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Analysis of the Effect of Using Marlstone Filler on Road Pavement (AC-WC) on Marshall Values

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Abstract

This study aimed to evaluate the performance of a greenhouse solar dryer with a vertical rotating rack system (GHSD-VRR), integrated with an air recirculation system and a biomass furnace with air preheater. This GHSD-VRR was able to reduce the weight of fish from 88.6 kg with a wet basis moisture content of 68.5% (2.18% on a dry basis) to 34.4 kg with a wet basis moisture content of 20% (0.21% on a dry basis) at an average air temperature of about 57.0°C and an average sunlight of 629 W/m² in 10.8 hours. The average drying rate (DR) and specific moisture extraction rate (SMER) reached 4.44 kg/s and 0.211 kg/kWh, respectively. The average specific energy consumption (SEC), specific thermal energy consumption (STEC), and specific electrical energy consumption (SEEC) were 7.724 kWh/kg, 6.408 kWh/kg, and 1.315 kWh/kg, respectively. The efficiency of biomass furnace, dryer, and exergy were recorded at 66.9%, 38.7%, and 80.5%, respectively. The contribution of heat energy from sunlight and biomass to the dryer system was 19.18% and 64.7%, respectively.

Keywords: *Filler, Marl Stone, Ac-Wc, Marshall Test, Asphalt*

INTRODUCTION

Over time, population and economic development in Indonesia has increased, especially in Riau Province. This population growth has led to an increase in human needs. Increased population mobility has led to the emergence of many large vehicles on the highway. Roads are the most important infrastructure built to facilitate the development of a region. Roads function as a link between one region and another for various purposes, both in terms of government, social, economic, cultural, and so on [3]. With the existence of good roads, of course, it will provide a sense of comfort for every vehicle that will pass through it. Therefore, road improvement and maintenance are necessary, as roads are a vital factor in the life of the community's economic movement. Asphalt concrete mixtures (Asphalt Concrete) in Indonesia are known as surface layers or Concrete Asphalt Layers (Lapis Asphalt Concrete (Laston) is a layer in road construction consisting of coarse aggregate, fine aggregate and hard asphalt filler that are mixed, spread, and compacted in a hot state at the appropriate temperature [1]. The material used to build roads is one of the supporting factors that can determine the stability of the road pavement. Therefore, the coating must be made of good quality materials.

Filler, or filling material, can be produced from the breakdown of artificial or natural rocks. Fine-grained fillers increase stability against shear or resistance to shear forces due to their larger surface area, which also increases the contact area between grains [2], [7]. One alternative filler is marlstone, marlstone contains chemical compounds in the form of CaCO3, the purpose of this study is to determine the effect of marlstone in the AC-WC mixture on the marshall value [4], [10]. Variations in the percentage of marlstone as a filler substitute are 0%, 25%, 50%, 75%, 100%. This study uses the marshall method which refers to the 2018 Bina Marga Specifications, Revision 2 [5]. Marlstone was obtained from Sungai Manau village, Kuantan Mudik District, Kuantan Singingi Regency.

Fig. 1 Marl Stone

RESEARCH METHODS

This research was conducted using an experimental method conducted at the Civil Engineering Laboratory of the Islamic University of Riau. This is because this research was conducted by mixing marl as a filler with an AC-WC asphalt mixture. A new variation of marl as a filler substitute to obtain a marshall value with the provisions of the 2018 Bina Marga specifications, Revision 2 [5]. The percentage variations used in this study were 0%, 25%, 50%, 75%, 100% [6], [11].

The calculation and planning process of the mixture between marl stone filler and other materials is obtained from the sieve analysis and specific gravity of coarse aggregate, fine aggregate, and stone ash [1], [8]. The results of the coarse aggregate mixture planning are 11.21%, medium aggregate 27.23%, sand 49.42% and stone ash 11.14%. Meanwhile, the total weight of the sample to be made is 1200 grams. This research was conducted to obtain the Stability, Flow, VIM, VMA and VFA values using the marshall test method [9], [12], [13].

1. Stability

   Stability is the ability of a road pavement to withstand traffic loads without permanent deformation such as waves, grooves, and bleeding. The need for stability is proportional to the road's function and the traffic load it will serve. Roads serving high traffic volumes and predominantly consisting of heavy vehicles require pavements with high stability. Conversely, road pavements intended to serve light vehicle traffic certainly do not require a high stability value. Stability testing is necessary to measure the resistance of the test specimen to loads. To obtain the hottest temperature in the field, the test specimen is heated for 30 or 40 minutes at a temperature of 60º C in a water bath before testing.
2. *Flow*

   The flow value can be read on the flowmeter read on the proving ring measuring watch value read at the time of failure, the flow value is used to measure the deformation that occurs due to the load. The measurement is carried out by placing the test object on the Marshall tool, and the load is given to the test object at a speed of 2 inches/minute or 51 mm/minute.
3. *Void In The Mix*

$$VIM = 100x\frac{Gmm-Gmb}{gmm} \quad (1)$$

   Where:

   VIM = Volume of voids in solid asphalt

   Gmm = Maximum specific gravity of asphalt

   Gmb = Bulk density of solid asphalt

4. *Void In The Mineral Agregat*

   a. Against the total mixture weight

$$\text{VMA}= 100-\frac{Gmm \times Px}{Gsb} \quad (2)$$

   b. Against the total aggregate weight

$$\text{VMA}= 100-\frac{Gmb}{Gsb}\times\frac{100}{100+Pb}\times 100 \quad (3)$$

   Where:

   VMA = Air voids in mineral aggregate, percentage of total volume (%)

   Gmb = Specific gravity of the mixture after compaction (gr/cc)

   Gsb = Aggregate bulk specific gravity (gr/cc)

   Ps = Aggregate content, percentage of total mixture weight (%)

   Pb = Asphalt content, percentage of total mixture (%)

5. *Void Filled with Aspalt*

$$VFA = \frac{100 \times (VMA - VIM)}{VMA} \quad (4)$$

Where:
VFA = The volume of voids between aggregate grains filled with asphalt
VMA = The volume of voids between aggregate grains in dense asphalt
VIM = Volume of voids in dense asphalt concrete

6. *Marshall Quotient*

$$MQ = \frac{Ms}{Mf} \quad (5)$$

Where:
MQ = Marshall Quotient (kg/mm)
Ms = Marshall Stability (kg)
Mf = Marshall Flow (mm)

RESULTS AND DISCUSSION.

Sieve analysis can determine the distribution of aggregate sizes in various aggregate fractions and the percentage of aggregate in the mixture of each type of aggregate. The following data were obtained by researchers from the results of sieve analysis of sand aggregate, rock ash aggregate, medium aggregate, coarse crushed stone aggregate 10-20 mm, and coarse crushed stone aggregate 20-30 mm which can be seen in **Table 1.**

Table 1. Aggregate Pass Percentage

NOMOR SARINGAN	% LOLOS AGREGAT			
	CA	MA	FA	FS
1'	100,00	100,00	99,76	100,00
3/4"	92,07	100,00	99,51	100,00
1/2"	21,08	100,00	99,27	100,00
3/8"	3,65	94,95	99,02	100,00
NO.4	0,96	30,95	98,41	97,88
NO.8	0,96	6,01	80,10	68,76
NO.16	0,96	4,78	58,58	49,67
NO.30	0,96	4,52	35,86	33,11
NO.50	0,96	4,46	30,94	27,50
NO.100	0,96	3,91	16,29	11,07
NO.200	0,96	3,38	11,36	7,62

The percentages for each material in the AC-WC mixture were obtained using the matrix method. The calculation results showed that the mixture percentages were 15.71% coarse aggregate, 27.37% medium aggregate, 30.16% fly ash, and 26.75% sand [3], [11]. The results of the mixture composition calculations can be seen in Table 2 below.

Table 2. Combined Aggregate Gradation Results of AC-WC Mixture

NOMOR SARINGAN	KOMPOSISI MATERIAL (%)				GRADASI GAB.	SPEK.
	CA	MA	FA	FS		% LOLOS
	12,21	27,23	49,42	11,14		
1'	12,21	27,23	49,30	11,14	99,879	100
3/4"	11,24	27,23	49,18	11,14	98,790	100-100
1/2"	2,57	27,23	49,06	11,14	90,000	90-100
3/8"	0,45	25,86	48,94	11,14	86,376	77-90
NO.4	0,12	8,43	48,63	10,90	68,082	53-69
NO.8	0,12	1,64	39,59	7,66	49,000	33-53
NO.16	0,12	1,30	28,95	5,53	35,903	21-40
NO.30	0,12	1,23	17,72	3,69	22,758	14-30
NO.50	0,12	1,21	15,29	3,06	19,685	9,0-22
NO.100	0,12	1,07	8,05	1,23	10,466	6,0-15
NO.200	0,12	0,92	5,61	0,85	7,500	4,0-9

Based on table 2, the percentage of coarse aggregate (CA) usage is 15.71%, Medium Coarse Aggregate (MA) 27.37%, Rock Ash (FA) 30.16% and Sand 26.75%.

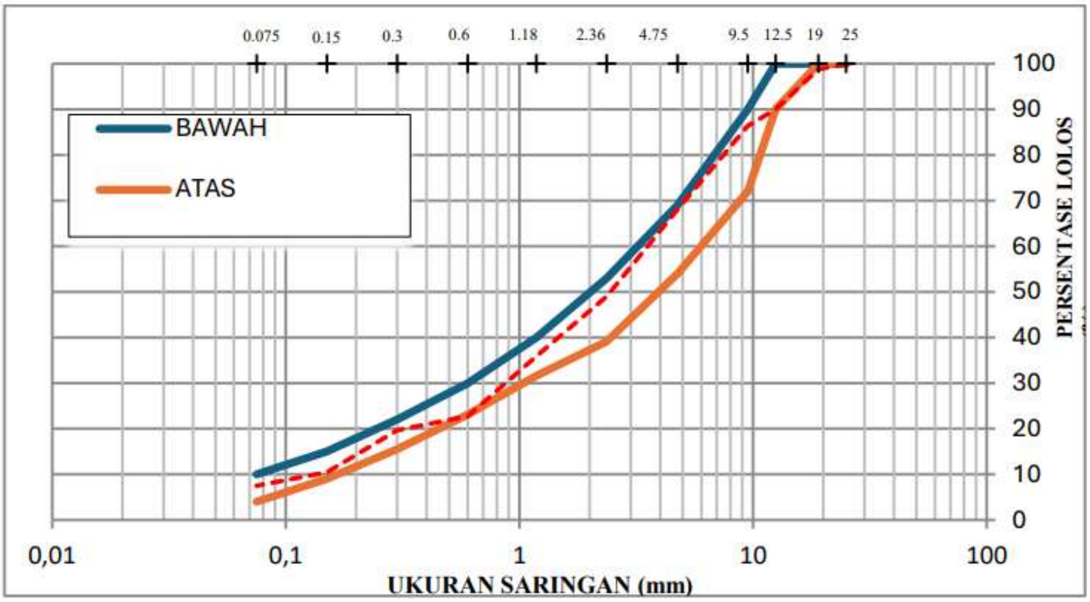

Fig. 2 Aggregate Analysis Chart for Asphalt Concrete Mixture Wearing Course

Specific gravity testing shows that the fine aggregates of stone dust, medium passability, and sand meet the established requirements. This means that the aggregates are suitable for use as a mixture, due to the water absorption requirement of a maximum of 3%, as shown in **Table 3.**

Table 3. Fine Aggregate Specific Gravity Test Results

No	Pengujian	FA	FS	Satuan	Syarat Spesifikasi Bina Marga 2018 Revisi 2	
					Min.	Max
1	Berat Jenis Curah *(Bulk)*	2,538	2,562	gr/cm³	2,5	-
2	Berat Jenis Jenuh Kering Permukaan *(SSD)*	2,576	2,625	gr/cm³	2,5	-
3	Berat Jenis Semu *(Apparent)*	2,638	2,734	gr/cm³	2,5	-
4	Penyerapan *(Absorption)*	1,502	2,459	%	–	3%

The specific gravity test of coarse aggregate in this study consisted of crushed stone aggregate with a size of 2/3 cm, crushed stone aggregate with a size of 3/4 cm and medium aggregate retained by sieve No. 4. The water absorption requirement is a maximum of 3% which can be seen in **Table 4.**

Table 4. Coarse Aggregate Specific Gravity Test Results

No	Pengujian	FA	FS	Satuan	Syarat Spesifikasi Bina Marga 2018 Revisi 2	
					Min.	Max
1	Berat Jenis Curah *(Bulk)*	2,7445	2,6294	Gr/cc	2,5	-
2	Berat Jenis Jenuh Kering Permukaan *(SSD)*	2,7599	2,6542	Gr/cc	2,5	-

3	Berat Jenis Semu *(Apparent)*	2,7875	2,6963	Gr/cc	2,5	-
4	Penyerapan *(Absorption)*	0,5618	0,9425	%	–	3%

The results of the Marshall KAO test + Percentage of filler addition according to the 2018 General Bina Marga Specification regulations can be seen that the addition of lightweight brick ash only in the 0% Filler variation meets all parameters according to the requirements. For the Stability and Flow values, all variations meet the requirements [12], [15]. Meanwhile, those that do not meet the requirements of the 2018 Bina Marga Specifications are the VMA value of the 100% filler variation, and the VFA value of the 75% filler variation.

Table 5. Mixed Marshall Test Results (AC-WC)

No	Parameter	Satuan	Kadar Aspal (%)					Spek.
			5	5,5	6	6,5	7	
1	VMA	%	16,1	16,5	15,81	16,16	17,21	Min 15
2	VFA	%	70,58	78,07	87,49	92,81	93,23	Min 65
3	VIM	%	4,74	3,99	1,98	1,16	1,17	Min 3 Maks 5
4	Stabilitas	Kg	976,98	934,5	991,13	884,94	842,46	Min 800
5	*Flow*	Mm	3,6	2,23	3,9	3,73	2	Min 2 Maks 4

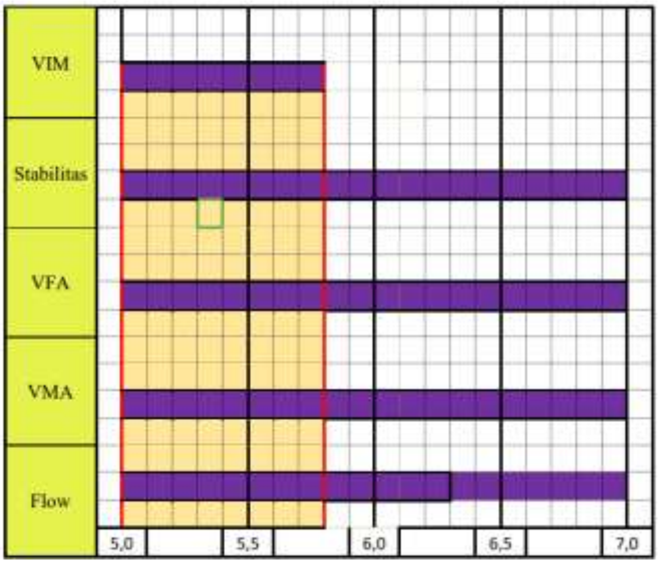

Fig. 3 Optimum Asphalt Content Diagram

The results of the Marshall KAO test + Percentage of filler addition according to the 2018 General Bina Marga Specification regulations can be seen that the addition of lightweight brick ash only in the 0% Filler variation meets all parameters according to the requirements. For the Stability and Flow values, all variations meet the requirements. Meanwhile, those that do not meet the requirements of the 2018 Bina Marga Specifications are the VMA value of the 100% filler variation, and the VFA value of the 75% filler variation.

Table 5 . Marshall Test Results of AC-WC Mixture with Marlstone Filler for Optimum Asphalt Content

No	Parameter	Satuan	0%	25%	50%	75%	100%	Spesifikasi
1	VMA	%	16,62	17,40	19,30	19,65	12,78	Min 15
2	VFA	%	73,42	69,50	61,20	59,86	90,38	Min 65
3	VIM	%	4,77	5,62	7,80	8,19	9,86	Min 3,0 – Maks 5,0
4	Stabilitas	kg	2396,19	2167,37	1826,29	2180,32	2422,10	Min 800
5	Flow	mm	2,90	2,82	3,25	3,73	3,57	Min 2 – Maks 4

The percentage of marl stone filler added in the stability test of 0%, 25%, 50%, 75%, and 100% meets the stability requirements according to the 2018 Bina Marga Specifications for all variations of filler content. The minimum stability limit is 800 kg. The highest stability value is at 100% filler variation, namely with a value of 2422.1 kg.

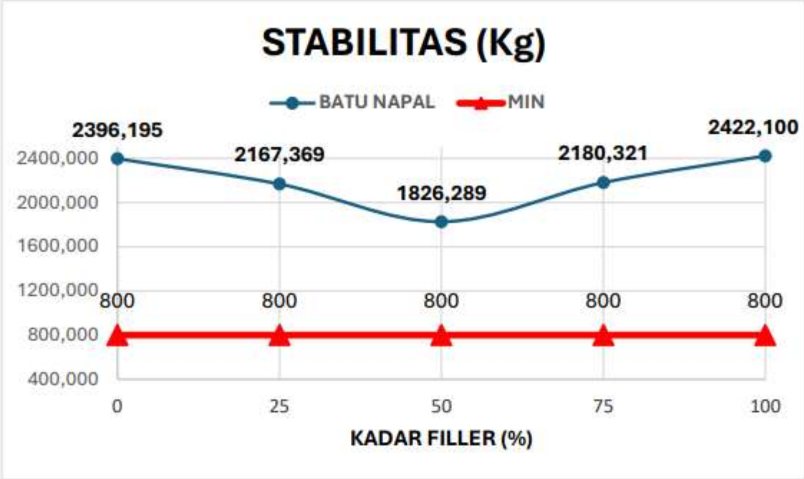

Fig. 4 Stability Value Against Marlstone Filler in KAO

The percentage of marl stone filler added in the flow test of 0%, 25%, 50%, 75%, and 100% meets the requirements of the 2018 Highways Specifications with the highest value of 3.73 mm at 75% filler variation. The minimum flow limit is 2 mm and the maximum limit is 4 mm.

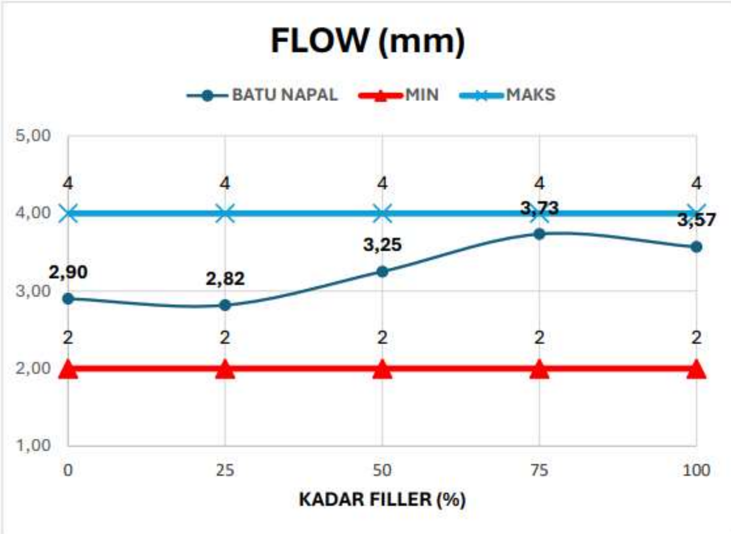

Fig. 5 Flow Value Against Marlstone Filler in KAO

The percentage of marl stone filler addition in the VMA test that meets the requirements according to the 2018 Highways Specification requirements at Filler levels of 0%, 25%, 50%, 75%. While the 100% filler variation does not meet the requirements of the 2018 Highways Specification with a value of 12.77%. The minimum limit for air voids in the mixed aggregate is 15%.

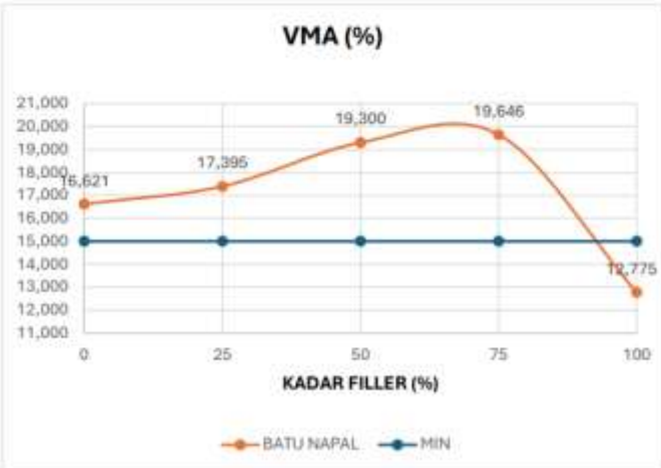

Fig. 6 VMA Value of Marlstone Filler in KAO

The percentage of marl stone filler addition in the VIM test was 0%, 25%, 50%, 75%, and 100% only at 0% levels, which met the requirements for voids in the mixture according to the 2018 Highways Specification requirements. The minimum limit for voids in the mixture is 3% and the maximum limit is 5%.

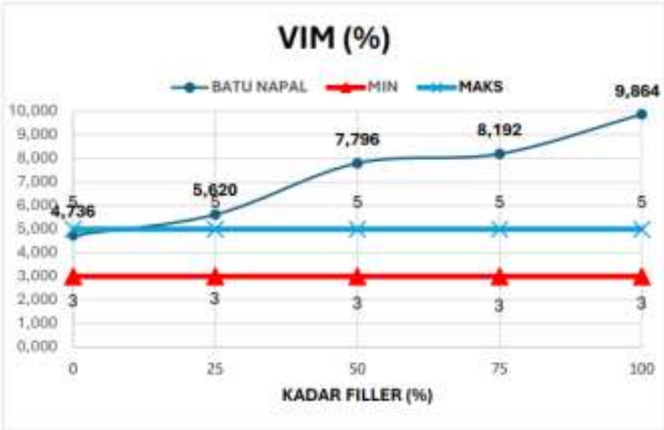

Fig. 7 Value of Marlstone Filler in KAO

The percentage of marl stone filler addition in the VFA test was 0%, 25%, 50%, 75%, and 100%, only the variations of 0%, 25%, and 100% met the requirements for asphalt-filled cavities according to the 2018 Bina Marga Specifications. The minimum limit for air cavities in the mixed aggregate is 65%.

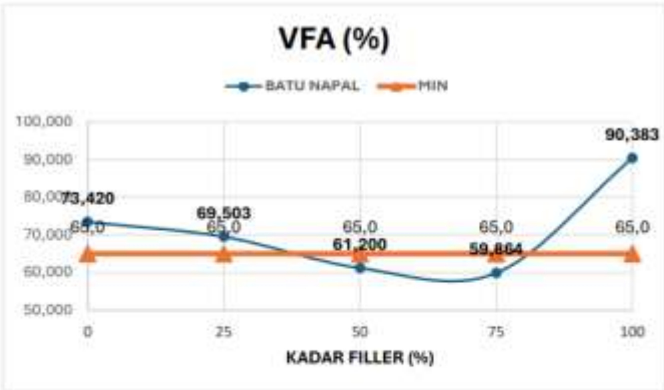

Fig. 8 FVA Value of Marlstone Filler in KAO

CONCLUSIONS

Based on the results of the research on the addition of Marl Stone filler that has been carried out, the stability and flow values meet the requirements for all variations, the VMA value at 100% variation does not meet the requirements, the VIM value only at 0% variation meets the requirements, the VFA value at 0%, 25%, and 100% variations do not meet the requirements, and the marshall test results on the AC-WC mixture do not meet the minimum requirements of the 2018 Highways Specifications.

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