SSRG International Journal of Civil Engineering
ISSN: 2348 – 8352 / https://doi.org/10.14445/23488352/IJCE-V9I1P103

Volume 9 Issue 1, 15-24, January 2022

Original Article

The Use of Dumoga River Sand Material on Stone Ash Material in AC-Base and Semi-Gap Graded HRS-WC Mixtures

Mecky R.E. Manoppo[1], Joice E. Waani[2], Meike Kumaat[3]

[123]*Department of Civil Engineering, Universitas Sam Ratulangi*

Received: 13 December 2021 Revised: 15 January 2022 Accepted: 28 January 2022 Published: 31 January 2022

Abstract *- This study aims to reduce the use of stone ash (fine aggregate) in a mixture of AC-Base and semi-gap graded HRS-WC by utilizing Dumoga river sand as fine aggregate.*

The research was carried out by making 3 variations for aggregate (combined graded aggregate) by trial and error for each mixture of AC-Base and semi-gap graded HRS-WC. the asphalt used was 5.5 %, 6%, 6.5% for the mixture of AC-Base and 6%, 6.5%, 7% for the mixture of semi-gap graded HRS-WC.

The results obtained under the Marshall criteria for the use of Dumoga sand in the AC Base mixture, namely in variation 2 with 6% asphalt content, generate a Stability value of 1971.82 kg, Flow 3.75 mm, VIM 4.%, VMA 14.25%, and VFB 74.09%. Then the semi-gap graded HRS-WC mixture using Dumoga sand, namely in variation 2 with an asphalt content of 6.5%, generates a Stability value of 1288.3 kg, Flow 3.31 mm, VIM 4.83%, VMA 23.25%, and VFB 71.54%. These results indicate that Dumoga sand material can be used in AC-Base mixtures up to 15% and up to 35% in semi-gap graded HRS-WC mixtures.

Keywords *- AC-Base, Dumoga Sand, Semi-gap Graded HRS-WC, Stone Ash.*

1. Introduction

In general, flexible pavement construction consists of several layers, namely the surface course and the base course, using a hot asphalt mixture. HRS WC (Hot Rolled Sheet Wearing Course) and AC Base (Asphalt Concrete Base) are hot asphalt mixtures used for surface course and base course

On roads, which are several parts of the types of hot asphalt mixtures that exist and are used in Indonesia. This mixture consists of coarse aggregate, medium aggregate, fine aggregate, filler, and asphalt. in its implementation in the field, the aggregates used are sourced from the results of stone crushing. for fine aggregate (stone ash) material, the amount required in the asphalt mixture is quite large, which is about 50% to 60% of the total weight of the mixture.

The process of providing aggregate through a stone crusher, especially fine aggregate (stone ash), takes longer and is quite expensive. Because of the difficulty of obtaining fine aggregates in large quantities with quality under specifications, the use of natural aggregates has become an alternative to be used as additional material.

The potential of natural resources in the mining sector is quite abundant in North Sulawesi. One of them is the availability of natural sand material found in the Dumoga river. Given the difficulties encountered in the field of supply or demand for large quantities of fine aggregate, it encourages researchers to use this natural sand material as an alternative to reduce the amount of fine aggregate or rock ash in a mixture of AC Base and HRS-WC. in terms of the economy, this sand is cheaper because it does not go through a treatment process and is widely available in Dumoga Village, Bolaangmongondow District, North Sulawesi.

2. Materials and Methods

2.1. Asphalt

Asphalt is a brownish-black sticky hydrocarbon and resistant to water. Its property is to bind the aggregate to the asphalt-concrete mixture and provide a waterproof layer. the

The asphalt used in this research is asphalt produced by Pertamina with penetration of 60/70. Asphalt requirements and the results obtained in this study are presented in Table 1

2.2. Aggregate

Aggregate is the dominant material in forming asphalt mixtures with an amount of about 90% to 95% of the total weight of the mixture. Aggregates are sourced from the result of the stone crusher. Based on the classification and size, the aggregate is divided into coarse aggregate with a size of 20-30 mm and 10-20 mm, medium aggregate with a size of 5-10 mm, fine aggregate (stone ash) with a size of 0-5 mm, and filler with a size smaller than 200 mm. Fine aggregate (stone ash) can also be made from natural sand. in this study, Dumoga natural sand was used, which was added to the fine aggregate (stone ash) by reducing the percentage of use of the fine aggregate (stone ash). the percentage of fine aggregate (stone ash) for each mixture is 50% to 60% of the total weight of the mixture. Aggregate requirements and yields obtained are presented in Table 2

2.3. Preparation of Specimens

2.3.1. Bituminous Specimen

Samples are prepared by making 3 variations between fine aggregate (stone ash) and Dumoga sand in each mixture, namely variation 1 for AC Base, which is 22.5% fine aggregate (stone ash) and 7.5% Dumoga sand. Variation 2 is composed of 15% fine aggregate (stone ash) and 15% Dumoga sand. Variation 3 is 7.5% fine aggregate and 22.5% Dumoga sand. for the mixture of semi-gap graded HRS-WC, Variation 1 is 52.5% fine aggregate and 17.5% Dumoga sand. Variation 2 is 35% fine aggregate, 35% Dumoga sand, and variation 3 is 17.5% fine aggregate, 52.5% Dumoga sand. the asphalt content of the AC base mixture was varied to 5.5%, 6%, and 6.5%, while the semi-gap gradation of the HRS–WC mixture was 6%, 6.5%, and 7%. for each variation, 3 samples were made with different amounts of asphalt content.

2.3.2. Marshall Mix Design

The Marshall Test method is the most commonly used and was standardized by the American Society for Testing and Materials (ASTM D -1559). in this study, samples were made with a weight of 1200 grams, consisting of coarse aggregate, medium aggregate, fine aggregate, and asphalt. Each sample was tested with Marshall criteria, namely stability, flow, VIM, and VFB. Marshall's test results can be seen in Table 5 to 10 and Figures 1 to 10

3. Test Result and Discussion

3.1. Inspection of Asphalt

Table 1. Results of Asphalt Physical Testing

No.	Test Type	Metode	Result	Codition
1.	Penetration	SNI 06-2456-1991	63.3	60 - 79
2.	Softening Point, °C	SNI 06-2434-1991	51.5	48 - 58
4.	Daktility 25 °C, cm	SNI-06-2432-1991	119	Min. 100
5.	Specfic Grafity	SNI 06-2441-1991	1.032	Min. 1,0

3.2. Inspection of Aggregate

Table 2. Results of aggregate physical testing

No	Test Type	Unit	Condition	Result
A.	**Aggregate 20-30 mm (SNI 03-1969-1990)**			
1	Bulk density	gr/cm3	>2.5	2.595
2	SSD density	gr/cm3	>2.5	2.619
3	Apperent density	gr/cm3	>2.5	2.659
4	Absorption	%	<3	0.930
B.	**Aggregate 10-20 mm (SNI 03-1969-1990)**			
1	Bulk density	gr/cm3	>2.5	2.652
2	SSD density	gr/cm3	>2.5	2.694
3	Apperent density	gr/cm3	>2.5	2.942
4	Apsorption	%	<3	1.382
C.	**Aggregate 5-10 mm (SNI 03-1969-1990)**			
1	Bulk density	gr/cm3	>2.5	2.593
2	SSD density	gr/cm3	>2.5	2.636
3	Apperent density	gr/cm3	>2.5	2.708
4	Apsorption	%	<3	1.365
D.	**Aggregate 0-5 mm (SNI 03-1969-1990)**			
1	Bulk density	gr/cm3	>2.5	2.534
2	SSD density	gr/cm3	>2.5	2.656
3	Apperent density	gr/cm3	>2.5	2.786
4	Apsorption	%	<3	1.370
E.	**Dumoga Sand (SNI 03-1969-1990)**			
1	Bulk density	gr/cm3	>25	2.521
2	SSD density	gr/cm3	>2.5	2.595
3	Apperent density	gr/cm3	>2.5	2.788
4	Apsorption	%	<3	4.320
F.	**Aggregate impact test (SNI 03-4426-1997)**	%	Maks 30	22.19
G.	**Los Angeles abrasion test** (SNI-03-2417-1991)	%	Maks 40	23.45

Table 3. AC-Base combined graded

Sieve		Aggregate				Combined Gradation			Bina Marga Specification
ASTM	(mm)	Coarse Aggregate 20-30 mm	Coarse Aggregate 5-10 mm	StoneAsh (Fine Agreggregate) 0-5 mm	Dumoga Sand	Variation 1	Variation 2	Variation 3	
1 1/2"	37.5	100.00	100.00	100.00	100.00	100.00	100.00	100.00	**100**
1"	24.40	81.50	100.00	100.00	100.00	94.45	94.45	94.45	**90 - 100**
3/4"	19.10	25.37	100.00	100.00	100.00	77.61	77.61	77.61	**76 - 90**
1/2"	12.70	1.70	100.00	100.00	96.88	70.28	70.04	69.81	**60 - 78**
3/8"	9.52	1.45	98.85	100.00	92.55	69.42	68.86	68.30	**52 - 71**
#4	4.75	1.44	26.30	99.67	79.71	39.35	37.86	36.36	**35 - 54**
#8	2.36	1.44	5.12	82.86	67.15	26.16	24.98	23.80	**23 - 41**
#16	1.18	1.43	4.09	65.01	55.46	20.85	20.14	19.42	**13 - 30**
#30	0.60	1.42	3.70	53.94	40.88	17.11	16.13	15.15	**10 - 22**
#50	0.30	1.40	3.41	37.53	26.54	12.22	11.39	10.57	**6 - 15**
#100	0.15	1.37	3.03	27.58	12.27	8.75	7.60	6.45	**4 - 10**
#200	0.075	1.34	2.47	17.14	5.07	5.63	4.72	3.82	**3 - 7**
a	**Coarse Aggregate 20-30 mm**					30.00%	30.00%	30.00%	
b	**Coarse Aggregate 5-10 mm**					40.00%	40.00%	40.00%	
c	**Stone Ash (Fine Agreggregate) 0-5 mm**					22.50%	15.00%	7.50%	
d	**Dumoga Sand**					7.50%	15.00%	22.50%	
TOTAL						100%	100%	100%	

Table 4. Semi-gap graded HRS-WC combined graded

Sieve		Aggregate				Combined Gradation			Bina Marga Specifications
ASTM	(mm)	Coarse Aggregate 10-20 mm	Coarse Aggregate 5-10 mm	StoneAsh (Fine Agreggregate) 0-5 mm	Dumoga Sand	Variation 1	Variation 2	Variation 3	
1"	24.40	100.00	100.00	100.00	100.00	100.00	100.00	100.00	**-**
3/4"	19.10	81.50	100.00	100.00	100.00	100.00	100.00	100.00	**100**
1/2"	12.70	25.37	100.00	100.00	100.00	90.51	89.97	89.42	**87 - 100**
3/8"	9.52	1.70	100.00	100.00	96.88	85.54	84.24	82.94	**55 -88**
#4	4.75	1.45	98.85	100.00	92.55	70.36	66.87	63.38	**-**
#8	2.36	1.44	26.30	99.67	79.71	56.15	53.40	50.65	**50 - 62**
#16	1.18	1.44	5.12	82.86	67.15	44.58	42.91	41.23	**-**
#30	0.60	1.43	4.09	65.01	55.46	36.15	33.87	31.58	**20 - 45**
#50	0.30	1.42	3.70	53.94	40.88	24.98	23.06	21.13	**15 - 35**
#100	0.15	1.40	3.41	37.53	26.54	17.19	14.51	11.84	**-**
#200	0.075	1.37	3.03	27.58	12.27	10.36	8.25	6.13	**6 - 10**
a	**Coarse Aggregate 10-20 mm**					15.00%	15.00%	15.00%	
b	**Coarse Aggregate 5-10 mm**					15.00%	15.00%	15.00%	
c	**Stone Ash (Fine Agreggregate) 0-5 mm**					52.50%	35.00%	17.50%	
d	**Dumoga Sand**					17.50%	35.00%	52.50%	
TOTAL						100%	100%	100%	

3.3. Marshall's Test

The use of Dumoga sands in the AC Base mixture for variations 1 to 3 are presented in Table 5 to 7 and Figures 1 to 5

Table 5. Marshall test results for AC-Base mixture variation 1 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)			VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result
5.5	1800	2170.18	3	3.32	6	13	15.210	3.0	4.720	5.0	65	68.971
6	1800	2368.27	3	3.44	6	13	15.321	3.0	3.661	5.0	65	76.106
6.5	1800	2482.62	3	3.66	6	13	15.855	3.0	3.080	5.0	65	80.571

Table 6. Marshall Test Results for AC-Base Mixture Variation 2 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)			VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result
5.5	1800	1720.14	3	3.66	6	13	14.121	3.0	5.637	5.0	65	64.300
6	1800	1971.82	3	3.75	6	13	14.251	3.0	4.100	5.0	65	74.096
6.5	1800	2051.90	3	3.90	6	13	14.631	3.0	3.320	5.0	65	79.032

Table 7. Marshall Test Results for AC-Base Mixture Variation 3 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)			VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result
5.5	1800	1408.17	3	3.81	6	13	13.972	3.0	5.871	5.0	65	62.790
6	1800	1556.75	3	3.98	6	13	13.231	3.0	4.831	5.0	65	69.564
6.5	1800	1719.53	3	4,60	6	13	13.257	3.0	3.642	5.0	65	77.049

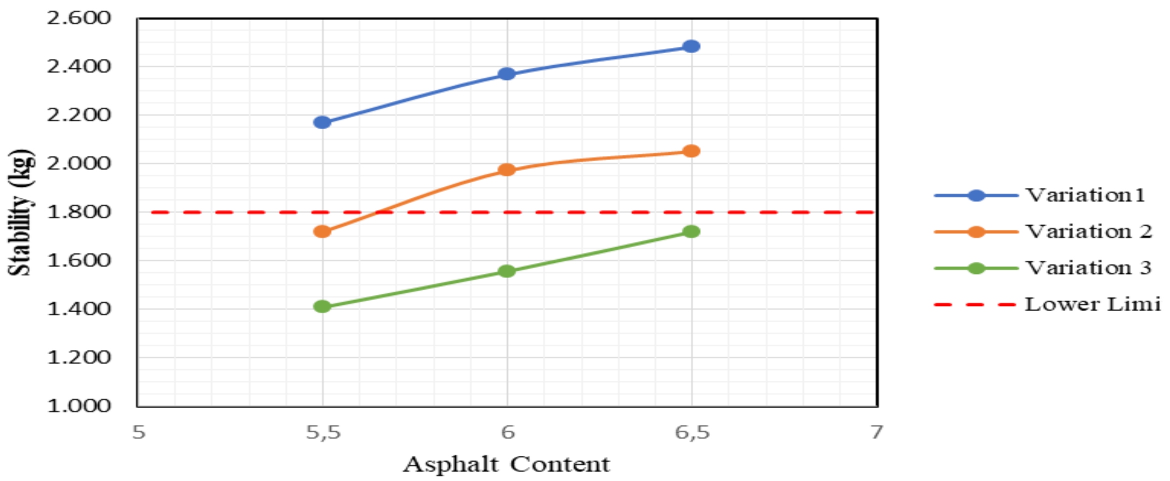

Fig. 1 Stability value

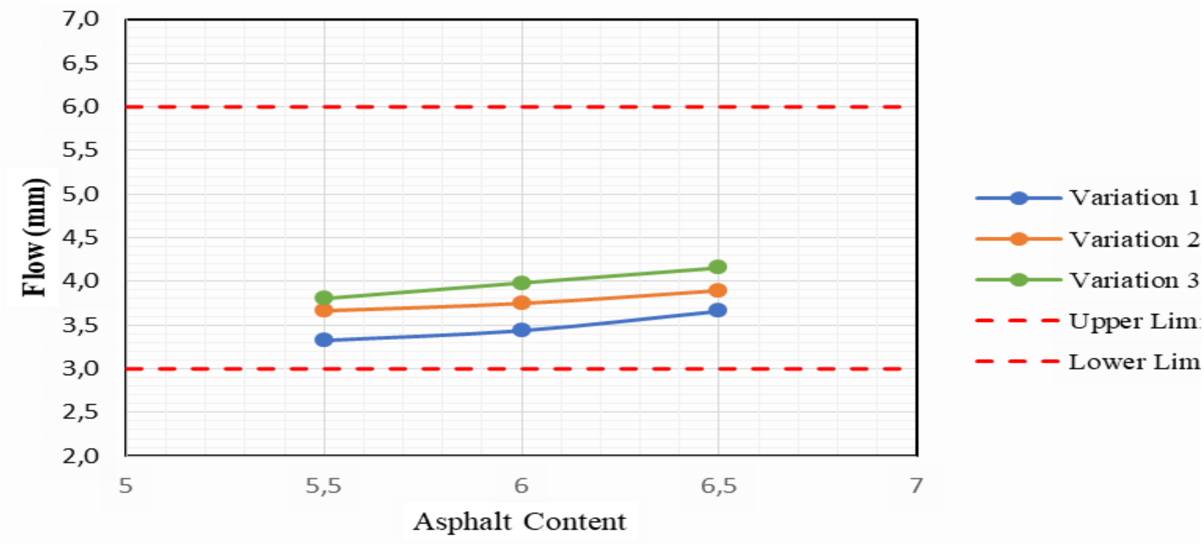

Fig. 2 Flow value

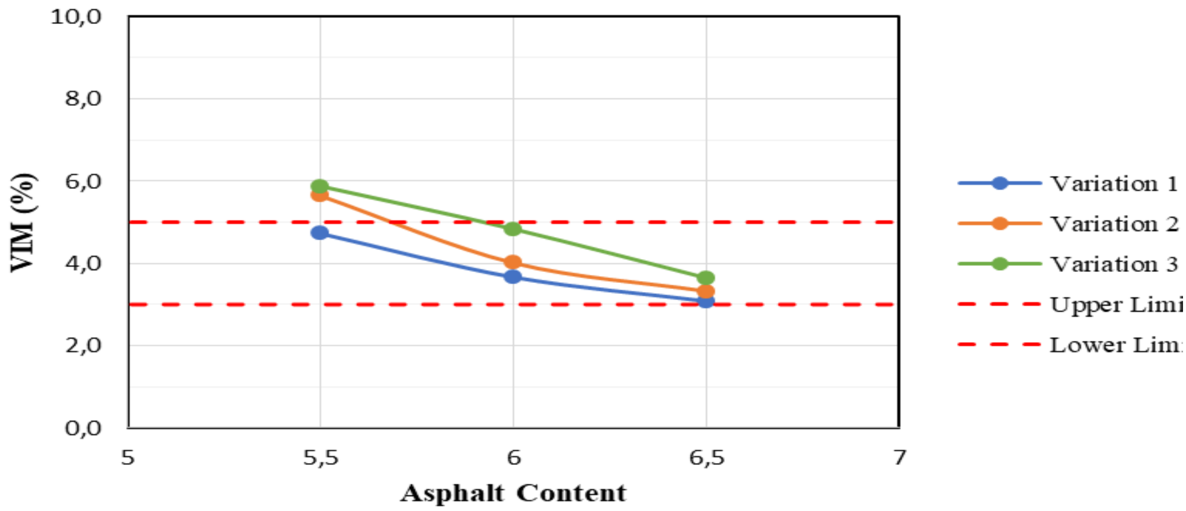

Fig. 3 VIM value

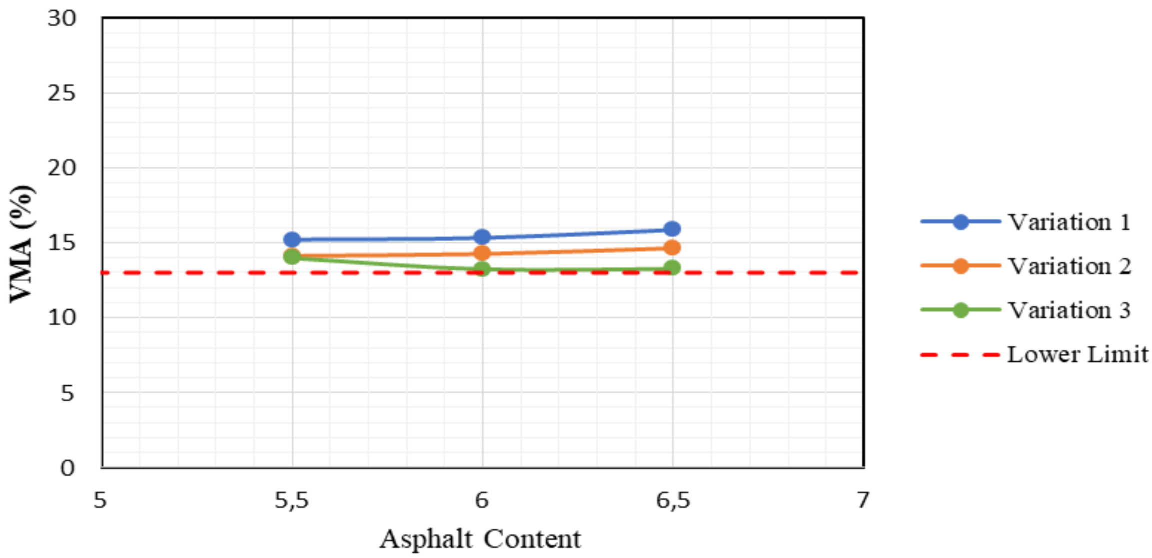

Fig. 4 VMA value

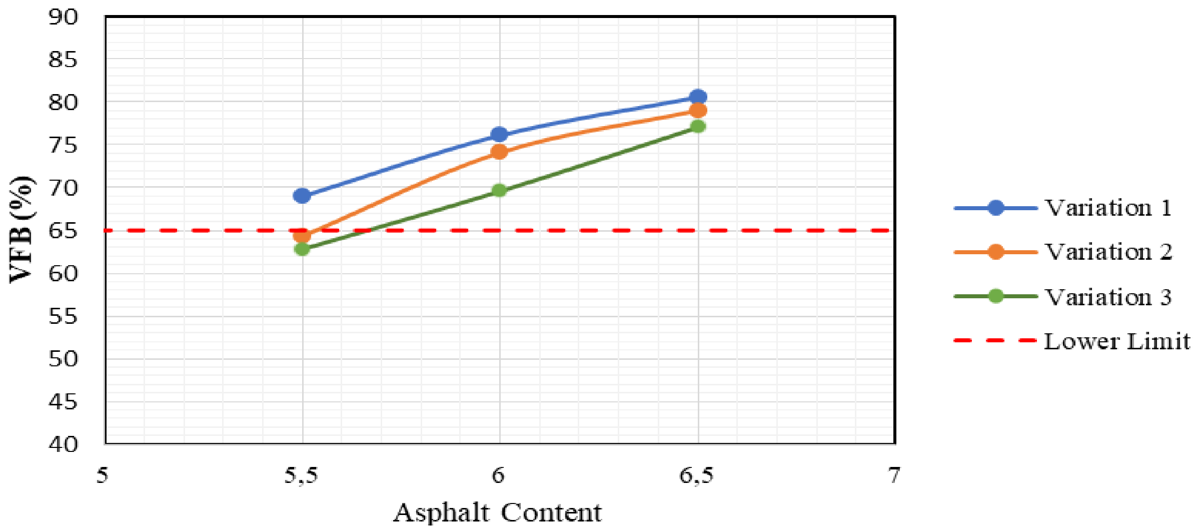

Fig. 5 VFB value

3.3.1. Stability

Based on the graph in Figure.1 above for the AC base mixture, it can be seen that although the stability value increases with the increase in the asphalt percentage, the stability value does not meet the increasing percentage of sand as fine aggregate (stone ash) in Variation 3.

In variation 2, the stability value meets the levels of 5.7% to 6.5%. in variation 1, the stability value is met with a reduced percentage of sand use. in general, the stability value of the AC-Base mixture with the greater amount of sand decreases with the asphalt content up to certain conditions. the relationship between the addition of asphalt content and the addition of Dumoga sand is that the higher the percentage of sand used, the higher the amount of asphalt content required.

3.3.2. Flow

According to the graph in Figure 2. the greater the value of the asphalt content used, the flow value will also be increased. the flow value for the AC-Base mixture shows that the greater the percentage of Dumoga sand used on the fine aggregate (variation 3), the higher the flow value will be. for variation 1, variation 2 and variation 3, the flow value meets the upper and lower limits.

3.3.3. VIM (Voids in Mix)

Based on the graph in Figure 3. it can be seen that the greater the percentage of asphalt content used, the lower the VIM value will be. for variation 1, the VIM value with asphalt content of 5.5% to 6.5% meets the upper and lower limits. for variation 2, VIM values are met, with asphalt content of 5.7% to 6.5%. for variation 3, VIM values are met, with the asphalt content of 5.9% to 6.5%. in general, for the use of Dumoga sand with a large percentage of fine aggregate (stone ash), the VIM value will be greater. This is because more asphalt is absorbed by the sand material.

3.3.4. VMA (Void in Mineral Aggregate)

Based on the graph in Figure. 4, it can be seen that the VMA value will increase along with the increase of asphalt content. the VMA value is influenced by aggregate gradation, aggregate size, number of collisions, and asphalt content. from the test results for the use of Dumoga sand, the VMA value for variation 1, variation 2, and variation 3 still meets the required limit, which is > 13% of the set by Bina Marga. However, of the three variations that were made, the VMA values from variation 2 and variation 3 are still lower than variation 1.

3.3.5. VFB (Voids filled bitumen)

The volume of VFB (Void Filled Bitumen) is the volume of asphalt concrete pores filled with asphalt after the compaction process. from the graph in Figure.5, it can be seen that the greater the addition of asphalt content, the greater the VFB value will be. This is because the asphalt that fills the voids will also be greater. in the graph, it can be seen that for variation 1 with an asphalt content of 5.5% to 6.5%, the VFB value meets the specified requirements, which is > 65%. for variation 2, VFB values meet the asphalt content of 5.58% to 6.5%, and for variation 3, VFB values meet the asphalt content of 5.7% to 6.5%. from the results obtained, it can be seen that the greater the addition of sand (variation 3), the VFB value will decrease as well.

The use of Dumoga sands in the semi-gap graded HRS-WC mixture for variations 1 to 3 are presented in Table 8 to 10 and figures 6 to 10.

Table 8. Marshall test results for semi-gap graded HRS-WC mixture variation 1 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)		VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result
6	800	1114.20	3.0	3.12	18	21.214	4.0	5.875	6.0	68	66.241
6.5	800	1288.30	3.0	3.31	18	23.245	4.0	4.823	6.0	68	71.536
7	800	1365.23	3.0	3.44	18	24.495	4.0	3.197	6.0	68	80.570

Table 9. Marshall test results for semi-gap graded HRS-WC mixture variation 2 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)		VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Upper Limit	Lower Limit	Test Result
6	800	1114.20	30	3.12	18	21.214	4.0	5.875	6.0	68	66.241
6.5	800	1288.30	3.0	3.31	18	23.245	4.0	4.823	6.0	68	71.536
7	800	1365.23	3.0	3.44	18	24.495	4.0	3.197	6.0	68	80.570

Table 10. Marshall test results for semi-gap graded HRS-WC mixture variation 3 (Bina Marga Specifications)

Asphalt Content	Stability (kg)		Flow (mm)		VMA (%)		VIM (%)			VFB (%)	
	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Test Result	Lower Limit	Lower Limit	Test Result
6	800	748.34	3.0	2.86	18	19.190	4.0	9.780	6.0	68	49.150
6.5	800	787.49	3.0	2.94	18	18.867	4.0	7.473	6.0	68	58.808
7	800	796.51	3.0	3.24	18	19.543	4.0	6.238	6.0	68	65.477

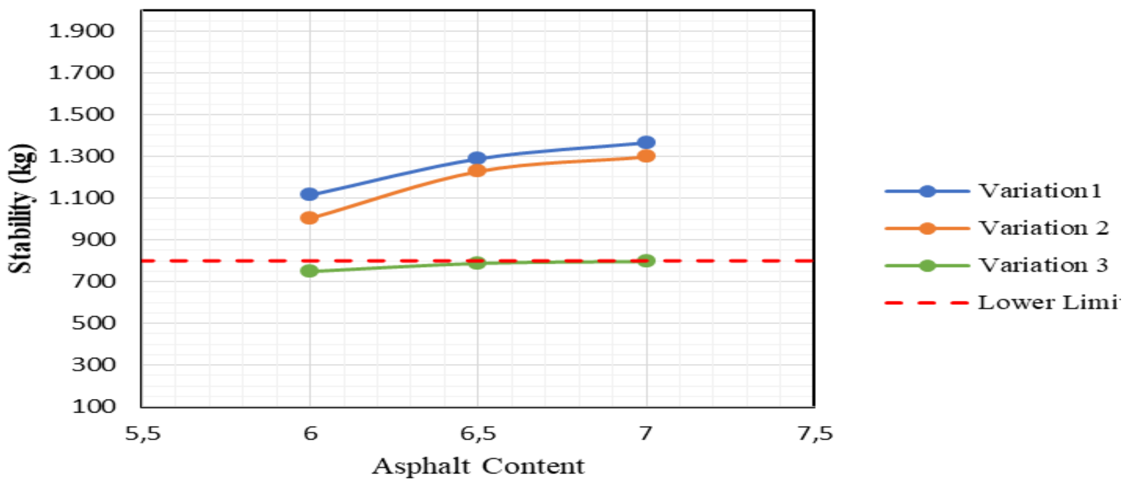

Fig. 6 Stability value

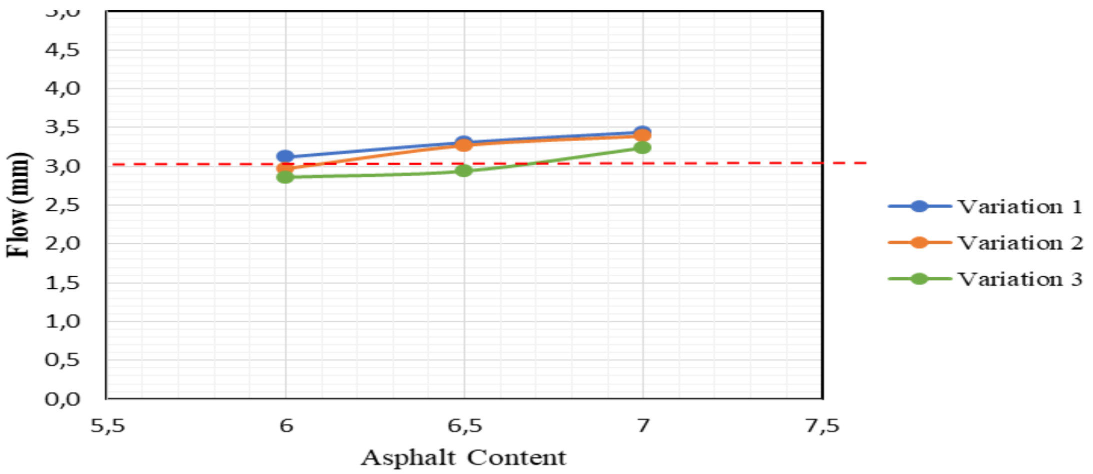

Fig. 7 Flow value

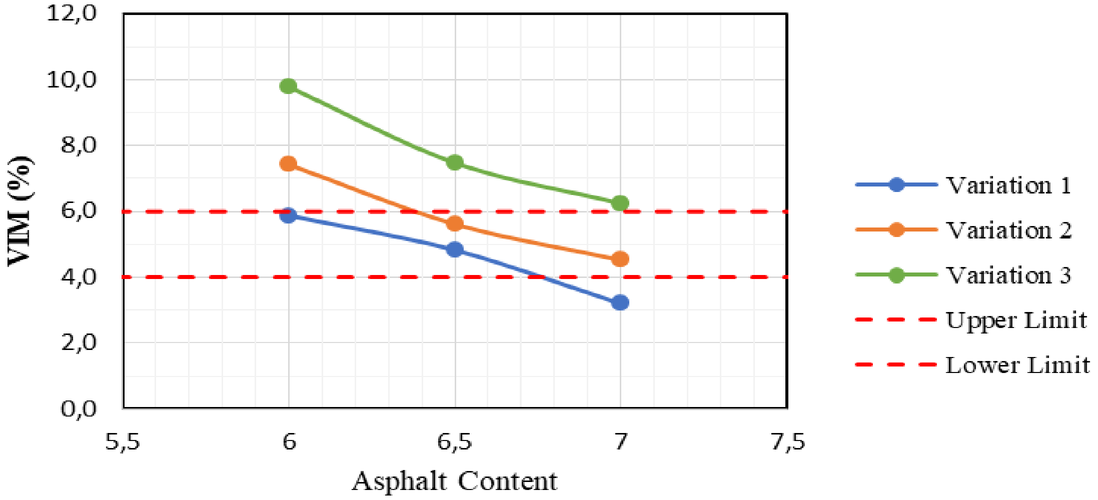

Fig. 8 VIM value

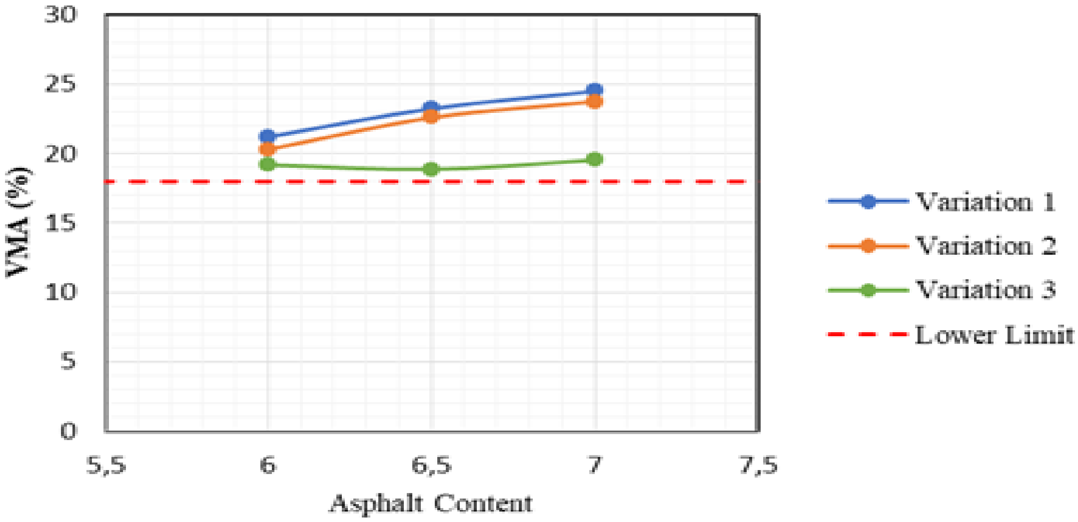

Fig. 9 VMA value

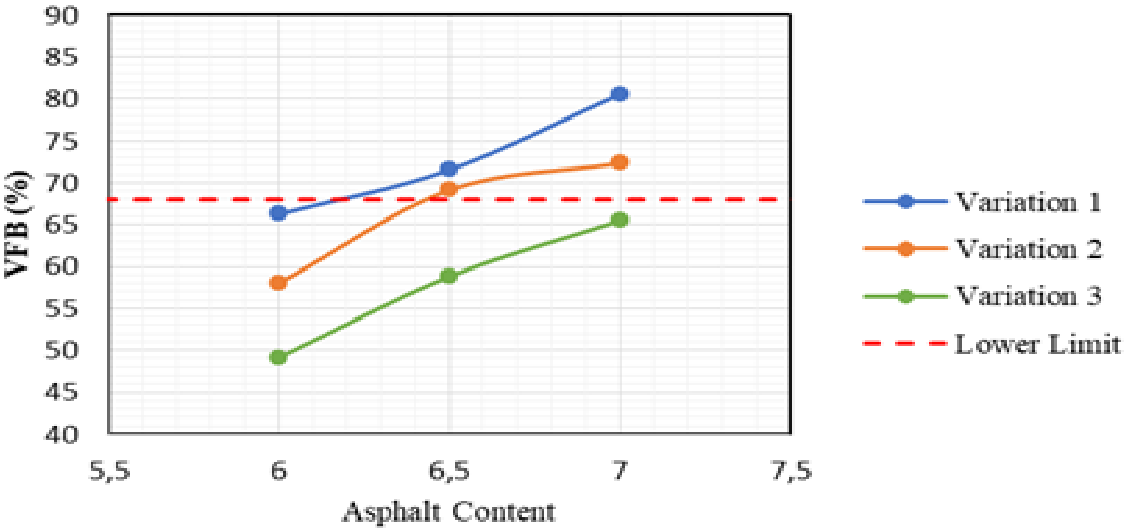

Fig. 10 VFB Value

3.3.6. Stability

Based on the graph in Figure 6. above for the HRS-WC mixture, it can be seen that although the stability value increases with increasing asphalt percentage, for variation 3, the stability value does not meet the increasing percentage of sand used on fine aggregate (stone ash). in variation 2, the stability value meets the level of 6% to 7%. in variation 1, the stability value is greater than variation 2 with a reduced percentage of sand use. in general, the stability value of the

HRS-WC mixture with the addition of sand decreases with increasing asphalt content up to certain conditions. the relationship between the addition of asphalt content and the addition of Dumoga sand is that the higher the percentage of sand used, the higher the asphalt content required.

3.3.7. Flow

from the graph in Figure 7. it can be seen that the greater the asphalt content value used, the flow value will also be increased. the flow value for the HRS-WC mixture shows that the greater the percentage of Domato sand used on the fine aggregate (variation 3) used, the lower the flow value will be.

3.3.8. VIM (Voids in Mix)

Based on the graph in Figure 8. it can be seen that the greater the percentage of asphalt content used, the lower the VIM value will be. for variation 1, the VIM value with asphalt content of 6% to 6.7% meets the upper and lower limits. for variation 2, VIM values meet the asphalt content of 6.4% to 7%. for variation 3, the VIM value does not meet the asphalt content of 6% to 7%. in general, for the use of Dumoga sand with a large percentage of fine aggregate (stone ash), the VIM value will be greater. This is because more asphalt is absorbed by the sand material.

3.3.9. VMA (Void in Mineral Aggregate)

Based on the graph in Figure 9. it can be seen that the VMA value will increase along with the increase of asphalt content. in general, the VMA value will decrease with the increase of asphalt content and begin to increase after reaching the optimum limit. the VMA value is influenced by aggregate gradation, aggregate size, number of collisions, and asphalt content. from the test results for the use of Dumoga sand, the VMA value for variation 1, variation 2, and variation 3 still meets the required limit, which is > 18% of the set by Bina Marga. However, of the three variations that were made, the VMA values from variation 2 and variation 3 are still lower than variation 1.

3.3.10. VFB (Voids Filled Bitumen)

VFB (Void Filled Bitumen) is the volume of asphalt concrete pores filled with asphalt after the compaction process. from the graph in Figure 10. it can be seen that the greater the increase of asphalt content, the greater the VFB value will be. This is because the asphalt that fills the voids will also be greater. the graph shows that for variation 1 with an asphalt content of 6.3% to 7%, the VFB value meets the specified requirements, namely > 68%. for variation 2, the VFB value meets the asphalt content of 6.5% to 7 %, and for variation 3, the VFB value does not meet the asphalt content of 6% to 7%. the results obtained can be seen that the greater the addition of sand, the VFB value will decrease as well.

4. Conclusion

Based on the research conducted, the following conclusions have been drawn :

1. In the AC Base asphalt mixture, for Variation 1, the stability, flow, VIM, VMA and VFB values meet the specifications that have been set. in variation 2, the Stability values met with the asphalt content of 5.7 to 6.5%, Flow with asphalt content 5.5 % to 6.5 %, VIM with asphalt content of 5.7% to 6.5%, and VFB with asphalt content of 5.6% to 6.5%. for variation 3, the values of flow and VMA meet the specified specifications, while the VIM values meet the asphalt content of 6% to 6.5%, and VFB meets the asphalt content of 5.7% to 6.5%, while the stability does not meet the asphalt content of 5.5 % to 6.5 %.

2. in the semi-gap graded HRS-WC asphalt mixture, for Variation 1, the Stability, Flow, VMA, and Density values meet the specified specifications, while the VIM value meets the asphalt content of 6% to 6.7% and VFB with the asphalt content of 6.3 % to 7%. in Variation 2, the stability values, Flow, VMA, and Density meet the specifications that have been set, while the VIM value meets the asphalt content of 6.4% to 7% and VFB with the asphalt content of 6% to 6.5%. in Variation 3, the Stability value, VIM, and VFB do not meet the specified specifications, while the values of Flow, VMA, and density meet the asphalt content of 6% to 7%.
3. for the addition of Dumoga sand to the fine aggregate, the values of the Stability, Flow, VIM, VMA, VFB, and Density decreased for both AC Base asphalt mixture and semi-gap graded HRS-WC asphalt mixture.
4. for the value of the Marshall criteria, according to the use of Dumoga sand, the results obtained are still within the ideal limits, namely for the AC Base mixture in variation 2 with an asphalt content of 6% producing the values of Stability 1971.82 kg, Flow 3.75 mm, VIM 4 %, VMA 14.25 %, and VFB 74.09 %. Then the semi-gap graded HRS-WC mixture in variation 2 with an asphalt content of 6.5% produces the values of Stability 1288.30 kg, Flow 3.31 mm, VIM 4.83 %, VMA 23.25 %, and VFB 71.54 %.

These results indicate that Dumoga sand material can be used in AC-Base mixtures up to 15% of the percentage of fine aggregate and 35% of the percentage of fine aggregate for semi-gap graded HRS-WC Asphalt mixture.

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