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Performance Of Asphalt Coated Concrete Flexible Pavement (AC-WC) Using Bottom Ash And Natural Asphalt Lawele Granular Asphalt (LGA)

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Abstract – The construction of new roads and the maintenance of existing roads in Indonesia require large amounts of bituminous materials and aggregates. Given the high price of bitumen imported from other countries, encouraging the use of local natural asphalt, which is commonly called asbuton, Utilization of natural materials like Lawele Granular Alphat (LGA) and bottom ash as aggregate substitutes can contribute well to the environment. The purpose of this study was to compare the effect of using Asbuton Lawele Granular Asphalt and bottom ash as aggregate substitutions in the manufacture of Asphalt Concrete Wear Coarse (AC-WC). To achieve this goal, 3 variations of the mixed design were made, namely variations of control aggregates, variations of LGA, and variations of bottom ash. Each sample was then tested based on Marshall parameters. From the research results, it was found that the optimal asphalt content (KAO) for the LGA variation was 4.20% and the bottom ash variation was 5.7% with a stability value of 1495.0 kg; flow 3.47 mm; VIM 3.77%; VMs 14.78%; VFA 74.51%; and MQ 435.8 kg/mm. Reviewing the results of this study, it is necessary to carry out further studies to determine the durability and extract LGA before planning the asphalt concrete mix wear layer (AC-WC).

Keywords – AC-WC, Bottom Ash, Lawele Granular Asphalt (LGA), Fly Ash, Parameter Marshall

I. INTRODUCTION

Asphalt concrete is a flexible type of road pavement comprised of asphalt as a binder and gravel. To prevent deformation, asphalt concrete needs to be highly stable and able to withstand traffic loads. Asphalt is a viscoelastic substance that is temperature-sensitive. However, asphalt freezes at low temperatures and, in some cases, fuses at high ones. If asphalt concrete that was made using subpar asphalt receives a heavy weight while the temperature is high, a side effect will result. The exfoliation between the asphalt and the aggregate is a consequence of that. Additionally, it could result in potholes, corrugation, rutting, shoving, fatigue, and other damages to the pavement layers. The addition of the additional component could fix the asphalt's temperature-sensitive characteristics. However, compared to the standard one, this step would be more expensive. The more cost-effective replacement for this stage is to include a new element that contains latex, discarded tires, and other plastic materials. The melting points of polystyrene and polyethylene terephthalate are 90° C and 250° C, respectively, while asphalt melts at 48° C (Mahmuda et al., 2019).

Combining these three substances should be able to improve the physical qualities of asphalt. The use of 10% Low-Density Polyethylene (LDPE) and 4% High-Density Polyethylene (HDPE) on asphalt weight can improve the pavement layer against rutting damage and withstand temperatures of 70°C (Khan et al., 2016). Research aims are to improve the physical properties of asphalt by adding or replacing a portion of asphalt with plastic waste. A flexible and plastic combination can be made by adding HDPE at 4% of the weight of heated asphalt mixes (Kofteci, 2016). To lessen harm to rutting resistance and resistivity, polystyrene modified asphalt can be employed in a combination of asphalt pavement layers (Mohamed et al., 2017).

According to studies utilizing PEN 40/50 asphalt, the value of void-filled asphalt (VFA), minimum air voids (AV), and flow from asphalt pavement can all be improved by adding 8% of mineral water plastic bottle trash to the asphalt weight (Rasool, 2015).

Highways, as land transportation infrastructure, support human activities that have a significant role in the quality of life in the community. The availability of roads is absolutely essential for community mobility; therefore, the pavement's design is determined by its resilience to repetitive traffic loads and environmental conditions, including temperature and rainfall (Pangaraya, 2015)

The construction of new roads and the maintenance of existing roads in Indonesia require large amounts of bituminous materials and aggregates. Given the high price of bitumen imported from other countries, encouraging the use of local natural asphalt located on Buton Island, Southeast Sulawesi, known as asbuton, Asbuton is divided into two types, namely Asbuton Lawele Granular Asphalt (LGA) and Buton Granular Asphalt (BGA) (Mahmuda et al., 2019).

Previous research on asphalt wear-resistant concrete has been directed to utilize natural materials (Asbuton Lawele Granular Asphalt) and waste (bottom ash), so that they can contribute well to the environment.The purpose of this study was to compare the effect of using Asbuton Lawele Granular Asphalt and bottom ash as aggregate substitutions in asphalt mixtures with wear-coated concrete.

II. Materials And Methods

One sort of layer construction used in flexible pavement is called asphalt concrete wearing course (ACWC). Long recognized and frequently used in road construction, ACWC is a material for making pavement (Permana et al., 2018). Due to the availability of asphalt mixing plants and the growth of the road infrastructure, the usage of Asphalt Concrete Wearing Course (AC-WC) on the pavement has risen (AMP). Before a recent concert, a lot of road damage occurred. Because there is frequently disagreement over nomenclature and because professionals from various engineering organizations and geographical regions may use different descriptions to describe the same sort of pavement distress, discussing failures in highway pavements can be challenging (Hveem, 1952).

Based on the underlying source of the issue, pavement failures can be divided into three groups, claims Hveem (1958). First, there is a problem with the composition of the pavement or top layer. These deficiencies can manifest as disintegration (caused specifically by a lack of asphalt, the hardening of asphalt, and water action), cracking (caused specifically by a lack of asphalt, low temperatures, and a hardening of asphalt), and instability of the road surface (specific causes are excess asphalt, excess water, and smoothly polished aggregate particles).

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 study used a laboratory scale experimental method. The independent variable in this study was the use of LGA (Asbuton Lawele Granular Asphalt) and bottom ash as coarse aggregate substitutes. The dependent variable is asphalt, fine aggregate, and filler using fly ash.

1) Material testing. The 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 Objects.
   a. AC-WC Test with Control AggregateSpecimens of asphalt concrete mixture with a wear layer and control aggregate used seven variations of asphalt content, namely: 4.0%, 4.5%, 5.0%, 5.5%, 6.0%, 6.5%, and 7.0%. The proportion of aggregate in the asphalt concrete wear layer mixture (AC-WC) compared to the control aggregate is attached in Table 1.
   b. LGA Variation as Aggregate SubstitutionAggregate substitution test objects were made with concrete waste using 6 variations of asphalt content, namely 3.0%, 3.5%, 4.0%, 4.5%, 5.0%, and 5.5%. The proportion of aggregate in the asphalt mixture with wear layer concrete (AC-WC) with aggregate substitution using LGA is attached in Table 1.
   c. Bottom Ash Variation as Aggregate SubstitutionAggregate substitution test objects were made with concrete waste using 5 variations of asphalt content, namely 5.0%, 5.5%, 6.0%, 6.5%, and 7.0%. The proportion of aggregate in the asphalt concrete mix with wear layer (AC-WC) with aggregate substitution using bottom ash is attached in Table 1.

Table 1. Aggregate Proportion in AC-WC

Variation	Ratio			
	(10-15 mm)	(5-10 mm)	(0-5 mm)	Filler
AC-WC Control Aggregate	26%	30%	42%	2%
AC-WC Bottom Ash	35%	28%	35%	2%
AC-WC LGA	45%	20%	33%	2%

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:

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

   Information:

   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:

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

Information:

VIM = air voids in the mixture (%);

GMM = density (gr/cm³);

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

The void in mineral aggregate (Void in Mineral Aggregate), or VMA, is a parameter that indicates the volume of voids between mixed aggregates that have gone through compaction and is expressed in percent (%). VMA can be calculated using the following equation:

$$VMA = 100 - \frac{GMM}{GSB} \times \frac{100}{(100 - Pb)} \times 100$$

Information:

VMA = voids in mineral aggregate (%);

GMM = density (gr/cm³);

GSB = specific gravity of bulk aggregate (gr/cm³).

Pb = asphalt content (%)

Voids filled by asphalt (Void Filled by Asphalt, or VFA) are parameters that indicate the volume or pores in the mixture covered or filled with asphalt and are expressed in percent (%). VFA can be calculated using the following equation:

$$VFA = 100 \times \frac{VMA - VIM}{GMM}$$

Information:

VFA = cavity filled with aggregate (%);

VMA = voids in mineral aggregate (%);

VIM = voids in the mix (%);

GMM = density (gr/cm³);

Calculating the Marshall Quotient value using the following equation:

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

Information:

MQ = Marshall Qoutient Value;

S = Stability (kg);

flow = dial flow reading (mm).

5) Data Calculation. The data from the test results is processed and presented in the form of tables and graphs, and then a conclusion is drawn as to whether or not the asphalt concrete wear layer (AC-WC) mixture has been tested according to the general specifications of highways in 2018 (Revision 2).

III. RESULTS AND DISCUSSION

Combined Gradation Examination Results

Sieve analysis was carried out to check the combined gradation. The gradation used is a continuous gradation, attached in Table 2.

Table 2. Combined Gradations for Porous Asphalt Mixtures

Filter Size		Control Aggregate	LGA	*Bottom Ash*	Specification	
ASTM	(mm)				Minimum	Maximum
¾"	19	100.00	100.00	100.00	100.00	100.00
½"	12.5	95.10	92.40	92.64	90.00	100.00
$^{3}/_{8}$”	9.5	81.60	77.40	82.26	77.00	90.00
No. 4	4.75	56.70	49.60	60.14	53.00	69.00
No. 8	2.36	35.20	37.90	41.60	33.00	53.00
No. 16	1.18	20.80	24.20	30.49	21.00	40.00
No. 30	0.6	13.30	17.60	20.30	14.00	30.00
No. 50	0.3	9.00	12.90	17.06	9.00	22.00
No. 100	0.15	7.70	7.10	10.08	6.00	15.00
No. 200	0.075	6.10	4.60	7.19	4.00	9.00

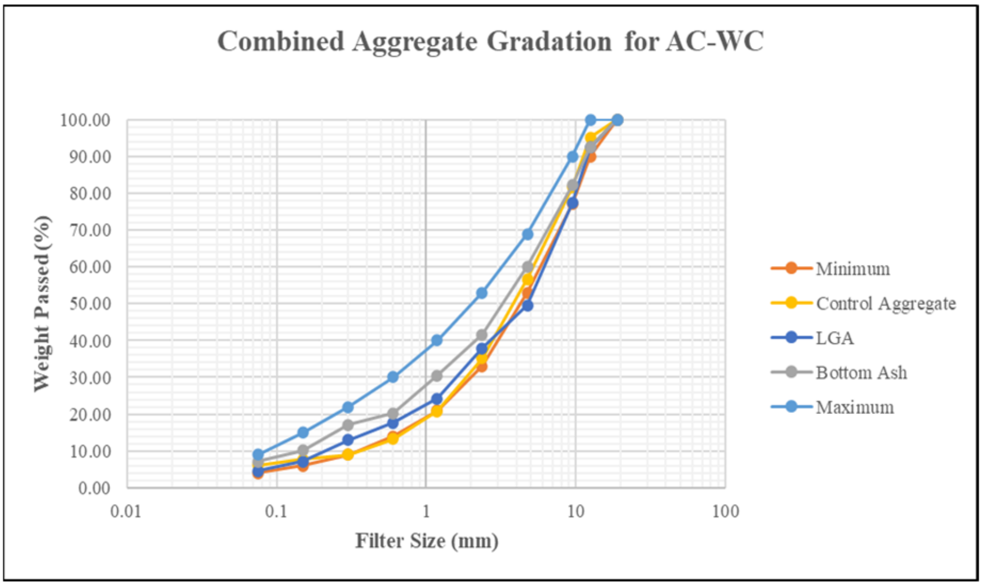

Figure 1. Aggregate Combined Gradation Chart for AC-WC

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%	7.00%	
1	Stability	942.5	973	1047.2	1208.8	1247.9	1099.6	1082.1	Min. 800
2	Melt (flow)	2.6	2.9	2.9	3.3	3.3	2.9	2.9	2 – 4
3	VIM	4.38	4.35	3.82	3.71	3.56	2.55	2.02	3 – 5
4	VMA	12.9	13.9	14.4	15	15	15.1	16.3	Min. 15
5	VFA	55.23	68.79	73.4	77.89	80.97	83.14	87.61	Min. 65
6	Marshall Quotient	362.50	335.52	361.10	366.30	378.15	379.17	373.14	Min. 250

Marshall Test Results with LGA

The mixture of test specimens uses aggregate, LGA, fly ash filler, and pen asphalt. 60/70 production PT. Pertamina with variations in asphalt content of 3.0%; 3.5%; 4.0%; 4.5%; 5.0%; and 5.5%. Marshall test results with LGA are attached in Table 4.

Table 4. Marshall Test Results with LGA

No	Mixed Characteristics	Asphalt Content						Specification
		3%	3.50%	4.00%	4.50%	5.00%	5.50%	
1	Stability	1387.5	1492.3	1387.5	1335.2	1274.1	1195.6	Min. 800
2	Melt (flow)	2.5	2.8	3.2	3.3	3.5	3.7	2 – 4
3	VIM	5.35	5.24	4.98	4.15	3.58	2.88	3 – 5
4	VMA	13.2	14.1	15	15.3	15.8	16.2	Min. 15
5	VFA	59.46	62.98	66.7	72.8	77.33	82.21	Min. 65
6	Marshall Quotient	555.00	532.96	433.59	404.61	364.03	323.14	Min. 250

Marshall Test Results with Bottom Ash

The mixture of test objects uses aggregate, bottom ash, fly ash filler, and pen asphalt. 60/70 production PT. Pertamina with variations in asphalt content of 5.0%; 5.5%; 6.0%; 6.5%; and 7.0%. Marshall test results with bottom ash are attached in Table 5.

Table 5. Marshall Test Results with Bottom Ash

No	Mixed Characteristics	Asphalt Content					Specification
		4.90%	5.40%	5.90%	6.40%	6.90%	
1	Stability	1397.5	1447.5	1577.3	1225.3	1114.2	Min. 800
2	Melt (flow)	2.37	3.7	3.17	2.8	2.63	2 – 4
3	VIM	5.95	4.79	3.48	1.45	0.9	3 – 5
4	VMA	14.99	15.03	14.96	14.23	14.84	Min. 15
5	VFA	60.34	68.16	76.73	89.84	94.14	Min. 65
6	Marshall Quotient	589.66	391.22	497.57	437.61	423.65	Min. 250

Review of Stability Values

The use of LGA and bottom ash as aggregate substitution in asphalt concrete mixes has an effect on the increased stability value. The highest stability value in the AC-WC LGA variation is 1492.3 kg with an asphalt content of 3.5%; while the AC-WC bottom ash variation is 1506.9 kg. All variations meet the requirements of a minimum of 800 kg.

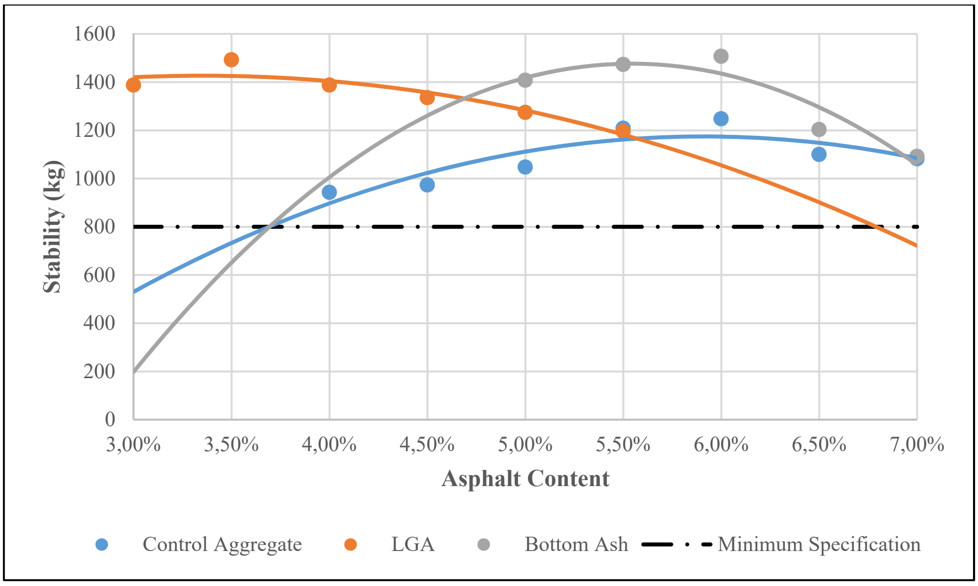

Figure 2. Graph of the Effect of Using LGA and Bottom Ash on Stability Values

Overview of Melt Value (flow)

Figure 3 proves that all variations of asphalt concrete mix with control aggregate, LGA, and bottom ash meet the requirements for flow values, which are between 2 and 4 mm. AC-WC with bottom ash tends to have lower melting values than the control aggregate variation and AC-WC variation with LGA.

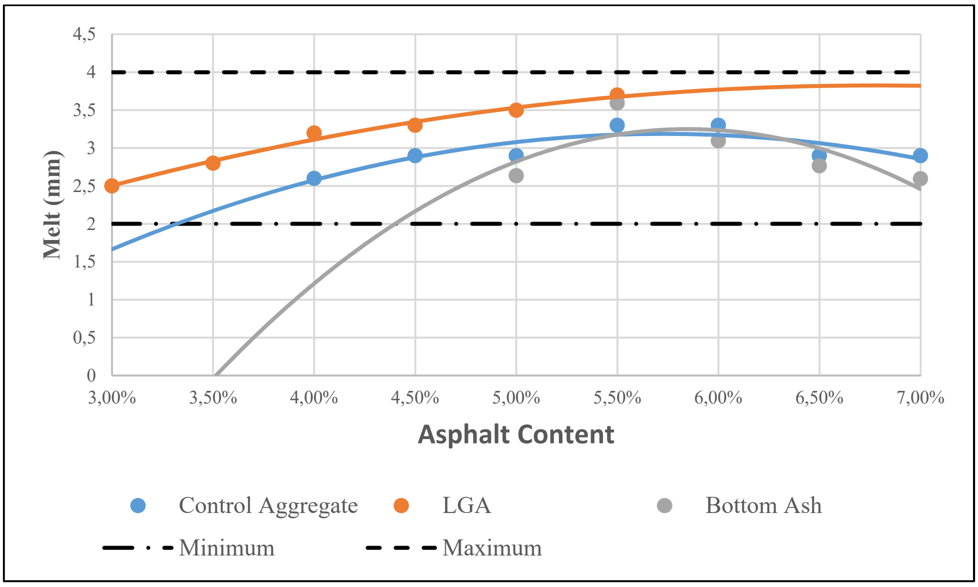

Figure 3. Graph of the Effect of Using LGA and Bottom Ash on Melt Value (flow)

Review of Void in Mixture or VIM

All variations have a tendency for VIM values to decrease with increasing asphalt content. In Figure 4, it can be concluded that the variations that meet the requirements of the 2018 Highways general specifications (revision 2) for VIM values are AC-WC with LGA asphalt content of 4.0%–5.5% and AC-WC with bottom ash asphalt content of 5.3%–6.0%.

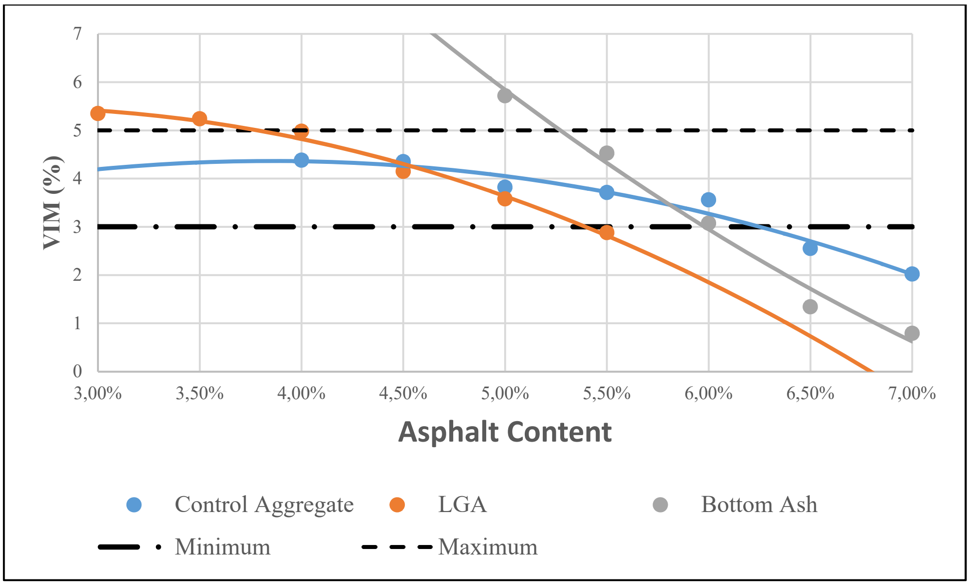

Figure 4. Graph of the Effect of Using LGA and Bottom Ash on the VIM Value

Overview of Void in Mineral Aggregate (Void in Mineral Aggregate) or VMA

Variations of substitution with LGA have a tendency for VMA values to increase with increasing asphalt content, while variations of substitution with bottom ash have a tendency for VMA values to decrease with increasing asphalt content.

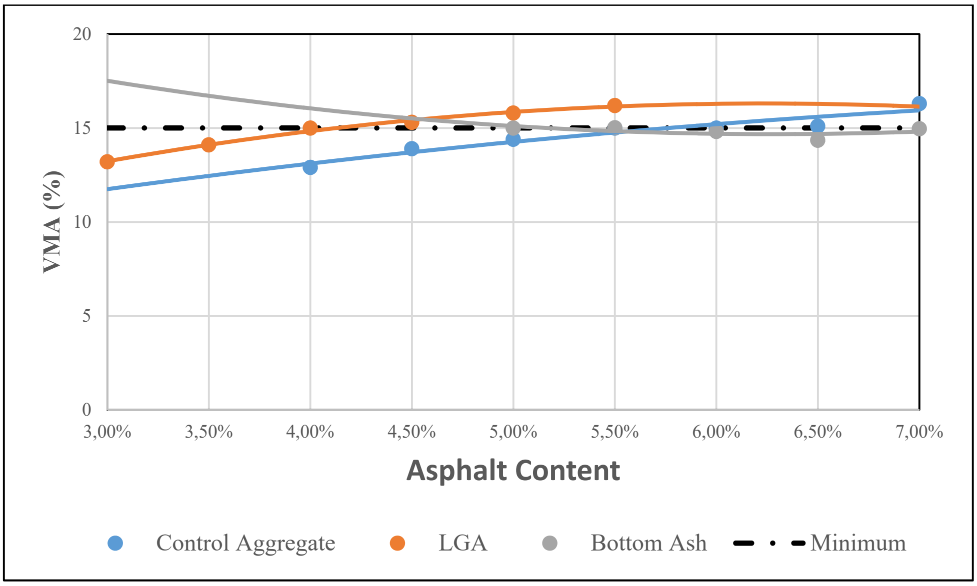

Figure 5. Graph of the Effect of Using LGA and Bottom Ash on VMA Values

Overview of Void Filled by Asphalt or VFA

All variations have a tendency for VFA values to increase with increasing asphalt content. Figure 6 shows the highest VFA value for the LGA variation is 82.21% with 5.5% asphalt content, and the bottom ash variation is 95% with 7.0% asphalt content.

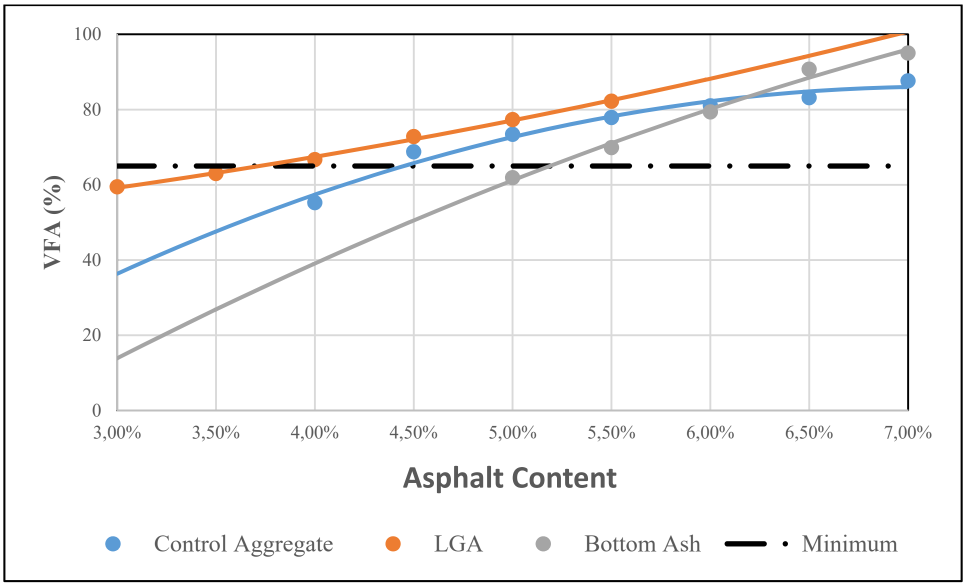

Figure 6. Graph of the Effect of Using Waste Concrete on the VIM Value

Overview of the Marshall Quotient (MQ)

The MQ value for each variation tends to decrease as the asphalt content increases. Figure 7 shows that the highest MQ value in the LGA variation is 555 kg/mm with 3.0% asphalt content, while it is 533.95 kg/mm with 5.0% asphalt content.

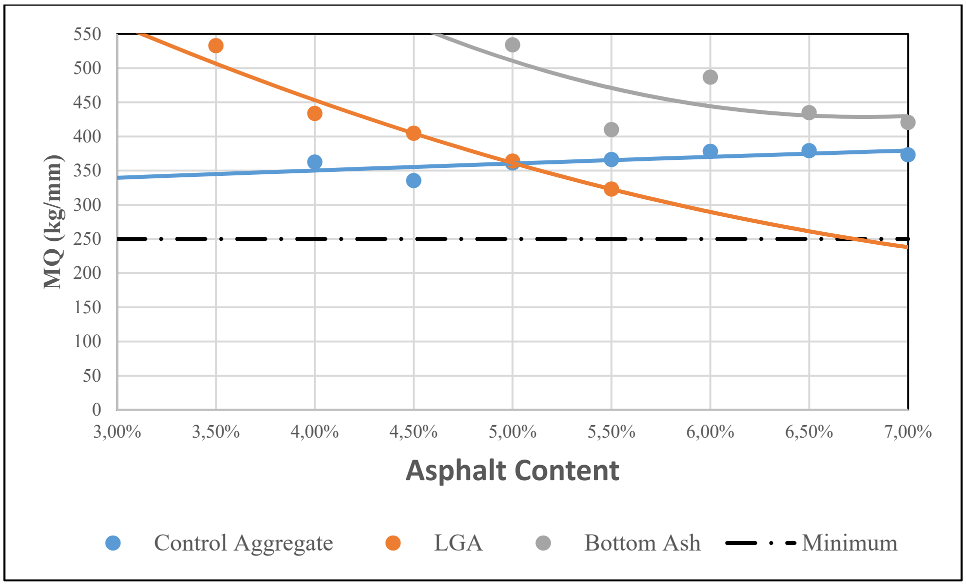

Figure 7. Graph of the Effect of Using LGA and Bottom Ash on MQ Values

IV. Conclusion

Based on the research that has been done, several conclusions can be drawn, namely that the optimal asphalt content (KAO) value for the LGA variation of wear-coated asphalt concrete (AC-WC) is 4.20%. Furthermore, the bottom ash variation has a stability value of 1495.0 kg, a flow of 3.47 mm, a VIM of 3.77%, a VMs of 14.78%, a VFA of 74.51%, and a MQ of 435.8 kg/mm at the optimal asphalt content (KAO) value for asphalt concrete wear layer mixture (AC-WC). Based on the conclusions obtained, the advice that can be given after conducting this research is based on the results of laboratory tests. LGA and bottom ash can be used as aggregate substitutions in asphalt concrete wear layers (AC-WC), but it is necessary to do a durability test. After obtaining the optimal asphalt content (KAO), it is necessary to test the Marshall parameter with the KAO value. Further research needs to be carried out by extracting bitumen from LGA before planning the asphalt concrete mix wear layer to determine the total asphalt content obtained from LGA and bitumen.

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