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Permeability and Dynamic Stability in Porous Asphalt Mixtures Using Cariphalte Asphalt and Gilsonite Additives

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ABSTRACT

Porous asphalt mixture is a new generation of flexible pavement that allows water to seep into the top layer (wearing course) both vertically and horizontally. This condition is possible, because the gradation used has a coarse aggregate fraction of not less than 85% of the mixture volume. This layer uses an open gradation (open graded) which is spread over a layer of waterproof asphalt to prevent seepage into the road foundation. This porous asphalt layer can effectively provide a greater level of safety, especially during rainy times to prevent aqua-planing, resulting in rougher surface roughness and can reduce noise (noise reduction). In this research, a test will be carried out on porous asphalt with a mixture using Cariphalte modified asphalt and gilsonite as the added ingredient. Variations in asphalt content used are 4%, 5%, 6%, 7%, 8%. Determination of variations in levels of variation is based on research that has been conducted. This research involves analysis of calculation results based on experimental data from laboratory scale experiments including Marshall Testing, Immersion Index, Permeability, Slip Resistance, Dynamic Stability, and Resilient Modulus. The test results show that the smallest permeability value is in the 8% gilsonite mixture but it does not meet the requirements of AAPA 2004 so the mixture with the greatest stability value is used. From the results of dynamic stability testing, it shows that the mixture of test objects with a content of 7% gilsonite has a dynamic stability value of 5250 passes/mm at a temperature of 45°C and 3150 passes/mm at a temperature of 60°

Keywords: *Porous Asphalt, Permeability, Dynamic Stability, Resilient Modulus*

INTRODUCTION

Porous asphalt mixture is a new generation in flexible pavement that allows water to seep into the top layer (wearing course) both vertically and horizontally. This condition is possible because the gradation used has a coarse aggregate fraction of not less than 85% of the mixture volume. This layer uses open graded gradation which is spread over a waterproof asphalt layer so that there is no seepage into the road foundation. This porous asphalt layer can effectively provide a higher level of safety, especially during rainy seasons so that aqua-planing does not occur, resulting in a rougher surface roughness and can reduce noise (noise reduction) [1]. Porous asphalt mixture is designed to obtain interconnected cavities with high permeability. Thus, water can easily enter the pavement structure and be transferred from the surface and then flowed towards the shoulder of the road [2]. The ability of porous asphalt as a drainage system can reduce the life of the pavement structure. The accumulation of fine material and dust in the surface cavities can reduce the ability of water flow. Porous pavement structures are a new technology, built for low traffic volume road sections, vehicle parking facilities, bicycle paths, pedestrian facilities/sidewalks and tennis courts, as an alternative water management technique or superior management practice [3].

Herrington, P., & Alabaster, D. (2008) conducted a study to evaluate the performance of porous asphalt using 3 gradations, namely Australia, California, and British. In terms of characteristic specifications used is the Australian standard. Test specimens were made as many as 12 pieces per gradation with asphalt content variations between 4% - 7%. The optimum asphalt content obtained was used in making 12 test specimens with Wetfix-Be additives. The Wetfix-be content used ranged from 0.2% - 0.5%. The test specimens were used for permeability testing using the falling head method. The results of the study using 3 gradations can be concluded that the Australian standard produces a higher permeability coefficient value than the California and British gradations. The characteristics of the Marshall standard, namely VIM, Flow, and MQ Australian and California standards meet the requirements, while the stability does not meet [4].

Legret et al., (2008) conducted a study on the effect of adding additives on marshall performance in porous asphalt mixtures by comparing additives between gilsonite and latex. The results of the study obtained the flow rate value of the porous asphalt mixture with gilsonite additives of 910 cm3/second, the stability obtained was 937 kg with an optimum gilsonite content of 9%, while the stability value of the porous asphalt mixture with latex additives obtained a flow rate of 1024 cm3/second, stability of 627 kg and an optimum latex content of 2% [5].

Li, M., Xu, B., (2016) conducted a study on the effect of marshall compaction on the stability and volumetric properties of the mixture using cariphalte asphalt. The results of the study produced stability values for the Cariphalte asphalt mixture and conventional asphalt penetration 80/100 respectively of 2078.33 kg and 1853.07 kg with the same amount of compaction, namely 75 blows. The results of this study show that the use of cariphalte modified asphalt provides a relatively greater stability value compared to conventional asphalt, a difference of 225.26 Kg [6].

Kuznetsov, D., Visotskaya, M., & Agamijan, B. (2014) in their research discussed the mechanical properties (Rheology) of Cariphalte-based modified asphalt (Superior Performing Asphalt Pavement) through Dynamic Shear Rheometer testing, a comparative analysis of two anti-fatigue properties of asphalt with different temperatures. Rheology is the relationship between stress and strain that is influenced by time. The results show that compared to 70# shell asphalt, cariphalte-modified asphalt has better rutting resistance over a wide temperature range, better resistance to permanent deformation and better resistance to fatigue at low temperatures. From the previous studies, research will be conducted to follow up on existing research. In this study, testing will be carried out on porous asphalt with a mixture using Cariphalte-modified asphalt and gilsonite additives. The variations in asphalt content used are 4%, 5%, 6%, 7%, 8%. The determination of the variation levels is based on research that has been conducted [7].

METHOD

Research on asphalt mixtures uses testing methods on several test objects tested at the Bandung Road and Bridge Research and Development Center, PUSJATAN. The additional ingredient used in the asphalt mixture is gilsonite.

Immersion Index Testing

Marshall Immersion Index Testing aims to measure the residual strength of a mixture due to the influence of water and temperature. In this test, the asphalt mixture will be immersed in water at a temperature of 60°C for 30 minutes (standard conditions) and 24 hours. The residual strength value of the hot asphalt mixture is obtained from the comparison between the stability obtained from the test object immersed for 30 minutes with the test object that has been immersed for 24 hours. The residual value is obtained in percent units called the Residual Strength Index (RSI). Based on the AAPA 2004 standard for specifications for testing the Immersion Index of porous asphalt mixtures is not written in the requirements [8].

Permeability Testing

Permeability testing aims to determine the ability of water to flow or pass through the asphalt mixture. Permeability testing in this study uses a falling head tool that produces a permeability coefficient value in cm/second. The asphalt content used in this test is 4%, 5%, 6%, 7% and 8%.

Skid Resistance Testing

Skid resistance testing is the force generated between the road surface and the vehicle tires to compensate for the forward motion of the vehicle when braking. The skid resistance value is influenced by the depth of the surface texture (texture depth) of the road pavement [9]. This study aims to determine the skid resistance value and the depth of the flexible pavement surface texture and how the correlation between the two. Measurement of the pavement surface skid resistance value was carried out using the British Pendulum Tester (BPT) based on SNI 4427:2008.

Dynamic Stability Testing

This test is conducted to provide an overview of the mixture's resistance to withstand wheel tracks and changes in shape that will be received by the pavement in the field. The ability to withstand wheel tracks is expressed by dynamic stability using the Wheel Tracking tool. Testing is conducted at temperatures of 45°C and 60°C using the optimum asphalt and gilsonite content for each gradation [10]. The parameters obtained from the permanent deformation test are dynamic stability, deformation rate and total deformation.

Figure 1. Test Objects and Wheel Tracking Test Equipment

Resilient Modulus Testing

Resilient Modulus is one of the parameters used for planning and evaluating the performance of asphalt mixtures. Because asphalt mixtures are materials that are not perfectly elastic, the terminology of elastic modulus (E) is not suitable and instead the term Resilient Modulus (MR) is used. The Resilient Modulus value is obtained from laboratory testing using the Universal Material Testing Apparatus (UMATTA). The Resilient Modulus test is carried out at a range of temperatures and loading frequencies to simulate environmental conditions and traffic loads in the field [11].

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RESULTS AND DISCUSSION

Immersion Index Test Results

The residual strength value of the porous asphalt mixture is obtained from the comparison between the stability obtained from the test object soaked for 30 minutes with the test object soaked for 24 hours. This immersion aims to measure the residual strength of a mixture due to the influence of water and temperature [12]. In this test, the asphalt mixture will be soaked in water with a temperature of 60oC for 30 minutes (standard conditions) and 24 hours. The Immersion Index test procedure follows the SNI M-58-1990 reference. To evaluate the durability of the mixture, it can be known by the Immersion Index, namely by comparing the stability that is soaked with the standard stability. The residual value is obtained in percent units which are referred to as the Residual Strength Index (IKS). Based on the AAPA 2004 standard, the specifications for testing the immersion index of porous asphalt mixtures are not written in the requirements. The results of the immersion index test on this mixture are obtained as follows.

Table 1. Marshall Stability Values of Mixtures with Variations in Gilsonite Content

Asphalt Content (%)	**Stability**					
	Gilsonite Content (%)					
	0	**4**	**5**	**6**	**7**	**8**
4.5	666.45	650.21	678.39	698.00	700.10	712.88
5.0	694.58	697.76	700.20	720.10	724.85	744.62
5.5	736.67	748.70	753.55	769.56	787.90	767.10
6.0	712.35	719.34	734.66	740.20	760.00	750.40

Table 2. Residual Stability Values of Immersion Index Testing with Gilsonite Variations

Stability After Immersion (Kg)	**Gilsonite Content (%)**					
	0%	**4%**	**5%**	**6%**	**7%**	**8%**
Immersion for 30 minutes	238,19	633,08	644,29	653,29	716,81	756,77
Immersion for 24 hours	198,38	529,05	532,63	558,29	523,49	542,21
Residual Stability	78,37%	81,28%	82,80%	84,59%	73,09%	71,47%

Based on Table 2 above, the residual stability value tends to increase along with the increasing gilsonite content. The highest Residual Strength Index (RSI) is with the use of 8% gilsonite. At a content of 5% gilsonite, the residual stability value begins to decrease. The Residual Strength Index value indicates the amount of stability that is still possessed by the mixture after being affected by water from soaking for a certain period of time. The higher the RSI value indicates the better durability potential of the mixture. With the use of 0% gilsonite, the residual stability value obtained was 78.37% and with the use of 8% gilsonite, it was 82.47%. Thus, the residual stability value of the mixture with the use of 8% using the Australian gradation decreased by 8.8%.

Mixture Permeability Test Results

Permeability testing aims to determine the ability of water to flow or pass through the asphalt mixture. Permeability testing in this study used a falling head tool that produces a permeability coefficient value in cm/second [13]. The optimum asphalt content used in this test is 5.5%. Based on the requirements of the Australian Asphalt Pavement Association 2004, the permitted permeability coefficient value is 0.1 cm/second to 0.5 cm/second. The results of the Permeability Test can be seen in Table 3.

Table 3. Results of Mixture Permeability Testing at Optimum Asphalt Content

Optimum Asphalt Content (%)	Permeability Coefficient at Variation of Gilsonite Content (cm/sec)						AAPA 2004 Requirements
5,5	0%	4%	5%	6%	7%	8%	
	0,4219	0,3819	0,2548	0,1538	0,1027	0,0921	0,1- 0,5 cm/sec

Based on Table 3, the permeability value decreased along with the addition of gilsonite (Tetra Oktaviani, 2018). The overall permeability value of the porous asphalt mixture has met the requirements of the Australian Asphalt Pavement Association 2004 except for the gilsonite mixture content of 8% > 0.1 cm/sec so that it does not meet the requirements of AAPA 2004. The permeability value of the porous asphalt mixture is directly proportional to the VIM (Void in Mix) value. The smaller the VIM (Void in Mix), the smaller the permeability coefficient value produced by the porous asphalt mixture. Thus, it is proven that the smaller the voids in the mixture, the smaller the permeability coefficient value produced by the test object. Both of these values will be inversely proportional to the stability value of the mixture, where the smaller the voids in the mixture, the greater the stability value produced. The test results show that the smallest permeability value is in the 8% gilsonite mixture but does not meet the AAPA 2004 requirements, so a mixture with the largest stability value is used but still meets the existing permeability requirements, namely a mixture with a 7% gilsonite content which is then used in dynamic stability testing, slip resistance, and stiffness modulus.

Dynamic Stability Test Results of Mixtures

Dynamic stability/permanent deformation testing using a Wheel Tracking Machine was carried out to determine the amount of deformation that occurs due to continuous vehicle wheel loads. Testing was carried out at temperatures of 45 oC and 60 oC based on previous research conducted [14]. This temperature is the average annual pavement temperature in Indonesia based on the 2018 Highway Pavement Design Manual. Testing was carried out using the optimum asphalt content and the optimum gilsonite content with the highest Marshall stability value but still meeting the requirements for permeability and normal mixtures without gilsonite additives.

Table 4. WTM Test Results for Asphalt Mixtures with 5.5% and 0% Gilsonite Content

Time (minutes)	Tracks	Mixed Groove Depth Temperature 45°C	Temperature 60°C	Unit
0	0	0.00	0.00	mm
1	21	0.50	2.35	mm
5	105	1.68	3.73	mm
10	210	2.35	4.57	mm
15	315	2.68	5.18	mm
30	630	3.21	6.44	mm
45	945	3.68	7.28	mm
60	1260	3.93	7.87	mm
Deformation Speed		0.0167	0.0395	mm/min
Dynamic Stability		2520.0	1062.4	track/mm

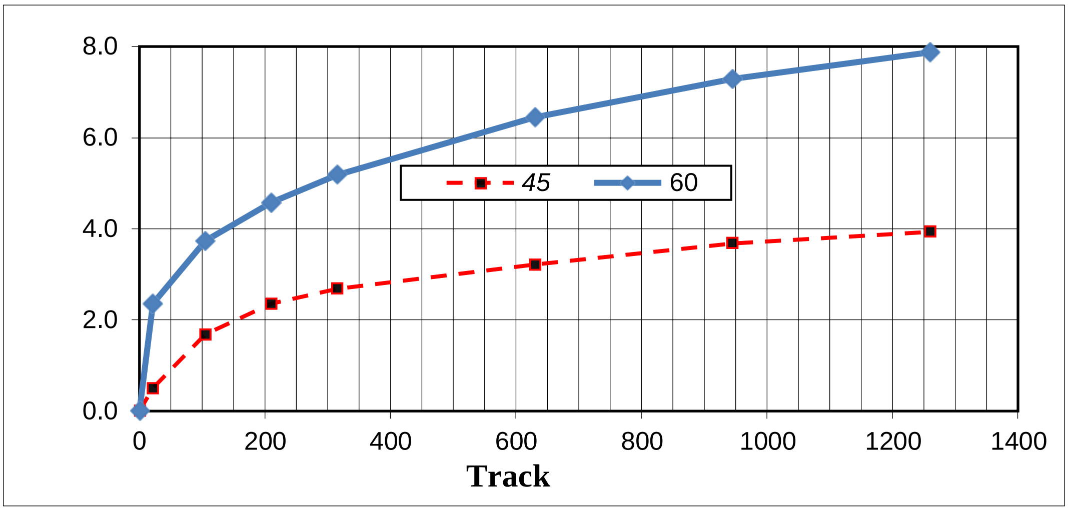

Figure 3. Dynamic Stability Value of Asphalt Mixture with 5.5% and 0% Gilsonite Content

Table 5. WTM Test Results for Asphalt Mixtures with 5.5% and 7% Gilsonite Content

Time (minutes)	Tracks	Mixed Groove Depth Temperature 45ºC	Temperature 60ºC	Unit
0	0	0.00	0.00	mm
1	21	0.29	0.09	mm
5	105	0.70	0.22	mm
10	210	1.08	0.26	mm
15	315	1.25	0.43	mm
30	630	1.56	0.80	mm
45	945	1.74	1.07	mm
60	1260	1.86	1.27	mm
Deformation Speed		0.0080	0.0133	mm/min
Dynamic Stability		5250	3150.0	track/mm

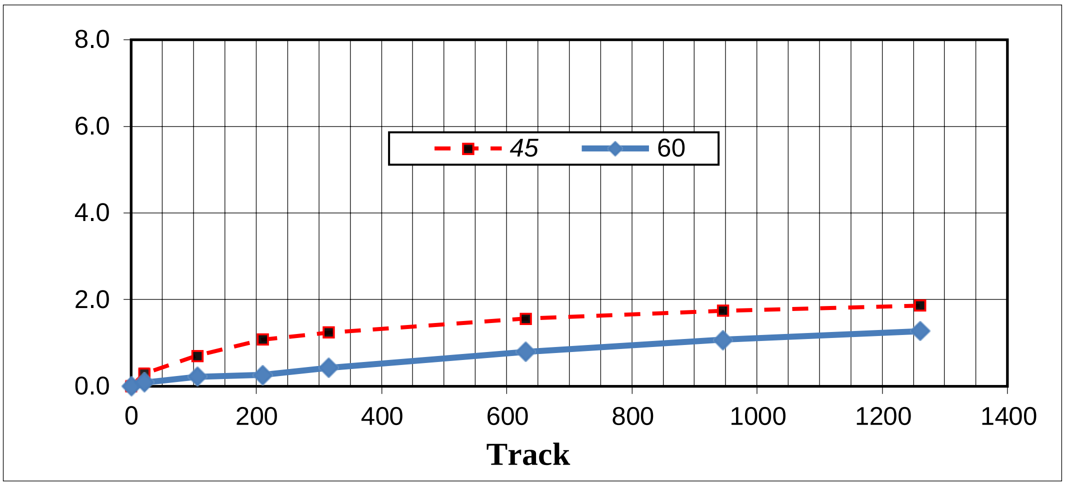

Figure 4. Dynamic Stability Value of Asphalt Mixture with 5.5% and 7% Gilsonite Content

Based on Figure 3 and Figure 4, the deformation velocity and dynamic stability values are obtained. The figure shows that the deformation velocity value is directly proportional to the temperature. As the temperature increases, the resulting deformation velocity value will increase. While the deformation velocity value is inversely proportional to the gilsonite content.

Along with the addition of gilsonite, the deformation value will decrease. The faster the deformation occurs, the deeper the groove produced on the test object. With these results, it can be proven that the addition of gilsonite will reduce the deformation velocity value that occurs so that the resulting rutting value is relatively small [15]. Table 4 and Table 5 also show the dynamic stability value. The mixture of test objects with a content of 7% gilsonite has a dynamic stability value of 5250 paths/mm at a temperature of 45°C and 3150 paths/mm at a temperature of 60°C. This dynamic stability value is higher than other porous asphalt mixtures. With the addition of gilsonite, it affects the resulting dynamic stability value. This shows that the mixture of test specimens with a 7% gilsonite content has better performance than the porous asphalt mixture without using gilsonite.

Skid Resistance Test Results

Skid resistance testing is carried out using the British Pendulum Tester. The value obtained from the test results is the skid resistance value in British Pendulum Number (BPN) units. Based on (SNI 4427:2008) the skid resistance value is shown in Table 6.

Table 6. BPN Correction Value

Temperature (°C)	Correction Value
<27	0
27-32	+1
32-37	+2
>37	+3

From the results of the sliding resistance test using the British Pendulum Tester (BPT), the sliding resistance value was obtained as shown in Table 7. The surface temperature of the test object was 30°C, so the correction value used was +1.

Table 7. Skid Resistance Test Results

No.	Mix Type	Surface Temperature (°C)	Average	Correction	BPN Value
1	5,5% Asphalt 0% gilsonite	30	61,2	1	62,2
2	5,5% Asphalt 7% gilsonite	30	64,8	1	65,8

Table 8. Minimum Value of Skid Resistance

Category	Location Type	Minimum Value of Skid Resistance
A	Difficult locations such as: Roundabouts; curves with a radius of <150 m on expressways; grades of 1:20 or steeper, with a length of >100 m; signalized intersection approach arms on expressways.	65
B	Main/fast roads, continuous and class 1 roads and heavy traffic roads in urban areas (>2000 vehicles per day)	55
C	Other locations	45

Note: For categories A and B where vehicle speeds are high (>95 km/h) an additional requirement is a minimum texture depth of 0.65 mm.

Based on Table 8, the BPN value obtained from the porous asphalt mixture using 7% gilsonite content has the largest slip resistance value of 65.8. This value, when compared with the existing standards as in Table 8, the resulting slip resistance value still meets the standards of the three existing categories.

Resilient Modulus Test Results

Takahashi, S., & Partl, M. N. (2001) explained that the stiffness modulus is a modulus based on the recoverable strain due to repeated loads. The higher the stiffness modulus value, the less the shape changes that occur when given a load. Temperature and loading time factors also affect the stiffness modulus value, where the higher the temperature, the smaller the stiffness modulus value [16]. The results of the test of the stiffness modulus of porous asphalt mixtures can be seen in Figure 5.

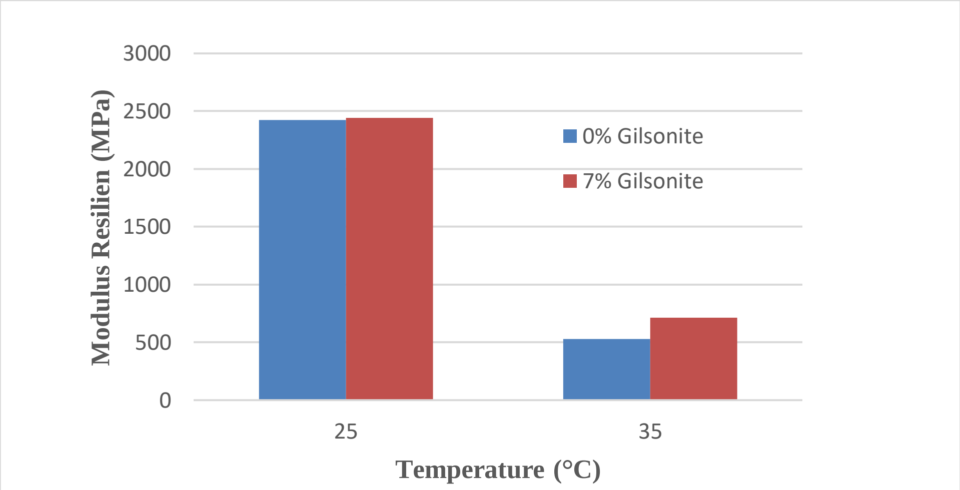

Figure 5. Stiffness Modulus Test Results

Based on Figure 5, the stiffness modulus value of the porous asphalt mixture using 7% gilsonite produces a value of 2,444 MPa at a temperature of 25°C. The stiffness modulus value of this mixture is higher than the porous asphalt mixture without using gilsonite. This shows that the porous asphalt mixture using 7% gilsonite is better than the porous asphalt mixture without using gilsonite at a temperature of 25°C and meets the requirements of the 2017 Pavement Design Manual (MDP) which is 1100 MPa.

Brown and Brunton (1984) stated that the structural value of the pavement can be expressed in the stiffness modulus of the asphalt aggregate mixture. This stiffness modulus is used to express a stress value divided by strain at a certain temperature and loading time due to dynamic vehicle traffic loads. Brown and Brunton also stated that the stiffness modulus value of the asphalt aggregate mixture is determined by the stiffness of the adhesive material (asphalt) and the aggregate gradation.

This UMATTA test was conducted according to ASTM 4123-82 with a test temperature of 25°C and 35°C. The modulus value for the asphalt concrete mixture using Pen asphalt ranges from 2000-2100 Mpa at a temperature of 25°C. While the modulus value of the porous asphalt mixture obtained in this study reached 2444 Mpa at the same temperature. In this test, the asphalt mixture used was PG-76 asphalt which from its constituent materials contains Styrene Butadine Styrene (SBS) which reduces susceptibility to temperature. In addition, this porous asphalt mixture uses gilsonite additives which reduce the sensitivity of the asphalt mixture to temperature.

When compared to asphalt concrete mixtures using Pen asphalt, the resulting stiffness modulus value is smaller. This happens because the Pen asphalt used does not have the property of being less susceptible to temperature. In this case, the temperature and loading time factors also affect the stiffness modulus value, where the higher the temperature, the smaller the stiffness modulus value.

The stiffness modulus value produced from the porous asphalt mixture using PG-76 asphalt and gilsonite is indeed greater than the ordinary asphalt concrete mixture. However, when viewed from the stability value of the mixture, the stability value of this porous asphalt mixture is much smaller than the stability value of the asphalt concrete mixture. The stability produced from the highest porous asphalt mixture only reaches 787 Kg while in the asphalt concrete mixture it reaches 1100 Kg.

This is because the temperature parameter does not affect the resulting stability value. The most influential parameter is the gradation of the mixture. Compared to porous asphalt mixtures whose gradation has many cavities, asphalt concrete has a denser and denser gradation. This is what causes the stability value of the resulting asphalt concrete to be higher.

CONCLUSION

The test results show that the smallest permeability value is in the 8% gilsonite mixture but does not meet the requirements of AAPA 2004 so a mixture with the largest stability value is used. The mixture of test objects with a content of 7% gilsonite has a dynamic stability value of 5250 lines/mm at a temperature of 45°C and 3150 lines/mm at a temperature of 60°C. This dynamic stability value is higher than other porous asphalt mixtures. With the addition of gilsonite, it affects the resulting dynamic stability value. This shows that the mixture of test objects with a content of 7% gilsonite has better performance than the porous asphalt mixture without using gilsonite. Based on the modulus value for the asphalt concrete mixture using Pen asphalt, it ranges from 2000-2100 Mpa at a temperature of 25°C, while the modulus value of the porous asphalt mixture obtained in this study reached 2444 Mpa at the same temperature. When compared to asphalt concrete mixtures using Pen asphalt, the resulting stiffness modulus value is smaller. This is because the Pen asphalt used does not have the property of being less susceptible to temperature.

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