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The Effect of Aggregate Characteristics in the Waisikabiri River in Lilibooi on the Bending Pavement of the Highway; A Quantitative Study

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Abstract: *This study was motivated by the need to evaluate the feasibility of flaky and elongated aggregates from the Waisikabiri River, Lilibooi Village, for flexible pavement construction because aggregate shape significantly influences asphalt mixture performance. The study aimed to analyze the effect of aggregate characteristics on the Marshall properties of Asphalt Concrete-Wearing Course (AC-WC) mixtures. This research used a quantitative experimental method through laboratory testing based on Bina Marga 2010 Revision 3 Division 6 specifications. The population consisted of aggregates obtained from the Waisikabiri Quarry, while the samples included coarse aggregates 5–10 mm and 10–20 mm, fine aggregates, asphalt penetration grade 60/70, and filler materials. Data were collected using sieve analysis, abrasion testing, specific gravity testing, asphalt characteristic testing, and Marshall testing instruments. Data analysis was conducted quantitatively using Marshall parameter calculations including stability, flow, VIM, VMA, and MQ values. The results showed that aggregate gradation met Bina Marga specifications, while the Marshall stability values varied according to asphalt content. The conclusion indicates that high flaky and elongated aggregate content reduced mixture stability and caused several Marshall parameters to fall below specification limits.*

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Introduction

The strength and durability of a road pavement construction is highly dependent on the quality of the aggregate and the type of asphalt used as the main material to bind these materials until a durable, durable, strong and rough pavement is obtained. The two types of pavement that are commonly used are flexible pavement that uses asphalt as a binding material and rigid pavement that uses cement as an aggregate binding material. The aggregate as the main component of this road pavement consists of coarse aggregate and fine aggregate which has its own proportions according to the specifications used. Coarse aggregate is an aggregate consisting of fractured stone or broken gravel that is clean, dry, strong, durable, and free from other materials that will interfere, and fine aggregate is natural sand or artificial sand that is free from clay lumps and is a grain that has a sharp angle and has a rough surface (Masarrang et al., 2024; Paul et al., 2024). Crude aggregates in the form of broken stones are generally obtained from the results of breaking large stones by stone crushers. The results of breaking stone crusher tools are obtained in various sizes and shapes. The most common grain shapes obtained from the use of this tool are cube (square), flaky and oval (elongated).

Aminsyah (2020), in his research, stated that cube-shaped aggregate is an aggregate of the effect of flatness and ovalness of aggregate on road bending pavement that is best used as a road pavement material, this is because the aggregate has a wider contact field so that it can lock each other well. Meanwhile, flat aggregates and oval aggregates in general are also produced by stone crushers, so that in the field it is inevitable that the use of these two forms of aggregate is inevitable. Because of this, research was carried out on the influence of the shape of flat grains (flatness index) and the shape of oval grains (obelisk index) on the bending pavement of the road (Jihad & Kadir, 2024; Onibala et al., 2023).

The method of determining the flatness index is based on the classification of aggregate particles as flaky objects with a thickness of less than 0.6 nominal size. Meanwhile, the method for determining the ovality index is based on the classification of aggregate particles as oval (elongated) objects (Yuniarti et al., 2023). The main parameters for assessing the feasibility of flat and oval grain shapes as aggregates on bending pavement were obtained from the Marshall test. The results of Aminsyah's (2024) research are presented in the form of Marshall test tables and graphs, so it is hoped that a feasible description of the use of aggregates in flat and oval shapes will be obtained.

To get road pavement that meets the expected quality, it is necessary to know about the properties, procurement, and processing of aggregates in addition, knowing about the properties of binding materials such as asphalt and cement is the basis for designing the mixture according to the type of pavement desired. Quality control of the pavement implementation process is inseparable to be able to achieve the expected quality. Sukirman (2003) in his book describes as follows; what kind of aggregate characteristics in the research river; What distinguishes it from aggregates in other rivers; and what is the use & function of the aggregate from this river for?

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In addition to the quality expected in the aggregate selection, it is also necessary to pay attention to the number of available reserves. Waisikabiri Quary is one of the quarries in Central Maluku Regency located in Lilibooi Village, West Leihitu District with a distance of ± 23 km from Ambon Island. This quary has never been used for road pavement and has not been tested on the aggregate in the quary, because the Waisikabiri quary is a new quary in the Ambon area and not too many people know about it. Quary Lilibooi or often referred to by the surrounding community as "Waisikabiri "

Based on the above background, the author compiled a study on the use of asphalt materials and mixtures in Waisikabiri Quary, Lilibooi Country, Ambon Island. The research is stated in a title. "Effect of Aggregate Characteristics in the Waisikabiri River in Lilibooi Country on Highway Bending Pavement: A Quantitative Study"

Research Methods

This research was conducted in Lilibooi Village, Ambon Island, using a quantitative experimental approach through laboratory testing to analyze the effect of aggregate characteristics from the Waisikabiri River on flexible pavement performance. The materials used consisted of coarse aggregates in the form of crushed stone measuring 5–10 mm and 10–20 mm, fine aggregates from natural sand and stone ash, Pertamina asphalt penetration grade 60/70, and cement as filler material. The study began with material preparation by collecting aggregates from the river and transporting them to the laboratory for testing. The tests carried out on coarse aggregates included abrasion, specific gravity and absorption, flatness and elongation index, angularity, sieve analysis, and asphalt adhesion tests. Fine aggregates were tested for specific gravity, absorption, sand equivalent value, and sieve analysis, while asphalt testing included penetration, softening point, flash point, ductility, and specific gravity tests. Furthermore, the combined aggregate gradation for Asphalt Concrete-Wearing Course (AC-WC) was designed according to Bina Marga 2010 Revision 3 Division 6 specifications, followed by determining the optimum asphalt content, mixing aggregates with asphalt, and producing Marshall test specimens.

The Marshall method was used to evaluate the characteristics of the asphalt mixture, including stability, flow, density, and void parameters such as VIM, VMA, and VFB. A total of 10 test specimens were produced with different asphalt contents of 4.5%, 5.0%, 5.5%, 6.0%, and 6.5%, where each variation consisted of two specimens. The aggregates were heated to 150°C and mixed with asphalt heated to 120°C before compaction using 75 blows on each side to simulate heavy traffic conditions. After compaction, the specimens were cooled, weighed, immersed in water, and tested using the Marshall testing apparatus to determine maximum load and flow values. The collected data were quantitative in nature and analyzed experimentally based on SNI standards and Marshall procedures to determine the influence of Waisikabiri aggregate characteristics on the quality and stability of flexible highway pavement mixtures.

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Result and Discussion

Aggregate Sieve Analysis

This test aims to determine the gradation of coarse aggregates and fine aggregates by using manual sieve analysis of coarse and fine aggregates tested are coarse aggregates of 1/2 mm size, coarse aggregates of 5 -10 mm, sand which are all taken from the Waisikabiri River of Lilibooi State

1. Aggregate 1-2

Table 1 Analysis of coarse aggregate sieve (Crushed stones 1-2)

Strainer No.		Retained Weight	Cumulative		% Passed
Inches	Mm	(gr)	Retained Weight (gr)	%Retained (gr)	(gr)
# 3/4"	19	60,00	60,00	1,20	98,80
# 1/2"	12,5	2027,00	2087,00	41,74	58,26
# 3/8"	9,5	2064,00	4151,00	83,02	16,98
No. 4	4,75	849,00	5000,00	100,00	0,00
No. 8	2,36	0,00	5000,00	100,00	0,00
No. 16	1,18	0,00	5000,00	100,00	0,00
No. 30	0,6	0,00	5000,00	100,00	0,00
No. 50	0,3	0,00	5000,00	100,00	0,00
No. 100	0,15	0,00	5000,00	100,00	0,00
No. 200	0,075	0,00	5000,00	100,00	0,00
PAN	PAN	0,00	5000,00		
Quantity		5000,00			

Source: Laboratory Test Results, 2024

Figure 1 Graph of Aggregate Sieve Analysis 1-2

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From table 1 and figure 1, it can be seen that the test results of the gradation of coarse aggregate (1/2 crushed stone) meet the Bina Marga 2010 specification standards, namely the coarse aggregate (1/2 crushed stone) passed the no. 1 filter and was stuck in the no. 4 filter. The size of the coarse aggregate (10/20 crushed stone) is 12.5 mm.

2. Aggregate 5-10

Table 2 Coarse Aggregate Sieve Analysis Table (5-10 Stones)

Strainer No.		Retained Weight	Cumulative		% Passed
pearl	Mm	(gr)	Retained Weight (gr)	%Retained (gr)	(gr)
# 3/4"	19,00	0,00	0,00	0,00	100,00
# 1/2"	12,5	0,00	0,00	0,00	100,00
# 3/8"	9,50	5,00	5,00	0,10	99,90
No. 4	4,75	2472,00	2477,00	49,54	50,46
No. 8	2,36	2523,00	5000,00	100,00	0,00
No. 16	1,18	0,00	5000,00	100,00	0,00
No. 30	0,60	0,00	5000,00	100,00	0,00
No. 50	0,30	0,00	5000,00	100,00	0,00
No. 100	0,15	0,00	5000,00	100,00	0,00
No. 200	0,08	0,00	5000,00	100,00	0,00
PAN	PAN	0,00	5000,00		
Quantity		5000,00			

Source: Laboratory Test Results, 2024

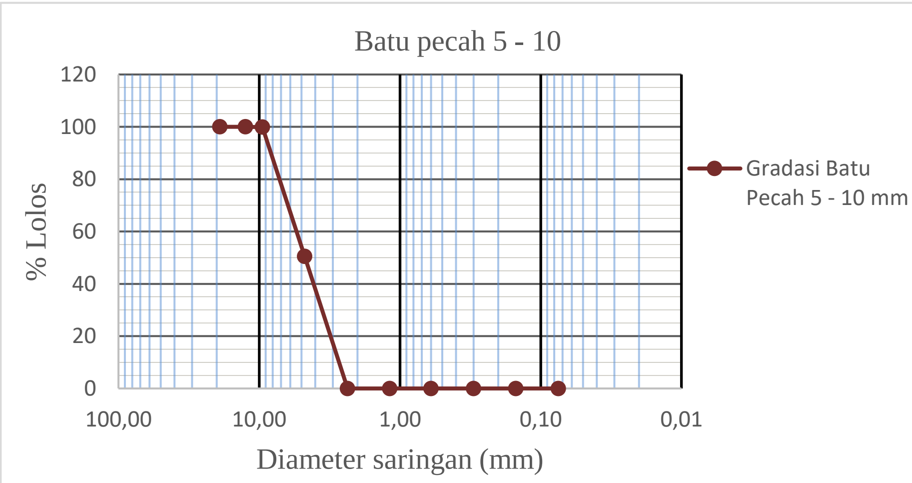

Figure 2 Graph of Analysis of Aggregate Sieve 5-10

From table 6 and figure.3, it can be seen that the results of the coarse aggregate gradation test (crushed stones 5-10) meet the standards of the Bina Marga 2010 specification, namely coarse aggregates (crushed stones 5-10) passed sieve no. #1/2 and were retained in sieve no. 8 and were included in the category of medium coarse aggregate.

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3. Fine aggregate (Sand)

Table 3 Fine Aggregate Sieve Analysis (Sand)

Strainer No. pearl	mm	Retained Weight (gr)	Cumulative Retained Weight (gr)	Cumulative %Retained (gr)	% Passed (gr)
# 3/4"	19,00	0,00	0,00	0,00	100,00
# 1/2"	12,50	0,00	0,00	0,00	100,00
# 3/8"	9,50	0,00	0,00	0,00	100,00
No. 4	4,75	15,00	15,00	0,60	99,40
No. 8	2,36	46,00	61,00	2,44	97,56
No. 16	1,18	104,00	165,00	6,60	93,40
No. 30	0,60	738,00	903,00	36,12	63,88
No. 50	0,30	1023,00	1926,00	77,04	22,96
No. 100	0,15	250,00	2176,00	87,04	12,96
No. 200	0,08	233,00	2409,00	96,36	3,64
PAN	PAN	91,00	2500,00		
Quantity		2500,00			

Source: Laboratory Test Results, 2024

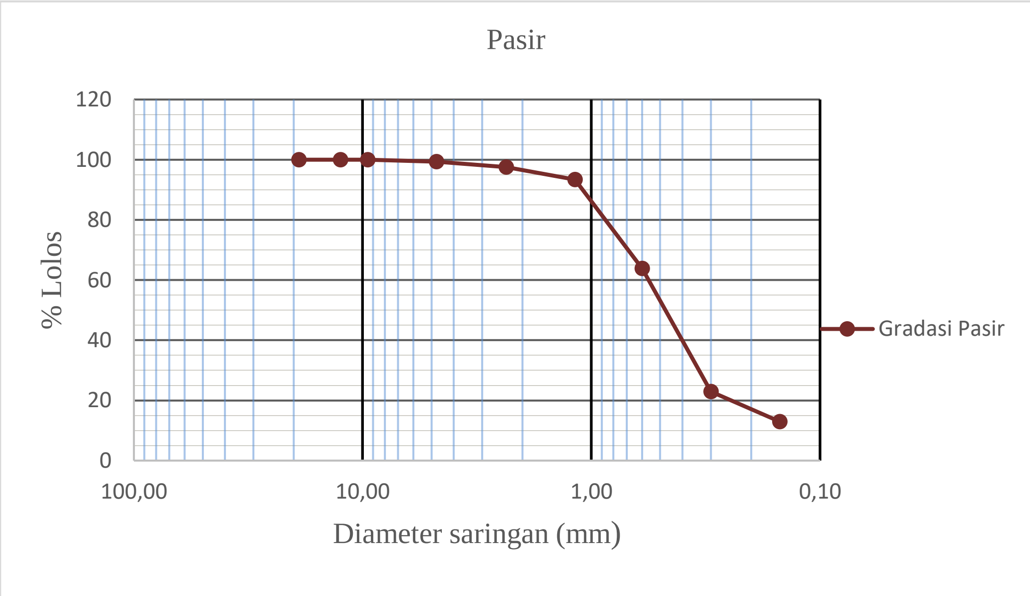

Figure 3 Fine aggregate sieve analysis graph

From table 3, figure 3 and table 4 and graph 4, it can be seen that the results of the testing of fine aggregate gradation (sand) meet the Bina Marga 2010 specification standard, namely fine aggregate (sand) passes sieve no.#3/8 and is retained in sieve no. 200 and is included in the category of coarse-grained fine aggregate.

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1. The percentage of passes in each aggregate

Table 5 Percentage of passes on each aggregate

Strainer No.	1/2 Stone	Stone 5-10	Pasir
# 3/4"	98,80	100,00	100,00
# 1/2"	58,26	100,00	100,00
# 3/8"	16,98	99,90	100,00
No. 4	0,00	50,46	99,40
No. 8	0,00	0,00	97,56
No. 16	0,00	0,00	93,40
No. 30	0,00	0,00	63,88
No. 50	0,00	0,00	22,96
No. 100	0,00	0,00	12,96
No. 200	0,00	0,00	3,64

Source : Labrotorium Test Results, 2024

From table 5, it is known that the percentage of passing in each aggregate meets the 2010 bina marga specification standards

Abrasion Testing

This test aims to know and determine durability and wear. A high value indicates that many parts of the test specimen were destroyed by the rotation of the Los Angeles engine.

a. Abrasion Testing Abrasion Test 1-2 Fracture

Table 6 Abrasion Test Abrasion Test Abrasive Aggregate 1-2

Remarks	Rumus	Test Results
Lolos 3/4"; Restrained 1/2" (gr)	A	2500
Pass 1/2"; Stuck 3/8" (gr)	B	2500
Sieve restrained weight No.12 (gr)	C	4089,17
Wear with 11 steel balls (%)	$\frac{(A+B)-C}{(A+B)}\,x\,100$	18,22

Source: Laboratory Test Results, 2024

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b. Abrasion Test 5-10 Fracture Stone

Table 7 Abrasion Test Abrasion Test Abrasive Aggregate 5-10

Remarks	Formula	Test Results
Lolos 3/4"; Restrained 1/2" (gr)	A	2500
Pass 1/2"; Stuck 3/8" (gr)	B	2500
Sieve restrained weight No.12 (gr)	C	4065,26
Wear with 11 steel balls (%)	$\frac{(A+B)-C}{(A+B)} x\,100$	18,69

Source: Laboratory Test Results, 2024

Specific Gravity Testing

This test aims to determine the bulk specific gravity (Bulk), saturated surface dry weight (SSD) and apparent specific gravity, and aggregate absorption percentage.

1. Specific gravity and absorption of 1-2 coarse aggregates

Table 8 Specific Gravity Testing and Absorption of Crude Aggregates 1-2

No	Remarks	Test Pieces 1
1	Weight of the test specimen in saturated wet state (Bj)	5059
2	Test weight in water (BA)	3088
4	Oven Dry Test Weight(BK)	5000
5	$\text{Berat jenis (Bulk)} = \frac{\text{BK}}{\text{BJ} - \text{BA}}$	2,54
6	$\text{Berat jenis }(SSD) = \frac{\text{BJ}}{\text{BJ} - \text{BA}}$	2,57
7	$\text{Berat jenis (Semu)} = \frac{\text{BK}}{\text{BK} - \text{BA}}$	2,62
8	$\text{Penyerapan Air} = \frac{BJ - BK}{\text{BK}} \text{ x } 100\%$	1,18

Source: Laboratory Test Results, 2024

2. Specific gravity and absorption of coarse aggregate 5-10

Table 9 Specific Gravity Testing and Absorption of 5-10 Crude Aggregates

No	Remarks	Test Pieces 1
1	Weight of the test specimen in saturated wet	5076

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	state (Bj)	
2	Test weight in water (BA)	3128
3	Oven Dry Test Weight(BK)	5000
4	$\text{Berat jenis (Bulk)} = \frac{BK}{BJ - BA}$	2,57
5	$\text{Berat jenis (SSD)} = \frac{BJ}{BJ - BA}$	2,61
6	$\text{Berat jenis (Semu)} = \frac{BK}{BK - BA}$	2,67
7	$\text{Penyerapan Air} = \frac{BJ - BK}{BK} \times 100$	1,52

Source: Laboratory Test Results, 2024

3. Specific gravity and absorption of fine aggregates of Sand

Table 10 Specific Gravity Testing and Fine Aggregate Absorption of Sand

No	Remarks	Test Pieces 1
1	Weight of the test specimen in saturated wet state (Bj)	500
2	Weight of the piknometer + water (B)	812
3	Weight of the picnometer + water + test specimen (BT)	1088
4	Dry test piece weight (BK)	486
5	$\text{Berat jenis (Bulk)} = \frac{BK}{(B + BJ) - BT}$	2,17
6	$\text{Berat jenis (SSD)} = \frac{BJ}{(B + BJ) - BT}$	2,23
7	$\text{Berat jenis (Semu)} = \frac{BK}{(B + BK) - BT}$	2,31
8	$\text{Penyerapan Air} = \frac{(BJ - BK)}{BK} \times 100$	2,88

Source: Laboratory Test Results, 2024

Mixed Composition

The composition of this mixture aims to determine the aggregate and asphalt levels that we use for testing and the composition of this mixture I made refers to the Job Mix Formula (JMF).

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Table 11. Composition of AC-WC JMF

NO	COMPOSITION OF THE AC-WC *JOB MIX FORMULA*		
1	Broken stones 10-20	:	15,06 %
2	Broken Stone 5-10	:	25,41 %
3	Pasir	:	12,23 %
4	Aspal B5/20	:	2,94 %
5	Pertamina Asphalt	:	5,90 %
	Total	:	61,54 %

Source : Job Mix Formula (AC-WC) 2024

From table 12, it is known the composition of the Job Mix Formula that the composition is used for reference in the tests carried out, the Job Mix Formula used from paving work on the preservation of Ambon city roads.

Table 12. Mixed composition

Rock ash rate	Pertamina Asphalt	Aspal B5/20	Broken Stone 1-2	Broken Stone 0.5-10	Pasir	Total
(%)	(Gram)	(Gram)	(cm)	(Mm)	(Gram)	(Gram)
36	70,8	35,28	180,72	304,92	182,76	1200
37	70,8	35,28	180,72	304,92	170,76	1200
38	70,8	35,28	180,72	304,92	146,76	1200
39	70,8	35,28	180,72	304,92	134,76	1200
40	70,8	35,28	180,72	304,92	122,76	1200

Source : Job Mix Formula Calculation Results, 2024

From table 13, the composition of the mixture used according to the Job Mix Formula for testing is appropriate and only variations in coal ash as a substitute for rock ash and materials used according to JMF which are a reference for the research conducted.

Mixed Specific Gravity

Table 13.Mixed Specific Gravity

Sample	No Sample	Test Piece Thickness (mm)	Test Object Weight(gr)		
			Dry	In Water	SSD
36%	I	62	1091	681	1191,11
	II	62	1124	675	1189,25
	III	60	1110	679	1187,22

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37%	I	62	1076	678	1191,81
	II	63	1077	671	1189,66
	III	62	1066	675	1189,66
38%	I	63	1057	666	1189,75
	II	62	1060	679	1187,63
	III	62	1056	674	1192,5
39%	I	63	1060	668	1190,2
	II	62	1052	666	1189,07
	III	63	1074	670	1196,35
40%	I	63	1113	684,00	1199,08
	II	63	1120	678,00	1194,79
	III	63	1094	680,00	1195,83

Source: Laboratory Test Results, 2024

Readings Against the Marshall Instrument

Stability is the ability of the pavement to accept a load until fatigue occurs. The effect of asphalt content on stability will increase. if the asphalt content increases to a certain extent. Then if it is added again, the stability will decrease (exceeding the optimal asphalt level). If the asphalt content is too small, the asphalt cannot bind the aggregate properly. The following is a table of the results of the Marshall stability test.

Table 14 . Readings on the Tool

Test Item No.	Test Pieces	Asphalt Rate (%)	Stability Value (kg)
1	1	4,5	1223,92
	2	4,5	1757,89
	3	4,5	1192,00
	Average		1391,27
2	1	5,0	349,02
	2	5,0	255,41
	3	5,0	272,42
	Average		292,28
3	1	5,5	224,16
	2	5,5	356,92
	3	5,5	172,42
	Average		251,16
4	1	6,0	384,52
	2	6,0	122,44
	Average		253,48
5	1	6,5	1087,57

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2	6,5	1002,29
3	6,5	1606,67
Average		1232,17
Specification		**Min. 800**

Source: Laboratory Test Results, 2024

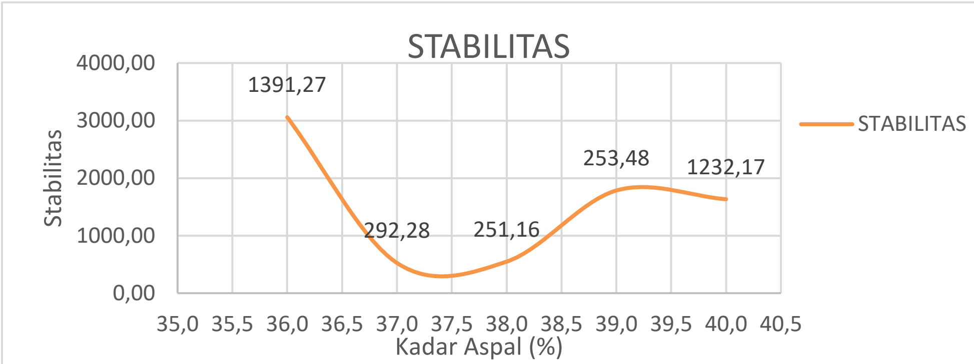


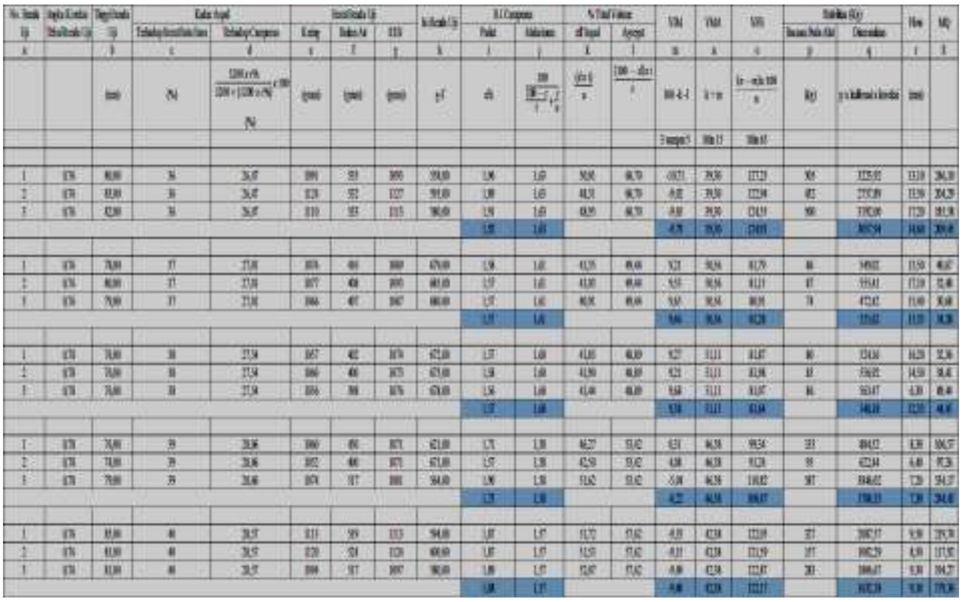
Figure 5 Stability Testing Graph

From table 15 resulting in figure 5, it can be seen that the stability value increases if the coal ash content increases, at a certain point the stability value will decrease again with the increase in asphalt content. This shows that the stability value is highly dependent on the amount of asphalt used. In accordance with the 2010 bina marga specifications.

Marshall Testing

The analysis of marshall data is based on Bina Marga, where for concrete asphalt mixture (AC-WC) Marshall parameters are recommended to be met in determining the optimum asphalt content is density, stability, fatigue (Flow), Marshall Qu

Table. 15 Marshall Calculation Results



Source: Laboratory Test Results, 2024

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Table 16 Flow Values

Test Item No.	Test Pieces	Asphalt Rate (%)	Flow Value (mm)
	1	4,5	3,10
1	2	4,5	3,50
	3	4,5	5,20
	Average		3,93
	1	5,0	3,50
2	2	5,0	7,10
	3	5,0	5,40
	Average		5,33
	1	5,5	6,20
3	2	5,5	4,50
	3	5,5	6,30
	Average		5,66
	1	6,0	3,30
4	2	6,0	3,40
	3	6,0	3,20
	Average		3,03
	1	6,5	4,50
5	2	6,5	3,50
	3	6,5	4,30
	Average		4,01
	Specification		**Min. 2 - Max. 4**

Source: Laboratory Test Results, 2024

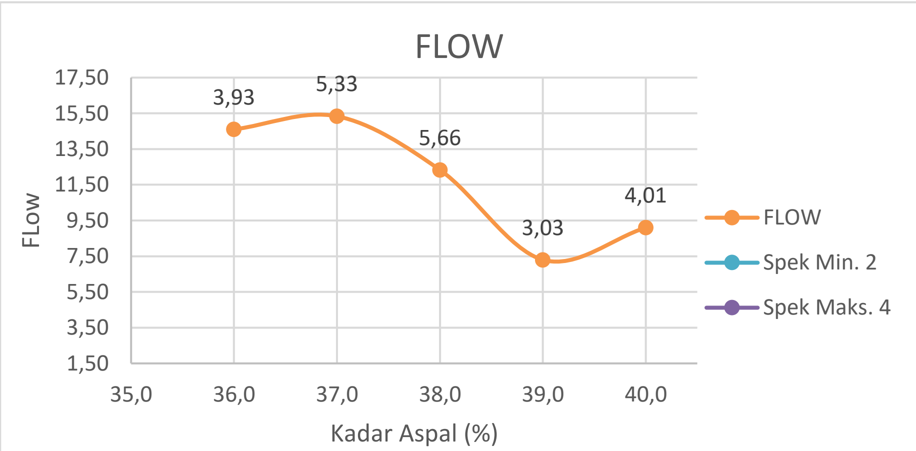

Figure 6 Flow value graph

From table 17 resulting in figure 6, it can be seen that the higher the asphalt content, the higher the Flow value. This is because the use of asphalt is so high that the asphalt no longer covers the aggregate well so that the binding power of the asphalt is reduced. Tincreased the flow value from 4.5%, 5.0%, 5.5%, 6.0%, and 6.5%. meeting the 2010 Bina Marga specifications.

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Test Item No.	Test Pieces	Asphalt Rate (%)	VIM value (%)
	1	4,5	5,71
1	2	4,5	4,02
	3	4,5	6,65
	Average		5,46
	1	5,0	5,21
2	2	5,0	4,53
	3	5,0	6,65
	Average		5,46
	1	5,5	5,27
3	2	5,5	3,21
	3	5,5	4,68
	Average		4,38
	1	6,0	3,31
4	2	6,0	5,08
	3	6,0	6,04
	Average		4,81
	1	6,5	4,35
5	2	6,5	5,15
	3	6,5	4,69
	Average		4,73
	Specification		**Min 3 - Max 5**

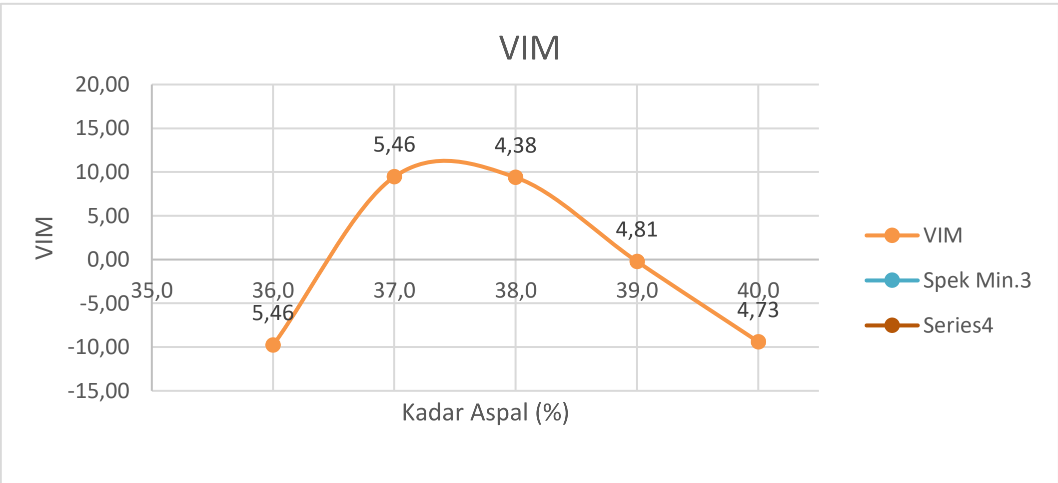

Figure 7 VIM Value Graph

From table 18 resulting in figure 7, it can be seen that the higher the asphalt content eating the air cavity in the solid mixture will be smaller, while the smaller the asphalt content, the greater the value of the blood cavity in the solid mixture. The percentage of asphalt content meets the 2010 highway specification.

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Table 18 MQ Values

Test Item No.	Test Pieces	Asphalt Rate (%)	MQ value (kg/mm)
	1	36	246,10
1	2	36	204,29
	3	36	185,58
	Average		209,45
	1	37	40,67
2	2	37	32,48
	3	37	30,68
	Average		34,28
	1	38	32,36
3	2	38	38,41
	3	38	89,44
	Average		44,45
	1	39	106,57
4	2	39	97,26
	3	39	534,17
	Average		244,43
	1	40	219,74
5	2	40	117,92
	3	40	194,27
	Average		179,36
	Specification		**Min. 250**

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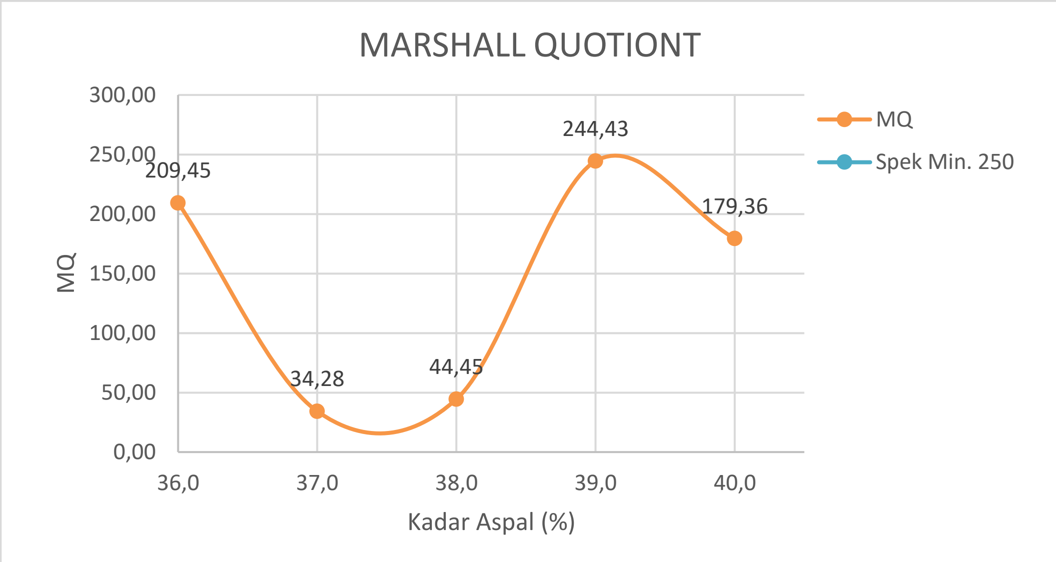

Figure 10 MQ Value Graph

figure 10, the results for the Marshall Quotien in this test show that the value on the Marshall Quotien has not met the specification with a minimum of 250

CONCLUSION

Based on the results of the study, it can be concluded that the addition of flat aggregates in the AC-WC asphalt mixture affects the Marshall characteristics, particularly the VIM value, where higher flat aggregate content causes the mixture to fail to meet the required specifications. The Marshall test results showed that only the 0% and 20% flat aggregate variations achieved the optimum asphalt content (KAO), with values of 6.24% and 6.26%, indicating that the allowable flat aggregate content in the fine-graded AC-WC mixture is a maximum of 20% of the coarse aggregate retained on sieve No. 4 and above. In addition, aggregates with high flatness and elongation indices negatively affect Marshall stability because the aggregate structure becomes less stable under compression, reducing the performance of the asphalt mixture. Therefore, greater attention should be given to the use of flat aggregates in road pavement construction to ensure compliance with Bina Marga specifications and maintain pavement durability. Further studies are also recommended using higher planned asphalt contents ranging from 5% to 7% to obtain more accurate optimum asphalt content values.

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