Utilization of HDPE Waste in Asphalt Concrete Mixture AC-WC with Recycled Aggregate using *Fly Ash* and Rock Ash as *Filler*

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ABSTRACT

The development of all aspects in Indonesia at this time does not rule out the possibility also due to the increasingly rapid development of roads in Indonesia. This development was also accompanied by the need for material, the majority of which came from nature. One type of pavement used in Indonesia is Laston AC-WC. More and more heavy vehicles result in road damage. The solution is to dredge it using a tool called a *cold milling machine* which results in what is called *Reclaimed Asphalt Concrete*. The use of RAP can be a solution so that the use of natural resources does not increase. In addition to using RAP as a recycled material, HDPE (*High Density Polyethylene*) plastic waste is used which has stiff characteristics, this stiffness can improve pavement quality to minimize*rutting*at high enough temperatures. In this study, it is reviewed how the effect of adding RAP, HDPE, and *fly ash filler* will be compared with test objects using *filler* rock ashInfluence seen in the results of asphalt characteristics through the Marshall test in the form of stability, *flow*, VIM, VMA, VFB, and MQ. The KAO was obtained using *filler* of 5%% with details of the marshall test results being Stability 1244.68 Kg, *Flow* 3.48 mm, VIM 4.98 %, VMA 15.2%, VFB 68%, and MQ 370 Kg/mm. In the specimens using *fly ash filler* KAO was obtained at 5.5% with details of the results of the Marshall test Stability 1142.19 Kg, *Flow* 3 mm, VIM 4.8 %, VMA 15.55 %, VFB 69 %, and MQ 359 Kg/mm. The results of adding HDPE with levels of 0%, 1.6%, 1.8%, 2%, 2.2%, and 2.4% obtained optimum plastic content results in the test specimens using *filler* of 1.8% with the results of the Marshall test, Stability 1282.01 Kg, *Flow* 3.5 mm , VIM 4.75 %, VMA 15.75 %, VFB 71 %, and MQ 360 Kg/mm. For the specimens using *fly ash filler* , the optimum plastic content yield was 1.8% with details of the marshall test results namely Stability 1249.55 Kg, *Flow* 3.75 mm, VIM 4.51 %, VMA 15.3 %, VFB 69.5 %, and MQ 340 Kg/mm. All results have met the General Specification Standards for Highways Division 6.

Keywords: Laston AC-WC, Reclaimed Asphalt Pavement, HDPE, Stone Ash, *Fly Ash*

INTRODUCTION

The development of all aspects in Indonesia at this time does not rule out the possibility also due to the increasingly rapid construction of roads in Indonesia. The government continues to build road infrastructure to remote areas. This has a positive impact because equity can occur and mobility can be done easily. Asphalt pavements are widely used in highway construction all over the world due to their advantages of good flatness, aesthetics, driving comfort, and ease of repair (Li et al., 2020).

This development was also accompanied by the need for material, the majority of which came from nature. One type of pavement used in Indonesia is Laston AC-WC which is a mixture consisting of coarse aggregate, fine aggregate, hard asphalt, filler which is mixed and spread at a certain temperature. According to Bina Marga (1987), laston is expected to be a waterproof surface layer that can contribute to providing carrying capacity and protecting the construction underneath. The laston layer is used for roads with heavy traffic loads (Sukirman, 2003).

Heavy loads result in road damage. The solution to overcome this is dredging using a tool called *cold milling machine*. The result of dredging using a *cold milling machine* is called *Reclaimed Asphalt Pavement*. The use of RAP as an aggregate on new pavement can be a solution so that the use of natural resources does not increase, but it is necessary to take into account during the design and planning process to ensure that the mixture using RAP can work as well as the mixture using natural aggregate because during the service life of RAP, it will definitely experience physical changes. and rheology (Imad, 2007). Conducted a comparison of performance on pavement fields using RAP between 20% -50% with conventional pavements, obtained results that did not differ much in terms of pavement conditions and ease of workmanship Paul (1996).

In addition to using RAP as a recycled material, HDPE (*High Density Polyethylene*) type plastic waste can also be used which has stiff characteristics, this stiffness can improve pavement quality to minimize*rutting*at high enough temperatures (Catt, 2004). In a study conducted by Kofteci (2016), the results showed an increase in stability and water resistance in mixing 4% HDPE in HMA. So it is felt that the best modification is at 4% because it does not have a negative impact on flexibility and plasticity.

Utilization of other materials, namely the use of filler in the asphalt mixture using *fly ash* and rock ash. The difference between fly ash and rock ash is that *fly ash* is a by-product of burning coal, while rock ash is a mineral by-product of cement or stone crushing. *Filler* functions as a filler in the asphalt mixture, so there is a condition that the material can be used as a *filler*, namely 75% passes sieve no. 200. The pavement surface temperature can be reduced by 3–5 C by regular watering and evaporative cooling. However, the cooling effect is significant only near the pavement surface, since impermeable dense graded asphalt mixtures are commonly used as the top asphalt layer (Chen, 2008).

In this study, it is reviewed how the effect of adding RAP, HDPE, and *fly ash filler* will be compared with test objects using *filler* rock ashThe influence is seen in the results of asphalt characteristics through the Marshall test, namely in the form of stability, *flow*, VIM, VMA, VFB, and MQ, research using the Laston AC-WC adheres to the 2010 Bina Marga specifications and will be carried out at several variations of asphalt content and also the percentage of HDPE that will be added. The application of TM modified asphalt binders has been extended by on-going studies at Hunan University [20–24], where the effects of base binder type, TM additive color, and TM additive content on the mechanical properties and aging performance of asphalt binders are being comprehensively investigated. The optimum TM additive contents have been determined in terms of various binder performances (Chen et al., 2019).

MATERIALS AND METHODS

The materials that will be used in the manufacture of test objects are Coarse Aggregate (new), Coarse Aggregate (RAP), Medium Aggregate (new), Fine Aggregate (new), HDPE plastic, Asphalt Pen 60/70, and *filler.*

a) Coarse Aggregate (*Coarse Aggregate*)

   Coarse aggregate has a grain size of 10-15 mm. In this study, two types of coarse aggregate were used, namely new coarse aggregate originating from nature and coarse aggregate using RAP. RAP is obtained from the dredging remains of Sukomulyo Street in Gresik which is carried out by separating the aggregates using a *crusher*.

b) Medium Aggregate (*Medium Aggregate*)

   Medium aggregate has a grain size between 5-10 mm. In this study, medium aggregates were used from PT. Merakindo Mix.

c) Fine Aggregate (*Fine Aggregate*)

   Fine aggregate is aggregate that has a grain size of 0-5 mm. In this study, fine aggregate from PT. Merakindo Mix.

d) Asphalt

   Asphalt, which is the key in the manufacture of test specimens, has a role as an adhesive between aggregate grains so that they can become a unified whole. In this study Pertamina pen 60/70 asphalt was used.

e) HDPE plastic

   In this study, additional HDPE type plastic was used as an addition to the asphalt mixture. HDPE plastic is obtained from recycled plastic shampoo bottles which are crushed into smaller granules. There are several variations in the percentage of the addition of HDPE to the total asphalt volume used, namely 0%, 1.6%, 1.8%, 2.0%, 2.2%, 2.4%.

f) *Fillers*

   Filler is usually added to the mixture so that the voids contained in the mixture can be filled so that the percentage of voids is not too large in a mixture. In this study, *fly ash* and rock ash were used as *fillers* where *fly ash* is a waste of burning coal and rock ash is a mineral by-product of rock breakdown, both of which will be compared to the use of *filler* which results in better performance of the test object. *Filler* must comply standard, namely having a grain size of 75% passing the No. sieve. 200.

Quantitative method is used in this study where the independent variables are HDPE, RAP, *filler*. The dependent variable is the result of the *Marshall test*. Conducted research on a laboratory scale using research methods. Following are the steps in conducting this research:

1) Testing Aggregate, Asphalt, *filler*, and RAP

The first stage in this research is to test the materials that will later be used in the manufacture of test objects, namely testing on aggregate, asphalt, and RAP. The tests carried out were sieve, specific gravity and absorption tests on aggregate, RAP, and *filler*, while on asphalt tests were carried out for all characteristic values of asphalt material.

The results showed that the specific gravity of fine aggregate (0-5mm) was 2,684 gr/cm^3 with an absorption of 1,688%. The specific gravity of medium aggregate (5-10 mm) is 2,683 gr/cm^3 with an absorption of 1,342%. The specific gravity of coarse aggregate (10-15 mm) is 2,660 gr/cm^3 with an absorption of 1,214%. The specific gravity of the *filler* 2.63 gr/cm^3. The Gs RAP value is 1.33 gr/cc and the water content is 1%. Then for the inspection results on pen 60/70 asphalt, the penetration results were 68.5 mm, softness was 48.5ºC, flash point was 321ºC, asphalt weight loss was 0.0209%, solubility was 99.71%, ductility > 140 cm, and specific gravity was 1.03. These results have met the requirements.

For the combined gradation of aggregate and RAP obtained using several variations, for the test object using fly ash there are 2 variations of the combined gradation of aggregate and RAP, namely as follows:

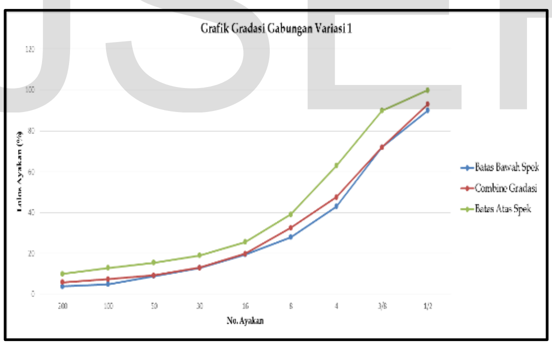

Figure 1. Graph of Gradation of Aggregate Mix Var.1 using *fly ash filler*

In var. 1 obtained a percentage of 37% coarse aggregate, 21% RAP Medium Aggregate, 40% fine aggregate, *fly ash filler*. The combined gradation meets the requirements of the 2010 General Highways Specification for road pavement division 6.

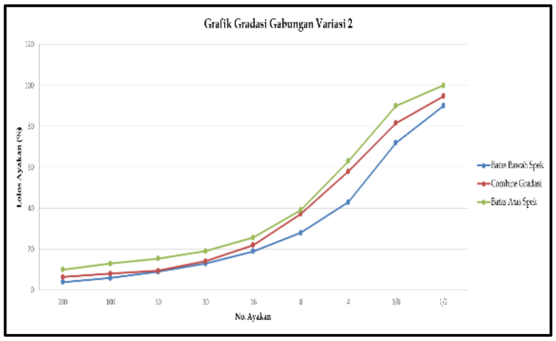

Figure 2. Gradation Graph of Aggregate Mix Var.2 using *fly ash filler*

In var. 1 obtained the percentage of 21% RAP coarse aggregate, 32% Medium Aggregate, 45% fine aggregate, *fly ash filler*. The combined gradation meets the requirements of the 2010 General Highways Specification for road pavement division 6.

Then for the test object using stone ash as filler, 6 variations of the combined gradation of aggregate and RAP were obtained, namely as follows:

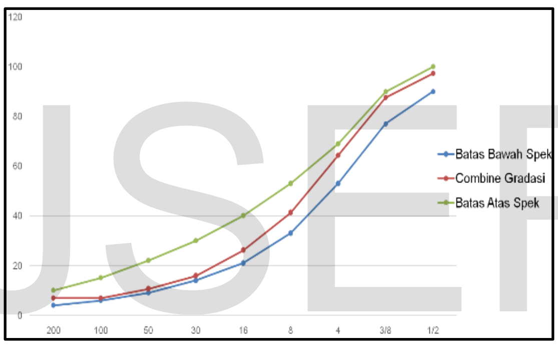

Figure 3. Graph of Var.1 Aggregate Mix Gradation using *filler* stone ash

In var. 1 obtained the percentage of RAP 11% coarse aggregate, 37% Medium Aggregate, 45% fine aggregate, *filler* 7% stone ash

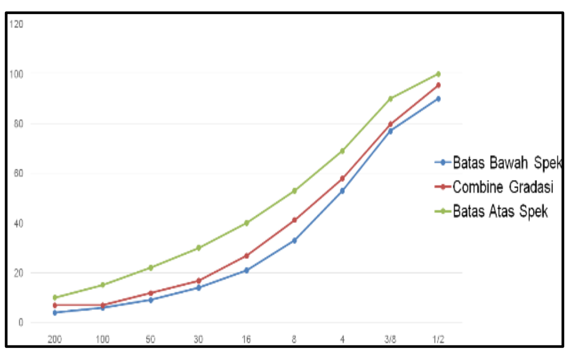

Figure 4. Gradation Graph of Aggregate Mix Var.2 using *filler* rock ash

In var. 2 obtained a percentage of 16% coarse aggregate, 30% RAP Medium Aggregate, 47% fine aggregate, *filler* 7% stone ash

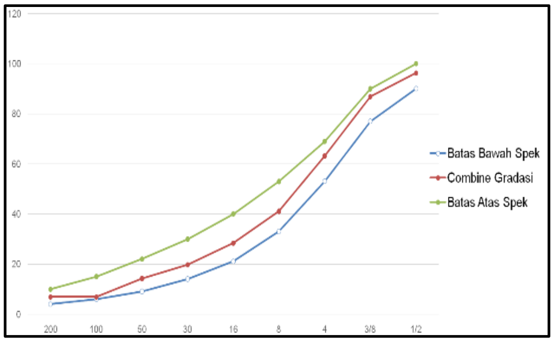

Figure 5. Gradation Graph of Aggregate Mix Var.3 using *filler* rock ash

In var. 3, the percentage of coarse aggregate is 13%, medium aggregate is 35%, RAP fine aggregate is 45%, *filler* rock ash

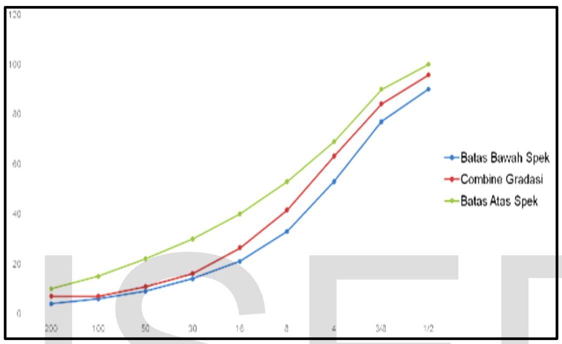

Figure 6. Gradation Graph of Aggregate Mix Var.4 using *filler* rock ash

In var. 4 obtained the percentage of RAP 17% coarse aggregate, 30% Medium Aggregate, 46% fine aggregate, *filler* 7% stone ash

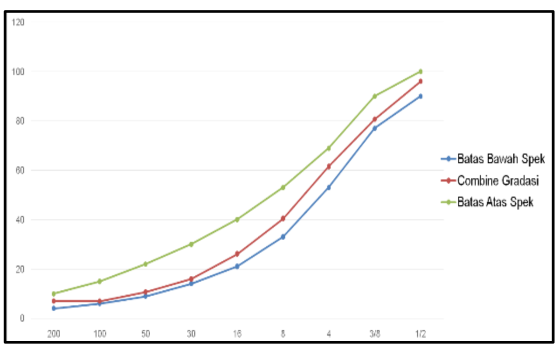

Figure 7. Gradation Graph of Aggregate Mix Var.5 using *filler* rock ash

In var. 5, the percentage of coarse aggregate is 14%, medium aggregate is RAP 34%, fine aggregate is 45%, *filler* and rock ash

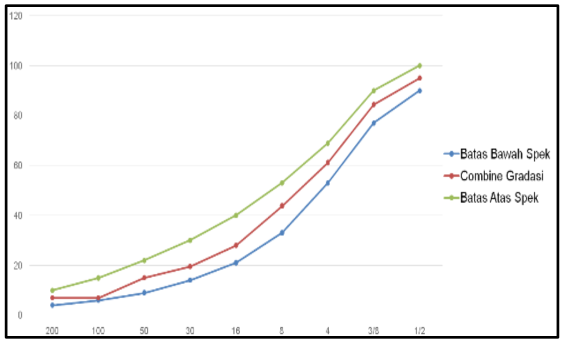

Figure 8. Gradation Graph of Aggregate Mix Var.6 using *filler* rock ash

In var. 6 obtained the percentage of coarse aggregate 17%, medium aggregate 34%, fine aggregate RAP 42%, *filler* stone ash 7%.

2) Calculations

In the mixture using *fly ash filler* from two variations of mixed aggregate gradations, variation 2 was selected for further testing, namely with asphalt content of 4%, 4.5%, 5%, 5.5%, and 6%. Then for the mixture that uses rock ash filler, 6 variations of the mixed aggregate gradation are still used and how much the KAO will be determined. The asphalt content used was 4.5%, 5%, 5.5%, 6%, 6.5% with 3 test objects for each asphalt content.

RESULTS AND DISCUSSION

***Marshall Test* (Aggregate+RAP+*filler*)**

Mixed performance data obtained in the form of Stability, *Flow*, VIM, VMA, VFB, and *Marshall Quotient* (MQ) values. Standard Specification for Highways 2010 Division 6[7] as a reference for checking whether the results meet the requirements or not. The following are the results of the marshall test for each asphalt content:

1. Stability The

Stability value is obtained by reading the clock on the machine and multiplying it by the tool calibration. Stability is the ability of the mixture to accept the load expressed in units of Kg. The following is a graph of the stability of the test object using *fly ash* and rock ash fillers:

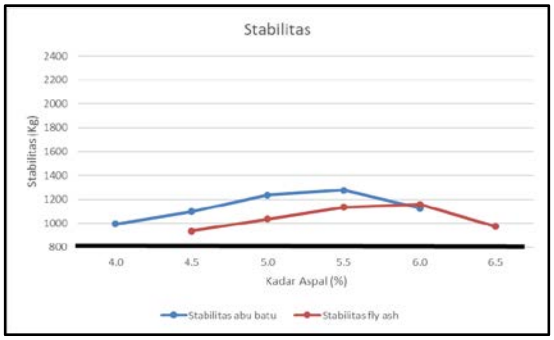

Figure 9. AC-WC stability graph

It was found that the stability of the test object using *fly ash* and *filler* rock ash filler met the 2010 Highways Division 6 Specification Standard for a minimum stability of 800 kg .

2. Melting (*Flow*)

The value *flow* is a state of change in the shape of the test object after being exposed to a load. *Flow* is also determined according to the watch reading on the marshall tool in mm. The following are the *flow* for each asphalt content:

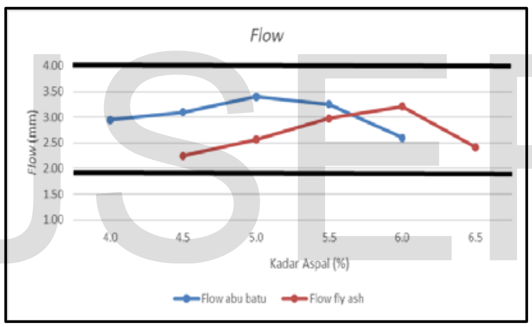

Figure 10. Graph *flow* of AC-WC

It was found that the *flow* of the test object using *fly ash* and *filler* complied with the 2010 Highways Division 6 Standard Specifications, namely a minimum of 2 mm and a maximum of 4 mm.

3. *Void in Mix* (VIM)

Void in Mix is the percentage of voids that are in the mixture. The VIM results for each asphalt content are as follows:

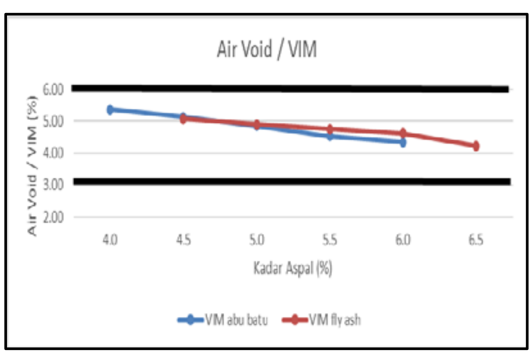

Figure 11. VIM AC-WC Graph

The VIM curve results show that the VIM value of the test object using *fly ash* and *filler* rock ash filler meets the 2010 Highways Specification Division 6 Standard, namely a minimum of 3% and a max 5%.

4. *Void in Mineral Aggregate* (VMA)

Void in Mineral Aggregate is the percentage of pore voids between aggregate grains. The following graph compares the VMA values for each asphalt content:

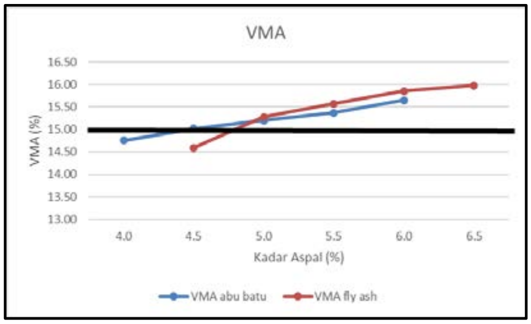

Figure 12. VMA AC-WC

Graph The VMA graph shows that there are two asphalt content that do not meet the 2010 Highways Specification Division 6 Standard Specifications of at least 15%, namely asphalt content of 4.0% and 4.5%.

5. *Void Filled with Bitumen* (VFB)

In the VFB calculation, it is obtained that the percentage of voids that have been filled with bitumen does not include the bitumen that coats the aggregate.VFB results for each asphalt content can be seen in the following graph:

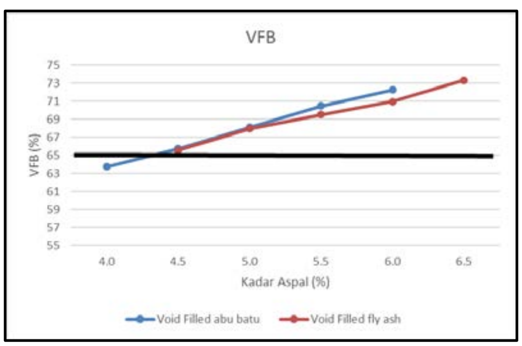

Figure 13. VFB AC-WC Graph

The results in the graph above show that there is one asphalt content in the test object using *filler* rock ashBina Marga 2010 Division 6 which is at least 65%.

6. *Marshall Quotient* (MQ)

The Marshall Quotient (MQ) value can be determined by dividing the stability value by the flow value. MQ has units of Kg/mm. The following is the graph of the MQ value for each bitumen content:

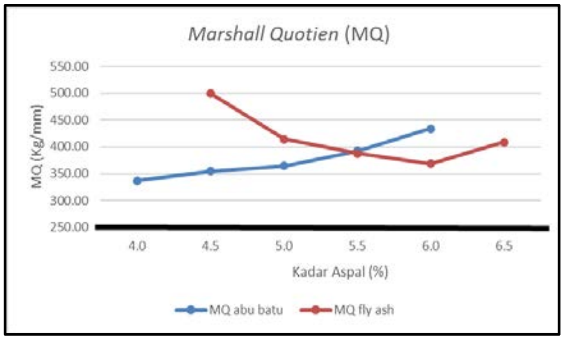

Figure 14. AC-WC Marshall Quotient graph

MQ results on all test objects have met the 2010 Highways Division 6 Standard Specifications, namely a minimum of 250 kg/mm.

7. Determination of Optimum Asphalt Content (KAO)

The next step is to find the optimum asphalt content (KAO) by using a stability polynomial graph to obtain the max y value. Following are the results of the stability polynomial graph on the test object using *filler* rock ash

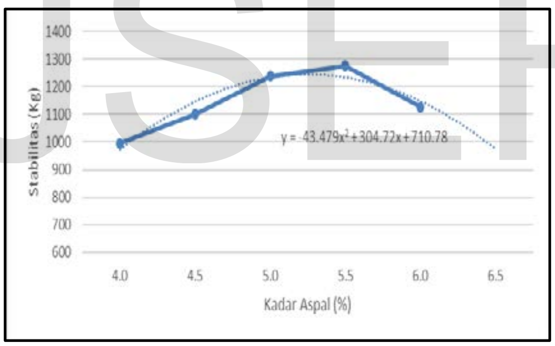

Figure 15. Polynomial graph of AC-WC stability using *filler* rock ash

So, the following equation is obtained

$$y = -43.479x^2 + 304.72x + 710.78$$

so that y max = 1244.68 is obtained and is at bitumen content 5.0%. The results of the Marshall test with KAO can be seen in the table below:

Table 1. Marshall results with KAO

Parameter	Specification	Result	Description
Stability (Kg)	Min. 800	1244.68	fulfilled
Flow (mm)	2 until 4	3.48	fulfilled
VIM (%)	3 until 5	4.98	fulfilled
VMA (%)	min. 15	15.2	fulfilled

Parameter	Specification	Result	Description
VFB (&)	min. 65	68	fulfilled
MQ (Kg/mm)	min. 250	370	fulfilled

Following are the results of the stability polynomial graph on the test object using fly ash filler:

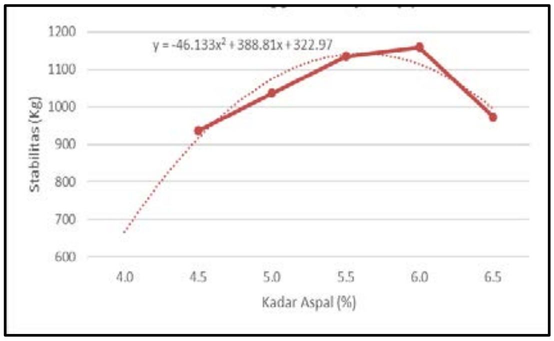

Figure 16. Graph of AC-WC Stability Polynominal

Polynominal stability of AC-WC using fly ash filler Obtained the equation:

$$y = -46.133x^2 + 388.81x + 322.97$$

so that y max = 1142.19 is obtained and is at an asphalt content of 5.5%. The results of the Marshall test with KAO can be seen in the table below:

Table 2. Marshall results with KAO

Parameter	Specification	Result	Description
Stability (Kg)	Min. 800	1142.19	fulfilled
Flow (mm)	2 until 4	3	fulfilled
VIM (%)	3 until 5	4.8	fulfilled
VMA (%)	min. 15	15.55	fulfilled
VFB (&)	min. 65	69	fulfilled
MQ (Kg/mm)	min. 250	359	fulfilled

Results *Marshall Test* (KAO+HDPE)

After obtaining KAO (*Filler*+ RAP) then the optimum plastic level is determined.Marshall test results (KAO+HDPE):

Table 3. *Marshal Test* (KAO+HDPE)

Kadar HDPE (%)		0.0	1.6	1.8	2.0	2.2	2.4
Air Void (VIM) (%)	*Filler* abu batu	4.98	4.69	4.56	4.42	4.18	3.72
	Filler fly ash	4.80	4.83	4.68	4.55	4.30	3.13
Stabilitas (Kg)	*Filler* abu batu	1245	1274	1270	1292	1257	1213
	Filler fly ash	1142	1279	1248	1187	1135	1095
Flow (mm)	*Filler* abu batu	3.48	3.50	3.60	3.50	3.60	3.80
	Filler fly ash	3.0	3.4	3.7	3.7	3.8	4.0
VMA (%)	*Filler* abu batu	15.20	15.73	15.61	15.49	15.28	14.88
	Filler fly ash	15.55	15.41	15.28	15.16	14.93	13.90
Void Filled (VFB) (%)	*Filler* abu batu	68	70.18	70.81	71.48	72.64	74.98
	Filler fly ash	69	68.64	69.42	69.98	71.25	77.50
MQ (Kg/mm)	*Filler* abu batu	370.00	364.26	356.10	372.64	352.64	322.53
	Filler fly ash	359.00	380.21	338.96	318.54	298.65	271.54

The above data can also be presented in graphical form as below:

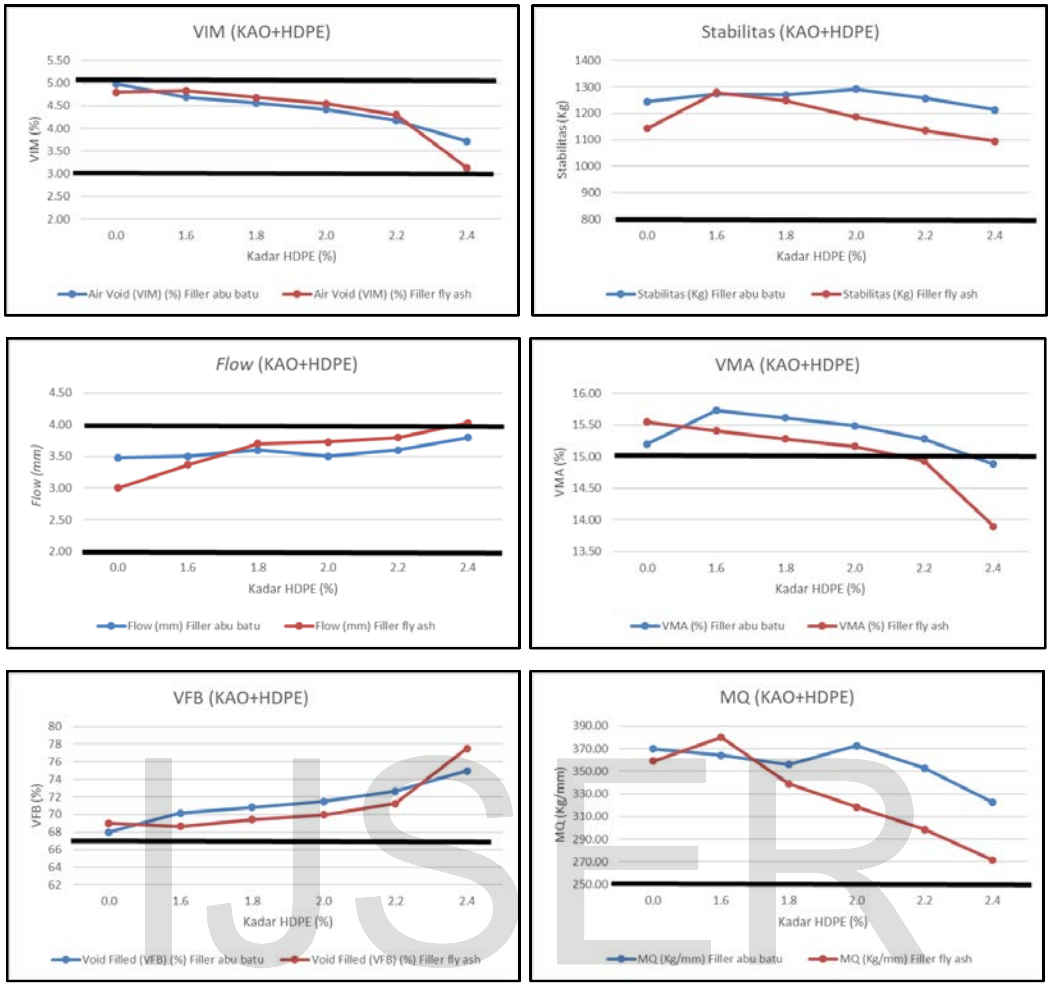

Figure 17 ***Marshall*** Graph

Determination of Optimum Plastic Content

The next step is to find the optimum plastic content using the stability polynomial graph to get the max y value. Following are the results of the stability polynomial graph (KAO+HDPE) on the test object using rock ash filler

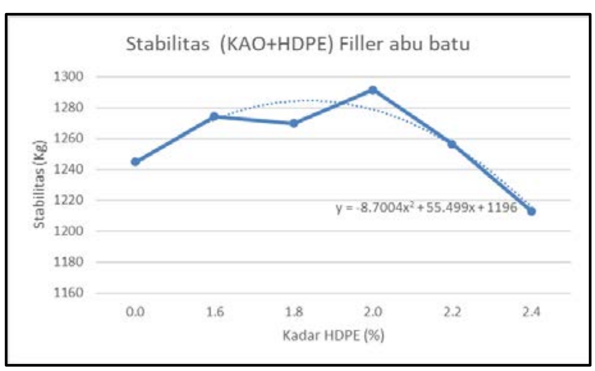

Figure 18. Polynomial graph of AC-WC stability (KAO+HDPE)

Polynomial graph of AC-WC stability (KAO+HDPE) using *filler* rock ash, the equation

$$y = -8.7004x^2 + 55.499x + 1196$$

so that obtained y max = 1282.01 and is at 1.8% HDPE content. The results of the marshall test with KAO+HDPE can be seen in the table below:

Table 4. Marshall results with KAO+HDPE

Parameter	Specification	Result	Description
Stability (Kg)	Min. 800	1282.01	fulfilled
Flow (mm)	2 until 4	3.5	fulfilled
VIM (%)	3 until 5	4.75	fulfilled
VMA (%)	min. 15	15.75	fulfilled
VFB (&)	min. 65	71	fulfilled
MQ (Kg/mm)	min. 250	360	fulfilled

Following are the results of the stability polynomial graph (KAO+HDPE) on the test object using *fly ash filler*:

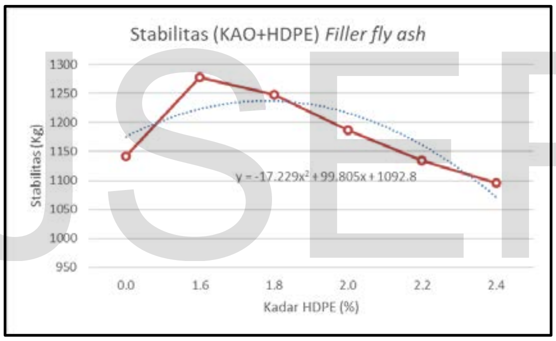

Figure 19. Polynomial graph of AC-WC stability (KAO+HDPE)

Polynomial graph of AC-WC stability (KAO+HDPE) using *fly ash filler*, the equation:

$$y = -17.229x^2 + 99.805x + 1092.8$$

so that y max = 1249.55 and is at 1.8% HDPE content. Marshall test results with KAO+HDPE can be seen in the table below:

Table 5. Marshall results with KAO+HDPE

Parameter	Specification	Result	Description
Stability (Kg)	Min. 800	1249.55	fulfilled
Flow (mm)	2 until 4	3.75	fulfilled
VIM (%)	3 until 5	4.51	fulfilled
VMA (%)	min. 15	15.3	fulfilled
VFB (&)	min. 65	69.5	fulfilled
MQ (Kg/mm)	min. 250	340	fulfilled

CONCLUSION

After testing the pavement using asphalt pen 60/70 with the use of RAP, HDPE, *fillers* rock ash and *fly ash* with variations in HDPE levels of 0%, 1.6%, 1.8%, 2%, 2.2%, and 2.4%, it can be concluded:

1) The percentage of aggregate in the specimens using *filler* is 16% RAP coarse aggregate, 30% medium aggregate, 47% fine aggregate, *filler* 7% rock ashWhile the percentage of aggregate in the test object using fly ash filler is 21% RAP coarse aggregate, 32% Medium Aggregate, 45% fine aggregate, *fly ash filler*.
2) After the *marshall test* obtained the parameters used to analyze the performance of the test object. KAO was obtained using a polynomial graph on the test object using *filler* 5% stone ash *Flow* 3.48 mm, VIM 4.98 %, VMA 15.2%, VFB 68%, and MQ 370 kg/mm. Then on the test object using *fly ash filler*, KAO was obtained using a polynomial graph of 5.5% with details on the results of the Marshall test Stability 1142.19 Kg, *Flow* 3 mm, VIM 4.8 %, VMA 15.55 %, VFB 69 %, and MQ 359 Kg/mm.
3) The results of adding HDPE with levels of 0%, 1.6%, 1.8%, 2%, 2.2%, and 2.4% obtained optimum plastic content results in the test specimens using *filler* of 1.8% with details of the Marshall test results namely Stability 1282.01 Kg, *Flow* 3.5 mm, VIM 4.75 %, VMA 15.75 %, VFB 71 %, and MQ 360 Kg/mm. And for the specimens using *fly ash filler*, the optimum plastic content yield was 1.8% with details of the Marshall test results namely Stability 1249.55 kg, *Flow* 3.75 mm, VIM 4.51 %, VMA 15.3 %, VFB 69.5 %, and MQ 340 kg/mm.
4) All results have met the General Specification Standards for Highways Division 6.

REFERENCE

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