Utilizing Lawele Granular Asphalt (LGA) and Buton Granular Asphalt to Produce Porous Asphalt from Precast Pile Concrete Waste (BGA)

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ABSTRACT

Numerous agricultural lands have been transformed into residential or industrial sectors in several urban regions as a result of the high population expansion in such locations. These circumstances make the land less able to absorb water, particularly during the rainy season, which increases flooding and depletes groundwater. The goal of this research is to create a porous asphalt mixture with superior permeability and load-bearing capabilities. To accomplish this, three variations of the porous asphalt mixture design were created, each with six different asphalt contents. These variations included control aggregate, concrete scrap, and Asbuton Lawele Granular Asphalt (LGA) and Buton Granular Asphalt (BGA). The Marshall test and the permeability test were then performed on each sample. Based on the study's findings, it was determined that a porous asphalt mixture with a 6.0% asphalt content, a characteristic stability value of 959.9 kg, a melting value of 3.2 mm, a VIM value of 19.6, a MQ value of 299,97 kg/mm, and a permeability of 0.19 cm/sec was the best option for replacing concrete waste. The best substituted porous asphalt mixture, however, consists of Asbuton Lawele Granular Asphalt (LGA) and Buton Granular Asphalt (BGA), and it has the following characteristics: 3% asphalt content, 741.8 kg characteristic stability value, 3 mm melting value, 18.93 VIM value, 247.27 kg/mm MQ value, and 0.12 cm/sec permeability. In light of the study's findings, it is necessary to conduct additional research by extracting asphalt from Buton and Asbuton Lawele Granular Asphalt (LGA) before designing porous asphalt mixtures. Additionally, it is necessary to conduct core tests for a duration of 5–10 years to assess durability in the field.

Keywords: Porous Asphalt, Waste Concrete, Buton Granular Asphalt (BGA), Lawele Granular Asphalt (LGA), Marshall Fly Ash¸Parameter, Permeability

INTRODUCTION

Approximately 60 million tons (24 million barrels of oil equipment) of natural rock asphalt are present in the Lawele district in south Buton (Suryana, 2003). The natural rock asphalt is crushed to a maximum size of 1.16 mm and then homogenized to create buton granular asphalt (BGA). In addition to assisting with the development of road infrastructure, the use of BGA directly helps to the expansion of the national economy. For use as asphalt wearing course (AC-WC) in the construction of roads, buton rock asphalt generated with granular shape has been studied during the past few decades (Furgon, 2008). Gaus et al. (2014) used buton granular asphalt (BGA) to evaluate the properties of an asphalt concrete carrying coarse (AC-BC) mixture. No matter how much BGA was present, the stress-vertical strains curve and the stress-horizontal strains curve pattern were similar for the specimens. In compared to the AC-BC mixture without BGA, the compressive stress and elasticity modulus improved with the application of BGA as a partial replacement for petroleum asphalt. For all mixtures, there is no discernible variation in the Poisson ratio (Gaus et al., 2015).

Numerous agricultural lands have been transformed into residential or industrial sectors in several urban regions as a result of the high population expansion in such locations. These circumstances make the land less able to absorb water, particularly during the rainy season, which increases flooding and depletes groundwater. Up to 20% of the land in metropolitan areas might be taken up by roads, which significantly contributes to flooding and groundwater subsidence. Consequently, using porous asphalt as pavement has a number of benefits (Djakfar et al., 2013). Porous asphalt is one of the flexible pavement technologies. Given its great porosity, porous asphalt is a type of asphalt mixture that can serve as a drainage system by allowing water to permeate its layers both vertically and horizontally (Marizka, 2021)

Large voids are produced in porous asphalt, which is an asphalt mixture that uses more coarse material than fine aggregate. However, compared to other asphalt combinations, porous asphalt mixtures have lesser strength and durability due to their large void content (Noris, 2017). Prior research on porous asphalt aimed to improve the mixture's capacity for infiltration. In a developing nation like Indonesia, where the majority of the populace lives in metropolitan areas with poor infrastructure and is densely populated, it is crucial to examine this issue. Therefore, it is necessary to research whether porous asphalt can absorb water. In addition, using aggregate (LGA and BGA) and recycling concrete trash from the neighborhood, which originates from precast piles' broken heads, can both benefit the environment (Djakfar et al., 2013). With reference to the Australian Asphalt Pavement Association (AAPA) standard 2004, the aim of this study was to ascertain the impact of employing Concrete Waste, Asbuton Lawele Granular Asphalt (LGA), and Buton Granular Asphalt (BGA) as aggregate replacements in Porous Asphalt Mixture.

MATERIALS AND METHODS

Aggregate is a collection of crushed stone grains, sand, gravel, or other minerals, both natural and artificial. Aggregate is the main component of road pavement, as much as 90-95% by weight or 75-80% by volume (Center for Research and Development of Roads and Bridges, 1989).

The aggregate used as one of the ingredients in the porous asphalt mixture must be in a clean condition without any impurities, organic matter, or other unwanted materials to prevent a decrease in the quality of the porous asphalt mixture. The aggregate retained on sieve No. 4 and passed through sieve No. 3/4 is referred to as coarse aggregate. Whereas in fine aggregate, the aggregate is retained on the No. 200 sieve and passes filter No. 4 (Directorate General of Highways, 2020).

Asphalt is a natural material resulting from exploration that is black in color and is liquid to plastic, with hydrocarbons as the main chemical component. The function of asphalt on road pavement is as a binder with aggregate and as a filler in the voids between the aggregate grains, or the aggregate cavity (Saodang, 2005).

Concrete waste is the remains or waste from the destruction of a concrete structure. Concrete waste can be obtained from the renovation or construction of buildings or from the results of breaking the heads of precast piles in the construction of high-rise buildings. The use of concrete waste is expected to reduce waste concrete waste for nothing and become an innovation for porous asphalt mixtures, in addition to the use of new materials.LGA (Asbuton Lawele Granular Asphalt) is one of the asbuton products that functions as a partial replacement for oil asphalt because it has a high bitumen content (25–30%) and is soft for asphalt mixtures (Nur, 2022).

BGA (Buton Granular Asphalt) is one of Buton's asphalt products in the form of fine grains with a maximum size of 1.2 mm (passing filter No. 16) and a bitumen content of 18–22% (Bitu, 2020). Filler material is a non-plastic material with at least 75% of its weight passing through sieve number 200 of the total weight (Directorate General of Highways, 2020). Fly ash is ash from burning coal in a steam power plant (PLTU) that flies into the air (Yuanda et al., 2021).

This research is an experimental test on a laboratory scale using quantitative methods. The independent variable in this study was the use of concrete valleys, LGA (Asbuton Lawele Granular Asphalt), and BGA (Buton Granular Asphalt) as coarse aggregate substitutes. The dependent variable is fine aggregate, filler made from fly ash, and asphalt.

1) Material testingThe material used in the mixture needs to be examined for its physical properties to find out whether the required specifications are met or not.
2) Porous Asphalt Mixture Planninga.
    a. Selection of aggregate gradation. The size of the voids in the porous asphalt mixture is determined by the aggregate gradation. The arrangement of aggregate grains is determined by examining the aggregate sieve analysis.
    b. Determination of asphalt content variations. According to Siswadi (2019), the determination of asphalt content variation is obtained from the ideal asphalt content value or estimated initial asphalt content, which can be calculated by the equation:

       $$Pb = 0.035\ (\%C) + 0.045\ (\%F) + 0.18\ (\%ff) + K$$

       Where:

       Pb = optimal asphalt content

C = percentage of aggregate retained on sieve No. 4 and passed through sieve 34;

F = percentage of aggregate retained on Sieve No. 200 and passed through the No. filter.4;

ff = percentage of aggregate passing No. sieve 200;

K = constant (0.5–1.0).

c. Determination of aggregate substitution variations. The determination of variations in aggregate substitution is based on the 2004 Australian Asphalt Pavement Association (AAPA) standards.

3) Making Test Objectsa.

a. Porous Asphalt Test Objects with Control Aggregates. Porous asphalt specimens with control aggregates used six variations of asphalt content: 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, and 6.5%. The proportion of aggregate in the porous asphalt mixture with control aggregate is attached in Table 1.

b. Variation of Concrete Waste as Aggregate Substitution. Porous asphalt specimens with aggregate substitution with concrete waste used six variations of asphalt content, namely 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, and 6.5%. The proportion of aggregate in the porous asphalt mixture with aggregate substitution using waste concrete is attached in Table 1.

c. Variation of LGA and BGA as Partial Aggregate Substitution. Porous asphalt test specimens were created by substituting aggregate with concrete waste and varying the asphalt content by 2.0%, 2.5%, 3.0%, 3.5%, 4.0%, and 4.5%. The proportion of aggregate in the porous asphalt mixture with aggregate substitution using waste concrete is attached in Table 1.

Table 1. Aggregate Proportion in Porous Asphalt Mixture

Variation	Ratio			
	CA (10-15 mm)	MA (5-10 mm)	FA (0-5 mm)	Filler
Porous Asphalt Control Aggregate	17%	40%	41%	2%
Porous Asphalt Concrete Waste	18%	45%	45%	2%
LGA and BGA Porous Asphalt	65%	MA 11,5%	FA 5%	2%
		LGA 11,5%	BGA 5%	

4) Marshall Test. Marshall test aims to obtain the value of stability (stability), plastic melting (flow), density (density), voids in the mixture (VIM), and marshall quotient (MQ). Stability is the ability of a porous asphalt mixture to accept loads without changing shape. The magnitude of the stability value can be calculated by the following equation:

$$S = Q \times O \times E'$$

Where:

S = stability (kg);

Q = Marshall instrument calibration;

O = stability dial reading (lbf);

E' = correlation number of test objects.

Cavity in the mixture (Void in Mixture) or VIM is a parameter that indicates the volume of pores or air voids in a mixture and is expressed in percent (%). VIM can be calculated by the following equation:

$$\text{VIM} = 100 - \frac{GMM-GMB}{GMM}$$

Where:

VIM = air voids in the mixture (%);

GMM = density (gr/cm³);

GMB = density of solid mixture (gr/cm³).

In ASTM D 1559-89 to calculate the Marshall test results use the following equation:

$$\text{MQ} = \frac{S}{flow}$$

Where:

MQ = Marshall Qoutient Value;

S = Stability (kg);

flow = dial flow reading (mm).

5) Permeability Testing. Permeability testing is intended to determine the ability of porous asphalt pavements to transmit water. Permeability affects the durability and stability of asphalt mixtures. The permeability coefficient can be known from the following equation.

$$\text{K} = 2{,}3 \text{ x } \left(\frac{H}{T}\right) \text{ x } \log A \left(\frac{H+5}{H}\right)$$

Where:

MQ = Marshall Qoutient Value;

S = Stability (kg);

flow = dial flow reading (mm).

6) Data Calculation. Test result data is then processed and presented in the form of test result tables, calculation result tables, and graphs. Then a conclusion is drawn as to whether or not the porous asphalt mixture meets the parameters tested according to the standards (Australian Asphalt Pavement Association, 2004).

RESULTS AND DISCUSSION

Combined Gradation Examination Results

Inspection of the combined gradation is carried out by means of sieve analysis. The gradation used is a continuous gradation for porous asphalt mixtures according to the 2004 Australian Asphalt Pavement Association (AAPA) standards, attached in Table 2.

Table 2. Combined Gradations for Porous Asphalt Mixtures

Filter Size		Control Aggregate	Concrete Waste	LGA and BGA	Specification	
ASTM	(mm)				Minimum	Maximum
¾"	19	100.00	100.00	100.00	100.00	100.00
½"	12.5	98.30	94.00	96.00	85.00	100.00
3/8"	9.5	65.30	65.00	45.00	45.00	70.00
No. 4	4.75	25.40	18.00	16.00	10.00	25.00
No. 8	2.36	15.30	14.00	10.00	7.00	15.00
No. 16	1.18	9.90	9.00	8.00	6.00	12.00
No. 30	0.6	6.70	8.00	7.00	5.00	10.00
No. 50	0.3	4.90	6.00	5.00	4.00	8.00
No. 100	0.15	3.30	4.00	3.00	3.00	7.00
No. 200	0.075	2.10	3.00	2.00	2.00	5.00

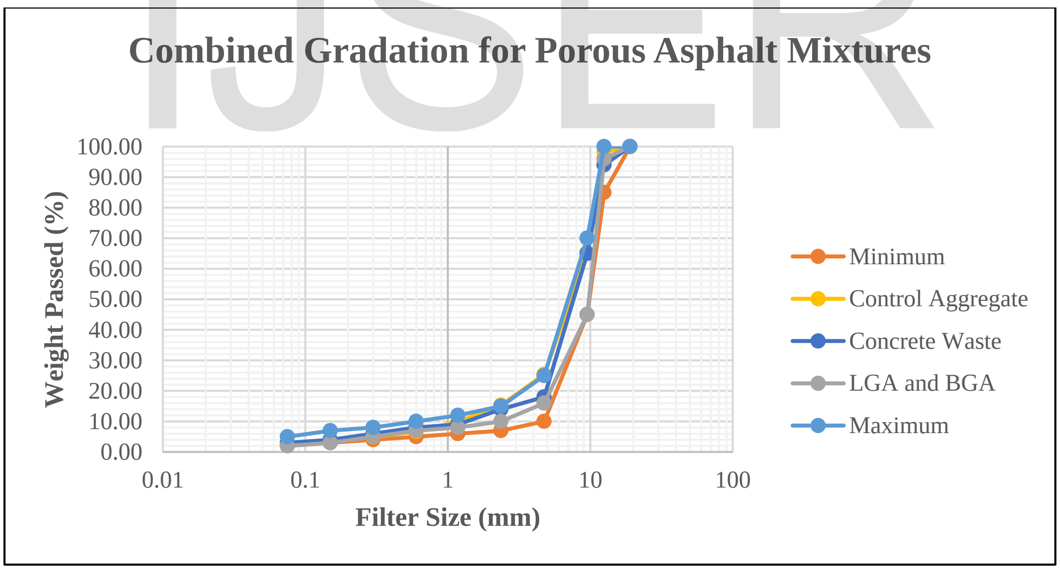

Figure 1. Aggregate Combined Gradation Graph for Porous Asphalt Mixture

Marshall Test Results with Control Aggregate

The mixture of test specimens uses control aggregate, fly ash filler, and pen asphalt. 60/70 production PT. Pertamina with variations in the asphalt content used, namely 4.0%; 4.5%; 5.0%; 5.5%; 6.0%; 6.5%. Marshall test results with control aggregates are attached in Table 3.

Table 3. Marshall Test Results with Aggregate

No	Mixed Characteristics	Asphalt Content						Specification
		4%	4.50%	5%	5.50%	6%	6.50%	
1	Stability	506.1	536.7	610.9	567.2	549.8	506.1	Min. 500
2	*Flow*	2.83	2.87	2.97	3.1	3.03	2.87	2 – 6
3	VIM	19.54	18.73	18.69	18.33	18.15	17.8	18 - 23
4	Marshall Quotient	178.83	187.00	205.69	182.97	181.45	176.34	Max. 400

Marshall Test Results with Concrete Waste

The mixture of test objects uses concrete waste, fly ash filler, and pen asphalt. 60/70 production PT. Pertamina with variations in the asphalt content used, namely 4.0%; 4.5%; 5.0%; 5.5%; 6.0%; 6.5%. Marshall test results with concrete waste are attached in Table 4.

Table 4. Marshall Test Results with Waste

No	Mixed Characteristics	Asphalt Content						Specification
		4%	4.50%	5%	5.50%	6%	6.50%	
1	Stability	903.2	925	938.1	955.6	959.9	942.5	Min. 500
2	*Flow*	3.1	3.1	3.3	3.3	3.2	3	2 – 6
3	VIM	24.32	23.18	21.51	20.66	19.6	18.71	18 - 23
4	Marshall Quotient	291.35	298.39	284.27	289.58	299.97	314.17	Max. 400

Marshall Test Results with LGA and BGA

The mixture of test objects uses aggregate, LGA, BGA, fly ash filler, and pen asphalt. 60/70 production PT. Pertamina with variations in asphalt content used, namely 2.0%; 2.5%; 3.0%; 3.5%; 4.0%; 4.5%. Marshall test results with LGA and BGA are attached in Table 5.

Table 5. Marshall Test Results with LGA and BGA

No	Mixed Characteristics	Asphalt Content						Specification
		2%	2.50%	3%	3.50%	4%	4.50%	
1	Stability	580.3	663.2	741.8	711.2	645.8	602.1	Min. 500
2	*Flow*	2.7	2.9	3	3.1	3	3.2	2 – 6
3	VIM	21.98	20.51	18.93	18.1	16.95	15.44	18 - 23
4	Marshall Quotient	214.93	228.69	247.27	229.42	215.27	188.16	Max. 400

Control Aggregate Permeability Test Results, Concrete Waste, and LGA-BGA

The results of the permeability test for the three variations of porous asphalt mixtures are attached in Table 6. Table 6 describes the results of the porous asphalt permeability test with three variations of the mixture.

Table 6. Results of Porous Asphalt Permeability Tests

Asphalt Content	Permeability Variation (cm/sec)			Specification
	Control Aggregate	Concrete Waste	LGA & BGA	
2.0%	-	-	0.22	0.1 - 0.5 (cm/sec)
2.5%	-	-	0.17	
3.0%	-	-	0.12	

3.5%	-	-	0.1	
4.0%	0.36	0.26	0.08	
4.5%	0.29	0.24	0.06	
5.0%	0.27	0.22	-	
5.5%	0.24	0.20	-	
6.0%	0.21	0.19	-	
6.5%	0.20	0.17	-	

Review of Stability Values

Figure 2 proves that the use of waste concrete in a porous asphalt mixture has an effect on increasing the stability value compared to a porous asphalt mixture with control aggregate variations. The highest stability value in the variation of concrete waste is 959.9 kg at 6% asphalt content. All variations of control aggregates and variations of waste concrete meet the stability value requirements, namely 500 kg.

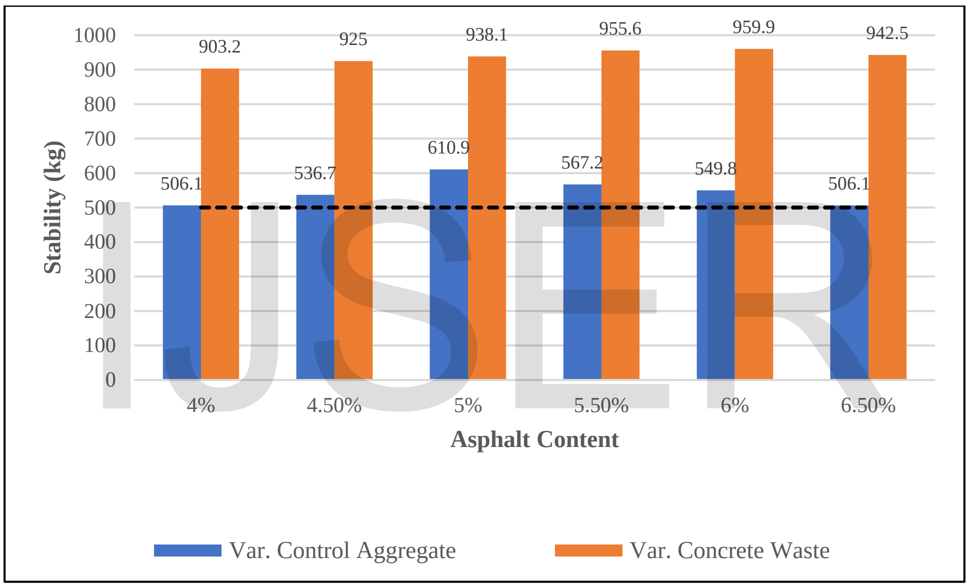

Figure 2. Graph of the Effect of Using Waste Concrete on Stability Values

Figure 3 proves that the use of LGA and BGA as partial substitutions of aggregate in a porous asphalt mixture obtained a stability value that met the requirements of the 2004 Australian Asphalt Pavement Association (AAPA) standard. The highest stability value for the LGA and BGA variations was 741.8 kg at asphalt content. 3%.

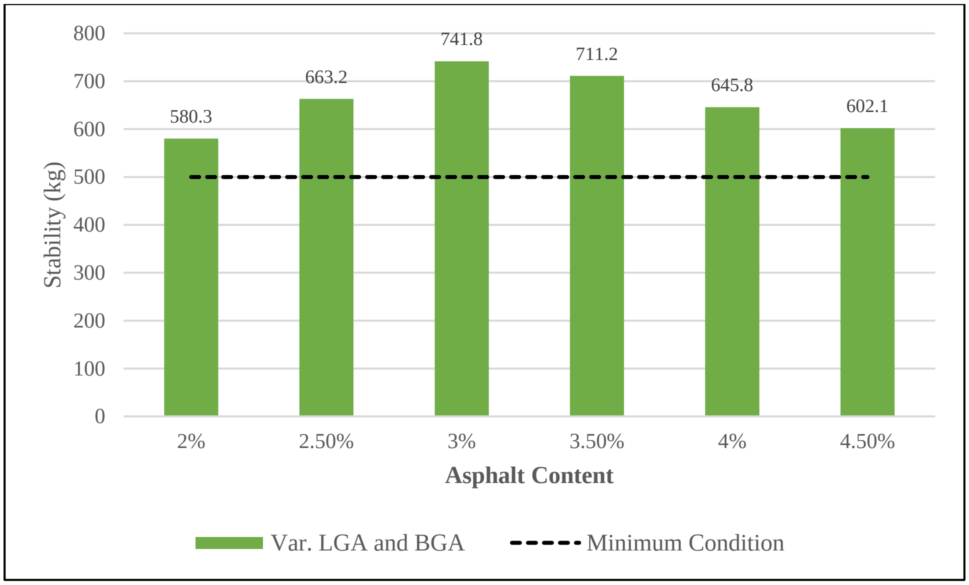

Figure 3. Graph of the Effect of Using LGA and BGA on Stability Values

Overview of Melt Value (flow)

Figure 4 proves that all variations of the porous asphalt mixture with control aggregate and waste aggregate meet the requirements for the flow value, which is between 2 and 6 mm. The porous asphalt mixture using waste concrete tends to have a higher melting value than the porous asphalt mixture with the control aggregate variation, with the highest melting value of 3.3 mm at 5% asphalt content.

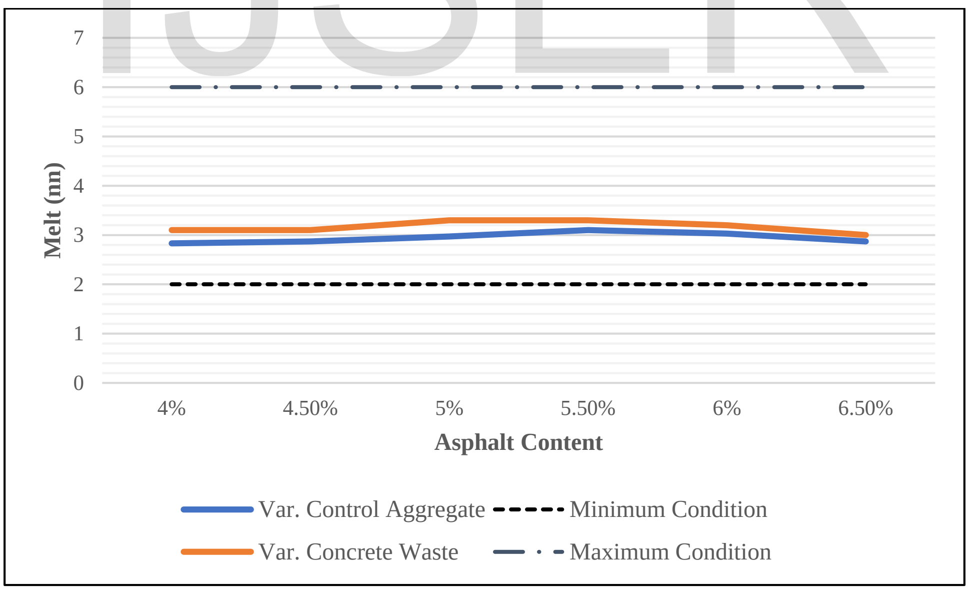

Figure 4. Graph of the Effect of Using Waste Concrete on the Meltability Value (flow)

Figure 5 shows that the use of LGA and BGA as partial substitutes for aggregates in porous asphalt mixtures obtains a melt value that meets the requirements of the 2004 Australian Asphalt Pavement Association (AAPA) standard. The highest flow value for the LGA and BGA variations is 3.2 mm at 4.50% asphalt content.

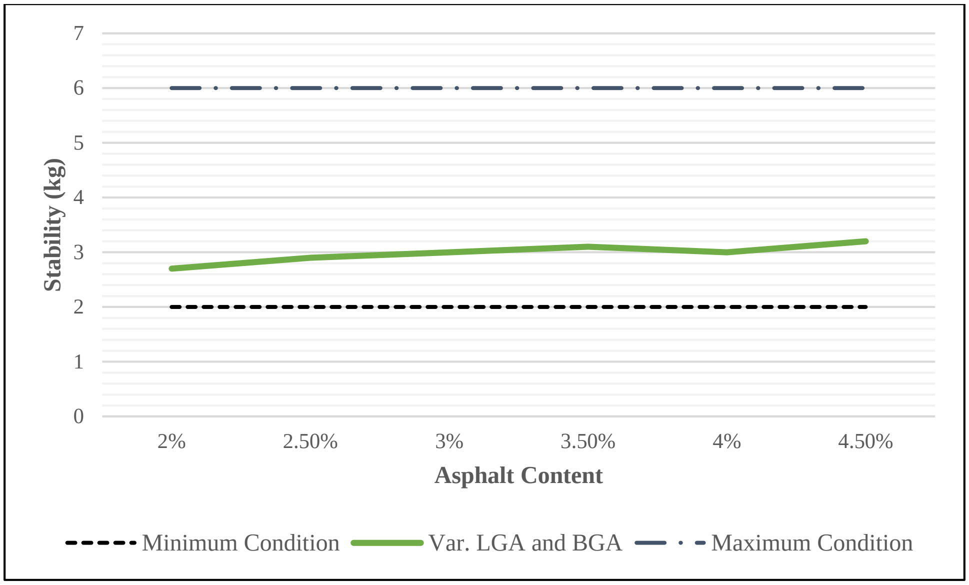

Figure 5. Graph of the Effect of Using LGA and BGA on Melt Value (flow)

Review of Void in Mixture or VIM

Figure 6 proves that the use of waste concrete in a porous asphalt mixture has an effect on increasing the VIM value compared to a porous asphalt mixture with a control aggregate variation. Cavity in the mixture (VIM) tends to decrease with increasing asphalt content in porous asphalt mixtures. a mixture of porous asphalt and concrete waste variations that meet the standard VIM values, namely with an asphalt content of 5%, 5.5%, 6%, and 6.5% and VIM values between 18 and 23%.

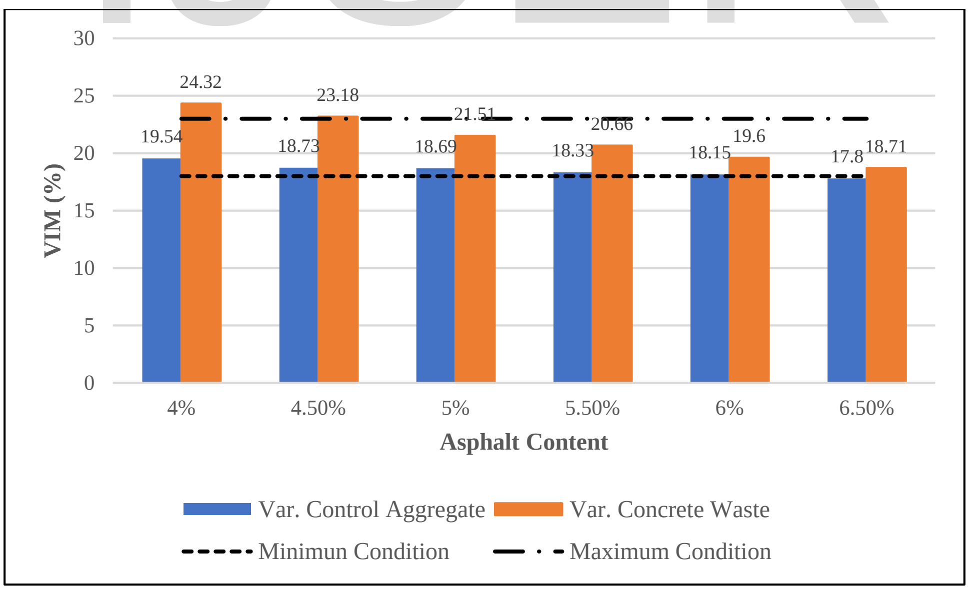

Figure 6. Graph of the Effect of Using Waste Concrete on the VIM Value

Figure 7 proves that the use of LGA and BGA in porous asphalt mixtures decreased the VIM value with increasing levels. Porous asphalt mixtures of LGA and BGA variations that meet the VIM standard, namely with an asphalt content of 2%, 2.5%, 3%, and 3.5% with VIM values between 18 and 23%,

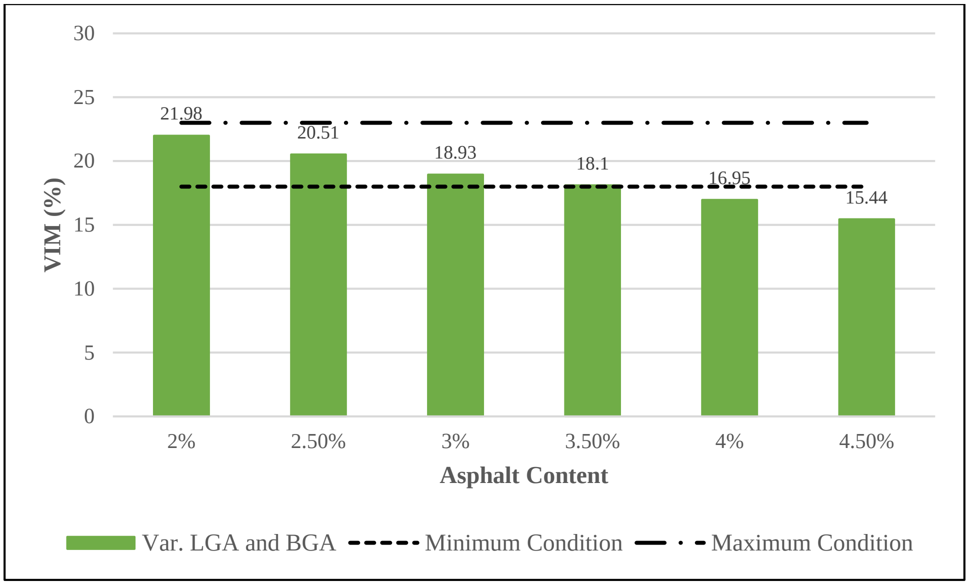

Figure 7. Graph of the Effect of Using LGA and BGA on VIM Values

Overview of the Marshall Quotient (MQ)

Figures 8 and 9 prove that the use of waste concrete as well as LGA and BGA in porous asphalt mixtures obtains an MQ value that meets the requirements of the 2004 Australian Asphalt Pavement Association (AAPA) standard, namely a maximum of 400 kg/mm. The highest MQ value for the porous asphalt mix with the concrete waste variation was 314.17 kg/mm, while for the LGA and BGA variations it was 247.27 kg/mm.

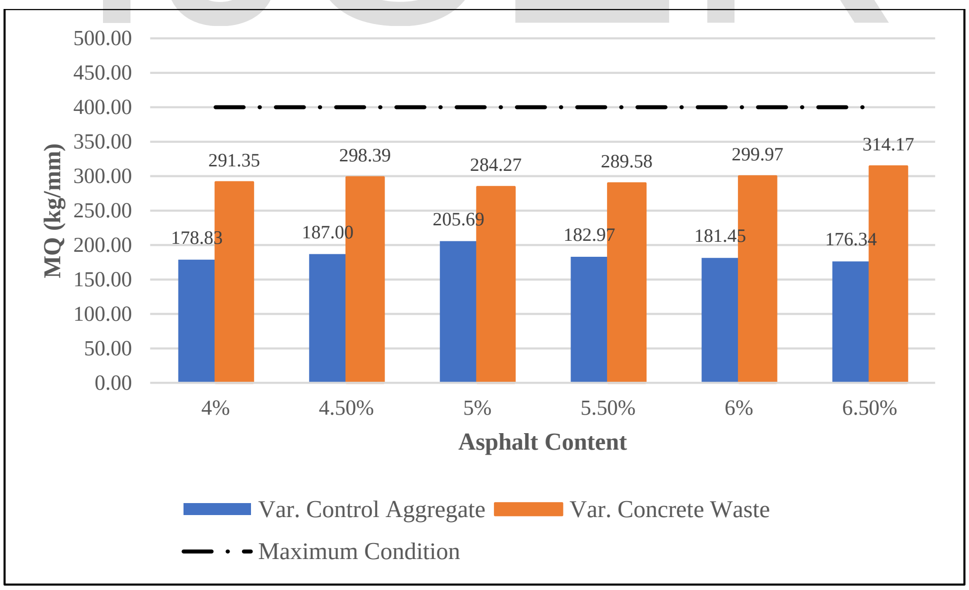

Figure 8. Graph of the Effect of Using Waste Concrete on the MQ Value

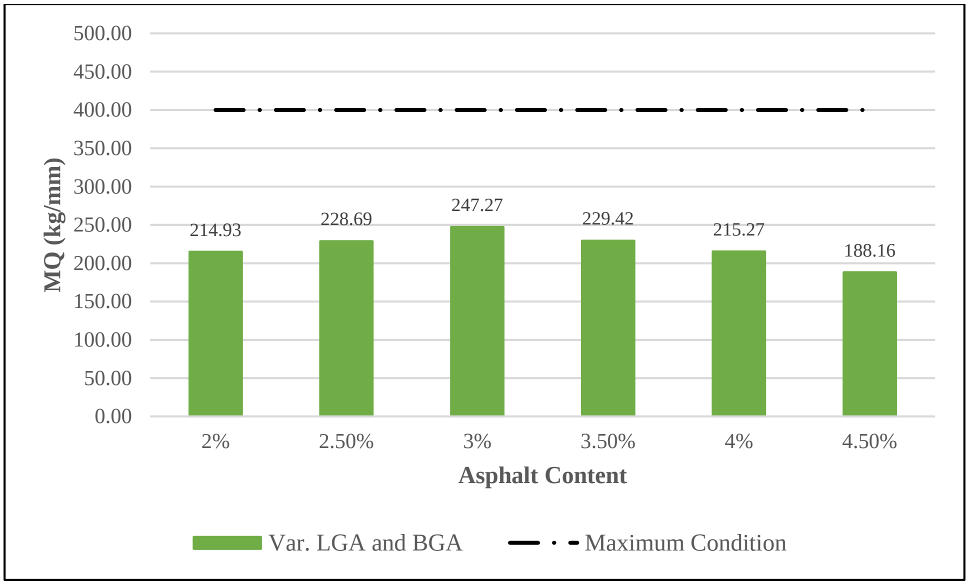

Figure 9. Graph of the Effect of Using LGA and BGA on MQ Values

Review of Permeability

Figure 10 proves that the higher the asphalt content in the porous asphalt mixture, the lower the permeability. The highest permeability for the concrete waste variation is 0.26 cm/second, while for the LGA and BGA variations, it is 0.22 cm/second. Porous asphalt mixtures that do not meet permeability standards are LGA and BGA variations with asphalt contents of 4% and 4.5%, respectively.

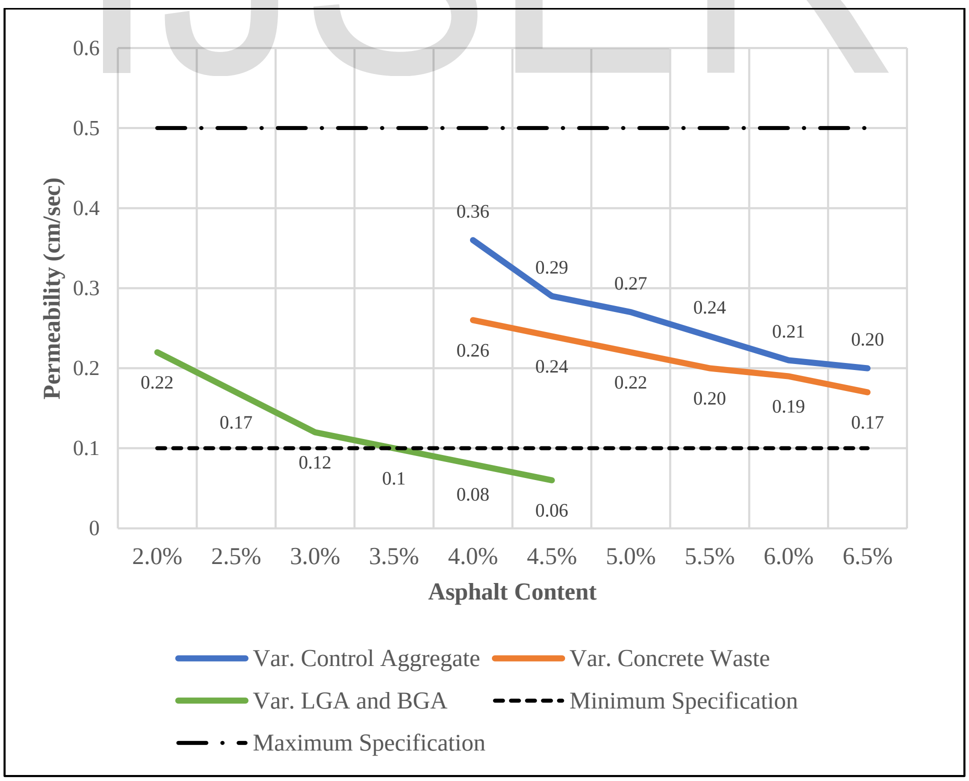

Figure 10. Graph of the Effect of Using Waste Concrete as well as LGA and BGA on Permeability

CONCLUSION

Based on the research that has been done, several conclusions can be drawn, namely that porous asphalt mixture is the best substitute for concrete waste, with an asphalt content of 6.0% and a characteristic stability value of 959.9 kg, a melting value of 3.2 mm, a VIM value of 19.6, a MQ value of 299.97 kg/mm, and a permeability of 0.19 cm/sec. The best mixture of LGA and BGA substitution porous asphalt is 3% asphalt content with a characteristic stability value of 741.8 kg, a melting value of 3 mm, a VIM value of 18.93, a MQ value of 247.27 kg/mm, and a permeability of 0.12 cm/sec. The higher the asphalt content in the porous asphalt mixture, the fewer voids there will be, resulting in reduced permeability. Suggestions that can be given after conducting this research are based on laboratory test results. Waste concrete, LGA, and BGA can be used as aggregate substitutions in porous asphalt mixtures, but it is necessary to carry out core tests for a period of 5–10 years to determine durability in the field. Further research is needed on extracting asphalt from LGA and BGA before planning porous asphalt mixtures. This was done to determine the total asphalt content obtained from LGA, BGA, and added bitumen.

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