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Review Article

Effect of Aggregate Abrasion Value on Marshall Parameters in Mixed LGA (Lawele Granular Asphalt)

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Abstract *- The purpose of this research is to examine the influence of aggregate abrasion on the various parameters in the LGA (Lawele Granular Asphalt) mixture. In this investigation, the aggregate composition was determined by trial and error. Oil modification and asphalt were mixed in a 70:30 ratio. The amount of lawele bitumen in the combination was 25%, while the overall amount of bitumen in the mixture was 5.5% and 6.0%, respectively. Each sample was made using the heat transfer process. Marshall testing was performed following the heating procedure to a temperature of 150ºC before distributing. The abrasion values utilised vary by 24.45%, 32.68%, and 38.01%. According to the results of the Marshall test, the higher the abrasion value of the aggregate, the lower the stability. At an abrasion value of 24.45%, the greatest stability value of 1114 kg was attained. The abrasion levels that satisfy all Marshall characteristics (Stability, Meltability, MQ, Density, VIM, VMA, and VFA) fall between 24.45% and 38.01%.*

Keywords *- Aggregate, Abrasion value, Marshall parameter.*

1. Introduction

Asphalt Buton (Asbuton) is natural asphalt found in rock formations around the island of Buton. With butane asphalt resources of 650 million metric tonnes, Indonesia is the world's largest producer of natural asphalt. The surface layer is the layer that bears the most load on road pavements. As a result, the material used to construct this layer must be sufficiently robust. It is made up of wide varieties, one of which is asbuton lame, with aggregate as its major component. The aggregates employed in this study were of local origin, specifically crushed and medium crushed stones from Sorawolio, Lolibu, and Masiri in Batauga Village.

The stability of the Sorawolio material, the somewhat stable Lolibu material, and the stable Masiri material are unknown among the three aggregates' features. The three materials will be tested for abrasion to determine strength, durability, and resistance to mechanical loads, namely the abrasion value by abrasion testing using a Los Angeles abrasion machine and the Marshall test to determine the extent to which it affects the asphalt concrete mix's characteristics (density, VMA, VIM, VFB, flow, stability, and MQ). In addition, the range of abrasion values that fulfil the properties of asphalt concrete mixes. The researchers evaluated the abrasion value of coarse aggregate to assess its influence on the various parameters in the LGA (laminated granular asphalt) mixture, as described above.

2. Literature Approach

The surface layer of road pavement is the layer that bears the most weight. As a result, the material used to construct this layer must be sufficiently robust. Many surface layers of road pavement construction are routinely employed [1], [2]. Asphalt concrete is one form with great stability, with aggregate being the primary component of the mixture. Therefore, the carrying capacity, durability, and quality are mostly governed by the qualities of the constituent aggregates [3], [4]. The hardness of aggregate is one of the aggregate qualities that determine the quality of road pavement [5]. This attribute is strongly connected to the aggregate's resistance to load [6]. Hard aggregates can keep the asphalt mixture from dissolving during shipping, spreading, and compacting [7,8]. The resistance of an aggregate to mechanical stresses is shown by its abrasion value, which is achieved by abrasion testing with a Los Angeles abrasion instrument [22].

At room temperature, asphalt is characterised as a black or dark brown substance that is solid to slightly solid. Asphalt may become soft/liquid when heated to a particular temperature, allowing it to wrap aggregate particles for creating asphalt concrete [9], [10]. When the temperature drops, the asphalt hardens and binds the aggregate in place. That is why asphalt is known as thermoplastic [11] [12,15]. Aggregate abrasion or wear is the process of breaking down or breaking down aggregate, in this case, coarse aggregate, as a result of mechanical processes such as forces encountered during the road construction process (backfilling, spreading, compaction [5], [14]), service to traffic loads, and chemical processes such as the influence of humidity, overheating, and temperature changes throughout the day [16], [23].

Abrasion value is a measurement that reflects the resistance of a coarse aggregate to mechanical load destruction (degradation) [17]. The abrasion value is determined in the laboratory by performing an abrasion experiment (Los Angeles Abration Test) with a Los Angeles abrasion instrument. Abrasion values are checked in accordance with SNI-03-2417-1991 or AASHTO T 96-87. The mechanical forces measured by the Los Angeles abrasion instrument are derived from steel balls put into the test aggregate [18], [5]. Aggregate with predefined gradations and weights is placed into the Los Angeles machine with steel balls and spun at 30-33 rpm for 500 revolutions [20]. The final value (abrasion value) is stated in percent. It is calculated by comparing the original weight of the test object minus the weight of the test item retained by the No. 12 sieve with the weight of the original test object [21].

The aggregate is the most important component of an asphalt concrete mixture. There are numerous methods for determining the aggregate content in an asphalt concrete mix. The Ideal Gradation Method is a popular method, particularly in laboratory experiments (Ideal Spec) [4], [9]. The aggregate composition is determined using this approach by calculating the mean value of the gradation up and down the scale. The retained percentage of aggregate required for each sieve number is derived using this median value [10].

A prior study examined aggregate wear and tear testing using the Los Angeles technique and the impact test to determine the difference in aggregate resistance values using the impact test method and the Los Angeles method. The investigation was carried out by comparing the robustness of aggregates collected from various sites. The study's analysis and discussion revealed that river stone from the Kalisat river has the highest strength, with an average impact value of 7.93% and an average Los Angeles value of 25.83%. The crushed stone from Jambuan has the lowest strength, with an average Impact score of 42.86% (exceeding the standard, a maximum of 30%) and an average Los Angeles score of 77.90% (exceeding the standard, a maximum of 40%). The investigation indicated that aggregates from Jambuan and Sumberejo should not be used in road and construction designs since their values do not meet the standards.

Another investigation was carried out to determine the influence of aggregate abrasion value on the features of asphalt concrete by varying the aggregate abrasion value from 16.41 to 20.44, 25.71 to 28.57, and 35.86%. According to the research findings, the higher the aggregate abrasion value, the worse the performance of the asphalt concrete mixture, with a maximum stability value of 1787.477 kg occurring at an abrasion value of 20.44%. Furthermore, the study's findings concluded that the range of abrasion values that meet the characteristics of asphalt concrete mixtures is 7.592% to 64.98%. The maximum required aggregate abrasion value is 40%, but the study's findings show that an abrasion value of 64.98% can still produce an asphalt concrete mixture that meets specifications.

Buton asphalt, in general, is a material that has not been well investigated in terms of its use and its influence on numerous material characteristics. However, with adequate deposits, the use of asphalt must be carried out with greater depth and intricacy. So, this study fills a gap in previous research by putting Buton Asphalt on the map as a local material likely to be used a lot after many correlations are found, and the effect of physical properties on total strength is understood.

3. Materials and Methods

In general, three approaches are utilised in research: the survey method, the case method (case study), and the experimental method. The experimental approach was employed in this investigation. The experimental approach involves conducting research by creating a number of test objects to be used as samples to create a formula that meets standards. In general, the method will consist of collecting materials in the field and then proceeding to the testing, measurement, and laboratory observation stages of the research materials (aggregate and liquid asphalt), followed by the creation of a mix design and the production of briquettes using the hot spread hot mix method. The data was analysed using the "General Specifications of Bina Marga Division 6 Asphalt Pavement 2018" by comparing the results of laboratory testing with existing values that meet the performance criteria of the AC-WC mixture.

The key elements in this study were coarse aggregate, fine aggregate, filler, and Lawele asphalt, and all of these materials were tested before a mix design was created using the trial and error method. Then, using the hot spread hot mix technique, determine the asphalt content variation, which is 5.5% and 6.0%, whereas asbuton lawele is 15% of the total weight of the mixture in one briquette. Marshall Stability, Density, Flow, Void In Mix, Void Filled Bitumen, and Marshall Qouitien are all variables that must be determined.

The sampling of coarse and fine aggregate is done immediately on-site. This is done to ensure that the samples gathered are straight from that site. The samples were subsequently transferred to Dayanu Ikhsanuddin University's Civil Engineering Laboratory to be examined for characteristics and mix design data. Location of coarse aggregate material collection in Sorawolio District, Baubau City, Lolibu Village, Mawasangka Tengah District, Buton Tengah, and Masiri Village, South Buton Regency, and fine aggregate collection in Sorawolio District, Baubau City, manufactured by PT. Lakina Wolio. Then, on Buton Island, Asbuton Lawele was taken from PT. Wika Bitumen. It is officially located in Lawele Village, Lasalimu District, Buton Regency, Southeast Sulawesi Province.

The research materials used are:

[1] Coarse aggregate sourced from Sorawolio District, Baubau City, produced by PT. Lakina Wolio, Lolibu Village, Mawasangka Tengah District, Central Buton Regency, and Masiri Village, South Buton Regency

[2] Fine aggregate sourced from Sorawolio District, Baubau City, produced by PT. Lakina Wolio

[3] Modifier (used oil modifier)

[4] Lawele Asphalt from PT. Wika Bitumen
This study's material testing includes an analysis of coarse aggregate, fine aggregate, and asphalt in accordance with the Ministry of Public Works' General Specifications for Bina Marga Division 6 Asphalt Pavement, 2018. The following table shows the laboratory examination and standard coarse aggregate test standards for General Bina Marga Division VI Asphalt Pavement 2018:

Table 1. Laboratory Examination and Coarse Aggregate Test Standard

Num	Laboratory Test	Test Standard
1	Abrasion	SNI 03-2417-2008
2	Sieve Analysis	ASTM C136:2012
3	Specific Gravity and Water Absorption	SNI 03-1969-2016
4	Fine-grained material analysis (>sieve #200)	ASTM C117:2012

Table 2. Aggregate Characteristic Examination Results

Test	Unit	Testing Method	Result	Specification	
				Min	Max
A. Course Aggregate Sorawolio					
1. Bulk	gr/cc	SNI 1969:2008	2,7	2,5	-
2. Apparent	gr/cc	SNI 1969:2008	2,9	2,5	-
3. Effective	gr/cc	SNI 1969:2008	2,7	2,5	-
4. Absorption	%	SNI 1969:2008	2.4	-	3
5. > sieve #200	%	ASTM C117:2012	0,73	-	1
6. Abrasion using *Los Angeles*	%	SNI 2417:2008	24,45	-	40
B. Course Aggregate Lolibu					
1. Bulk	gr/cc	SNI 1969:2008	3,15	2,5	-
2. Apparent	gr/cc	SNI 1969:2008	3,45	2,5	-
3. Effective	gr/cc	SNI 1969:2008	3,24	2,5	-
4. Absorption	%	SNI 1969:2008	2,58	-	3
5. > sieve #200	%	ASTM C117:2012	0,71	-	1
6. Abrasion using *Los Angeles*	%	SNI 2417:2008	32,68	-	40
C. Course Aggregate Masiri					
1. Bulk	gr/cc	SNI 1969:2008	2,24	2,5	-
2. Apparent	gr/cc	SNI 1969:2008	2,26	2,5	-
3. Effective	gr/cc	SNI 1969:2008	2,25	2,5	-
4. Absorption	%	SNI 1969:2008	0,45	-	3
5. > sieve #200	%	ASTM C117:2012	0,68	-	1
6. Abrasion using Los Angeles	%	SNI 2417:2008	38,01	-	40
D. Fine Aggregate Sorawolio					
1. Bulk	gr/cc	SNI 1970:2008	2,18	-	-
2. Apparent	gr/cc	SNI 1970:2008	2,26	-	-
3. Effective	gr/cc	SNI 1970:2008	2,22	-	-
4. Absorption	%	SNI 1970:2008	0,86	-	3
5. > sieve #200	%	ASTM C117:2012	0,75	-	1
E. Filler					
1. Bulk	gr/cc	SNI 1970:2008	2,10	-	-
2. Apparent	gr/cc	SNI 1970:2008	2,16	-	-
3. Effective	gr/cc	SNI 1970:2008	2,13	-	-

The method of combining aggregates is to combine coarse and fine aggregates into a homogenous mixture with the expected grain arrangement or according to the standard requirements necessary. The aggregates were initially blended using a trial and error approach before combining the asphalt mixture components for the Hot Mix Asphalt mixture. The test object is planned by determining the mixture's composition, aggregate composition and asphalt content of the plan. The aggregate composition is determined via trial and error. LGA utilised is 15% of the overall weight of the combination in a 70:30 ratio, and an oil modifier is used. The overall bitumen content of the combination is between 5.5% and 6.0%. The hot mixing procedure was utilised in this investigation, and the specimens were subsequently prepared for the Marshall test.

4. Results and Discussion

Material testing, as mentioned in the sequence, relates to the 2018 General Highways Division 6 Asphalt Pavement General Specifications standards as a reference. The aggregate properties are tested as part of the material testing (Split, Medium, Filler). The material is inspected and tested in line with the 2018 General Specifications Division 6 Asphalt Pavement. Table 2 shows the results of the inspection and testing of aggregate features based on data analysis results.

Material inspection and testing are performed in accordance with SNI 03-3640-1994. The table 3 shows the results of the inspection and testing of aggregate features based on data analysis results.

Based on the analysis, the results of combining aggregate data using continuous gradations can be seen in Figure 1. The aggregate's specific gravity outside the asphalt material is the mixed aggregate specific gravity. The following aggregate specific gravity values were obtained based on the test results: bulk aggregate specific gravity = 2.41, aggregate apparent specific gravity = 2.23, effective specific gravity = 2.48, and asphalt absorption to total aggregate = 1.13%.

Table 3. Asbuton Lawele Characteristics Examination Result

Test		Unit	Testing Method	Result	Specification	
					Min	Max
1	Specific Gravity	gr/cc	SNI 06-2433-91	1.07	1.0	-
2	Penetration	Mm	SNI 06-2456-91	68	60	70
3	Ductility	Cm	SNI 06-2432-91	120	100	-
4	Weight Loss	%	SNI 06-2441-91	4,62	-	0.8

Table 4. Marshall Test Result

Characteristics	Variation in Total Bitumen in Mixtures						Specifications Bina Marga 2018
	Lolibu		Sorawolio		Masiri		
	5,5%	6,0%	5,5%	6,0%	5,5%	6,0%	
Stability (kg)	710	883	1114	974	766	965	Min. 800
Flow (mm)	1.73	1.49	2.37	2.14	1.97	2.08	02 – 04
Density (t/m²)	2.09	2.13	2.13	2.12	2.08	1.69	
VIM (%)	9.57	7.11	7.69	7.83	9.96	7.94	03 – 05
VMA (%)	18.01	16.73	16.30	17.38	18.36	17.48	Min. 15
VFA (%)	46.87	57.53	56.81	55.06	45.88	43.56	Min. 65
MQ (kg/mm)	426.63	604.53	464.29	474.74	396.18	603.13	Min. 250

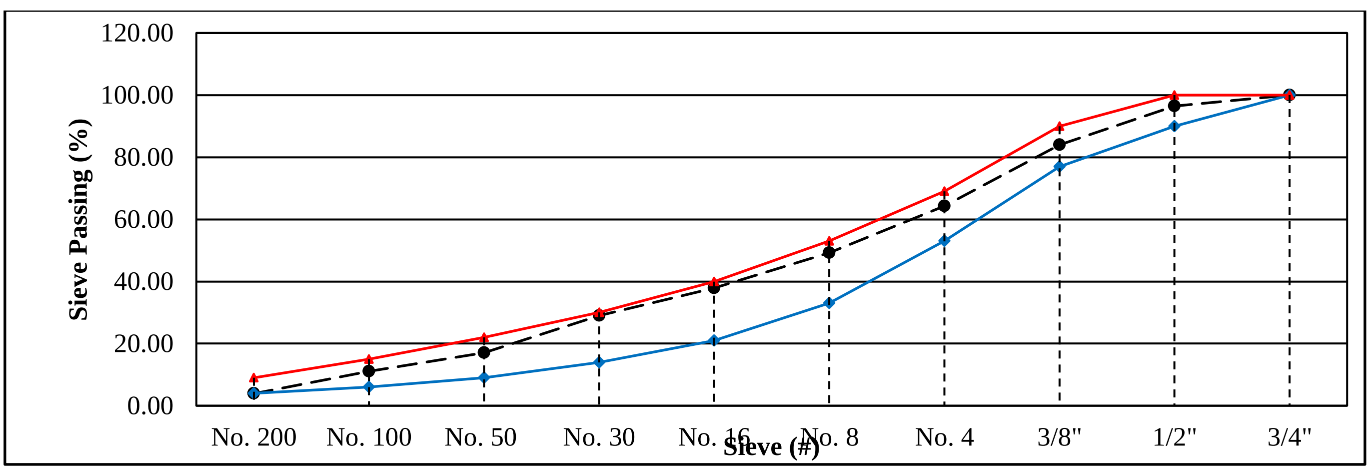

Fig. 1 Graph of Combined Aggregate Mixed Laston Coated Wear Coated (AC-WC)

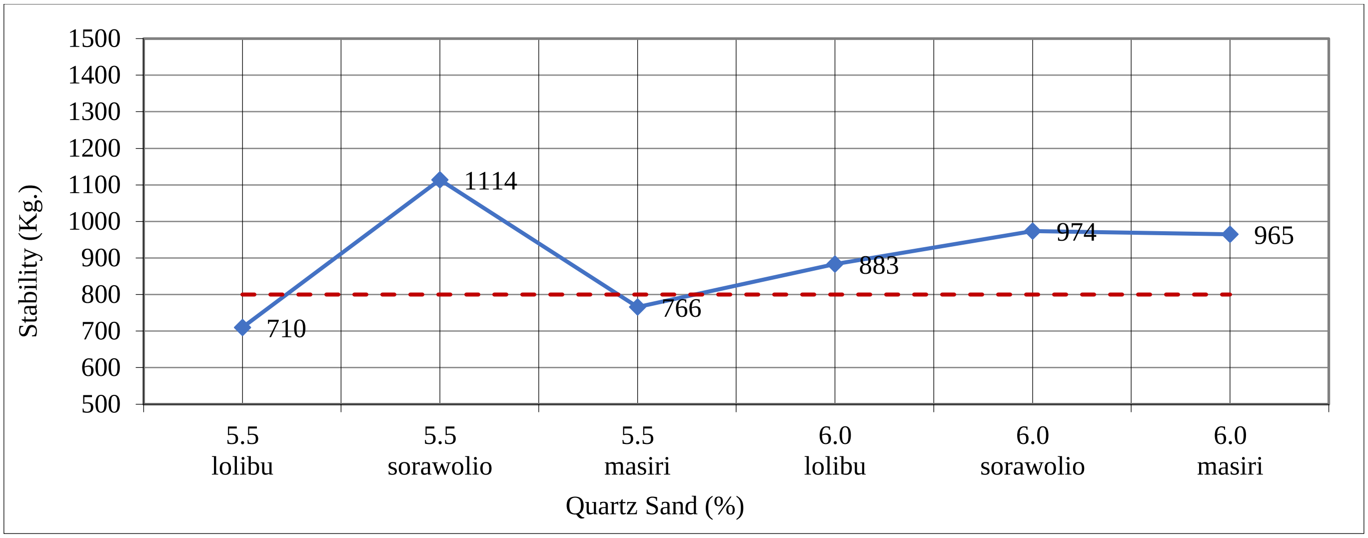

Fig. 2 Review of Material Asphalt Mixture on Stability Value

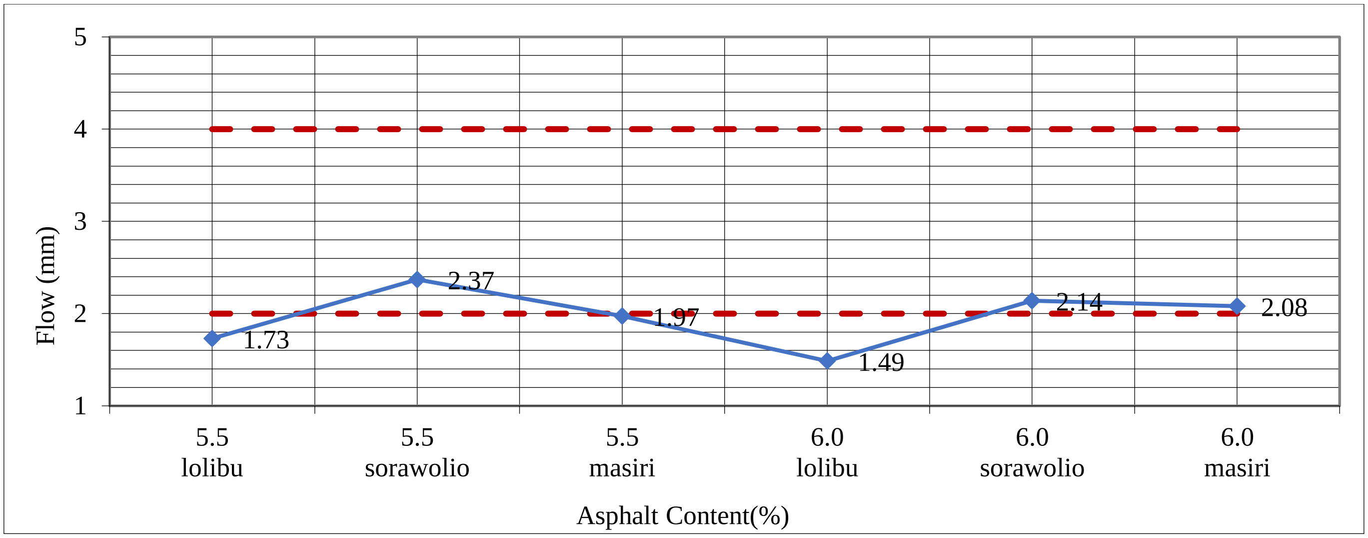

Fig. 3 Review of Asphalt Mixture Material on Flow

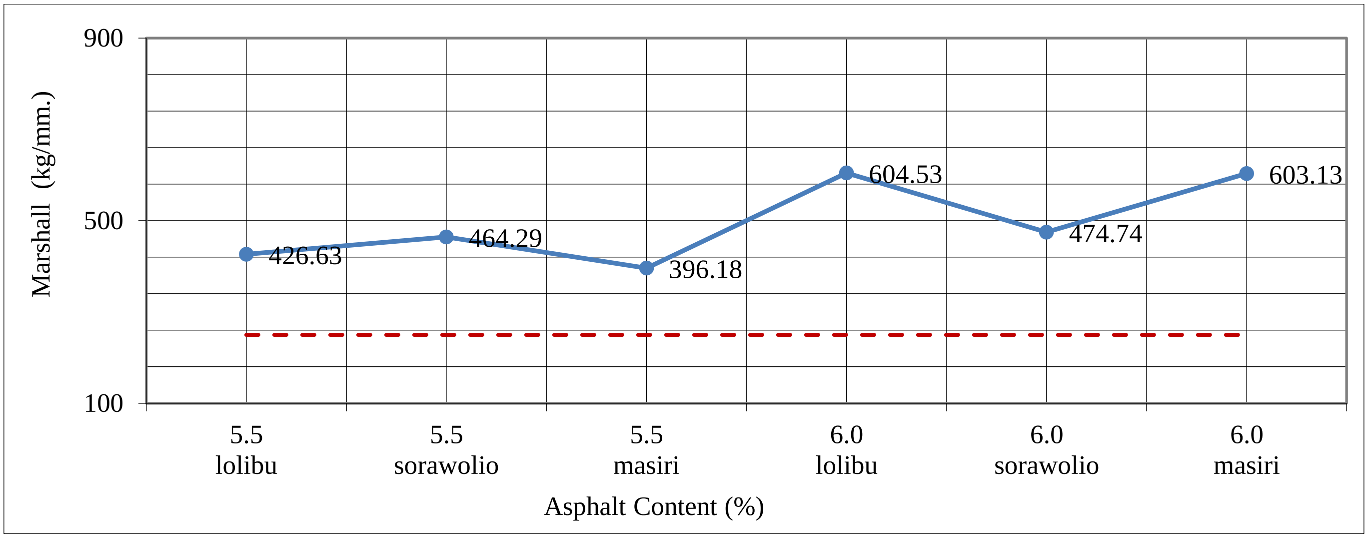

Fig. 4 Review of Asphalt Mixture Material on Marshall Quotient

According to Figure 2, the stability value of Lolibu 5.5 is 710 kg, while the stability value of Lolibu 6.0% is 883 kg. Those that satisfy the requirements are just 6.0% lolibu of 883 kg 800 kg. This is because as the amount of asphalt covering the aggregate grows, the density of the mixture increases, increasing the contact between the particles. The stability value of 5.5% Sorawolio is 1114 kg, while the stability value of 6.0% Sorawolio is 974 kg. As a result, both of them fulfil the 2018 Bina Marga standards of 800 kg.

According to the graph above, the stability value of 5.5% is 766 kg, and 6.0% is 965 kg. Masiri only met the criteria of 965 kg 800 kg by 6.0%. Looking at the graph above, the stability value decreases and subsequently increases. This is due to an increase in the amount of asphalt covering the aggregate, the density of the mixture increasing so that contact between the aggregates increases, then the stability decreases because the asphalt, which initially serves as a binder, transforms into a lubricant, resulting in less friction between the aggregates.

According to Figure 3, the flow value of 5.5% lolibu is 1.73, and the flow value of 6.0% lolibu is 1.49. None of the two bituminous versions fulfills the 2018 Bina Marga standards, which call for a thickness of 2 to 4 mm. According to the graph above, the flow value is dropping. This is due to the fact that as the asphalt concentration grows, the mixture becomes more plastic. When subjected to an excessive load, the asphalt content in the mixture causes the asphalt to soften, the deformation to increase, and the flow value to drop. Sorawolio 5.5% has a flow value of 2.37, whereas Sorawolio 6.0% yields a flow value of 2.14. The two bitumen variants match the 2018 Bina Marga standards of 2–4 mm. This is because as the asphalt concentration increases, the mixture becomes more plastic. When subjected to an excessive load, the asphalt content in the mixture causes the asphalt to soften, the deformation to increase, and the flow value to drop. According to Figure 4, the flow value acquired from Masiri 5.5% is 1.97, while the flow value obtained from Masiri 6.0% is 2.08. Masiri 6.0% of 2.08 between 2 and 4 mm is the bitumen variant that satisfies the Bina Marga criteria in 2018. This is due to the bitumen being absorbed by the aggregate, causing the mixture to soften.

According to Figure 4, the Marshall Quotient (MQ) value of 5.5% lolibu is 426.63 kg/mm, and the Marshall Quotient (MQ) value of 6.0% lolibu is 604.53 kg/mm. Both fulfil the Bina Marga standards for 2018, which are 250 kg/mm. 5.5% lolibu had a Marshall Quotient (MQ) of 426.63 kg/mm, whereas 6.0% lolibu had an MQ of 604.53 kg/mm. Both fulfil the Bina Marga standards for 2018, which are 250 kg/mm. According to Figure 5, the Marshall Quotient (MQ) value of 5.5% masiri is 396.18 kg/mm, and the Marshall Quotient (MQ) value of 6.0% masiri is 603.13 kg/mm. Both fulfil the Bina Marga standards for 2018, which are 250 kg/mm.

According to Figure 5, the density of 5.5% lolibu is 2.09 gr/cm3, and that of 6.0% lolibu is 2.13 gr/cm3. This demonstrates that the density value tends to drop as the fine aggregate content decreases. Sorawolio 5.5% has a density of 2.13 gr/cm3, and sorawolio 6.0% has a density of 2.11 gr/cm3. This demonstrates that the density value tends to drop as the fine aggregate content decreases. According to Figure 6, the density of 5.5% masiri is 2.08 gr/cm3, and that of 6.0% masiri is 1.69 gr/cm3. This demonstrates that the density value tends to drop as the fine aggregate content decreases.

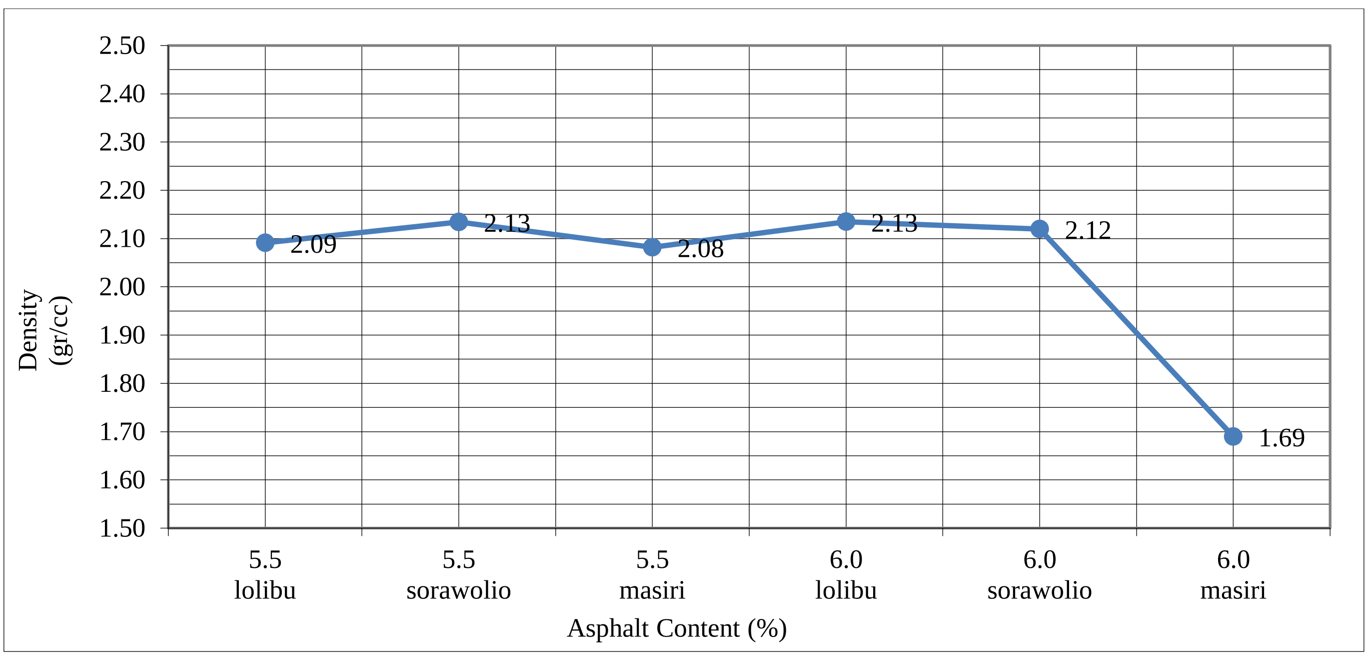

Fig. 5 Review of Asphalt Mixture Material on Density

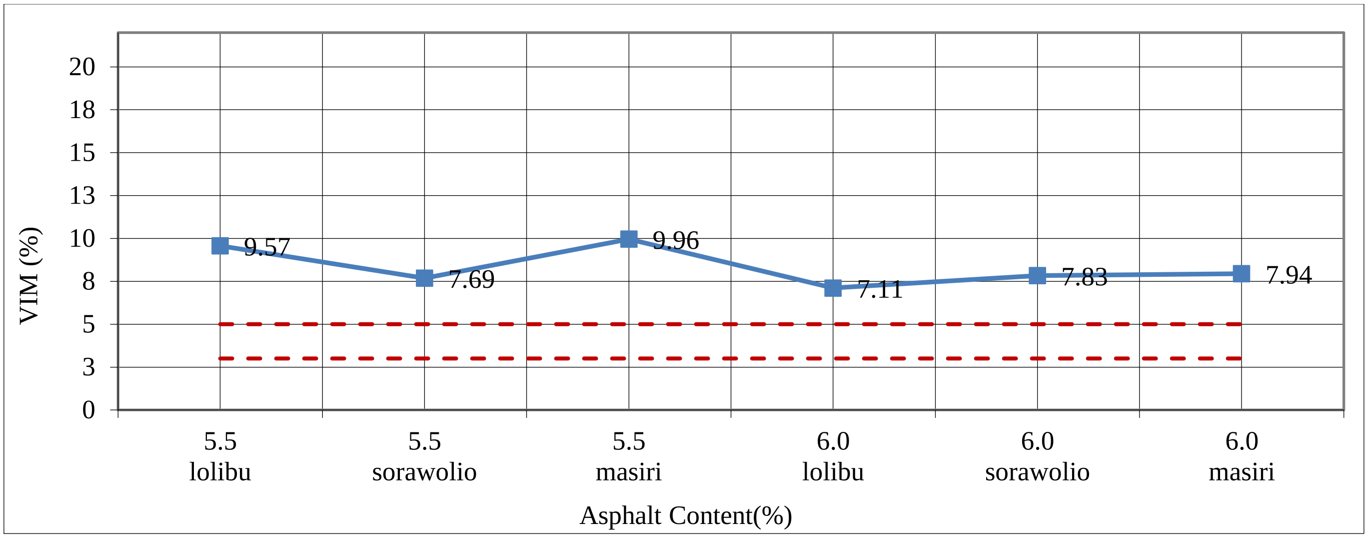

Fig. 6 Review of Asphalt Mixture Material on VIM

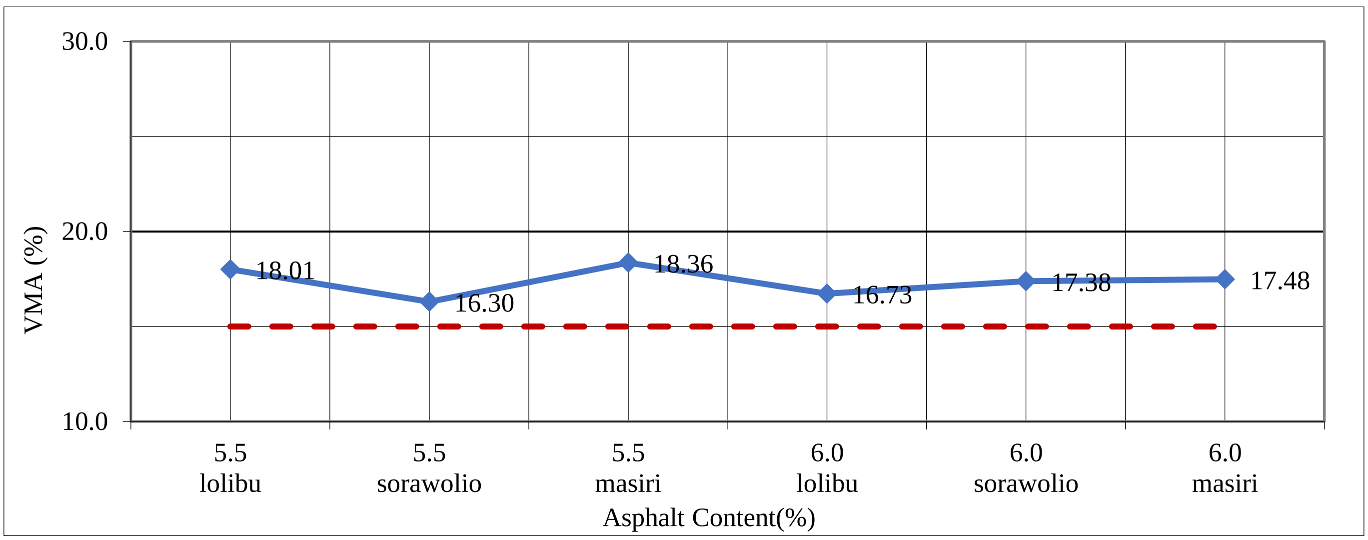

Fig. 7 Review of Asphalt Mixture Material on VMA

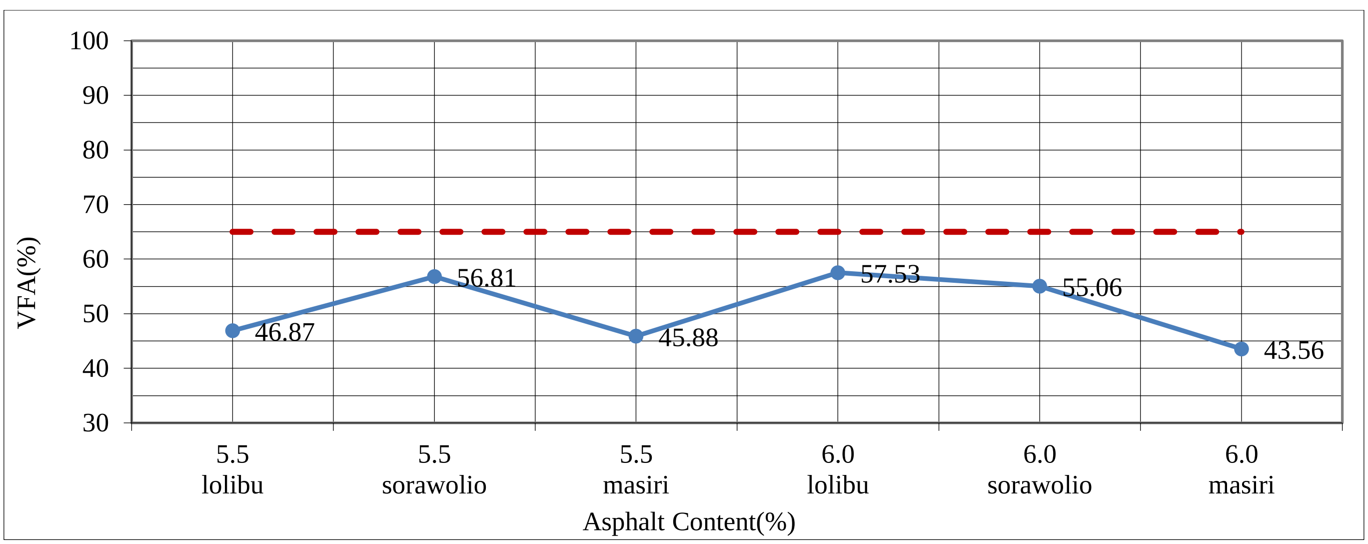

Fig. 8 Review of Asphalt Mixture Material on VFA

According to Figure 6, the voids in the mixture (VIM) for 5.5% lolibu is 9.57, and for 6.0% lolibu is 7.11. The two bitumen deviations are over the standards, namely 3-5%. This demonstrates that the more asphalt is utilised, the more the asphalt will fill the holes in the mixture. The void value in the mixture (VIM) was 9.57 for 5.5% sorawolio and 7.11 for 6.0% sorawolio. The two bitumen deviations are over the standards, namely 3-5%. In Figure 7, the value of voids in the mixture (VIM) is 9.96 for 5.5% masiri and 7.94 for 6.0%. The two bitumen deviations are over the standards, namely 3-5%. This demonstrates that when additional asphalt is used, the asphalt will cover the voids, causing the cavities to shrink. Suppose the VIM value exceeds the standard or is very high. In that case, the water tightness of the asphalt concrete mixture will decrease, resulting in a substantial asphalt oxidation process that accelerates the ageing process. Meanwhile, if the VIM number is too low, it will produce bleeding on the pavement.

Figure 7 shows that the value of voids in the aggregate (VMA) for 5.5% of lolibu is 18.01, and for 6.0% of lolibu is 16.73. VMA levels of 5.5% and 6.0% in lolibu variants satisfy Bina Marga standards of 15%. 5.5% sorawolio's VMA value is 16.30, and 6.0% sorawolio's value is 17.38. The VMA value of 5.5% and 6.0% sorawolio satisfies the 2018 Bina Marga standards of 15%. Figure 8 also shows the mass-specific void in aggregate (VMA) value of 5.5% at 18.36 and 6.0% at 17.48. VMA readings of 5.5% and 6.0% masiri satisfy the 2018 Bina Marga standards of 15%. The VMA value that fulfills the criteria is intended to allow enough space on the asphalt to adhere to the aggregate. The flexibility of the pavement layers is enhanced by high VMA levels and asphalt content. If the VMA value is low, the asphalt covering the aggregate is restricted, resulting in a thin asphalt layer.

According to Figure 8, the value of 5.5% of the lolibu VFA is 45.87, and the value of 6.0% of the lolibu is 57.53. They both failed to fulfill the 2018 Bina Marga standards of 65%. 5.5% sorawolio had a VFA value of 56.81, whereas 6.0% sorawolio had a VFA value of 55.06. They both failed to fulfill the 2018 Bina Marga standards of 65%. The graphic clearly shows that the VFA value is increasing. This is because the spaces between the grains are still large enough that the asphalt may easily enter the cavity of the mixture with each addition of asphalt until the mixture becomes tight. Figure 8 shows that the VFA value is 5.5%, or 45.88, and 6.0%, or 43.56. They both failed to satisfy the Bina Marga standards of 65%. This demonstrates that asphalt does not cover many aggregate grains, lowering the VFA value.

5. Conclusion

Based on the results of the Marshall test, it is possible to conclude that the material suitable for use as an asphalt mixture is material from Sorawolio and Masiri because the stability and flow values match the minimum standard criteria necessary for road operations in Indonesia. Each of the three materials meets the maximum aggregate abrasion value criterion of 40%. The most stable substance is Sorawolio material because its stability and flow exceed standards, followed by Masiri's material and Lolibu. The maximum aggregate abrasion value required is 40%. However, the study's findings demonstrate that an abrasion value of 38.01% may still generate an asphalt concrete mixture that matches the standards of 24.45%.

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References

[1] Chien-Wei Huang, Tsung-Han Yang, and Guan-Bo Lin1 "The Evaluation of Short- and Long-Term Performance of Cold-Mix Asphalt Patching Materials," *Advances in Materials Science and Engineering*, vol. 2020, 2020, *Crossref*, https://doi.org/10.1155/2020/8968951

[2] Gito Sugiyanto, "Marshall Test Characteristics of Asphalt Concrete Mixture with Scrapped Tire Rubber as a Fine Aggregate," *Technology Journa*l, vol. 79, no. 2, pp. 55–64, 2017, *Crossref*, https://doi.org/10.11113/jt.v79.6965

[3] Ayuni Laurentia Bolung, Theo K. Sendow, and Joice E. Waani, "Comparison of Marshall Criteria on Hot Asphalt Mix (Hrs-Wc) Using Modified Asbuton (Retona Blend 55) With 60/70 Penetration Asphalt," *Journal of Civil Static*, vol. 7, no. 11, pp. 1537–1546, 2019.

[4] A. Fanani et al., "Against Stability Values in Mixed Asphalt Concrete (Hrs-Wc) Against Marshall Test Characteristics," *Journal.Pnk.Ac.Id*, vol. 2, no. 1, pp. 54–63, 2017.

[5] Pawel Polaczyk et al., "Influence of Aggregates Angularity on the Locking Point of Asphalt Mixtures," *Road Materials and Pavement Design*, vol. 20, no. Sup1, pp. S183–S195, 2019, *Crossref*, https://doi.org/10.1080/14680629.2019.1588151

[6] Arabiah, "Effect of Using Sea Sand as Fine Aggregate in Hot Asphalt Mixes (Ac-Bc) with Marshall Testing," *Indian Higher Education* vol. 3, no. 1, pp. 1689–1699, 2021.

[7] Magdi M. E. Zumrawi, and Faiza O. A. Khalill, "Experimental Study of Steel Slag Used as Aggregate in Asphalt Mixture," *American Journal of Construction and Building Materials*, vol. 1, no. 1, pp. 12–18, 2017.

[8] Sanjana Y C, Nikhil T R, and Yateen Lokesh, "Performance Evaluation of Hot Mix Asphalt Using Modified Binders for Bituminous Concrete Grade-2," *SSRG international journal of civil engineering,* vol. 5, no. 9, pp. 12-17, 2018. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V5I9P103

[9] Evie Dwi Labora Bancin, Kamaluddin Lubis, and Nuril Mahda, "Effect of Using Red Soil as Filler in Ac-Bc Asphalt Mixture on Marshall Values," *Journal of Civil Engineering Building and Transportation*, vol. 5, no. 1, pp. 17–25, 2021, *Crossref*, https://doi.org/10.31289/jcebt. v5i1.5072

[10] S. Sumiati, M. Mahmuda, and P. Puryanto, “Advantages of Pre-Mixed Asbuton and Asphalt Shell in Asphalt Concrete Mixts (Ac-Bc)” *Journal of Poly-Technology*, vol. 18, no. 1, 2019, *Crossref*, https://doi.org/10.32722/pt.v18i1.1289

[11] G. M. Harun-Or-Rashid et al., “Marshall Characteristics of Bituminous Mixes Using Reclaimed Asphalt Pavement,” *American Journal of Traffic and Transportation Engineering*, vol. 3, no. 4, pp. 57–61, 2018, *Crossref*, https://doi.org/10.11648/j.ajtte.20180304.11

[12] S. R. Aletba et al., “Marshall Properties of Asphalt Mixture Containing Garnet Waste,” *Journal of Advanced Research in Material Science*, vol. 43, pp. 22–27, 2018.

[13] Feng Wang et al., “Effect of Aggregate Morphologies and Compaction Methods on the Skeleton Structures in Asphalt Mixtures,” *Construction and Building Materials*, vol. 263, 2020, *Crossref*, https://doi.org/10.1016/j.conbuildmat.2020.120220

[14] Marcio Muniz de Farias, Ferney Quiñonez Sinisterra, and Hugo Alexander Rondón Quintana, “*Behavior of a Hot Mix Asphalt Made with Recycled Concrete Aggregate and Crumb Rubber*,” *Canadian Journal of Civil Engineering*, vol. 46, no. 6, pp. 544–551,00202019, *Crossref*, https://doi.org/10.1139/cjce-2018-0443

[15] Ch. Naveen Kumar, V. John Prashath, and Dr. K.Hari Krishna, "An Experimental Study on Bitumen Properties By Using Medical Plastic Waste," *SSRG International Journal of Civil Engineering*, vol. 6, no. 8, pp. 17-29, 2019. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V6I8P103

[16] Fauzie Nursandah, and Moch. Zaenuri, “Research on the Addition of Natural Rubber (Latex) in Mixes Laston Ac-Wc to the Characteristics of Marshall,” *Journal Civila*, vol. 4, no. 2, pp. 262–267, 2019.

[17] D. El-Tahan et al., “Evaluation of Recycled Concrete Aggregate in Asphalt Mixes,” *Innovative Infrastructure Solution*, vol. 3, no. 1, 2018. *Crossref*, https://doi.org/10.1007/s41062-018-0126-7

[18] Eduardi Prahara, and Chesia Claudia Hangewa, “Analyze Marshall Characteristic and Cantabro Abrasion Loss of Laston-Wc with High-Density Polyethylene Variations,” *IOP Conference Series: Earth and Environmental Science*, vol. 426, no. 1, p. 12037, 2020, *Crossref*, https://doi.org/10.1088/1755-1315/426/1/012037.

[19] Pankaj Joshi, U C Gupta Raj Kumar, and Rajeev Kumar, "Interrelation of Physical and Mechanical Properties of Basalt," *SSRG International Journal of Civil Engineering*, vol. 6, no. 10, pp. 37-41, 2019. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V6I10P105

[20] Dongliang Kuang, “Influence of Angularity and Roughness of Coarse Aggregates on Asphalt Mixture Performance,” *Construction and Building Materials*, vol. 200, pp. 681–686, 2019. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2018.12.176

[21] H. R. Jahanian, G. Shafabakhsh, and H. Divandari, “Performance Evaluation of Hot Mix Asphalt (HMA) Containing Bitumen Modified With Gilsonite,” *Construction and Building Materials,* vol. 131, pp. 156–164, 2017. *Crossref*, https://doi.org/10.1016/j.conbuildmat.2016.11.069

[22] Gunawan Tarigan, “Comparison of Marshall Properties Using Mixed Aggregates for Ac-Wc Layers,” *Semnastek Uisu*, pp. 177–181, 2021.

[23] Ni Luh Putu Shinta Eka Setyarini et al., “Marshall Characteristics of Asphalt Concrete Wear Layer Using LDPE (Low Density Polyethylene) Plastic Waste Covered Aggregate,” *Journal of Muara Science, Technology, Medicine and Health Sciences*, vol. 3, no. 1, p. 123, 2019. *Crossref*, https://doi.org/10.24912/jmstkik.v3i1.1697