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The Effect of Bentonite Powder as a Filler on HRS-WC Asphalt Performance

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Abstract. Wearing Course Lataston (HRS-WC) is a type of flexible pavement with durable and good durability and flexibility. The constituent materials of HRS-WC asphalt consist of aggregate, asphalt, and filler. Bentonite powder is an active chemical filler material with superior swelling ability, ion exchange properties, and large surface area. It quickly absorbs water to form a thick suspension. This research aims to determine and determine the Optimum Asphalt Content (OAC), optimum filler content, comparison of the percentage value of increase or decrease in Marshall test parameters, and the effect of adding bentonite powder filler to HRS-WC Asphalt on asphalt performance according to the General Specifications for Bina Marga Year 2018 Revision 2. Based on the research results on Marshall characteristics, the KAO value was obtained at 7.5%, and the optimum filler content value was 1.90%. The addition of bentonite filler shows changes in the characteristics of HRS-WC asphalt, namely an increase in stability, Marshall Quotient, and VFA, as well as a decrease in flow, VIM, and VMA. So, the effect of adding bentonite filler to HRS-WC asphalt can increase density, reduce the number of voids, fill voids between aggregates, and be able to bind asphalt to the asphalt mixture. However, the excessive addition of bentonite powder as a filler can reduce the flow value and make the asphalt mixture harder and stiffer.

Keywords: Wearing Course Lataston, Filler, Bentonite Powder

INTRODUCTION

In Indonesia, flexible pavement is also commonly called pavement, and its constituent material is asphalt. This pavement is applied on roads in Indonesia because of its good bending ability or flexibility when a vehicle load is passing on it. Flexible pavement makes flexible or asphalt pavement watertight and has a material mixture that meets the applicable criteria and requirements. However, the deterioration of flexible pavement on Indonesian roads is still frequently encountered. Selecting good-quality materials can overcome structural failure on flexible pavement [2]. On average, it is caused by increased vehicle volume and structural failure due to polled water, which can cause the asphalt and aggregate to loosen, causing potholes in the road and damaging the road foundation [3].

Based on the type of asphalt layer mixture, it can be divided into thin layers of sand asphalt or Latasir, thin layers of asphalt concrete or Lataston (Hot Rolled Sheet, HRS), and asphalt concrete layers or Laston (Asphalts Concrete, AC) [4]. One of them, Lataston, is usually used for low or light traffic loads and is generally applied on village roads. The characteristic of the Lataston asphalt layer mixture type is its good durability and flexibility, making it more flexible than other types of asphalt layer mixtures [5]. The materials that make up Lataston (HRS) consist of aggregate, asphalt, and additional filler. The purpose of adding filler is to fill the voids between the coarse and fine aggregates in the asphalt mixture. Two types of permitted fillers will be used for asphalt mixtures, namely active and inactive chemicals [4].

One of the alternative active chemical fillers that will be used in this research is bentonite powder, which is an abundant mineral resource found in Indonesia, so the use of bentonite powder in the construction sector is often encountered [6]. Bentonite powder can form a thick suspension after mixing with water, which is frequently used as a stability material for the subgrade in the layers that make up road pavement [7]. Bentonite powder also can expand, has ion exchange properties, has a large surface area, and quickly absorbs water [8].

In this research, the use of bentonite powder as a filler is used to provide good and optimum results in terms of durability and flexibility in HRS-WC asphalt on the characteristics of the Marshall Test, where the parameters looked at are the values of stability, flow, VMA, VIM, VFA. , and Marshall Quotient by the General Specifications for Bina Marga 2018 Revision 2, and it is hoped that the addition of bentonite powder as a filler in HRS-WC asphalt can fill the voids between aggregates in the asphalt itself to make it more watertight and make the asphalt not easy to damage and durable.

Flexible Pavement

Flexible pavement is a type of road pavement with the leading constituent material asphalt. Generally, this pavement is used on roads with traffic loads that tend to be light to moderate, such as urban road construction, road shoulders, and village road construction. So, the final result of flexible pavement is expected to provide good flexibility, be watertight, and be strong or not easily damaged. Based on its structure, flexible or asphalt pavement layers can be divided into several parts: subgrade layer, subbase layer, foundation layer, and surface layer.

Wearing Course Lataston (HRS-WC)

"Lapis Tipis Aspal Beton" or Lataston, also known as HRS (Hot Rolled Sheet), is a type of asphalt mixture layer with a mixed gradation percentage of fine aggregate which will be used more than coarse aggregate [13]. Lataston (HRS) includes asphalt concrete with a hot mixing temperature between 140˚C-160˚C. The characteristic of Lataston or HRS is that it has better flexibility and durability. To obtain a good level of flexibility and durability in this research, some requirements must be considered in the gradation of the combined aggregate when making the asphalt mixture itself. These requirements can be seen in Table 1 as follows:

TABLE 1. Mixed Aggregate Gradation Specifications for Lataston

Sieve		**the percentage of weight that passes to the total aggregate**	
		Lataston (HRS)	
ASTM	mm	HRS-WC	HRS-Base
1,5"	37,5	-	-
1"	25	-	-
0,75"	19	100	100
0,5"	12,5	90-100	90-100
3/8"	9,5	75-90	65-90
4	4,75	-	-
8	2,36	50-72	35-55
16	1,18	-	-
30	0,6	35-60	15-35
50	0,3	-	-
100	0,15	-	-
200	0,075	6-10	2-9

Source:[4]

Materials Testing

This material testing takes the form of asphalt testing and aggregate testing. The parameters for asphalt testing are the asphalt penetration test, the asphalt specific gravity test, the asphalt flash point and burning point test, and the asphalt softening point test. Meanwhile, the test parameters are tests of the physical properties of coarse and fine aggregate for aggregate testing. The regulations and procedures in this material test refer to the General Specifications for Highways 2018 Revision 2. Carrying out material tests is a form of knowing the quality of the materials used in this research.

Marshall Testing

This test was carried out to determine the stability of the asphalt mixture against plastic melting (flow). General Specifications for Bina Marga 2018 Revision 2 have determined Marshall test parameter requirements for lataston mixtures, which are shown in **Table 2** as follows:

TABLE 2. Aggregate Sieve Analysis Results for HRS-WC Asphalt

Marshall Indicator		**Lataston**	
		HRS-WC	HRS-Base
Stability	Min.	600 kg	

Flow	Min.	3mm
VIM	Min.	3%
	Maks.	5%
VMA	Min.	17%
VFA	Min.	68%
Marshall Quotient	Min.	250 kg/mm

Source:[4]

Asphalt Content Design

This determination is based on the percentage of coarse aggregate, fine aggregate, and filler used. In making asphalt test specimens, all the mixed materials can absorb and mix well and produce test specimens that are good, good and do not fail. The method used to determine the designed asphalt content is the Asphalt Institute method by the guidelines contained in SE Menteri PUPR Number 14/SE/M/2019, which will be calculated using **equation I** as follows:

$$Pb = 0{,}035\,a + 0{,}045\,b + Kc + F \qquad \text{i)}$$

Information:
Pb = Middle asphalt content
a = Percentage of coarse Aggregate (trapped on sieve number 8)
b = Percentage of fine Aggregate (trapped on sieve number 200 and pass on sieve number 8)
c = Percentage of filler (pass on sieve number 200)
K = 0,15 if Percentage Pass on sieve number 200 as big as 11-15%
= 0,18 if Percentage Pass on sieve number 200 as big as 6-10%
= 0,20 if Percentage Pass on sieve number 200 as big as <5%
F = $0 - 2\%$ for aggregate absorption

RESEARCH METHODE

In this research, stages or flows will be carried out so that the implementation occurs coherently and systematically. These stages or flows include:

1. Preparation and provision of equipment and materials used in this research.
2. Aggregate Analysis Test, using the equipment and materials used. Aggregate Analysis Tests that will be carried out are:
   a. Sieve analysis test of coarse aggregate and fine aggregate.
   b. Testing the specific gravity and absorption of coarse aggregate.
   c. Testing the specific gravity and absorption of fine aggregate.
3. The asphalt analysis test uses the equipment and materials used. Asphalt Analysis Tests that will be carried out are:
   a. Asphalt penetration testing.
   b. Testing the softening point of asphalt.
   c. Testing the ignition point and burning point of asphalt.
4. Planning a thin-layer mixture of asphalt concrete or HRS-WC asphalt.
5. Making Test Objects:
   a. First, we will calculate the planned asphalt content using the Asphalt Institute method to find the Optimum Asphalt Content value for HRS-WC asphalt.
   b. Continue with Marshall testing to determine the HRS-WC asphalt mixture's stability, flow values, density, and pore analysis.
   c. After obtaining the Optimum Asphalt Content (KAO) of the HRS-WC asphalt mixture and knowing the stability and melting (flow) values, as well as analyzing the density and pores of the HRS-WC asphalt mixture through the Marshall test, proceed with making test objects in the form of adding filler. (filler) by bentonite powder with varying levels of 0%, 1.5%, 3% and 4.5%.
   d. Next, a Marshall test will be carried out, and the results will be analyzed to determine the optimal filler content from these variations.
6. Testing using the Marshall tool:
   a. Test the specific gravity of the mixture
   b. Carrying out a Marshall test, the results will be analyzed to determine the asphalt mixture's stability value for melting (flow).

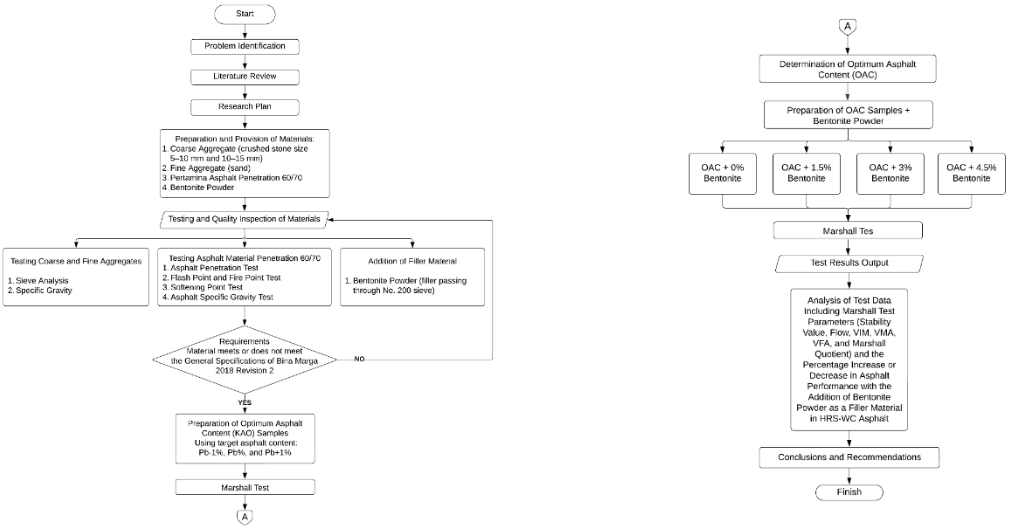

FIGURE 1. Research Flowchart

RESULT AND DISCUSSION

Sieve Analysis for Aggregates

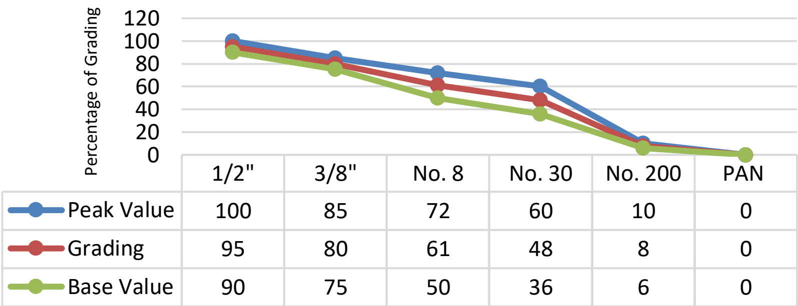

FIGURE 2. Sieve Analysis Plot

TABLE 3. Aggregate Sieve Analysis Results for HRS-WC Asphalt

Sieve		**Specification**	**Middle-Value Passes**	**Middle Value is Trapped**	**Weight**
ASTM	mm	%	%	%	gram
3/4"	19	100	100	0	0
1/2"	12,5	90 - 100	95	5	60
3/8"	9,5	75 - 85	80	15	180
No. 4	4,75				
N0. 8	2,36	50 - 72	61	19	228
No. 16	1,18				
No. 30	0,60	36 - 60	48	13	156
No. 50	0,30				
No. 100	0,15				
No. 200	0,075	6 -10	8	40	480
PAN	< 0,075		0	8	96
Bentonite	< 0,075		0	0	0
Total			100	100	1200

Based on the analysis results in Table 3, the aggregate material requirements or total aggregate weight for making 1 (one) HRS-WC asphalt mixture test object is 1200 grams. In this research, we will add 10% of the weight of each filter to minimize the lack of aggregate during and after the mixing process. The total aggregate weight for 1 (one) test object is 1320 grams.

Specific Gravity and Aggregate Absorption

TABLE 4. Specific Gravity and Aggregate Absorption Result

Materials	Specific Gravity	Result
Aggregate size 10-15 mm	Bulk Specific Gravity	2,71 gr/cm^3
	Surface Saturated Dry Specific Gravity	2,75 gr/cm^3
	Apparent Specific Gravity	2,83 gr/cm^3
	Absorption	1,57 %
Aggregate size 5-10 mm	Bulk Specific Gravity	2,60 gr/cm^3
	Surface Saturated Dry Specific Gravity	2,65 gr/cm^3
	Apparent Specific Gravity	2,73 gr/cm^3
	Absorption	1,85 %
Aggregate size < 5 mm	Bulk Specific Gravity	2,61 gr/cm^3
	Surface Saturated Dry Specific Gravity	2,65 gr/cm^3
	Apparent Specific Gravity	2,72 gr/cm^3
	Absorption	1,55 %

Asphalt Testing

TABLE 5. Asphalt Testing Result

Type of Testing	Specification	Result
Asphalt Penetration	60-70 mm	65,15 mm
Flash Point	Min. 232˚C	356˚C
Burn Point	-	360˚C
Soft Point	Min. 48˚C	52,5˚C
Asphalt Specific Gravity	Min. 1 gr/cm^3	1,043 gr/cm^3

Results of The Planned Asphalt Content

TABLE 6. Results of The Planned Asphalt Content

Variations in Planned Asphalt Content	Percentage (%)	Weight (gram)
Pb-1	5,9	77,88
Pb	6,9	91,08
Pb+1	7,9	104,28

Optimum Asphalt Content Results

In the research carried out, the method for determining KAO uses a graphical method by selecting the value limits for each Marshall indicator, which refers to the General Specifications for Highways 2018 Revision 2 on test objects that have been made, calculated, and tested in variations in the planned asphalt content, namely 5, 9%, 69%, and 7.9% with a total aggregate of 1320 grams.

TABLE 7. Recapitulation of The Average Value of Marshall Test Indicators

Asphalt Content	Stability	*Flow*	***Marshall Quotient*** **(MQ)**	***Void In Mix*** **(VIM)**	***Void In Mineral Aggregate*** **(VMA)**	***Void Filled with Asphalt*** **(VFA)**
5,9%	1715,13 kg	2,7 mm	635,77 kg/mm	6,53%	17,03%	61,64%
6,9%	1872,72 kg	3,05 mm	613,87 kg/mm	5,24%	17,72%	70,40%
7,9%	2162 kg	3,55 mm	608,97 kg/mm	3,98%	18,40%	78,36%
Specification	600 kg	3 mm	250 kg/mm	3-5%	17%	68%

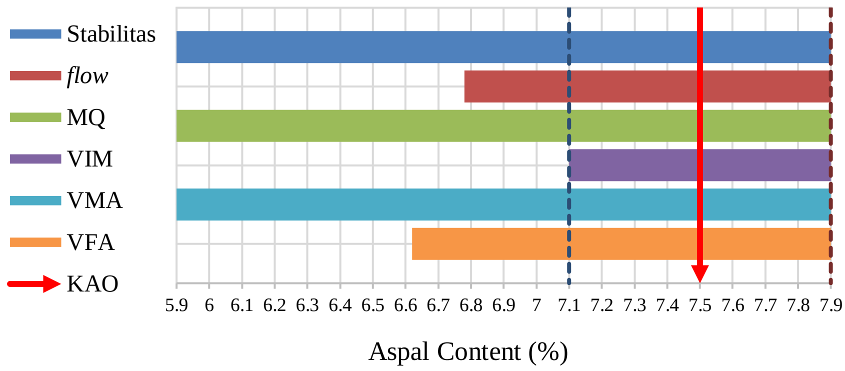

FIGURE 3. Excel Graphic Optimum Asphalt Content

Based on the Excel Graphic for Optimum Asphalt Content (KAO), the Optimum Asphalt Content (KAO) value was 7,5% in the manufacture of the following test object, and adding bentonite powder as filler to the HRS-WC asphalt used an asphalt content of 7,5%.

Results of Determining Optimum Filler Content

TABLE 8. Recapitulation of The Average Value of Marshall Test Indicators

Variations in bentonite filler content	**Stability**	***Flow***	***Marshall Quotient* (MQ)**	***Void In Mix* (VIM)**	***Void In Mineral Aggregate* (VMA)**	***Void Filled with Asphalt* (VFA)**
0%	2040,46 kg	3,40 mm	600,24 kg/mm	4,69%	18,30%	74,39%
1,5%	2247,02 kg	3,25 mm	690,68 kg/mm	4,13%	17,83%	76,81%
3%	2420,99 kg	3,17 mm	762,94 kg/mm	3,63%	17,39%	79,18%
4,5%	2503,33 kg	2,83 mm	883,82 kg/mm	2,92%	16,79%	82,60%
Specification	600 kg	3 mm	250 kg/mm	3-5%	17%	68%

1. Stability

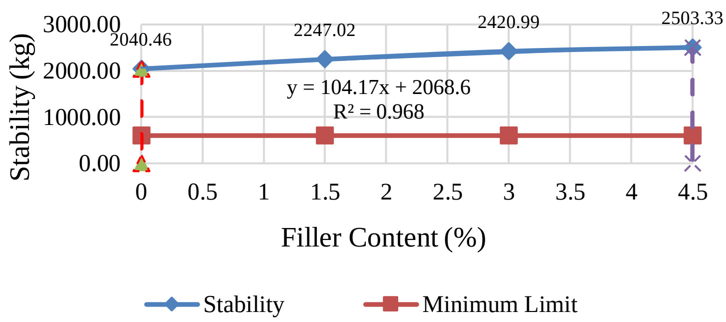

FIGURE 4. Excel Graphic of The Average Stability Value

Based on the average stability value graph, the stability value is obtained, which increases along with increasing levels of filler used in the HRS-WC asphalt mixture. According to the requirements of the General Specifications for Bina Marga 2018 Revision 2, the stability parameters for all variations in filler content are satisfactory. In contrast, the stability parameter value for the HRS-WC Asphalt mixture is not less than 600 kg.

2. *Flow*

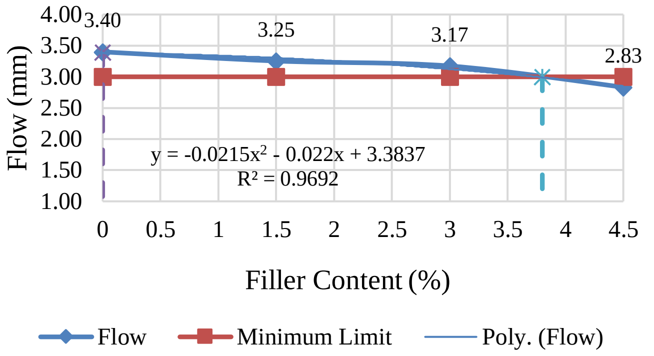

FIGURE 5. Excel Graphic of The Average Flow Value

Based on the graph of the relationship between the percentage of filler content and the flow value, it is obtained that the average flow value decreases with increasing filler content used in the HRS-WC asphalt mixture, By the General Specifications for Bina Marga 2018 Revision 2, the average value of flow parameters for variations in filler content is 0%; 1,5%; and 3% meets where the flow parameter value for the HRS-WC asphalt mixture is not less than 3 mm.

3. *Marshall Quotient* (MQ)

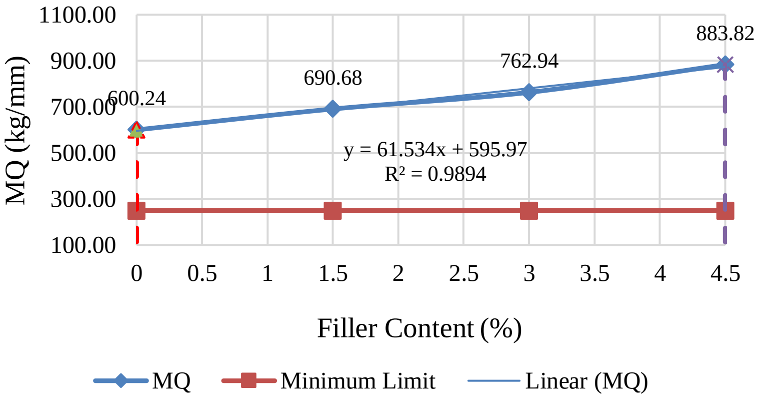

FIGURE 6. Excel Graphic of The Average MQ Value

Based on the graph of the average MQ value, it is obtained that the MQ value increases with increasing variations in the filler content used in the HRS-WC asphalt mixture; by the General Specifications for Bina Marga 2018 Revision 2, the average MQ value for all variations in filler content starts from 0%; 1,5%; 3%; and 4,5% meets the specifications where MQ parameter value for the HRS-WC asphalt mixture is not less than 250 kg/mm.

4. *Void In Mix* (VIM)

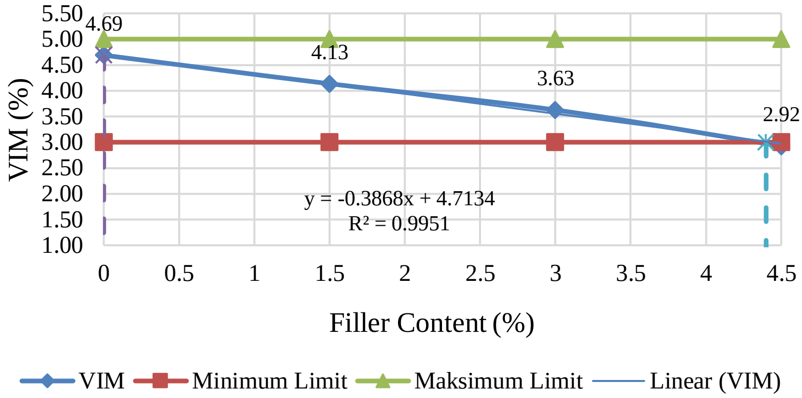

FIGURE 7. Excel Graphic of The Average VIM Value

Based on the graph of the average VIM value, the average VIM value is obtained, which decreases as the variation in filler content increases in the HRS-WC asphalt mixture; by the General Specifications for Bina Marga 2018 Revision 2, the average VIM value for variations in filler content is 0%; 1,5%; and 3% with an average VIM value of 4,69%; 4,13%; and 3,63% has met the specifications where the VIM parameter value for the HRS-WC asphalt mixture is not less than 3% and not more than 5%.

5. *Void In Mineral Aggregate* (VMA)

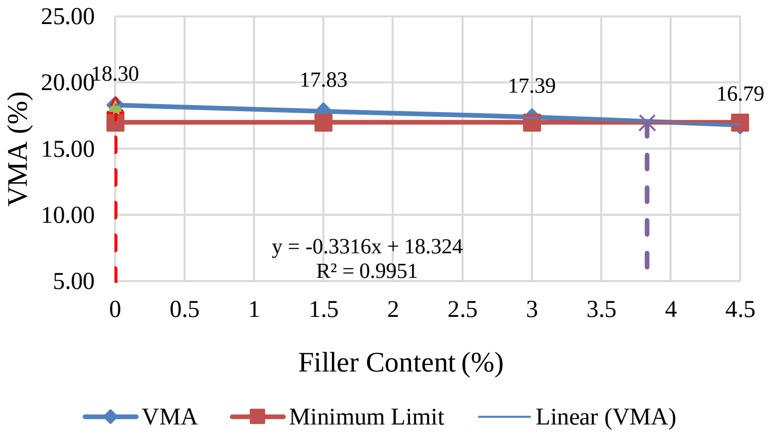

FIGURE 8. Excel Graphic of The Average VMA Value

Based on the graph of the average VMA value, the average VMA value is obtained, which decreases as the variation in filler content increases in the HRS-WC asphalt mixture; by the General Specifications for Bina Marga 2018 Revision 2, the average VMA value for variations in filler content is 0%; 1,5%; and 3% with an average VIM value of 18,30%; 17,83%; and 17,39% has met the specifications where the VMA parameter value for the HRS-WC asphalt mixture is not less than 17%.

6. *Void Filled with Asphalt* (VFA)

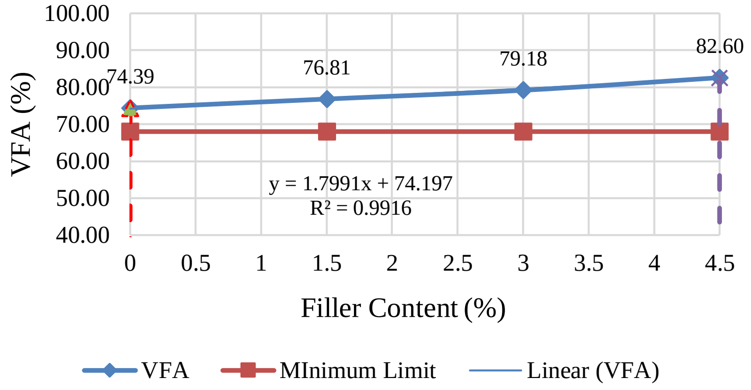

FIGURE 9. Excel Graphic of The Average VFA Value

Based on the average VFA value graph, the average VMA value is obtained, which decreases as the variation in filler content increases in the HRS-WC asphalt mixture. The average VFA value in the graph increases or increases with increasing variations in filler content in the HRS-WC asphalt mixture; by the General Specifications for Bina Marga 2018 Revision 2, the average VFA value for all variations in filler content is 0%; 1,5%; 3%; and 4,5% have met the specifications where the VFA parameter value is not less than 68%.

Optimum Filler Content Result

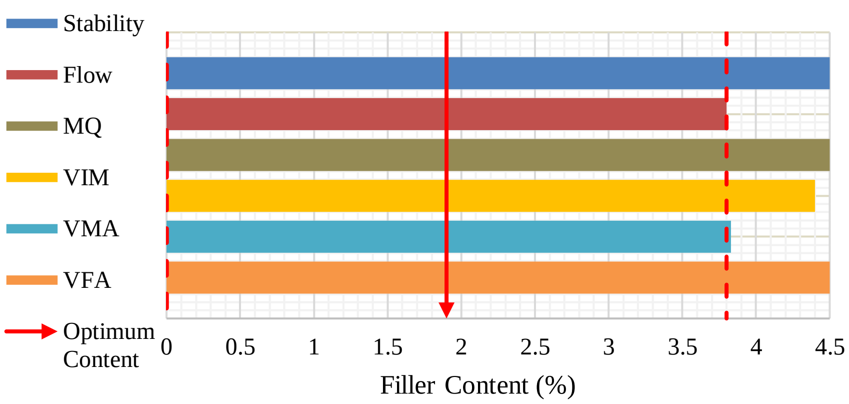

FIGURE 10. Excel Graphic Optimum Filler Content

Based on the Excel graph for optimum filler content, the optimum filler content value was 1,90%. The Marshall test results with a filler content of 1,90% have overall met the Marshall parameter requirements in the General Specifications for Highways 2018 Revision 2; this shows that the addition of bentonite as a filler has a good effect on the HRS-WC asphalt mixture.

TABLE 9. Marshall indicator comparison optimum filler content results.

***Marshall* Indicator**	**Specification**	**Unit**	**Variations in Bentonite Filler Content**		**Percentage (%)**	**Information**
			0%	**1,90%**		
Stability	Min. 600	kg	2040,46	2266,72	11,08	Increase
Flow	Min. 3	mm	3,40	3,26	-4,12	Reduction
Marshall Quotient (MQ)	Min. 250	kg/mm	600,24	712,88	18,77	Increase
Void In Mix (VIM)	3-5	%	4,69	3,98	-15,14	Reduction
Void In Mineral Aggregate (VMA)	Min. 17	%	18,30	17,69	-3,33	Reduction
Void Filled with Asphalt (VFA)	Min. 68	%	74,39	77,62	4,34	Increase

CONCLUSION

Based on the results of research conducted regarding the effect of adding bentonite powder as a filler to HRS-WC asphalt on asphalt performance, the following conclusions were obtained:

1. Marshall test results in research that has been carried out from variations in planned asphalt content of 5.9%, 6.9%, and 7.9% in the HRS-WC asphalt mixture obtained an Optimum Asphalt Content (KAO) value for HRS-WC Asphalt of 7.5%. By the General Specifications for Bina Marga 2018 Revision 2, the results of the Marshall test parameters for the HRS-WC Asphalt KAO value of 7.5% have met the specifications where the results of the Marshall test parameters for the Stability value obtained a value of 2040.46 kg, the Meltdown value (Flow) of 3.40 mm, Marshall Quotient (MQ) value of 600.24 kg/mm, Void In Mix (VIM) value of 4.69%, Void IN Mineral Aggregate (VMA) value of 18.30%, Void Filled with Asphalt (VFA) of 74.39%.

2. Optimum filler content value in adding bentonite powder as filler to HRS-WC Asphalt from variations in filler content of 0%; 1.5%, 3%; and 4.5% of the Stability, Meltability (*Flow*), Marshal Quotient (MQ), Void In Mix (VIM), Void In Mineral Aggregate (VMA), and Void Filled with Asphalt (VFA) values obtained from the Marshall Test results. Value of 1.90%. The results of the Marshall test parameters were obtained by calculating polynomial equations obtained from the Marshall test parameter graph by adding bentonite powder filler with varying levels of 0%, 1.5%, 3%, and 4.5%. By the General Specifications for Bina Marga 2018 Revision 2, the results of the calculation of the polynomial equation from the Marshall test parameters at the optimum filler content of 1.90% with the addition of bentonite powder as a filler material have met the specifications where the results of the Marshall test parameters for the Stability value are obtained. Of 2266.72 kg, Meltdown (*Flow*) value of 3.26, Marshall Quotient (MQ) value of 712.88 kg/mm, Void In Mix (VIM) value of 3.98%, Void In Mineral Aggregate (VMA) value of 17.69%, Void Filled with Asphalt (VFA) value of 77.62%.

3. Comparison results of the percentage increase or decrease in Marshall test parameters on HRS-WC Asphalt with the addition of bentonite powder as a filler, the optimum filler content is 1.90%, and on HRS-WC Asphalt without the addition of bentonite powder as a filler. Filler content of 0% obtained results that indicate changes, namely an increase in the Stability value with a percentage increase of 11.08%, a decrease in the Flow value with a percentage decrease of 4.12%, an increase in the Marshall Quotient value (MQ) with a percentage increase of 18.77%, a decrease in the value of Void In Mix (VIM) with a percentage decrease of 15.14%, a decrease in the value of Void In Mineral Aggregate (VMA) with a percentage decrease of 3.33%, as well as an increase in the value of Void Filled with Asphalt (VFA) with a percentage increase of 4.34%.

4. Overall, adding bentonite powder as a filler in the HRS-WC asphalt mixture to the performance of asphalt with optimum filler content can increase the stability, durability, flexibility, and stiffness of the asphalt mixture. This happens because bentonite powder has superior swelling ability, ion exchange properties, a large surface area, and quickly absorbs water. When mixed with water, it will form a thick suspension. So bentonite powder can increase density, reduce the number of voids in the asphalt mixture, fill the voids between aggregates in the asphalt mixture, and bind the asphalt mixture. However, the excessive addition of bentonite powder as a filler can reduce the flow value and make the asphalt mixture harder and stiffer. Road pavement with a more complex and stiffer HRS-WC asphalt mixture can cause cracks and reduce durability, flexibility, and elastic properties. In contrast, the HRS-WC asphalt mixture should have a high and good level of durability, flexibility, and elastic properties.

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