The Effect of Flatness and Looseness of Waai State Aggregate on Pavement of Flexible Roads

[1]J. Amahoru, [2]Vera Th C Siahaya, [3]R. H Waas, [4]Calvin Taniarie Tutuarima

[1,3]Lecturer, Civil Engineering Department, Indonesian Christian University Maluku Faculty of Engineering, Indonesia
[2]Lecturers, Department of Civil Engineering, Ambon State Polytechnic, Indonesia
[4]Student in the Department of Civil Engineering, Faculty of Engineering Indonesian Christian University Maluku, Indonesia

Abstract- **Flakiness index determination method based on the classification of aggregate particles as lamellar bodies (flaky) with a thickness of less than 0,6 nominal size. While the method of determining the kelonjongan index is based on the classification of aggregate particles as objects elliptical (elongated).**
This study aimed to analyze the influence of flakiness and kelonjongan aggregate of the flexible pavement highways using local materials domestic Waai, in terms of the method of Marshall a value Stability, Flow (melting), VIM (Void In Mix), VMA (Void In Mineral aggregate), and VFB (Void Filled Bitumen). Implementation of research conducted in the Laboratory of National Road Implementation XVI (Maluku and North Maluku). Stages of implementation include AC 60/70 bitumen examination, examination of aggregate (fine aggregate and coarse aggregate), the manufacture of test specimens of asphalt concrete mixtures and Marshall test.
The results of performance test values flat and oval and Marshall characteristics obtained on the result: the average value of Marshall Stability 836,8 kg, the average value of Flow (melting) of 5,45 mm, the average value of Quotient Marshall 18,61% kg / mm average value VIM (Void in Mix) 5,41%, the average value of VMA (Void in Mineral aggregate) 17,17% and the average value of the VFB (Void Filled Bitumen) 82,94%. Effect of aggregate flat and tapering towards the marshall of 16,58 %.

***Keywords*: Aggregate, Asphalt, Marshall**

I. INTRODUCTION

The strength and durability of a road pavement construction is very dependent on the quality of the aggregate as well as the type of asphalt used as the main material to bind these materials together to obtain a durable, long-lasting, strong and rough pavement. The aggregate is the main component of road pavement This consists of coarse aggregate and fine aggregate which have their respective proportions according to the specifications used. Coarse aggregate is aggregate consisting of crushed stone or crushed 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 lumps of clay and is granules that sharp corners and a rough surface. Coarse aggregate in the form of crushed stone is generally obtained from the results of breaking up large stones by a stone crusher. The results of breaking down the stone crusher tool obtained various sizes and shapes. The most common grain shapes obtained from using this tool are cube (square), flat (flaky) and oval (elongated) [1].

The method for determining the flatness index is based on the classification of aggregate particles as flaky objects with a thickness of less than 0m6 of their nominal size. Meanwhile, the method for determining the ovality index is based on the classification of aggregate particles as elongated. The main parameters for assessing the suitability of flat and oval grain shapes as aggregates in flexible pavement are obtained from the Marshall test. The results of this research will be presented in the form of Marshall test tables and graphs, so that it is hoped that we will get an idea of the feasibility of using flat and oval shaped aggregates [1]

II . METHODS

Research sites

This research took place in Waai Country, Ambon City, Sampling Location on the Old Wai River (Waai Country, Salahutu District, Central Maluku District).

Research locations and sampling locations can be seen in figure 1 below :

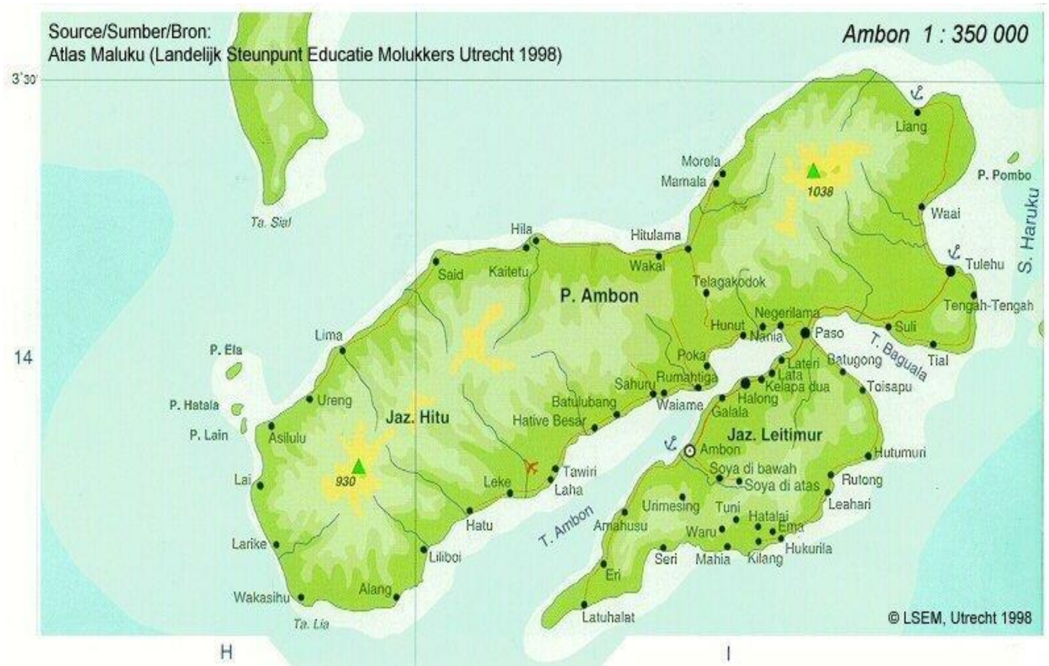

Figure 1 Sampling location

Data Type

Primary data is data on aggregate numbers in Waai Sungai Wai Tua Country. Secondary data is data that already exists and is collected by researchers to complete research data needs. The experimental method was obtained from laboratory test results including aggregate testing and asphalt characteristics testing.

Types of research

The type of research carried out is laboratory testing. Sampling of coarse aggregate, namely crushed concrete with a size of 5-10 mm, 10-20 mm from a stone crushing machine. The fine aggregate is natural sand originating from the Wai Tua Baru River and stone ash from stone crushing machines. These aggregates are used as basic ingredients for asphalt concrete mixtures , namely: Asphalt Concrete - Wearing Course (AC-WC).

Research design

The research design includes:

a. Material Preparation

The coarse aggregate and fine aggregate were taken by the river and then put into plastic sacks and then taken to the laboratory. Asphalt and cement have been prepared in advance for testing.

b. Material Testing

Coarse aggregate testing, consisting of:

1. Abrasion is to measure aggregate wear.
2. Specific gravity and absorption include bulk specific gravity, dry surface saturated specific gravity, apparent specific gravity and absorption.
3. Flatness and Ovalness of Aggregates.
4. Angularity.
5. Sieve analysis is the determination of the weight percentage of aggregate grains that pass through a set of sieves, then the percentage figures are depicted on a grain distribution or gradation graph.
6. Aggregate stickiness to asphalt is the percentage of aggregate surface area covered by asphalt over the entire surface.

Fine aggregate testing consists of:

1. Specific gravity and absorption, namely, include bulk specific gravity, dry surface saturated specific gravity, apparent specific gravity (appatent) and absorption.
2. Sand equivalent or sand equivalent value test, namely, to determine the quality of fine aggregate regarding the content of plastic materials (materials that contain or resemble clay and silt).
3. Sieve analysis, namely, determining the percentage of weight of aggregate grains that pass through a set of sieves, then the percentage figures are depicted on a grain distribution graph.

Asphalt Characteristics Testing, consisting of:

1. Penetration.
2. Soft point.
3. Flash point.
4. Ductility.

5. Specific gravity.

c. Design of combined aggregate gradations according to combined aggregate specifications for Asphalt Concrete - Wearing Course (AC-WC).
d. Determination of effective asphalt content (P_b).
e. Mixing aggregate with asphalt.
f. Making test objects or brickets for Asphalt Concrete - Wearing Course (AC-WC).
g. Marshall testing and calculation of Marshall meters, which include:
1. Determination of the volume weight of the test object.
2. The stability value test is the maximum ability of solid asphalt concrete to accept loads until plastic yielding occurs.
3. The yield test (flow) is the amount of change in the plastic shape of solid asphalt concrete due to a load up to the failure limit.
4. Marshall quotient calculation is a comparison between stability and flow values.
5. Calculation of various types of pore volume in dense asphalt concrete (VIM, VMA and VFB).
h. DMF (Design Mix Formula).
i. Conclusion, discussion of test results with data analysis based on research.

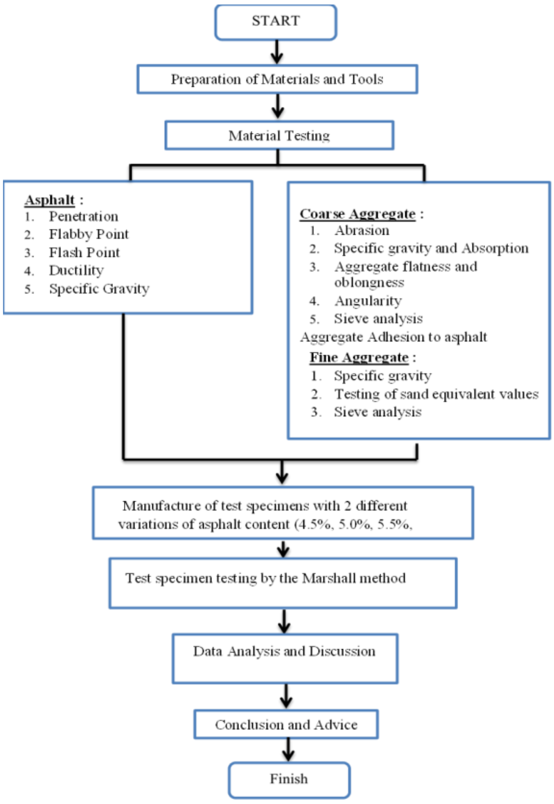

Figure 2 Research flow diagram

III . DATA AND ANALYSIS

Research results on flat and oval aggregates

1. Coarse aggregate

The test results of the Waai country coarse aggregate shown in Table 1 show that the Waai country coarse aggregate meets the requirements of the Indonesian National Standard (SNI). Waai country coarse aggregate taken from the Old Wai River apparently has a specific gravity and absorption value of 1,90%, or smaller than the maximum limit required by the Indonesian National Standard (SNI) Max 3%, while the absorption is 1,90% more. smaller than the maximum requirement (SNI) Max 3%. And the Angularity value of 99/92 is greater than the maximum requirement of the 2010 Bina Marga specifications revision 3 division 6 of 95/90.

Then to determine flat aggregate, namely aggregate that has dimensions smaller than 0,6 times the average of the sieve holes which limits the size of the particle fraction. An aggregate particle can be said to be flat if the aggregate has dimensions (size) that are smaller than the other two dimensions. Meanwhile, for oval aggregates, the aggregate that has dimensions greater than 1.8 times the average size of the sieve holes limits the size of the fraction. the particle. An aggregate particle can be said to be oval if the aggregate has dimensions (size) that are larger than the other two dimensions. From the test results on the ½ sieve, flat and oval aggregates were obtained, namely 350,5% and on the 3/8 sieve, flat and oval aggregates were obtained, namely 191,6%.

From the test results, it was found that the flat and oval particles were 16,58% greater than the requirements for Bina Marga 2010 revision 3, namely Max 10%. The following table below shows the results of test observations.

Table 1 Test results for flat and oval aggregates

Sieve Size	Aggregate Gradation	% Retained (pi)	Retained Weight (Wi) (Wi) grams	Number of Granules After reduction ≥ 10 %	Flat and Oval Details		Granules that are not flat and oval (Nfei)	
					Ratio 1:5		Ratio 1:5	
				Item 1	Item 1	%	Item 1	%
a	b	c	d=c*wt/pt	e	f	g=f/e*100	h	i=h/e*100
1.5"	100.0							
1"	100.0							
3/4 "	100.0	0.00	0.00					
1/2 "	34.12	65.88	2172.13	1954.92	315.92	16.14	1639.44	83.86
3/8 "	0.0	34.12	1124.97	1012.47	172.44	17.03	840.06	82.97
Total % retained (pt = p1+p2+p3+...) = 100 %					Mean² (%) = 16.58		Average² (%) = 83.42	

The results of the coarse aggregate wear test using a Los Angeles machine show that the coarse aggregate used is resistant to abrasion. This can be seen from the average wear value obtained, namely 32,85% or below the value required by the Indonesian National Standard (SNI). namely 40%. Then the test results for aggregate adhesion to asphalt showed 95% and the limit set by the 2010 specification revision 3 division 6 was Min 95%.

2. Fine aggregate

In testing the fine aggregate of Waai State, the results of the tests that have been carried out show that the fine aggregate of Waai State, namely the sand equivalent value, is 87,60% with the specifications set by Bina Marga 2010 revision 3 division 6 of Min 60%. The specific gravity and absorption value of Waai fine aggregate, namely sand, shows a value of 1,63% or below the maximum absorption value required by Bina Marga 2010 revision 3 division 6, namely Max 3%. And the Angularity value of 45,90% is greater than the Min requirement of 45%.

3. Specific gravity and absorption of rock ash

When examining the specific gravity of fine aggregate, namely stone ash, a value of 1,25% was obtained. The absorption value shows a value of 1,25% or below the required maximum absorption value, namely 3%.

Table 2 Results of aggregate inspection for Waai State

No.	**Checking type**	**Unit**	**Condition**		**Material Characteristics Test Results**	**Note**
			Min.	**Max.**		
Waai State Coarse Aggregate						
1.	Abrasion	%	-	40	32.85	Fulfil
2.	Aggregate adhesiveness to bitumen	%	95	-	95+	Fulfil
3.	Angularity	%	-	95/90	99/92	Fulfil
4.	Specific Gravity and Absorption	%		10	1.90	Fulfil
5.	Sieve Analysis	%	-	-	-	View Chart
6.	Flat and Oval Particles	%	-	10	16.58	Does not meet the
Waai State Fine Aggregate						
1.	Angularity	%	45	-	45.90	Fulfil
2.	Specific Gravity and Absorption	%	-	3	1.63	Fulfil
3.	Sand Equivalent Value	%	60	-	87.60	Fulfil
4.	Sieve Analysis	%	-	-	-	View Chart
Batu Ash						
1.	Specific Gravity and Absorption	%	-	3	1.25	Fulfil

Asphalt inspection results

From the results of Pertamina Pen 60/70 asphalt testing shown in the discussion as follows:

1. Asphalt Penetration Inspection .
2. Asphalt Softening Point Check .
3. Asphalt Flash and Burn Point Inspection .
4. Asphalt Specific Gravity Check .
5. Asphalt Ductility Check

Table 3 Results of inspection of Pertamina Pen 60/70

No.	Checking type	Specification	Unit	Condition	Asphalt Characteristics Test Results	Note
1.	Penetration at 25 °C (0.1 mm)	SNI 06-2456-1991		60-79	65	Fulfil
2.	Specific gravity	SNI 06-2456-1991	gr/cc	1.01 - 1.03	1,028	Fulfil
3.	Softening Point (°C)	SNI 06-2433-1991	°C	Min. 48	51	Fulfil
4.	Flash Point (°C)	SNI 06-2434-1991	°C	224	323	Fulfil
5.	Ductility at 25 °C (cm)	SNI 06-2432-1991	cm	Min. 100	130	Fulfil

Marshall test results

Marshall test results on hot asphalt concrete mixtures are stability, VMA (voids in mineral aggregate), VFA (voids filled with asphalt), VIM (voids in the mix) and flow, Marshall Quotient on each test object. 2 test objects for each asphalt content. To obtain asphalt characteristic values that meet all the requirements of the 2010 Bina Marga specifications revision 3 division 6, it is necessary to find the optimum asphalt content determined by experimental marshall testing with variations in asphalt content of 4,5%, 5,0%, 5,5%, 6,0%, and 6,5%. Marshall test results to determine optimum asphalt content are shown in Table 4 below :

Table 4 Marshall test results

No.	Types of Checks	Spesifikasi	Asphalt Grade (%)									
			4.5	Information	5.0	Information	5.5	Information	6.0	Information	6.5	Information
1.	VMA (%)	Min. 15	15.41	Meet	15.96	Meet	16.16	Meet	16.81	Meet	17.17	Meet
2.	VFB (%)	Min. 65	64.87	Meet	69.19	Meet	75.11	Meet	78.3	Meet	82.94	Meet
3.	VIM (%)	3 - 5	5.41	Does not meet	4.92	Meet	4.02	Meet	3.65	Meet	2.93	Meet
4.	Stabilitas (Kg)	Min. 800	537.6	Does not meet	674.9	Does not meet	733.4	Does not meet	806.6	Meet	836.8	Meet
5.	Flow (mm)	2 - 4	5.45	Does not meet	5.25	Does not meet	4.35	Does not meet	4.45	Does not meet	4.55	Does not meet
6.	Marshall Quotient	Min. 250	98.67	Does not meet	129.60	Does not meet	168.68	Does not meet	181.28	Does not meet	184.61	Does not meet

Marshall test parameters :

1. Stability

Stability is the ability of the pavement layer to withstand deformation due to the load of traffic acting on it, without experiencing deformation such as waves and grooves. The stability value is influenced by friction between aggregate grains (internal friction), interlooking locking and good bonding of the asphalt layer (cohesion), besides that the compaction process, aggregate quality, and asphalt content also have an effect.

Table 5 Marshall stability test results

Notation	Test Objects	Asphalt Content (%)	Stability Value (Kg)
I	1	4.5	546
	2	4.5	529
		Average	**538**
II	1	5.0	638
	2	5.0	712
		Average	**675**
III	1	5.5	755
	2	5.5	712
		Average	**733**
IV	1	6.0	804
	2	6.0	809
		Average	**807**

V	1	6.5	848
	2	6.5	825
		Average	**837**

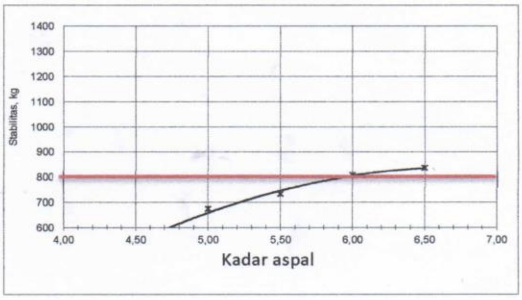

Figure 3 Graph of the relationship between asphalt stability and roughness

From figure 3 of the relationship between stability and asphalt content above, the Marshall Optimum stability value is achieved in asphalt concrete mixture with an asphalt content of 6,5% with an average stability value of 836,8 kg. Based on the 2010 Highways Specification revision 3 concerning the provisions for the properties of laston mixtures, the minimum stability value for medium traffic is 800 kg, so that all asphalt grades used in this thesis research meet the requirements.

2. Flow

Flow or melt indicates the amount of decrease or deformation that occurs in the hard layer due to resisting the load it receives. The decrease or deformation that occurs is closely related to the value of other Marshall characteristics, such as VFB (Vold Filled Bitumen), VIM (Void In Mix) and its stability. The flow value is influenced by, among others, aggregate gradation, asphalt content and compaction process which includes compaction temperature and compaction energy. The flow values specified in Specification 2010 revision 3 are 2 – 4. Table 6 Flow (meltdown) test results

Table 6 Flow test results

Notation	Test Objects	Asphalt Content (%)	Flow Value (mm)
I	1	4.5	5.60
	2	4.5	5.30
		Average	**5.45**
II	1	5.0	5.60
	2	5.0	4.90
		Average	**5.25**
III	1	5.5	4.30
	2	5.5	4.40
		Average	**4.35**
IV	1	6.0	4.50
	2	6.0	4.40
		Average	**4.45**
V	1	6.5	4.30
	2	6.5	4.80
		Average	**4.55**

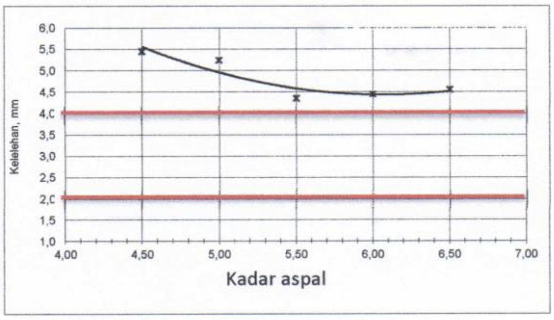

Figure 4 Graph of the relationship between flow and rough asphalt

Of the magnitude of the highest flow value, there is an asphalt content of 4,5% with an average of 5,45 mm.

3. VFB (Void Filled Bitumen)

Stating the percentage of air cavities filled with asphalt in mixtures that have undergone compaction, this VFB value is on the waterproof and airproof properties, as well as the elastic properties of the mixture. The VFB value is influenced by several factors such as: energy, compaction temperature, asphalt type and content, and aggregate gradation. Of the magnitude of the highest VFB value, there is an asphalt content of 6,5% with an average of 82,94%.

Table 7 VFB (Void Filled Bitumen) test results

Notation	Test Objects	Asphalt Content (%)	VFB Value (%)
I	1	4.5	65.27
	2	4.5	64.48
		Average	**64.87**
II	1	5.0	69.03
	2	5.0	69.35
		Average	**69.19**
III	1	5.5	74.88
	2	5.5	75.33
		Average	**75.11**
IV	1	6.0	78.37
	2	6.0	78.23
		Average	**78.30**
V	1	6.5	82.93
	2	6.5	82.95
		Average	**82.94**

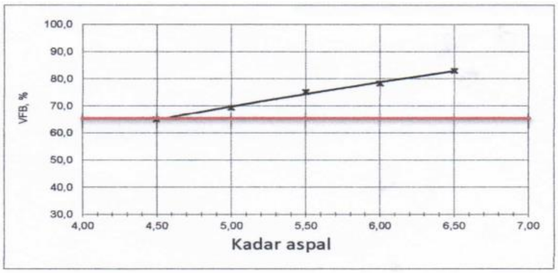

Figure 5 Graph of the relationship between VFB and asphalt roughness

4. VIM (Void In Mix)

The number of voids in the mixture is expressed as a percentage. The air cavities contained in the mixture are necessary for the availability of space for the mixed elements according to their elastic properties. Therefore, the VIM value largely determines the characteristics of the mixture. VIM (Void In Mix) value is influenced by aggregate gradation, asphalt content and density. Of the highest VIM values, there is an asphalt content of 4,5% with an average of 5,41%.

Table 8 VIM (Void In Mix) test results

Notation	Test Objects	Asphalt Content (%)	VIM value (%)
I	1	4.5	5.32
	2	4.5	5.50
		Average	**5.41**
II	1	5.0	4.95
	2	5.0	4.88
		Average	**4.92**
III	1	5.5	4.07
	2	5.5	3.98
		Average	**4.02**
IV	1	6.0	3.64

	2	6.0	3.66
		Average	**3.65**
V	1	6.5	2.93
	2	6.5	2.93
		Average	**2.93**

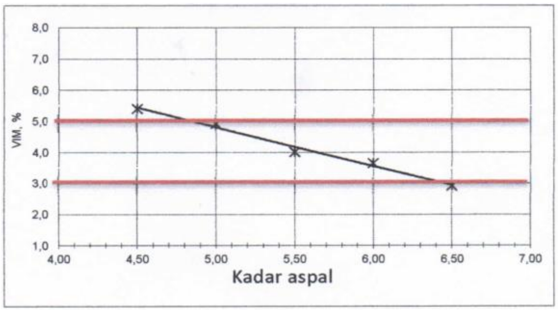

Figure 6 Graph of the relationship between VIM and asphalt roughness

Based on the requirements of the 2010 Highways Specification revision 3 concerning the provisions for the properties of the Laston mixture, the VIM (Void In Mix) value that meets the requirements is 3.0%-5.0%.

5. VMA (Void In Mineral Aggregate)

The air void that exists between the mineral aggregates in the hot paved mixture that has been obtained includes the space filled with asphalt. VMA is expressed as a percentage of the hot paved mixture. VMA is used as a space to accommodate asphalt and the volume of air cavities required in a hot paved mixture, the magnitude of the VMA value is influenced by the asphalt content, gradation of stacking materials, number of collisions and compaction temperature.

Table 9 VMA (Void In Mineral Aggregate) Test Results

Notation	Test Objects	Asphalt Content (%)	VMA Value (%)
I	1	4.5	15.33
	2	4.5	15.49
		Average	**15.41**
II	1	5.0	15.99
	2	5.0	15.93
		Average	**15.96**
III	1	5.5	16.20
	2	5.5	16.12
		Average	**16.16**
IV	1	6.0	16.80
	2	6.0	16.83
		Average	**16.81**
V	1	6.5	17.17
	2	6.5	17.17
		Average	**17.17**

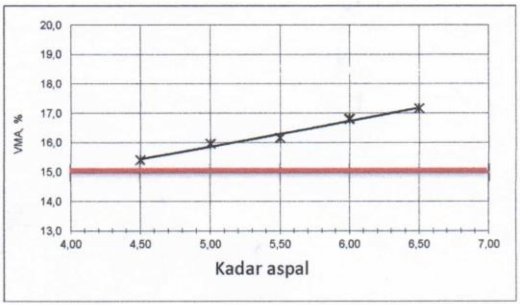

Figure 7 Graph of the relationship between VFB and asphalt roughness

Of the magnitude of the highest VMA value, there is an asphalt content of 6.5% with an average of 17.17%.

6. Determination of optimum asphalt content

The optimum asphalt grade is the amount of asphalt used in the mixture in order to achieve the Stability, Flow, VMA, VIM and VFB requirements. Determination of optimum asphalt content to determine the amount of effective asphalt content in the mixture required for the manufacture of new test specimens with the same aggregate composition but with a predetermined optimum asphalt content.

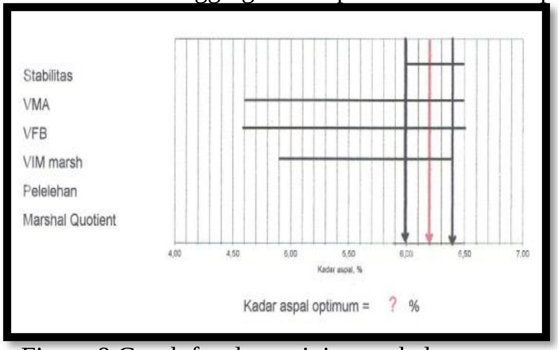

Figure 8 Graph for determining asphalt content

IV. CONCLUSION

1.The results of testing the characteristics of the Waai State Material are as follows:

Coarse Aggregate:

a. To determine flat aggregates, that is, aggregates that have dimensions smaller than 0.6 times the average of the filter hole, limiting the size of the fraction of such particles. An aggregate particle can be said to be flat if the aggregate has dimensions (sizes) smaller than the other two dimensions. While in oblong aggregates to determine, namely aggregates that have dimensions greater than 1.8 times the average size of the filter hole which limits the size of the particle fraction. An aggregate particle can be said to be oval if the aggregate has dimensions (size) greater than the other two dimensions. From the test results on filter 1/2, flat and oblong aggregates were obtained which were 350.5% and in filters 3/8 flat and oblong aggregates were obtained which were 191.6%. From the test results of Flat and oval Particles obtained by 16.58%.The Abrasion Value obtained was 32.85%.

b. Aggregate Adhesion Value to Asphalt is 95%.

c. Angularity value is 99/92%.

d. Specific Gravity Value is 1.90 Gs.

e. Absorption Value of 1.90%.

Test results from b – f meet the 2010 Bina Marga Specifications, Revision 3. Meanwhile, a does not meet or exceed the Max 10% limit determined by the 2010 Bina Marga specifications, revision 3, division 6.

Fine Aggregate (Sand):

a. Angularity value is 45.90%.

b. The specific gravity value is 1.63 Gs.

c. Absorption Value is 1.63%.

Test results meet the 2010 Bina Marga Specifications revision 3 division 6.

Fine Aggregate (Stone Ash):

a. Specific Gravity and Absorption Values are 1.25%.

Test results meet the 2010 Bina Marga Specifications revision 3 division 6.

2. The results of the Marshall characteristic test are as follows

a. VMA (Void in Mineral Aggregat) value of 17.17%

b. VFB (Void Filled Bitumen) value of 82.94%

c. VIM (Void In Mix) value of 5.41%

d. Marshall Stability Value of 836.8 kg

e. Flow value of 5.45 mm.

f. Marshall Quotient of 184.61 Kg/mm.

From the test results there are three variables, namely d – f, which do not meet the 2010 Bina Marga Specifications revision 3 division 6.

3. The influence of flatness and curvature can affect marshall stability and the Optimum Asphalt Content cannot be ascertained as an asphalt concrete mixture because there are three variables that are not met, namely:

a. The Stability Value is low from the expected results, because the flat and oval material exceeds the specified standards, so it can interfere with the carrying capacity of the planned asphalt content. From the estimated planned asphalt content, it was only discovered that it meets the 2010 Bina Marga Specifications Revision 3 Division 6, namely asphalt content of 6.0% and 6.5%.

b. The Flow value does not meet the expected requirements, from the 2010 Bina Marga Specifications revision 3 division 6 it is determined 2 – 4, this is because the shape of the material does not support it. So it interferes with changes in the shape of an asphalt mixture when it collapses.

c. The Marshall Qoutient value does not meet the requirements because of the division between low Stability values and high Flow values. So the Marshall Qoutient value determined by the Min Specification of 250 Kg/mm is not obtained.

V. ACKNOWLEDGMENTS

The author expresses his thanks thanks to Mr. Aaron. J. Manusama, ST as head of the BPJN Maluku laboratory who has provided many suggestions and directions for the perfection of this research. Thank you also to Mr Markus Bawotong, ST who helped with the research process and Elsye Novelin Mataheru who helped prepare this research journal.

REFERENCES:

[1]. M. Aminsyah, 2010. The Effect of Aggregate Flatness and Looseness on Highway Flexible Pavement. Journal of Civil Engineering

[2]. Put r o w ij o y o, R. 2006. *Laboratory Study of Marshall Properties and Durability of Asphalt Concrete-Wearing Course (AC-WC) by comparing the use of Portland cement and rock ash as filler*. Semarang: Postgraduate Program majoring in Civil Engineering, Faculty of Engineering, Diponegoro University.

[3] Revision of SNI 03-1737-1989. The Guideline on "Implementation of hot paved mixture layers" is a substitute for SNI 03-1737-1989, Procedures for implementing asphalt concrete laapis (LASTON) for highways: Research and Development Agency of the Ministry of Public Works.

[4] Revision of SNI 06-2456-1991. Asphalt Penetration Test: R&D Agency of Public Works Department.

[5] Revision of SNI 06-2434-1991. How to test the soft point of asphalt with a ring and ball tool (ring ang ball): R&D Agency of the Department of Public Works.

[6] RSNI M-01-2003. Test Method of Hot Paved Mixture with Marshall Tool: National Standardization Agency.

[7] SNI 03-1968-1990. Sieve Analysis Test Method of Fine Aggregate and Coarse Aggregate: Pustran Balitbang Public Works.

[8] SNI 03-2417-1991. Aggregate Wear Test Method With Los Angeles Abrasion Machine: Pustran Balitbang Public Works.

[9] SNI 06-2441-1991. Asphalt Specific Gravity Test Method: Pustran Balitbang Public Works.

[10] SNI 1970-2008. How to Test Specific Gravity and Water Absorption of Fine Aggregates: National Standardization Agency.

[11] SNI 2490-2008. How to Test Moisture Content in Oil Products and Materials Containing Asphalt by Distillation: National Standardization Agency.

[12] Sukirman, 2003. Hot mixed asphalt concrete. Jakarta: Granite.