) (b)

Fig. 1. Dimension of pavement structure constructed at the test section. (a) cross section, (b) long section

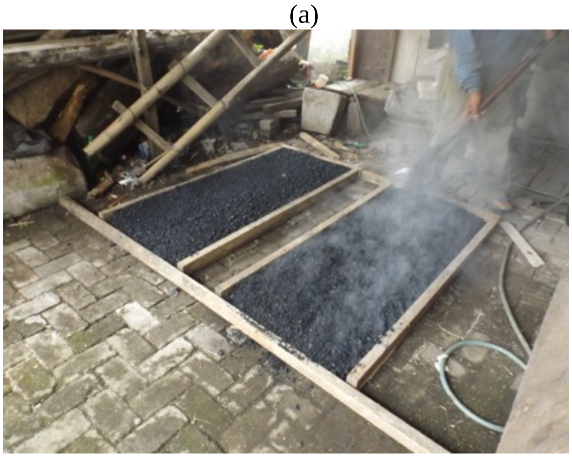
The thickness of base and subbase section was prepared simulating the common dimension encountered in the field, while the thickness of the surface was 3 cm. The reason of using 3 cm thick of surface material in the test section is to ensure that the strain gauge installed beneath each layer can respond and read the signal caused of the applied load. Since this is the preliminary testing, the researchers would like to make sure that the strain gauges could function as intended, by using a thinner surface course.

Materials. Materials used to construct the test section consist of Class A for base and Class B for subbase and conform to the Indonesian Directorate General of Highway (IDGH) Specifications. Tables 1 and 2 present the material characteristics for base and surface course. The conventional HMA surface course was designed to conform to the Specification requirement of the IDGH Specs, while porous HMA surface course was designed based on porous asphalt specification with 8% Gilsonite additive, since previous research showed that adding the Gilsonite additive increases the stability up to 800 kg without significantly reducing its permeability capability, as shown in Table 2 [17]. The pavement was constructed on the sandy soil subgrade with 10% CBR.

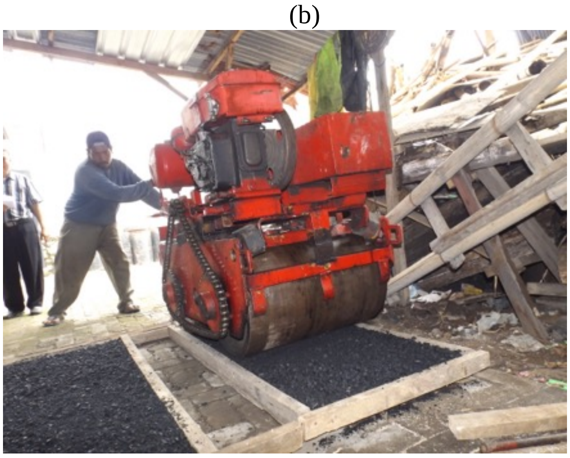
Fig. 2. Installation of strain gauges in base layer of the test section

(a)

(b)



(c)



(d)

Fig. 3. Preparation of asphalt layers (conventional and porous HMA) used in the test section, (a) preparation of asphalt formwork, (b) pouring asphalt layer to the formwork, (c) preparation of asphalt layer before being compacted, (d) asphalt layer compaction process.

Table 1. Unit weight and CBR of the subgrade, base and subbase materials

Layer	Unit Weight (gr/cm^3)		CBR (%)
	Laboratory	Field	
Subbase	1.80	1.83	75
Base	1.79	1.69	82
Subgrade	1.57		15

Installation of the strain gauge. To record the strain and stress occurring in the pavement due to load, a set of strain gauge was installed between the surface and base course as shown in Figure 4. Figures 5 and 6 show the field installation of the strain gauges.

Table 2. Marshall characteristics of the surface course

Marshall Characteristics	Conventional HMA	Porous HMA
VIM	3%	8,1 %
Stability	1500 kg	805 kg
Flow	2,5 mm	3,8 mm
MQ	550 kg/mm	219 kg/mm

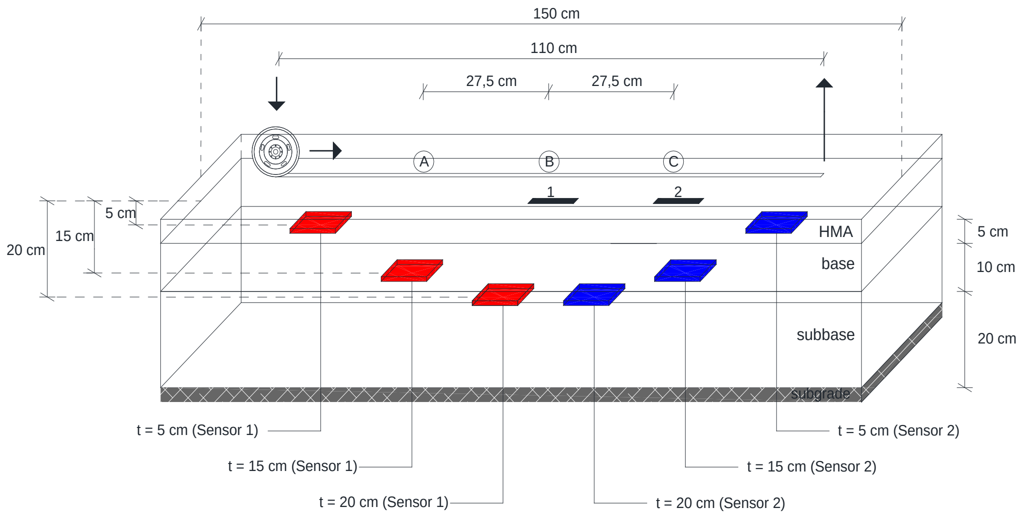


Fig. 4. Position of strain in the test section

(a)

(b)

Fig. 5. Strain gauge installation and operation. (a) installation of strain gauge in base layer, (b) soldering strain gauge to the cable connected to strain meter,

Loading Device. To simulate the traffic load, a loading device was developed as shown in Figure 7. The device can run at 3.2 km/h. The model test tire footprint is 1 cm x 1 cm with the applied load is 20 kg. The previous research used 17 kg, which is equivalent to the 8160 kg, a standard axle load [8,18]. In this research, the researchers used 20 kg, to simulate the overloading condition.

(a) (b)

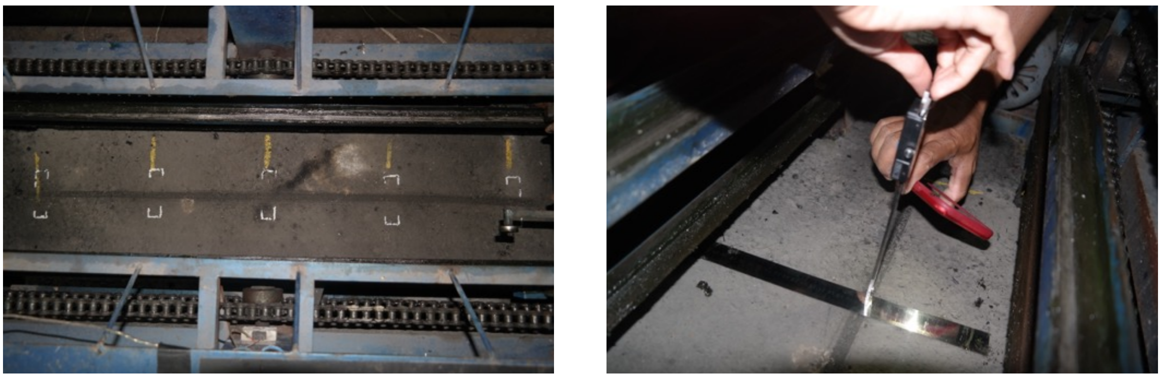
Fig. 6. Strain gauge operation and measurement. (a) strain meter used to measure the strain occurring in pavement, (d) connecting cable from strain gauge to strain meter

(a) (b)

Fig. 7. Loading device used to simulate traffic loading in the test section. (a) overall view of device, (b) loading mechanism of pavement

Deformation Measurement. To measure the deformation of the pavement after load applications, a caliper was used. The deformation was measured in 5 location as shown in Figure 8, and conducted every 100 passes of loading.

Post Test Evaluation. Each test section was loaded 5000 passes. After the load completion, a post evaluation was conducted to evaluate the pavement after loading. Figure 9 presents the post-test evaluation.



(a) (b)

Fig. 8. Deformation measurement; (a) location of deformation measurements, (b) measurement process

(a) (b)

Fig. 9. Post-test evaluation; (a) pavement test section, (b) tire condition

3. RESULTS

Figures 10 and 11 show the stress behavior of the test section with no moving load and with moving load condition, respectively. The stress was recorded using the stress meter.

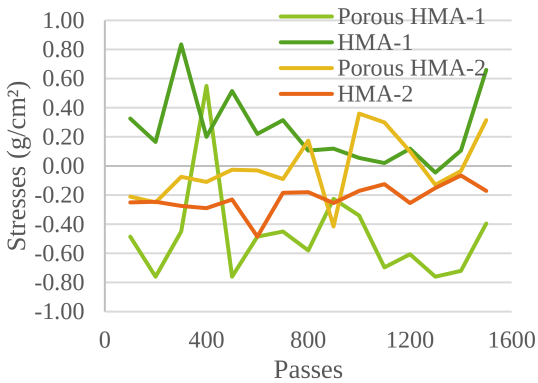


Fig. 10. Performance comparison of each test section in terms of stresses, measured every 100 passes with no moving load (static load) condition

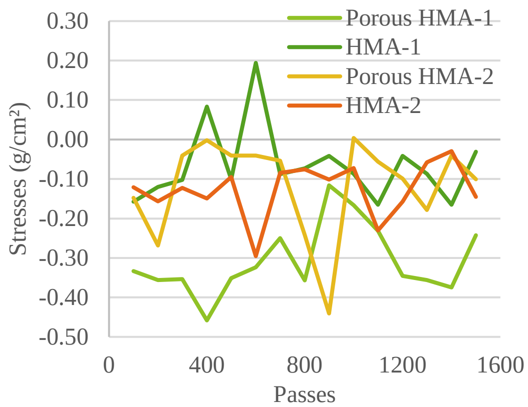


Fig. 11. Performance comparison of each test section in terms of stresses, measured every 100 passes with moving load condition

As shown in Figure 10, stress occurring in conventional HMA tend to be higher compared to the porous HMA. Although stresses recorded vary along passes, they generally tend to be constant with passes. Another important point from the result is when the trend in Figure 10 is compared with Figure 11. It shows that they have similar trend in which conventional HMA have higher stresses than porous HMA.

Figures 12 to 16 present the rutting or deformation occurring in the test section. As explained in the previous section, the measurement was conducted in 5 locations, as shown in Figure 8.

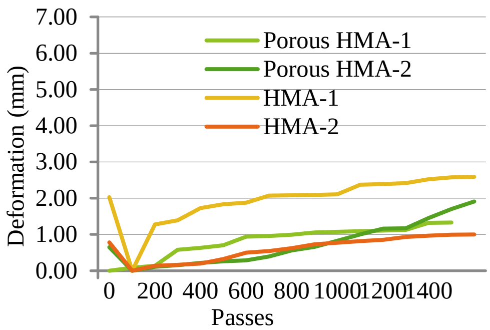


Fig. 12. Rutting development recorded at location 1

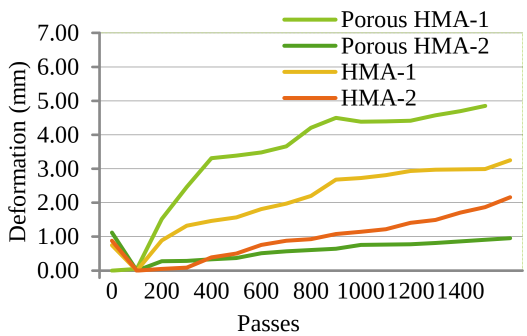


Fig. 13. Rutting development recorded at location 2

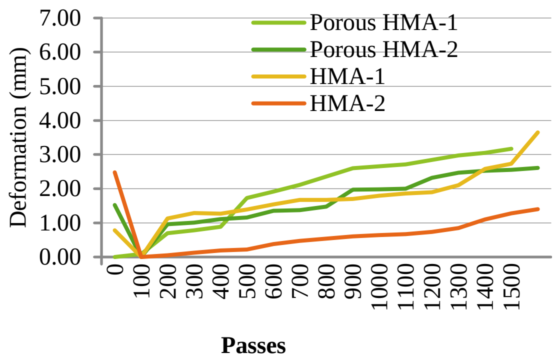


Fig. 14. Rutting development recorded at location 3

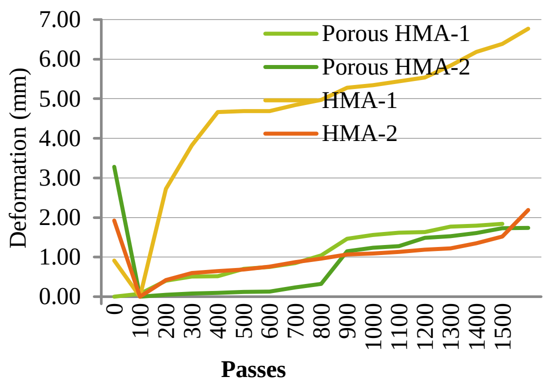


Fig. 15. Rutting development recorded at location 4

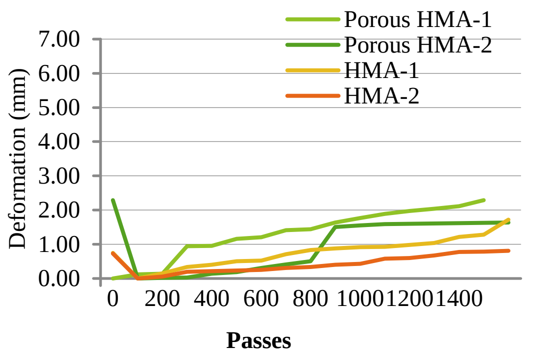


Fig. 16. Rutting development recorded at location 5

By examining the figures one may see that there are some similarities and differences on how at each location the sections responded to the applied load. In general, the response can be grouped into two: one is location 1 and 5, and the other is locations 2, 3, and 4. Rutting development that occurs at locations 1 and 5 tend to be smaller that those at locations 2, 3, and 4. It makes sense since locations 1 and 5 are located at the end of the test section in which the load just touched down and up at these locations. The load, which is operated using chain moves up and down cyclically. Hence, at the beginning of the test section the load may not freely go down the pavement. The similar pattern may also be true at the end of the loading cycle, where the chain drags the load up at near location 5. Therefore, the researchers believe that the rutting recorded in locations 2, 3, and 4 provide better data in simulating field condition, and more precisely, location 3, which is located in the middle of the test section should provide the better simulation.

As can be seen from Figures 12 to 16, rutting development in porous HMA tended to be higher compared to conventional HMA, except for location 1 and 4. This makes sense since porous pavement has slightly lower stability compared to conventional HMA. Generally, the rutting developed linearly as load passes increase. At location 2, the rutting development were higher than those with other locations. Plausible explanation on this case is that at location 2, it is close to the load touchdown, which may cause some additional load intensity due to impact load.

Figures 12 to 16 also show that although porous HMA has lower stability due to higher porosity in the mix, it still provides performance almost comparable to the conventional HMA. This is appealing particularly for the highway departments to start implementing porous HMA particularly in areas with lower traffic load by high rain intensity or prone to the hydroplaning, which matches with urban situation.

4. CONCLUSION AND RECOMMENDATION

The following conclusion can be drawn from the study:

a. The stress occurring in both conventional and porous pavement tends to constant at the constant loading.
b. The porous HMA has slightly lower performance compared to conventional HMA in terms of rutting.
c. Highway department may start implementing the porous HMA particularly in urban areas with lower load but high rain intensity and prone to hydroplaning.
d. The result presented in this paper is a preliminary one, further enhancement of the equipment and longer testing period is needed in order to better simulate the field behavior of pavement.
e. Future research is still needed to enhance the loading apparatus, particularly to automate the data acquisition

5. ACKNOWLEDGEMENTS

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