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Study on the Characteristics of Japanese Gradation Porous Asphalt Using Modified Buton Asphalt

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ABSTRACT

This study aims to determine whether Japanese graded using local materials can meet the characteristics of porous asphalt and what is the optimum asphalt content in the Japanese Graded Porous Asphalt mixture Using Asphalt Retona Blend 55, the results of the study for Japanese graded porous asphalt mixtures using modified asphalt and existing local materials. In Jayapura, the asphalt content value of 5.5% met the specifications. From the parameters for the porous asphalt mixture, the optimum asphalt content value is 5.5% based on the Cantabro test with a value of 7.37%, and porosity testing of 18.093%, while the marshall characteristics are stability of 538.633 Kg, Flow of 2 mm and MQ is 272.433 Kg/mm and also permeability test is 0.466 cm/s, these values meet all specifications for porous asphalt mixtures.

Keywords: Porous Asphalt, Japanese Gradation, Asphalt Retona Blend 55

1. INTRODUCTION

Porous asphalt mixture is a new generation of flexible pavement, which allows water to seep into the top layer (wearing course) vertically and horizontally [1]. This layer uses an open-graded layer that is laid on top of a waterproof asphalt layer. This porous asphalt layer can effectively provide a higher level of safety, especially when it rains so that aquaplaning does not occur, resulting in rougher surface roughness, and can reduce noise (noise reduction) [2, 3].

According to [4], research evaluated the use of aggregate grading applied in several countries such as England, Switzerland, Japan and Indonesia for the production of porous asphalt using local materials available around Surakarta. The experimental method applied in this research includes stability and Marshall flow to determine the optimum asphalt content, followed by Cantabrian and unconfined compressive strength at the optimum asphalt content [5]. The research results show that the Japanese gradation is the best gradation that can be applied to local materials around Surakarta, while the Indonesian gradation is the worst in terms of Marshall stability and resistance to segregation.

Therefore, the author raised the research topic: Study of the Characteristics of Japanese Graded Porous Asphalt Using Retona Blend 55 Asphalt.

A. Literature Review

A.1 Flexible Pavement

Flexible Pavement is a pavement system that utilizes asphalt as the binding material. The flexible pavement structure consists of layers placed on top of a compacted subgrade.

The subgrade is the original ground surface or excavated surface or fill material surface, which is compacted and serves as the foundation surface for the placement of other pavement layers.

The Subbase Layer is the portion of the pavement located between the base layer and the subgrade.

The Base Layer is the part of the pavement located between the surface layer and the subbase layer (or directly on the subgrade if no subbase layer is used) [6].

The Surface Layer is the topmost part of the pavement. Its functions include:

1) Serving as a load-bearing material to withstand wheel loads, with a high-stability layer to support the wheel loads during its service life.
2) Acting as a water-resistant layer to protect the roadbed from weather-related damage. It prevents rainwater from penetrating into the layers below and weakening them.
3) Functioning as a wearing course, which is the layer directly subjected to the friction caused by vehicle tires, making it prone to wear and tear.
4) Distributing the load to the lower layers, allowing it to be absorbed by other layers with better load-bearing capacity."

A.2 Characteristics of Porous Asphalt Mixtures

This Asphalt Porous construction, in principle, is an open-graded macadam with high porosity, often having porosity levels between 20-25%. Porous asphalt should be placed on a strong and waterproof base course with a thick tack coat [7, 8]. The intended use of Porous Asphalt construction is as follows:

1) Reducing water ponding/aquaplaning and water splashing on the road surface: One of the main advantages of Porous Asphalt is its ability to reduce water accumulation on the road surface. With its high porosity, it can efficiently absorb and drain rainwater, reducing the risk of aquaplaning (loss of traction due to water accumulation) and water splashing that can disrupt drivers and pedestrians [9].
2) Reducing the glare from vehicle headlights: The rough and porous surface of Porous Asphalt can help mitigate the reflection of vehicle headlights at night. This can enhance driving comfort and reduce glare from bright lights on the road surface [10].
3) Reducing noise from tire-vehicle interaction and road surface: The high porosity of Porous Asphalt also has the capability to absorb sound generated by tire-vehicle interaction and the road surface. This can reduce noise levels in the vicinity of the road, benefiting the environment and the well-being of nearby residents [11].
4) Maintaining good surface friction in wet conditions: Porous Asphalt is designed to provide adequate traction even in rainy conditions while still having a high level of porosity [12].

A.3 Porous Asphalt Mixtures

Hot mix asphalt is a road pavement mixture consisting of coarse aggregates, fine aggregates, filler, and asphalt binder in specific proportions, which are mixed together under hot conditions.

Coarse aggregate is a material used or mixed in the asphalt manufacturing process, which originates from rocks and plays a crucial role in both the quality and price of asphalt. It must meet the following requirements:

Table 1. Coarse Aggregate Requirements

Testing			Testing Method	Value
The viscosity of aggregate shape in a solution.	Natrium sulfat		SNI 3407:2008	Maks. 12%
	Magnesium sulfat			Maks. 18%
Abration with Los Angeles machine	Modified AC and SMA mixture	100 times	SNI 2417:2008	Maks.6 %
		500 times		Maks. 30%
	All other types of graded asphalt mixtures	100 times		Maks. 8%
		500 times		Maks. 40%
The adhesion of aggregates to asphalt.			SNI 2417:2008	Min. 95%
Cracks in coarse aggregates		SMA	SNI 7619:2012	100/90
		others		95/90
Flat and elongated particles		SMA	ASTM D4791-10 Perbandingan 1:5	Maks. 5%
		others		Maks. 10%
Passed Sieve No. 200			SNI ASTM C117:2012	Maks. 1%

Fine aggregate consists of smaller and finer grains compared to coarse aggregate. It is not easily broken or crushed by weather conditions. Fine aggregate should not contain more than 5% silt (particles that can pass through a 0.060 mm sieve); if it exceeds 5%, it must be washed. It must not contain organic matter, as it will affect the sample's quality. When immersed in a 3% NaOH solution, fine aggregate must also meet the following requirements:

Table 2. Fine Aggregate Requirements

Testing	Testing Method	Value
Sand Equivalent Value	SNI 03-4428-1997	Min. 50%
Density Void Content Test	SNI 03-6877-2002	Min. 45%
Clay Lumps and Friable Particles in Aggregates	SNI 03-4141-1996	Maks 1%
Passed Sieve No. 200	SNI ASTM C117:2012	Maks 10%

The filler material is a substance that passes through a No. 200 sieve with a 75% minimum passing rate. It can be composed of stone dust, limestone dust, hydrated lime, Portland Cement (PC), or other non-plastic materials. The filler material must be dry and free from any interfering substances. The filler must meet the requirements as specified in the following table:

Table 3. Filler Requirements

No.	Testing Type	Testing Method	Requirements
1	Passed Sieve No. 200	SNI 03-1968-1990	MIN 75%
2	Specific Gravity	SNI 03-2531-1991	3,0 - 3,2

Refined Buton Asphalt (Retona) is a type of bitumen extracted from Asbuton. The material properties of Retona include high viscosity, which makes it suitable for ease of handling, and it is often blended with asphalt oil. The extraction process of Retona can result in different Retona products, depending on the proportion of inorganic solvent used in the process. For example, Retona 60 is the result of extracting Asbuton with 60% bitumen and 40% filler, while Retona 90 contains 90% bitumen and 10% filler.

A.4 Planning Asphalt Porous Mix Gradation

The performance of Porous Asphalt is obtained through testing the characteristics of the asphalt mixture. Specifications for Porous Asphalt are defined by the following values:

Table 4. Specifications for Mixture Properties

No.	Planning Criteria	Value
1	Cantabro Loss Value (%)	Maks 35
2	Permeability Coefficient (cm/s)	0,1 - 0,5
3	Void content within mixture (VIM %)	18 -25
4	Marshall Stability (kg)	500
5	Flow (mm)	2 - 6
6	Marshall Quetiont (kg/mm)	Maks 400
7	Number of collisions per unit area	50

A.5 Porous Asphalt Testing

The volume of asphalt and concrete mixtures referred to here is the volume of the test specimen mixture after compaction [13]. The volume components of the asphalt mixture are as follows:

1) Volume of Air Voids (VMA): This represents the volume of voids or air gaps between the mineral aggregates within the mixture.
2) Bulk Volume of Compacted Mixture: It is the volume of the asphalt mixture in its compacted state.
3) Volume of Solid Mixture without Voids: This is the volume of the mixture that is entirely solid, without any voids.

4) Volume of Voids Filled with Asphalt (VFB): This represents the volume of voids within the mixture that is filled with asphalt.
5) Void in Mineral Aggregate (VIM): It indicates the void spaces within the mineral aggregates themselves.
6) Amount of Asphalt Absorbed by Aggregates: This quantifies the quantity of asphalt that has been absorbed by the aggregates in the mixture.

The Marshall mix design method, developed by Bruce Marshall and standardized by organizations like ASTM or AASHTO, through modifications such as ASTM D1559-76 or AASHTO T245-90, is based on fundamental principles. The primary purpose of the Marshall method is to assess the stability and flow characteristics, as well as analyze the density and porosity of the compacted solid mixture formed [14].

The Cantabro Abrasion Test is designed to assess the damage to asphalt mixtures, specifically the loss of aggregate due to reduced adhesion of asphalt caused by repeated friction from vehicle tires.

(CAL) Cantabro Abrasion Loss is calculated by comparing the weight of the original test specimen with the weight remaining after conducting the test. The CAL value obtained should conform to specifications, typically up to 35%, in normal non-immersion testing (Australian Asphalt Pavement Association, 2004).

The weight loss can be calculated using the following formula (Woodside, 1997):

$$\text{CAL} = \left(\frac{m1-m2}{m1}\right) \quad (1)$$

Where:

CAL = Cantabro Abration Loss (%)

m1 = Initial Weight (gr)

m2 = The Weight after 300 rotations (gr)

Permeability is a property that indicates the ability of a material to allow the passage of flowing substances, both air and water. Permeability testing is a very important tool for Porous Asphalt. The type of permeability test mentioned here is the falling head water permeability test.

2. MATERIALS AND METHOD

The initial steps of this research involve preparing the aggregate and asphalt materials, followed by collecting primary data through testing the coarse and fine aggregates. This is followed by collecting secondary data through asphalt testing. If the materials meet the requirements, the next step is planning the percentage composition of the aggregates based on Japanese specifications. If they do not meet the requirements, then the aggregate and asphalt preparation is redone.

Afterward, test specimens are prepared according to the test specimen plan. Subsequently, Marshall testing, Porosity testing, Cantabro Loss testing, and Permeability testing are conducted. Once the results are obtained, data analysis and discussions are carried out. Finally, conclusions are drawn based on the research findings.

3. RESULT AND DISCUSSION

The examination of aggregate characteristics is conducted to determine the suitability of the aggregates used in this research, considering that aggregates constitute the largest portion in an asphalt mixture, especially in porous asphalt mixtures.

Both coarse and fine aggregates used consist of aggregates retained on a No. 8 sieve (2.36 mm) and aggregates passing through a No. 8 sieve but retained on a No. 200 sieve (0.075 mm). These sieve sizes are essential for evaluating the properties and gradation of the aggregates, which are crucial factors in asphalt mixture design and performance.

Table 5. Results of Coarse Aggregate

No.	Testing Type	Result	Requirement
1	Bulk Specific Gravity	2,76	Max 3,3
2	SSD Specific Gravity	2,72	Max 3,3
3	Apparent Specific Gravity	2,82	Max 3,3
4	Absorption (%)	1,75	Max 4%
5	Aggregate Abrasion	19	Max 40%

Table 6. Results of Fine Aggregate

No.	Testing Type	Result	Requirement
1	Bulk Specific Gravity	2,72	Max 3,3
2	SSD Specific Gravity	2,79	Max 3,3
3	Apparent Specific Gravity	2,93	Max 3,3
4	Absorption (%)	2,85	Max 3%

Based on the test results of the characteristics of coarse and fine aggregates in the table above, it is evident that the examination of the characteristics of coarse aggregates meets the specifications of the 2018 building standards that have been established.

Table 7. Results of Retona Blend 55 Characteristics

No.	Testing Type	Result	Specifications	
			Min	Max
1	Penetration before weight loss (mm)	78,6	60	79
2	Softening point	52	48	58
3	Ductility at 25 degree C, 5 cm/minute (cm)	114	100	-
4	Flash point	280	200	-
5	Specific Gravity	1,12	1	-
6	Weight loss	0,3	-	0,8
7	Penetration after weight loss (mm)	86	54	-

The results of the examination of the characteristics of Retona Blend 55 asphalt, as presented in Table 7, indicate that the asphalt used in this study meets the specified requirements.

The combined aggregate proportions are obtained by multiplying the planned aggregate composition ratio by the percentage passing from the results of both the coarse aggregate and fine aggregate sieve analyses.

The combined aggregates and the specification intervals are plotted on a graph to determine the existing combined aggregate gradation, as shown in the following figure.

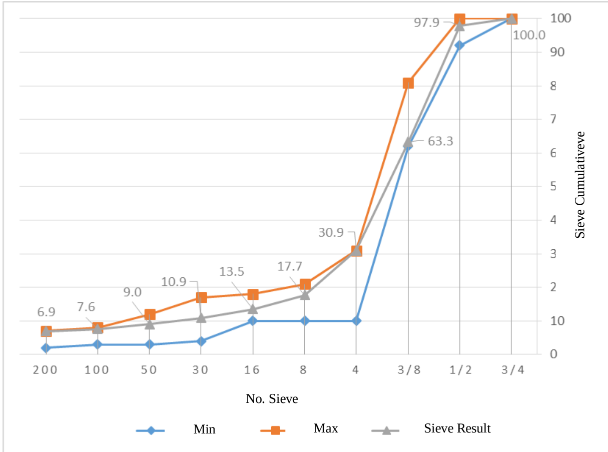

Figure 1. Japanese Gradation of Porous Asphalt Mixture

In the figure, it can be seen that the designed combined aggregate, which was created and obtained using local aggregates from Jayapura in this research, falls within the specified range as required by the Activities Of Porous Asphalt Expressway, Japan Highway Public Corporation. Therefore, it is expected to achieve an optimal porous asphalt mixture.

Based on the estimated asphalt content calculation, a value of approximately 5.2% was obtained, which was then rounded to 5.5%. Therefore, to determine the optimum asphalt content for the porous asphalt mixture in this research, the following asphalt content variations were considered: 4.5%, 5%, 5.5%, 6%, and 6.5%, as specified in Book III issued by the Directorate of Public Works in 2010.

The number of test specimens for each a alt content variation is three, and four tests are c ucted, resulting in a total of 45 test specimens for t ntire study.

The relationship between the modified asphalt content and the resistance to particle release (Cantabro) value is shown in the following figure.

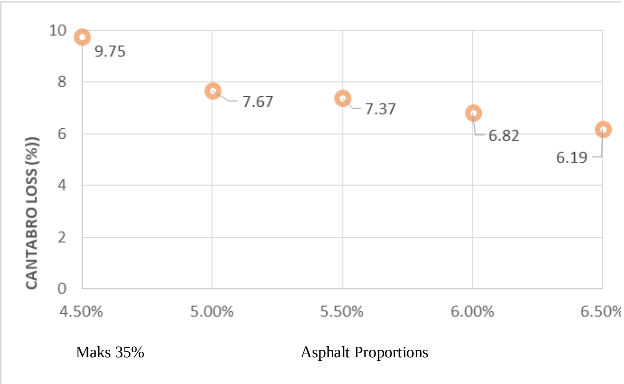

Figure 2. The Relationship between Asphalt Content and Cantabro Loss Value

The weight loss values obtained from this testing indicate that the smallest weight loss occurs at a modified asphalt content of 6.5%, with a value of 6.19%. However, at a modified asphalt content of 4.5%, the weight loss is the largest, at 9.75%. Additionally, at modified asphalt contents of 5.0%, 5.5%, and 6.0%, the respective weight loss values obtained are 6.82%, 7.37%, and 7.67%.

Porosity, also referred to as Void in Mix, is the measurement used to determine the amount of voids or empty spaces within a mixture, typically expressed as a percentage. The air voids generated are determined by the arrangement of aggregate particles within the mixture and the irregularities in the shape of the aggregates.

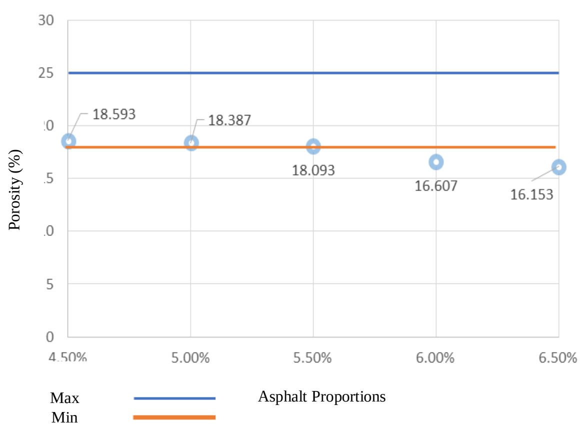

Figure 3. The Relationship between Asphalt Content and Porosity Value

From the graph above, it can be observed that the porosity values obtained from the porous asphalt mixture with Japanese gradation using Retona Blend 55 asphalt are in compliance with the specified range, which is a minimum of 18% and a maximum of 25%. However, this compliance does not apply to asphalt content levels of 6% and 6.5%. This deviation is attributed to the minerals contained in Retona Blend 55, which tend to break down and occupy the voids within the mixture, thereby filling the voids and resulting in a different porosity profile.

Here are the results of the Marshall testing in the form of stability values plotted on the following graph:

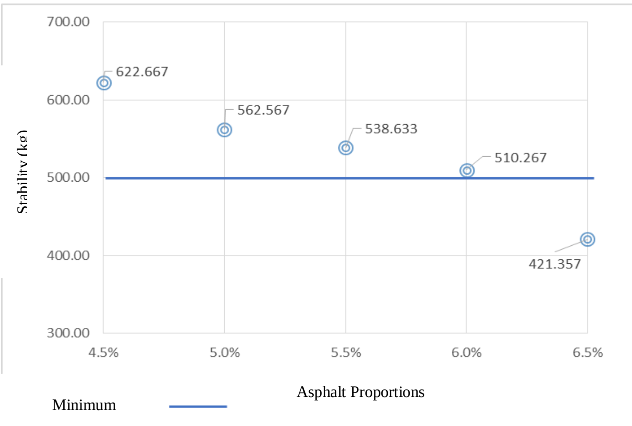

Figure 4. The Relationship between Asphalt Content and Stability Value

The graph above illustrates that the increase in asphalt content in the porous asphalt mixture with Japanese gradation using modified asphalt is accompanied by a decrease in stability values. The test results show that the highest stability value is achieved at an asphalt content of 4.5%, with a value of 622.667 Kg, while the lowest stability value is observed at an asphalt content of 6.5%, with a value of 421.357 Kg. Additionally, for asphalt contents of 5%, the stability is 562.567 Kg, for 5.5% it's 538.633 Kg, and for 6% it's 510.267 Kg.

The flow values for the porous asphalt mixture with Japanese gradation using modified asphalt can be observed as follows:

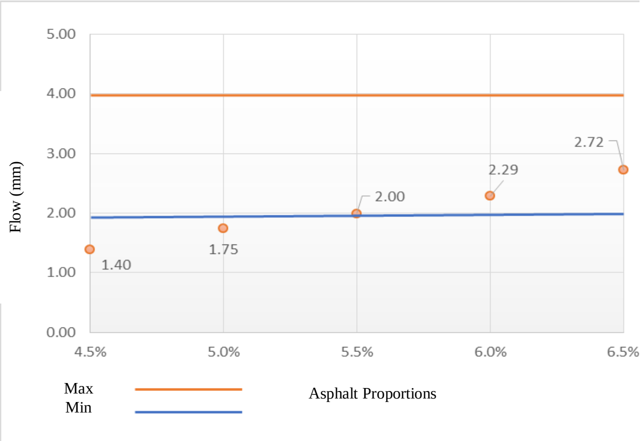

Figure 5. The Relationship between Asphalt Content and Flow

The graph above depicts that the flow values increase with the addition of asphalt content in the porous asphalt mixture with Japanese gradation using modified asphalt. The relationship chart shows that the lowest flow value is at an asphalt content of 4.5%, with a flow value of 1.40 mm. Meanwhile, the highest flow value is observed at an asphalt content of 6.5%, with a value of 2.72 mm. Additionally, for an asphalt content of 5%, the flow is 1.75 mm, followed by 2 mm at an asphalt content of 5.5%, and 2.29 mm at an asphalt content of 6%.

Here are the results of the MQ (Marshall Quotient) calculation for the porous asphalt mixture with Japanese gradation using modified asphalt:

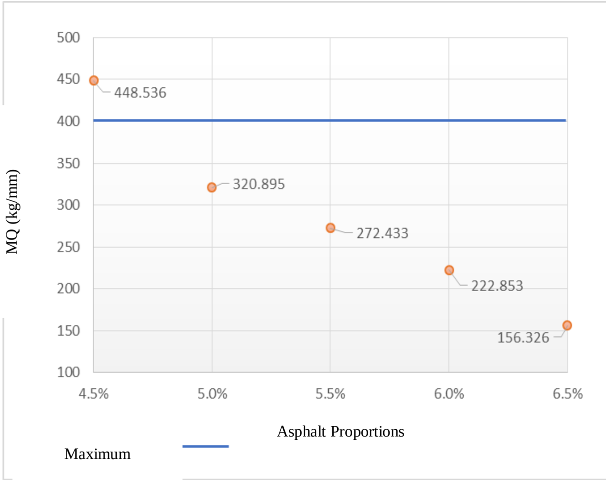

Figure 6. The Relationship between Asphalt Content and MQ Value

The Marshall Quotient (MQ) calculation results indicate that at an asphalt content of 4.5%, the MQ value is 448.536 Kg/mm. For an asphalt content of 5%, it is 320.895 Kg/mm, followed by 272.433 Kg/mm at an asphalt content of 5.5%. At an asphalt content of 6%, the MQ is 222.853 Kg/mm, and at an asphalt content of 6.5%, it's 156.326 Kg/mm.

From the calculation results, it can be observed that the asphalt content levels of 4.5% and 5% in the porous asphalt mixture with Japanese gradation using modified asphalt do not meet the specified maximum MQ value of 400 Kg/mm.

Here are the results of the permeability testing, which have been plotted on the following graph:

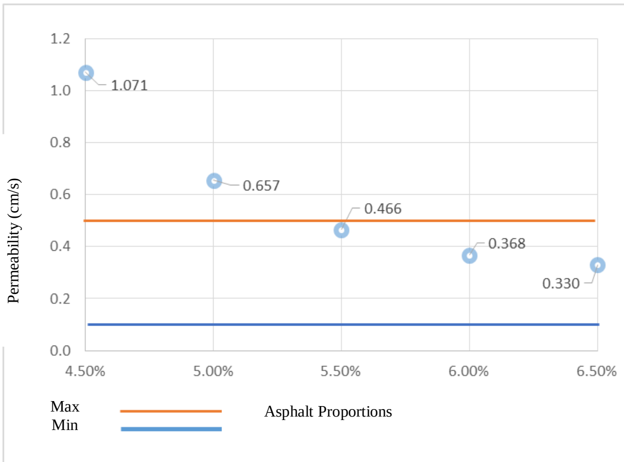

Figure 7. The Relationship between Asphalt Content and Permeability Value

The test results indicate that at an asphalt content of 4.5%, the permeability value is 1.071 cm/s, while at an asphalt content of 5%, it's 0.657 cm/s. For an asphalt content of 5.5%, the permeability is 0.466 cm/s, and at an asphalt content of 6%, it's 0.368 cm/s. At an asphalt content of 6.5%, the permeability is 0.330 cm/s.

Based on the test results, it can be observed that the asphalt content levels of 4.5% and 5% in the porous asphalt mixture with Japanese gradation do not meet the standard permeability value range, which typically falls between 0.1 and 0.5 cm/s.

From the test results, including Cantabro test, porosity, Marshall, and permeability testing, it is evident that in the case of the porous asphalt mixture with Japanese gradation using modified asphalt, only the asphalt content of 5.5% meets all the tested parameters. For asphalt contents of 4.5%, 5%, 6%, and 6.5%, they only partially meet some of the specifications. Therefore, the optimum asphalt content (OAC) for the porous asphalt mixture with Japanese gradation using modified asphalt is determined to be 5.5%.

4. CONCLUSIONS

The conclusions of this research are mentioned below:

1) From the test results for the porous asphalt mixture with Japanese gradation using modified asphalt and local materials in Jayapura, it is determined that an asphalt content of 5.5% meets the specifications.
2) Based on various parameters for porous asphalt, the optimum asphalt content is found to be 5.5%. This determination is supported by the Cantabro test result of 7.37%, porosity test result of 18.093%, as well as Marshall characteristics including stability of 538.633 Kg, flow of 2 mm, MQ of 272.433 Kg/mm, and permeability test result of 0.466 cm/s. These values meet all the specifications for porous asphalt mixture.

REFERENCES

[1] Ali.N, A. H. J. . (2013). Studi Permeabilitas Campuran Aspal Berpori Berbasis Aspal Buton (Asbuton). *Seminar Nasional III Teknik Sipil*, 239–245.

[2] Ariyanti, Kesbi, F. G., Tari, A. R., Siagian, G., Jamilatun, S., Barroso, F. G., Sánchez-Muros, M. J., Rincón, M. Á., Rodriguez-Rodriguez, M., Fabrikov, D., Morote, E., Guil-Guerrero, J. L., Henry, M., Gasco, L., Piccolo, G., Fountoulaki, E., Omasaki, S. K., Janssen, K., Besson, M., … A.F. Falah, M. (2021). Analisis Penuaan Jangka Panjang Secara Laboratorium Campuran Aspal Porus Yang Mengandung Limbah Plastik Pet Terhadap Nilai Kuat Tarik Tidak Langsung. *Jurnal Aplikasi Teknologi Pangan*, *4*(1), 1–2.

[3] Bria, O. K., Saputro, I. T., Samaila, M. A., & Mangi, J. (2018). *Kinerja Campuran Aspal Porus Berbagai Gradasi*. *4*(2).

[4] D. S. Mabui, Tjaronge, M. W., Adisasmita, S. A., & Pasra, M. (2020). Resistance to cohesion loss in cantabro test on specimens of porous asphalt containing modificated asbuton. IOP Conference Series: Earth and Environmental Science, 419(1), 12100.

[5] Irianto, Djamaluddin, A. R., Pasra, M., & Arsyad, A. (2020). Experimental study on marshall stability and flow of Asphalt Concrete Wearing Course (AC-WC) mixture using Asbuton semi extracted as binder. IOP Conference Series: Earth and Environmental Science, 419(1), 12074.

[6] Irianto, I., D. S. Mabui., & Faranita, A. (2018). Uji Eksperimental Penentuan Kadar Aspal Emulsi Optimum Dengan Menggunakan Buku 5 Bina Marga (Campuran Beraspal Dingin Dengan Asbuton Butir Peremaja Emulsi). Journal of Portal Civil Engineering, 1(1), 25–31.

[7] Irianto, I., & Wardani, S. W. (2017). Pengaruh Jumlah Tumbukan Terhadap Stabilitas Campuran Aspal Emulsi Dengan Menggunakan Metode Marshall (SNI 06-2489-1991). Jurnal Ilmiah Teknik Dan Informatika, 2(2), 39–46.

[8] Nakanishi, H., Hamzah, M. O., Mohd Hasan, M. R., Karthigeyan, P., & Shaur, O. (2019). Mix design and application

of porous asphalt pavement using Japanese technology. *IOP Conference Series: Materials Science and Engineering*, *512*(1).

[9] Nashir, M. (2013). *Menggunakan Aspal Polimer Modifikasi (Polymer Modified Binder) Dengan Stabilisasi Serat Polypropylene*. 1–10.

[10] Rachman, R., & Province, S. S. (2020). *PERMEABILITAS DAN KARAKTERISTIK KEKUATAN CAMPURAN ASPAL BETON*. *December 2010*.

[11] Sarwono, D. (2007). *Pengukuran Sifat Permeabilitas*. 131–138.

[12] Setyawan, A. (2009). Observasi Properties Aspal Porus Berbagai Gradasi Dengan Material Lokal. *Media Teknik Sipil*, *8*(1), 15–20.

[13] Syarwan, S., Mulizar, M., & Budidarmawan, B. (2018). Analisa Parameter Marshall Dan Durabilitas Aspal Poros Dengan Variasi Gradasi Menggunakan Spesifikasi Jepang. *Portal: Jurnal Teknik Sipil*, *10*(2), 28–34. https://doi.org/10.30811/portal.v10i2.985

[14] Yusuf, J., Widarto, H., & Hidayat, A. (2021). Studi Penggunaan Aspal Modifikasi pada Campuran Aspal Porus. *Jurnal Karajata Engineering*, *1*(1), 25–33