Performance of OGFC Using West Kalimantan Aggregates and Polymer Modified Bitumen

S. Mayuni, S. P. R. Wardani, and B. H. Setiadji

Abstract Open Graded Friction Course (OGFC) has been used as a permeable pavement in many countries. OGFC introduces safe road conditions as a pavement material compared to normal asphalt while facilitating the lateral and vertical drainage functions. In Indonesia, one type of OGFC researched to date is porous asphalt. This mix has an advantage in terms of its drainage function, but it lacks the ability to withstand against traffic loads. This research aims to see how binder content affected the performance of porous asphalt mixtures in order to create porous asphalt pavements that met structural and functional requirements. To do so, local aggregates from the West Kalimantan region and several contents of PG-76 polymer modified bitumen were used in this study. Marshall and Cantabro Loss tests were conducted to observe the structural performance, while volumetric properties were used to evaluate the functional performance. The outcomes of this study presents the insight of the relationship between the different content of the binder and the stability, durability, and voids content of the mixture.

Keywords Porous asphalt · Binder content · Stability · Durability · Voids content

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1 Introduction

OGFC (Open Graded Friction Course) as an open-graded pavement has been widely implemented in many developed and developing countries [1]. In Indonesia, commonly referred to as Porous Asphalt, is a thin layer of asphalt mixture placed on top of a conventional asphalt layer [2]. In other words, the open-graded porous asphalt is placed on top of the dense graded asphalt, as a drainage system that functions to remove rainwater that falls on the road surface. This layer has a structure with a high void content, which is 18% [3]. This serves as drainage during the rainy season, and as a safe road that can reduce the chances of hydroplaning [4], as well as overcoming the effects of sprays and splashes that interfere with the driver's view [5]. Coarse surfaces are also advantages in favor of road safety, good skid resistance which can prevent slippage between the road surface and the tire [6]. Widhianto et al. [6], Poulikakos and Partl [7] stated that porous asphalt is an environmentally friendly road construction technology, which can reduce noise and control rainwater puddles.

One country in Asia, Malaysia, which has a climate similar to Indonesia, started pioneering the application of porous asphalt in 1991 and officially announced the national specification standard in 2008. Malaysia succeeded in reducing the number of accidents and promoting porous asphalt as a safe road in the rainy season [8].

In addition to having advantages, porous asphalt mixture also has its drawbacks [9]. In terms of strength, it is generally lower than conventional dense graded asphalt. It has low stability which opens up a greater chance for deformation.

Structural performance and functional performance are the two main factors in the application of porous asphalt layers. High void content in an open-graded mix is needed to form a structure that can drain the water. Instead, mix with a high void content tend to have lower structural strength when compared with a dense-graded mixture [4].

Many cities in Indonesia having problems with puddles on the road due to heavy rainfall for a long time [1]. Djakfar et al. [10] recommend that structurally, porous asphalt mixtures can be used on roads with light traffic loads. In terms of void content, which is one of the functional performance parameters, the present invention is not adequate, because the void content (VIM 8.1%) produced does not meet specifications (18–23%).

Research development on porous asphalt mixtures in Indonesia is still limited. Djakfar et al. [11] suggested developing research with the approach of the material used. Several recent studies have experimented to improve the stability of the mixture by adding a variety of additives, powder, and fiber [10, 12–14]. The use of additives increases the interlocking so that the stability increases, but on the other hand it disturbs the permeable function.

For a long time, efforts to improve the performance and quality of porous asphalt mixtures have been continuously carried out with many studies in various countries, including the use of polymer modified asphalt [15], other modified asphalt [16], adding additives, including the use of fiber [17], or using coarser aggregate [18]. Cellulose fiber is one of the additives that are often used in studies of porous asphalt.

Adding 0.3–0.5% cellulose fiber to the OGFC mixture provides a good stability value compare to polypropylene fiber and polyester fiber [19]. In the Cantabro test, cellulose fibers significantly improved the behaviour, especially for porous asphalt mixtures with high binder content [20]. Polymer modified bitumen improves the adhesion between aggregate and the binder [21]. Like PG-76, it can increase the durability of the mixture [8]. This study tries to find the performance value of a porous asphalt mixture that meets the requirements, where the aim of the study is to determine the effect of different binder content on the value of stability, durability and voids content.

2 Experimental Program

2.1 Material Properties

The mixture contained of dry sieved aggregates with asphalt binder (PG-76) and 0.3% cellulose fiber. Indonesia Bina Marga Standard 2018 recommends 0.3% cellulose fiber for asphalt mixture [22]. The mixing temperature was 186 °C and at the temperature of 177 °C, 50 blows per side were applied. The temperature was determined based on the result of bitumen viscosity test. The aggregates were obtained from a crushed stone quarry in Sungai Kunyit, Kalimantan Barat, which is commonly used in Kalimantan Barat for asphalt mixture. Tables 1 and 2 demonstrate the physical properties of the modified asphalt (PG-76) and aggregate used in this analysis, respectively. All the material properties followed material quality specifications from Indonesia Bina Marga Standard 2018 [22].

Gradation has an important role in porous asphalt performance [23]. This study applies Australia porous asphalt gradation [24], which was recommended because it would create a mixture with the most homogenous void distribution and high enough permeability [25], with a little modifications where a 6.7 mm sieve is replaced by a 6.3 mm sieve, according to sieve availability (Table 3).

The sample of porous asphalt mixture was prepared using a Marshall Compactor with 4, 4.5, 5, 5.5 and 6% design binder content. Three specimens were tested for each binder content. The sample was compacted with 50 blows per side. After that,

Table 1 Properties of PG-76

Properties	Result	Requirement
Penetration at 25 °C (mm)	41.80	–
Softening point (°C)	66.50	≥ 48
Flash point (°C)	275.50	≥ 230
Ductility	101.67	≥ 100
Viscosity at 135 °C (CSt)	1587.65	≤ 3000
Specific gravity	1.119	≥ 1

Table 2 Properties of aggregate

Test	Result	Requirement
Los Angeles abrasion (%)	15.2	≤ 30
Flakiness (%)	1.29	≤ 5
Elongation (%)	1.49	≤ 5
Soundness (%)	5.93	≤ 12
Aggregate impact value (%)	6.00	≤ 30
Specific gravity	2.67	≥ 2.5
Water absorption (%)	0.37	≤ 3
Affinity for bitumen (%)	99	≥ 95

Table 3 Porous asphalt gradations (AAPA 2004 Modifications)

Sieve Size		Percentage passing (%)
ASTM	mm	
½”	12.7	100
3/8”	9.5	85–100
¼”	6.3	35–70
No. 4	4.75	20–45
No. 8	2.36	10–20
No. 16	1.18	6–14
No. 30	0.60	5–10
No. 50	0.30	4–8
No. 100	0.150	3–7
No. 200	0.075	2–5

the compacted samples were tested for volumetric properties (air void content) and mechanical performance using Stability Marshall and Cantabro tests. According to ASTM D1559, the Stability Marshall Test is used to assess the stability value of porous asphalt mixtures, which shows the strength of the samples. According to ASTM D7064, the Cantabro Test is used to determine the particle loss of porous asphalt mixtures, which indicates sample durability. Figure 1 illustrates the specimens with 4–6% binder content.

2.1.1 Volumetric Properties

Volumetric parameters depend on the mixture’s Bulk Specific Gravity (Gmb) and the Theoretical Maximum Specific Gravity (Gmm).

- *Theoretical Maximum Specific Gravity (Gmm).* According to ASTM 2041–11, maximum theoretical specific gravity is a virtual value reflecting a compressed sample without air voids.

Fig. 1 Specimen of porous asphalt

- *Bulk Specific Gravity of Mix (Gmb).* According to ASTM D3203-11, the bulk specific gravity of the compacted mixture is determined by the specimen's geometric measurements.

Air voids (%). Air voids content, commonly lies between 18 and 23%, is one of porous asphalt mixture's most significant parameters. In porous asphalt, Av (air voids) are calculated as [26]

$$\mathrm{Av} = \left(1 - \frac{\mathrm{Gmb}}{\mathrm{Gmm}}\right).100\% \tag{1}$$

2.1.2 Cantabro Loss Test

The durability of porous asphalt was assessed in terms of its resistance to abrasion loss. The Cantabro loss test is a special porous asphalt test commonly used to determine mixture resistance to particle loss from traffic impact and abrasion, as well as stripping resistance [27]. The procedures described by Jimenez and Perez (1990) [28] were used as the test method. In The Los Angeles Abrasion Machine, the compacted porous asphalt samples were subjected to 300 revolutions at 30 rpm, without the charge of steel spheres. Then, the mass loss percentage determined the sample's resistance to abrasion. Specimens and Loss Angeles Machine are shown in Fig. 2. The following equation determines the test result.

$$\mathrm{P} = \left[\frac{\mathrm{P1} - \mathrm{P2}}{\mathrm{P1}}\right].100\% \tag{2}$$

(a) Los Angeles Abrasion Machine

(b) Weighing specimen after Cantabro Loss Test

(c) Weighing specimen before Cantabro Loss Test

Fig. 2 Cantabro loss test

where: P = Cantabro abrasion loss (%).

P1 = initial weight of the sample (gram).

P2 = final weight of the sample (gram).

2.1.3 Marshall Test

Marshall test was used to determine the porous asphalt compacted sample's stability value. Stability indicates one of porous asphalt's most important structural performance and a measure of the asphalt layer's ability to resist deformation and distortion cause of traffic loads such as corrugation and rutting.

3 Result and Discussion

Table 4 and Fig. 3 display the values of the test, especially the value of stability

Table 4 Effect of binder content on porous asphalt performance

Binder content (%)	Stability (kg)	Cantabro loss (%)	Voids content (%)
4	418.81	46.1	22.29
4.5	512.54	24.09	21.77
5	567.81	14.19	21.07
5.5	525	5	18.6
6	466.07	3.58	17.65
Australian Standard	> 500	< 30	18–23

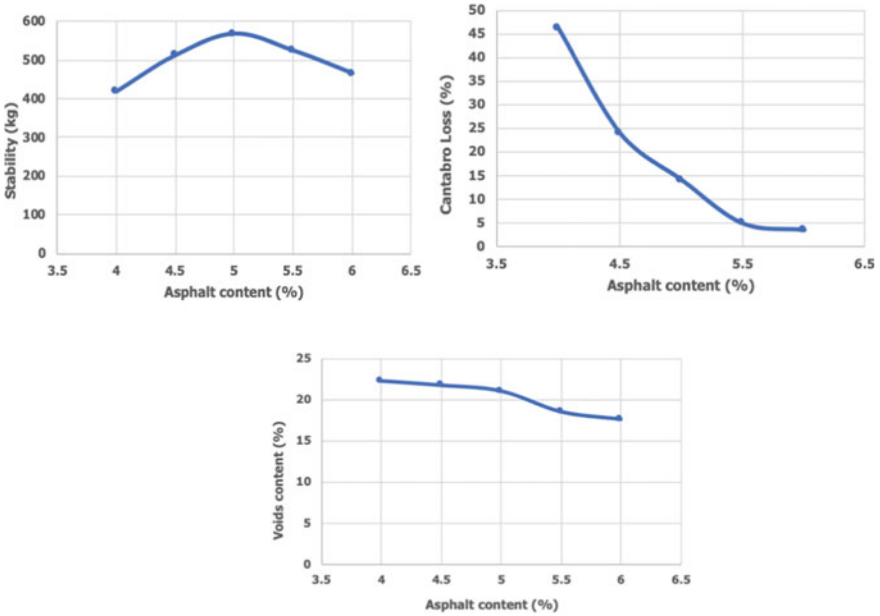

Fig. 3 Effect of binder content on porous asphalt performance

and Cantabro Loss as structural performance, and voids content as functional performance which follows Australia porous asphalt specifications [24]. It can be seen that the highest stability is achieved 567.81 kg in the mixture with 5% binder content. However, the 4.5 and 5.5% binder content mixture still meets the specifications.

The trend shows that as the binder content is increased, the durability is increased. The best durability is indicated by the smallest Cantabro Loss value, 3.58%; the result of a mixture with asphalt content of 6%, but in terms of stability and voids content do not meet the specification of porous asphalt mixture.

The trend shows that as the binder content is increased, the voids content is decreased. The mixture with 4–5.5% binder content has the voids content that meets the requirements (18–23%). Porous asphalt mixtures with open grading tend to have low strength and low durability as a result of relatively low interlocking due to high voids content, so the minimum voids content needs to be considered provided the structural performance records meet the specifications. The test results show that the voids content meet the requirements at the minimum value (18.6%) is produced by 5.5% binder content of porous asphalt mixtures, which the structural performance is eligible and meets the specifications; stability 525 kg and the Cantabro Loss 5% indicates that the mixture has high durability. The results of this study can be compared with studies in Malaysia [29] (Table 5). Although this study recommends a higher binder content than the Malaysian porous asphalt mixture, it has a better voids content which is closer to the minimum specifications, as well as better durability.

Table 5 Porous asphalt performance with polymer-modified bitumen PG-76

Year	Country	Additives	Binder content (%)	Stability	Voids content (%)	Cantabro loss (%)
2019	Malaysia	Mineral filler	5	–	21.7	6.1
2021	Indonesia	Cellulosa fiber	5.5	525 kg	18.6	5

4 Conclusions

This study evaluates porous asphalt's performance at varying binder content. Based on the findings, it can be concluded that different asphalt content affects the final product's volumetric and mechanical properties. As the binder content increases, porous asphalt's resistance against abrasion loss also increased. Decreased voids content due to the increasing of binder content, but can be seen best voids content was approaching the minimum requirements (18.6%). Then it can be recommended that the asphalt porous used aggregate of West Kalimantan with 5.5% polymer modified bitumen PG-76 and 0.3% cellulose fiber, which resulted in the performance of porous asphalt with 18.6% voids content and 5% Cantabro Loss, as well as the stability of 525 kg on the road with the light to the medium traffic load.

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