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The Effect of Adding Fly Ash as a Filler on Lataston Mixtures (HRS-WC)

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Abstract: Flexible pavement is the most commonly found type of road pavement in Indonesia. One asphalt mixture used in road construction is the Lataston Hot Rolled Sheet. The quality of road pavement can be enhanced by carefully selecting materials such as asphalt, aggregate, and filler. Filler plays a crucial role in asphalt pavement mixtures, and fly ash, containing pozzolanic elements, can be used as it fills voids and binds the mixture effectively. This research investigates the use of fly ash as a filler in the HRS-WC asphalt mixture, aiming to determine the optimum asphalt content, the best filler content, and the impact of fly ash as a filler on the performance of asphalt road materials in the Lataston Hot Rolled Sheet mixture (HRS-WC). The study employs the Marshall testing method in accordance with the 2018 General Bina Marga Specifications (Revision 2) The results of research on Marshall characteristics, obtained an optimum asphalt content value of 7.5% and an optimum filler content value of 1.35%. The addition of fly ash as a filler to the HRS-WC asphalt mixture increases the stability, durability and stiffness of the mixture by filling empty spaces, increasing density, reducing air voids and binding the asphalt mixture. However, excessive use of fly ash can make the mixture too stiff and reduce the flexibility of the pavement.

Keywords: Filler, Fly ash, Hot Rolled Sheet.

Introduction

Transportation plays an important role in the development and development of a region, closely related to the mobilization of the movement of people, goods, and services (Estikhamah & Utomo, 2019). Roads are land transportation infrastructure that connects various regions and has a very significant role in supporting economic growth, cultural development, the tourism industry, security, and strengthening national unity (Fatikasari, 2021). Currently, road infrastructure development is increasing along with increasing traffic volume. The increasing amount of traffic will certainly have an impact on the structure of the road pavement. Flexible pavement is the type of road pavement most often found in Indonesia. In road construction, one type of asphalt mixture is lataston or a thin layer of asphalt concrete or what is often known as Hot Rolled Sheet (HRS). Lataston has superior durability and flexibility properties compared to other asphalt concrete properties (Sukirman, 2016). The HRS asphalt mixture is a type of asphalt pavement mixture that is suitable for tropical areas because it has a high level of flexibility and can withstand the effects of plastic melting (Himawan & Mulia, 2013).

The quality of road infrastructure is a very important factor for smooth community mobility (Hilmi et al., 2023). To improve the quality of road pavement using asphalt pavement mixtures, the choice of material types such as asphalt, aggregate, and filler can affect the suitability of the road pavement(Kumari & Kumar, 2019). Filler is an important component in asphalt pavement mixtures. A small percentage of filler in the mixture does not mean it does not affect the marshall characteristics. Coal fly ash and cement are the best materials that can be used as fillers (Sadillah et al., 2018). The characteristics of fly ash can bind well, the grain size is very small so it can fill the voids between aggregates effectively (Sholichin & Sutama, 2019)

Coal fly ash is a residue produced in the combustion of the coal industry or Steam Power Plants, which consists of fine flying particles. In the East Java region, there is the Paiton Steam Power Plant which is one of the largest Steam Power Plants in Indonesia, which produces 1,000,000 tons of fly ash every year (Takim et al., 2016). The primary constituents of coal fly ash from power plants include silica (SiO2), alumina (Al2O3), iron oxide (Fe2O3), and calcium (CaO), with smaller quantities of magnesium, potassium, sodium, titanium, and sulfur (Sadillah et al., 2018). Coal fly ash contains pozzolan elements, so it plays an important role in filling voids in the asphalt mixture. Because the particles are very fine, coal ash can cause the mixture grains to lock together well, and increase the overall strength of the mixture (Tahir, 2009).

This research will use the addition of fly ash as a filler in the Lataston HRS-WC mixture. The author's reason for conducting this research is to find out how the addition of fly ash as a filler affects the performance of asphalt road materials in wear-coated Lataston mixtures (HRS-WC)(Salim et al., 2022).

Literature review

1. Flexible Pavement: Flexible pavement construction involves several layers on top of a compacted subgrade. These layers distribute the traffic load, decreasing the load on the subgrade so that it is less than the load on the surface layer and within the subgrade's capacity to support (Fithra, 2018).
2. Lataston (HRS): A thin layer of Asphalt Concrete, which is generally called Hot Rolled Sheet (HRS), is a covering layer made from a mixture of graded aggregate, filler, and hard asphalt in a certain ratio. There are two types of Lataston asphalt mixture, namely for the

surface layer (HRS-wearing course) with a minimum thickness of 30 mm and for the foundation layer (HRS-base) with an asphalt mixture thickness of 35 mm (Marga, 2020). The combined aggregate gradation envelope for the Lataston mixture according to the 2018 General Bina Marga Specifications (Revision 2) is shown in table 1 as follows:

Table 1. Combined Aggregate Gradation Envelope For Lataston Mixture

Sieve Size (mm)	% Passed Weight to Total Aggregate Lataston (HRS)	
	WC	Base
37,5		
25		
19	100	100
12,5	90 - 100	90 - 100
9,5	75 -85	65 - 90
4,75		
2,36	50 - 72	35 - 55
1,18		
0,6	35 - 60	15 - 35
0,3		
0,15		
0,075	6 - 10	2 - 9

3. Aggregate Testing Standards: Aggregate standard testing is an important step to ensure the suitability of the aggregate to be used in the asphalt mixture in the study. This aims to ensure that the research follows established guidelines and that the results obtained are in line with expectations. Aggregate testing includes sieve analysis and specific gravity and absorption tests on coarse and fine aggregates(He et al., 2023)
4. Asphalt Testing Standards: Asphalt standard testing is a series of tests carried out to assess the quality and characteristics of asphalt before it is used as a binder in the asphalt concrete mixture in this study. This aims to ensure that the research is carried out according to established procedures and to ensure the results are as expected. The type of asphalt used in this research is Pertamina asphalt penetration 60/70. Some of the standard asphalt tests carried out include asphalt penetration testing, asphalt specific gravity, asphalt softening point, asphalt flash point, and burning point using the Cleveland Open Cup(Amhadi & Assaf, 2021).
5. Determination of planned asphalt content: The planned asphalt content refers to the amount of asphalt used as a basis for creating test samples to determine the optimum asphalt content (KAO) through laboratory experiments. According to the SE Minister of PUPR Number 14/SE/M/2019, the Asphalt Institute method can be used to determine the planned asphalt content (Kementerian PUPR, 2019). Calculate the percentage of planned asphalt content (Pb) using the Asphalt Institute method, shown in the following formula: $Pb = 0.035\ a + 0.045\ b + Kc + F$

Information:

Pb : Estimated asphalt content in the asphalt mixture (% mixture weight)
a : Percentage of aggregate retained by sieve No. 8
b : Percentage of aggregate that passes the sieve No. 8 and is retained by the sieve No.200
c : Percentage of aggregate that passes the sieve No. 200
K : 0.18 for 6% - 10% passing sieve No.200 0.20 for ≤ 5% passing sieve No.200
F : 0% - 2% depending on aggregate absorption. If there is no data, then The recommended F value to use is 0.7%.

6. Marshall Test: In this study, the asphalt mixture on road pavement was tested based on the Marshall Test parameters. Marshall Test is a test carried out to determine the stability, yield, and pore values of asphalt concrete mixtures. Marshall Test parameters include stability, flow, Marshall Quotient, Void Filled of Asphalt (VFA), Void in Mineral Aggregate (VMA), and Void in Mix (VIM). The Marshall parameter requirements for the Lastaston mixture (HRS-WC) by the 2018 General Specifications for Bina Marga (Revision 2) are listed in table 2 as follows(Singh et al., 2022):

Table 2. Lataston Mix Requirements (HRS-WC)

No.	Marshall Parameters	Specifications
1	VIM	3 - 5 %
2	VMA	Min. 17 %
3	VFA	Min. 68%
4	Stability	Min. 600 kg
5	*Flow*	Min. 3 mm
6	*Marshall Quotient*	Min. 250 kg/mm

Methodology

Research Plan

The research was conducted at the Civil Engineering Road Materials Laboratory of Universitas Pembangunan Nasional "Veteran" Jawa Timur. This research involved creating test specimens with a diameter of 10 cm and a height of approximately 7.5 cm, weighing about 1200 grams when filled with materials(Hastuty & Rahman, 2019). The materials utilized included coarse aggregates in the form of crushed stones sized between 5-10 mm and 10-15 mm, fine aggregates in the form of stone ash measuring ≤ 5 mm, Pertamina asphalt with a penetration grade of 60/70, and coal fly ash used as a filler. The research commenced with the production of test specimens to determine the optimum asphalt content by calculating the planned asphalt content. This was followed by testing variations in asphalt content at Pb–1%, Pb, and Pb+1% of the total aggregate weight. Once the optimum asphalt content

(KAO) was identified through Marshall Test results, test specimens were then prepared using this optimal asphalt content. Subsequently, fly ash was incorporated as a filler at varying levels (0%, 1%, 2%, 3%, and 4% of the total aggregate weight), and Marshall tests were conducted to ascertain the optimal filler content. Each test specimen was assigned a unique code or name corresponding to the predetermined variations to facilitate grouping. The number of test specimens required to determine the optimum asphalt content was adjusted according to the pre-designed experimental plan, shown in table 3 as follows(Gutiérrez-Junco et al., 2019):

Table 3. Planned Asphalt Content Test Objects

Test Object Notation	Variations in Asphalt Content	Number of Test Objects
KAO 1	Pb-1%	5
KAO 2	Pb	5
KAO 3	Pb+1%	5
Total Test Objects		15

Determination of variations in fly ash filler content of 0%, 1%, 2%, 3% and 4% of the total aggregate weight. The number of test objects with added filler and using optimum asphalt content (KAO) is shown in table 4 as follows(Adji et al., 2023):

Table 4. Test Objects with Added Filler

Asphalt Content	Coal Ash Filler Content (Fly Ash)				
	0%	1%	2%	3%	4%
KAO (X)	5	5	5	5	5
Total Test Objects					25

Quality Inspection of Materials

Quality checks on asphalt mixture materials are carried out at the road materials laboratory of the UPN "Veteran" Jawa Timur Civil Engineering Study Program(Durak, 2023).

1. Aggregate Testing: The aggregates used are coarse aggregate and fine aggregate. This aggregate is then tested to determine whether it meets specifications or not. Types of aggregate testing and procedures include:
   a. The sieve analysis test uses SNI ASTM C136:2012 regulations
   b. Test the specific gravity and absorption of coarse aggregate using SNI 1969:2016 regulations
   c. Test the specific gravity and absorption of fine aggregate using SNI 1970:2016 regulations

2. Asphalt Testing: The asphalt used is 60/70 penetration asphalt. This asphalt is then tested to determine whether it meets specifications or not. Types of asphalt testing and procedures include:
    a. Asphalt penetration test uses SNI 2456:2011 regulations
    b. Test the softening point of asphalt using SNI 2434:2011 regulations
    c. Test the flash point and burning point of asphalt using SNI 2433:2011 regulations
    d. Asphalt specific gravity test uses SNI 2441:2011 regulations
3. Filler Testing: Fly ash is utilized as the filler, followed by testing to verify its compliance with the specified requirements. As for filler testing, namely sieve analysis using SNI ASTM C136:2012 regulations, the percentage of material that passes sieve No. 200 must not be less than 75% of its total weight.

Marshall Test

This test aims to assess the flow stability of the asphalt mixture according to SNI 06-2489-1991 standards. It involves applying a constant speed load (2 inches every minute) and noting the point where the loading ring stops rotating downward and then resumes, which corresponds to the point of failure(Mardiaman & Dewita, 2022). This moment is recorded to determine the flow characteristics. Subsequently, calculations are performed on various Marshall parameters including stability, flow, Marshall Quotient, VFA, VMA, and VIM. These calculations help identify the optimal asphalt content and optimal filler content in the asphalt mixture, adhering to the General Specifications for Bina Marga 2018 (Revision 2)(Tian et al., 2019).

Result and Discussion

Material Testing Results

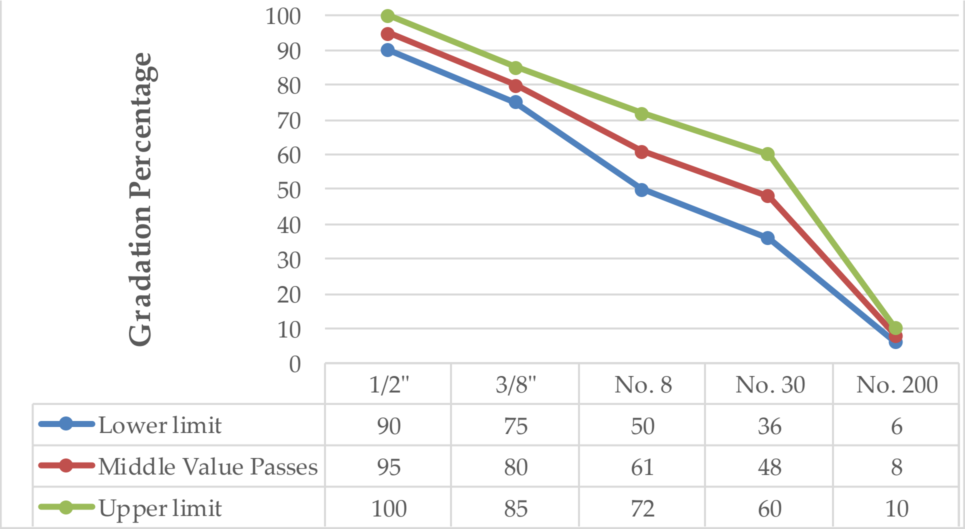
This research's material testing results encompass both asphalt 60/70 penetration testing and aggregate testing. The asphalt tests involve penetration tests, flash and burn points, softening points, and specific gravity. The aggregate tests cover sieve analysis, specific gravity, and water absorption. All testing follows the SNI standards and the General Specifications for Bina Marga 2018 (Revision 2)(Shaji et al., 2020).

1. Sieve Analysis Testing for Coarse Aggregate and Fine Aggregate
   Coarse and fine aggregate sieve analysis was carried out to determine the percentage of aggregate grains and size distribution of the two types of aggregate. In this test, the middle limit value from the combined aggregate gradation table was used by the Lataston mixture specifications. The results of the combined aggregate sieve analysis are shown in table 5 below(Alavi-Borazjani et al., 2024):

Table 5. Percentage Results of Combined Aggregate Sieve Analysis

Sieve Size		Specification	Middle Limit Passed	Stuck Middle Boundary	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				
No. 8	2,36	50 - 72	61	19	228
No. 16	1,18				
No. 30	0,6	36 - 60	48	13	156
No. 50	0,3				
No. 100	0,15				
No. 200	0,075	6 - 10	8	40	480
PAN	< 0,075		0	8	96
		Total		100	1200

Based on table 5 regarding the percentage of combined aggregate sieve analysis, it can be presented in graphical form in figure 1 as follows:



	1/2"	3/8"	No. 8	No. 30	No. 200
Lower limit	90	75	50	36	6
Middle Value Passes	95	80	61	48	8
Upper limit	100	85	72	60	10

Figure 1. Combined Aggregate Percentage Chart

1. Results of Specific Gravity and Absorption Tests on Aggregates

   The results of the specific gravity and aggregate absorption tests are shown in table 6 as follows:

Table 6. Test Results for Specific Gravity and Aggregate Absorption

Material	Specific gravity	Result
Aggregate Size 10-15 mm	Bulk	2,71
	Saturated Surface Dry	2,75
	Apparent	2,83
	Absorption	1,57%

Aggregate Size 5-10 mm	Bulk	2,6
	Saturated Surface Dry	2,65
	Apparent	2,73
	Absorption	1,85%
Aggregate Size ≤ 5 mm	Bulk	2,61
	Saturated Surface Dry	2,65
	Apparent	2,72
	Absorption	1,55%

2. Based on table 6, the test results have met the requirements by the specification namely with the difference in specific gravity values obtained between coarse aggregate and fine aggregate being no more than 0.2 and water absorption by the aggregate being a maximum of 3 %(Guo et al., 2021).
3. Asphalt Test Results

   The results of asphalt testing include penetration tests, flash point and fire point tests, asphalt softening point tests, and asphalt specific gravity tests. Shown in table 7 as follows:

Table 7. Asphalt Test Results

Test Type	Specification	Result
Asphalt Penetration	60-70 mm	65,15 mm
Asphalt Flash Point	Min. 232	356
Asphalt Burn Point	-	360
Asphalt Softening Point	Min 48	52,5
Asphalt Specific Gravity	Min. 1gr/cm	1,043

Based on table 7, the test results have met the requirements in accordance with the specification.

Calculation Results of Planned Asphalt Content

In designing asphalt mixtures, determining the correct asphalt content is very important. This research uses the Asphalt Institute method formula approach to determine ideal asphalt content. The variations in asphalt content used are Pb-1%, Pb%, and Pb+1%, as shown in table 8(Liu et al., 2022).

Table 8. Plan Asphalt Content

Variations in Asphalt Content	Percentage (%)	weight (Gram)
Pb-1	5,9	70,8
Pb	6,9	80,8
Pb+1	7,9	94,8

Marshall Test Results to Determine Optimum Asphalt Content

Determining the optimum asphalt content in this research uses a graphic method by creating Marshall parameter value limits that meet the 2018 General Specifications for Bina Marga (Revision 2) from test objects that have been made, calculated and tested according to the planned asphalt variation levels, namely 5, 9%, 6.9%, and 7.9% with a total of 5 variations of each test object. A recapitulation of the average Marshall test results carried out in this study is shown in table 9 as follows(Guo et al., 2021):

Table 9. Recapitulation of Average Marshall Test Results

Marshall Parameters	Specification	Unit	Variations in Asphalt Content		
			5,9%	6,9%	7,9%
VIM	3-5	%	6,52	5,23	3,97
VMA	Min. 17	%	17,02	17,71	18,39
VFA	Min. 68	%	61,70	70,46	78,42
Stability	Min. 600	kg	1715,13	1872,72	2162
Flow	Min. 3	mm	2,7	3,05	3,55
Marshall Quotient (MQ)	Min. 250	kg/mm	635,77	613,87	608,97

Determination of the optimum asphalt content is obtained by determining the middle value of the Marshall parameters values and has been meeting the requirements by the specification. From the table for each Marshall parameter that has been obtained previously, a graph of the relationship between asphalt content and Marshall parameters can be presented to determine the optimum asphalt content which is shown in figure 2 as follows:

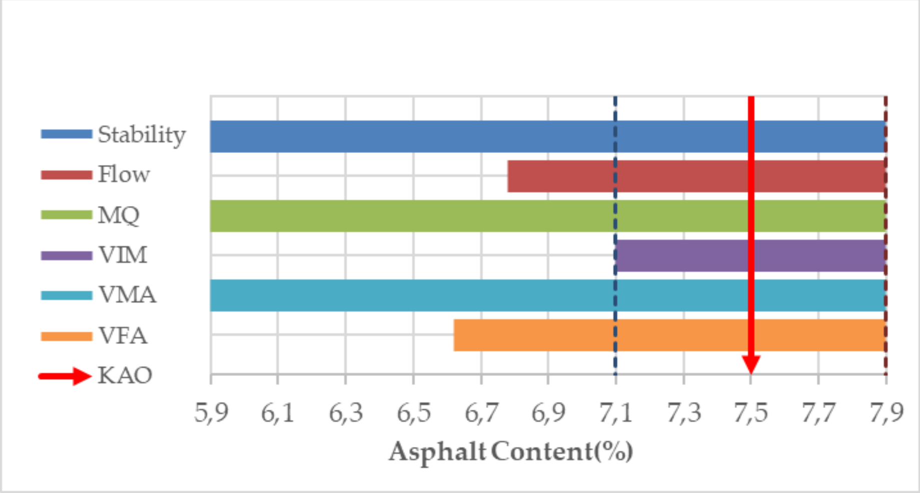


Figure 2. Graph Showing the Relationship between Asphalt Content and Marshall Parameters

Based on the graph depicting the relationship between various asphalt content variations and Marshall parameters, the optimal asphalt content (KAO) is identified as 7,5%. Consequently, when preparing test specimens with the inclusion of coal fly ash as a filler, each test specimen will be made using the KAO of 7,5% of the total aggregate weight(Leclercq-Dransart et al., 2019).

Marshall Test Results with Fly Ash Filler

The results of the Marshall Test with Fly Ash Filler are used to determine the optimum filler content. This research uses a graphic method by creating Marshall parameter value boundaries that meet the 2018 General Bina Marga Specifications (Revision 2) from test objects that have been made, calculated and tested according to filler variation levels of 0%, 1%, 2% , 3%, and 4% with a total of 5 variations of each test object. A recapitulation of the average Marshall test results with variations in filler content carried out in this study is shown in table 10 as follows(Tian et al., 2019) :

Table 10. Recapitulation of Average Marshall Test Results for Filler Content

Marshall Parameters	Specification	Unit	Filler Level Variations				
			0%	1%	2%	3%	4%
VIM	3-5	%	4,68	4,22	3,94	3,64	2,86
VMA	Min. 17	%	18,29	17,90	17,67	17,40	16,74
VFA	Min. 68	%	74,45	76,42	77,68	79,10	82,89
Stability	Min. 600	kg	2040,46	2122,64	2167,45	2202,79	2272,14
Flow	Min. 3	mm	3,4	3,27	3,14	2,91	2,53
Marshall Quotient (MQ)	Min. 250	kg/mm	600,24	649,76	689,69	756,23	898,42

a. Void In Mix (VIM)

From table 10, it can be presented in graphical form the relationship between filler content and VIM value which is shown in figure 3 as follows:

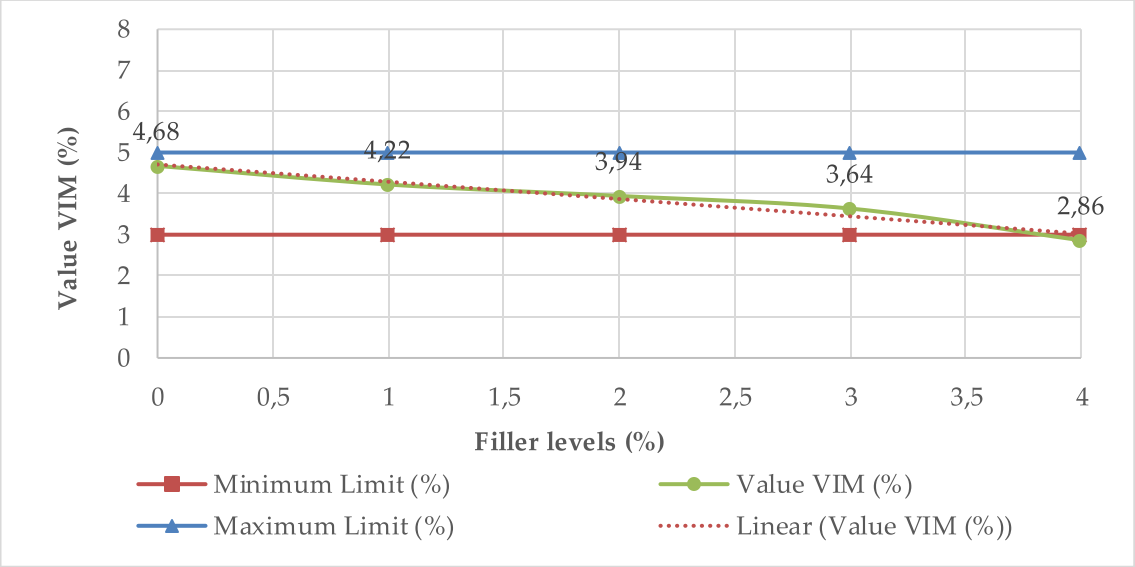


Figure 3. Graph of the Relationship between Filler Levels and VIM Values

b. Void In Mineral Aggregate (VMA)

From table 10, it can be presented in graphical form the relationship between filler content and VMA value which is shown in figure 4 as follows:

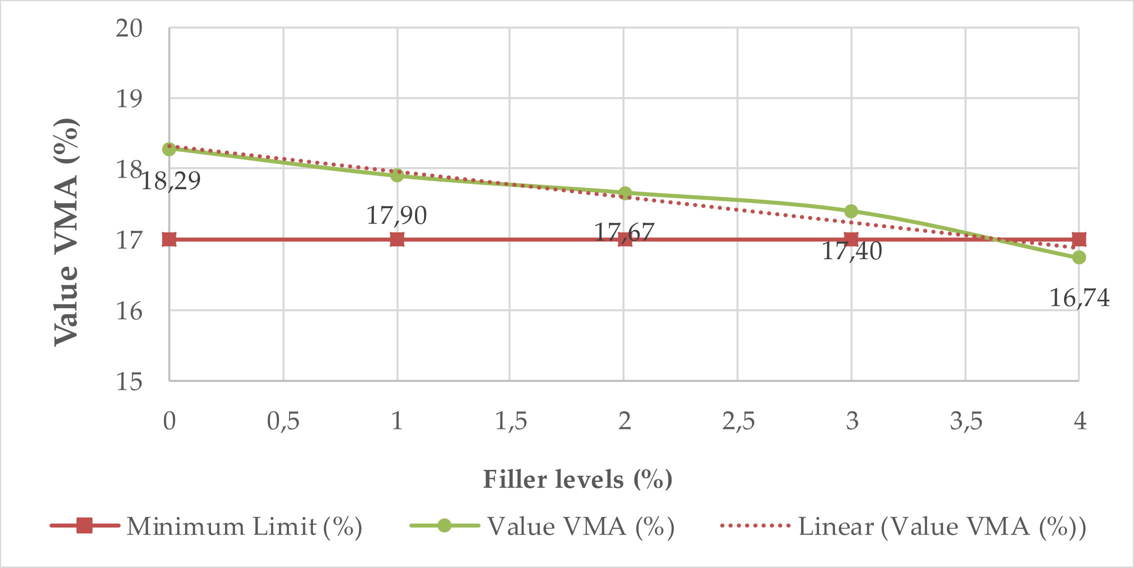


Figure 4. Graph of the Relationship between Filler Levels and VMA Values

c. Void Filled with Asphalt (VFA)

From table 10, it can be presented in graphical form the relationship between filler content and VFA value which is shown in figure 5 as follows:

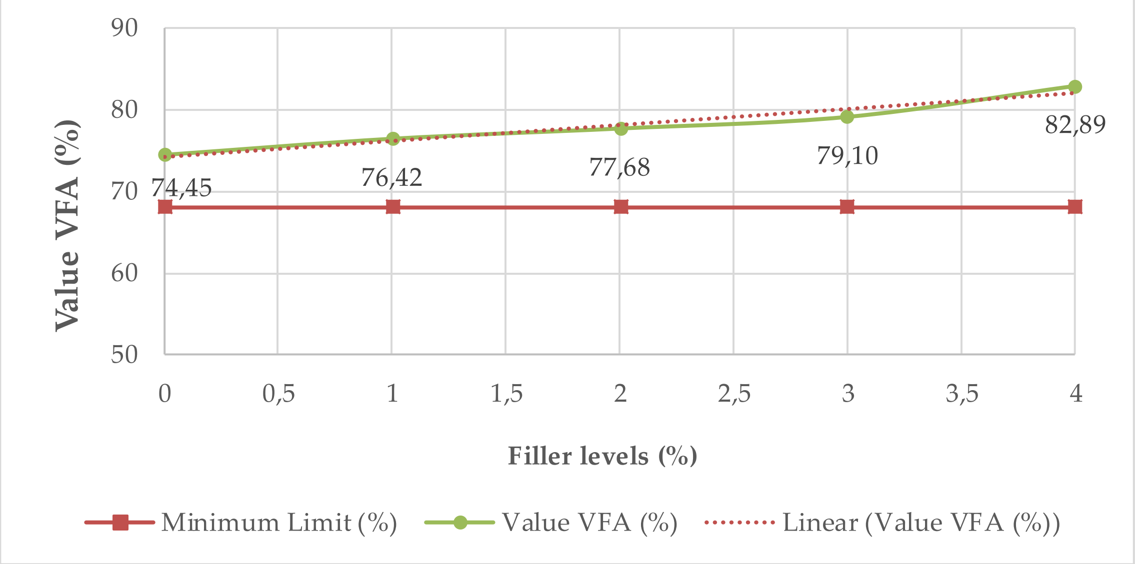


Figure 5. Graph of the Relationship between Filler Levels and VFA Values

d. Stability

From table 10, it can be presented in graphical form the relationship between filler content and stability value which is shown in figure 6 as follows:

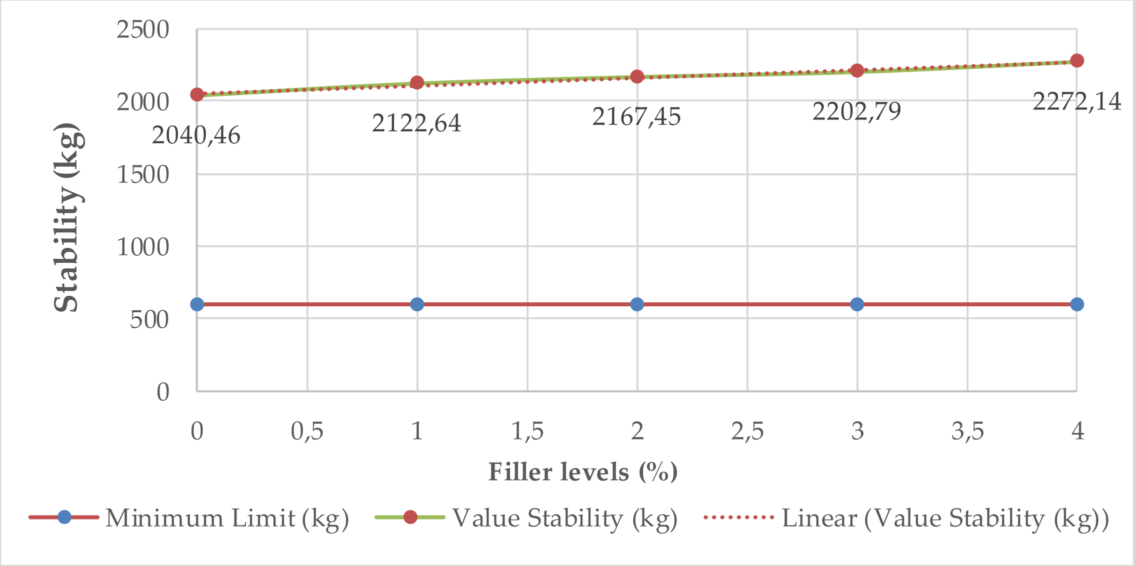


Figure 6. Graph of the Relationship between Filler Levels and Stability Value

e. Flow

From table 10, it can be presented in graphical form the relationship between filler content and flow value which is shown in figure 7 as follows:

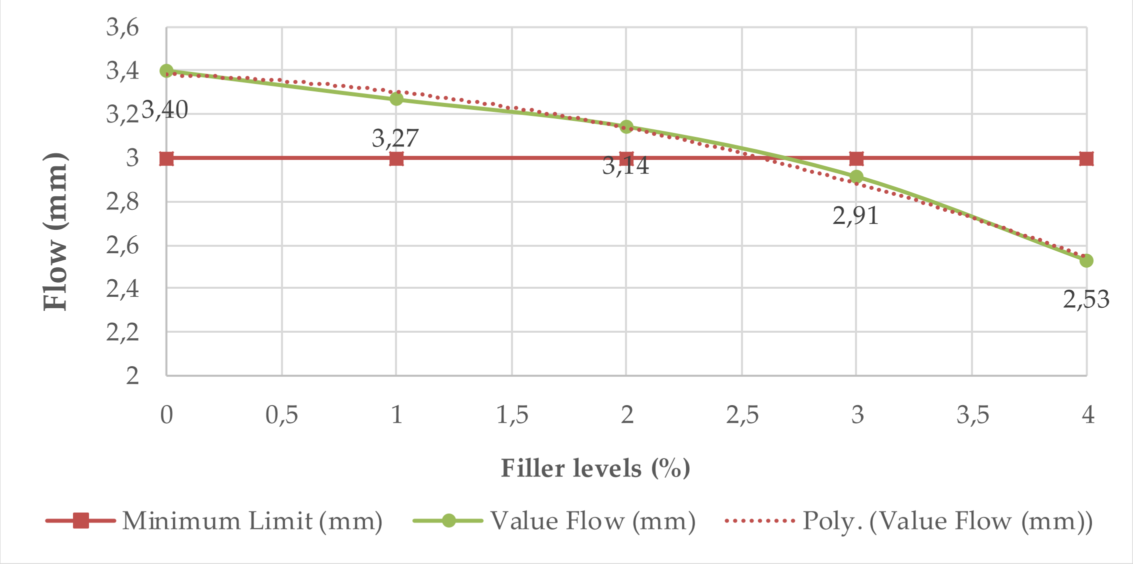


Figure 7. Graph of the Relationship between Filler Levels and Flow Values

f. Marshall Quotient
From table 10, it can be presented in graphical form the relationship between filler content and Marshall Quotient value which is shown in figure 8 as follows:

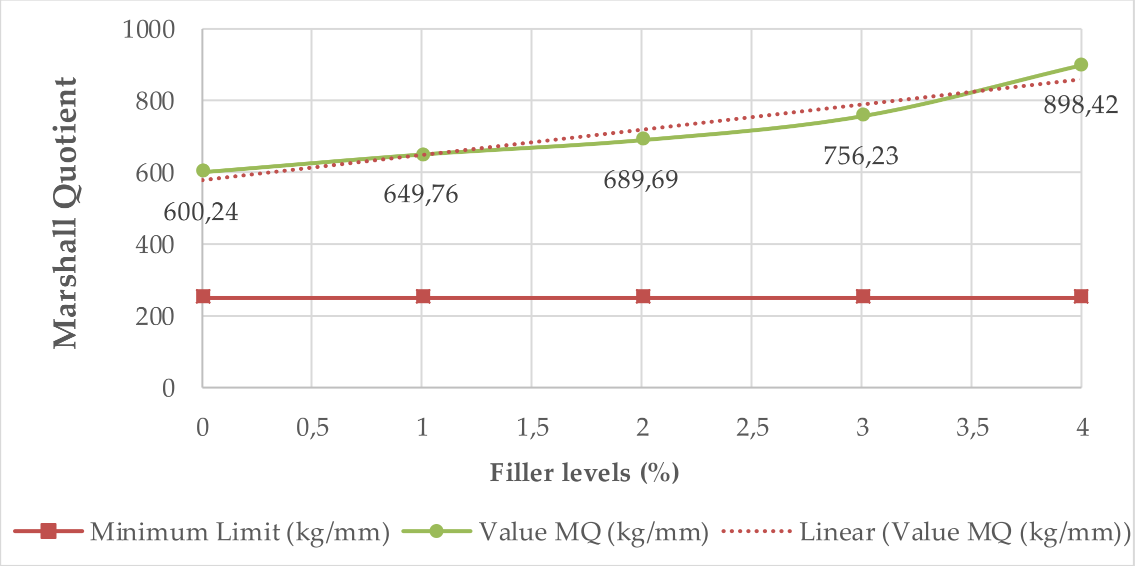


Figure 8. Graph of the Relationship between Filler Levels and Mashall Quotient Values

Marshall Test Results with Fly Ash Filler

Determination of the optimum filler content is obtained by determining the middle value of the Marshall parameters which include the VIM, VMA, VFA, stability, flow, and Marshall Quotient (MQ) values and has been meet the requirements in accordance with the specification. Based on the tables and graphs depicting each Marshall parameter obtained earlier, a graph illustrating the relationship between filler content and Marshall parameters can be presented to identify the optimal filler content, as demonstrated in Figure 9 as follows(Gutiérrez-Junco et al., 2019):

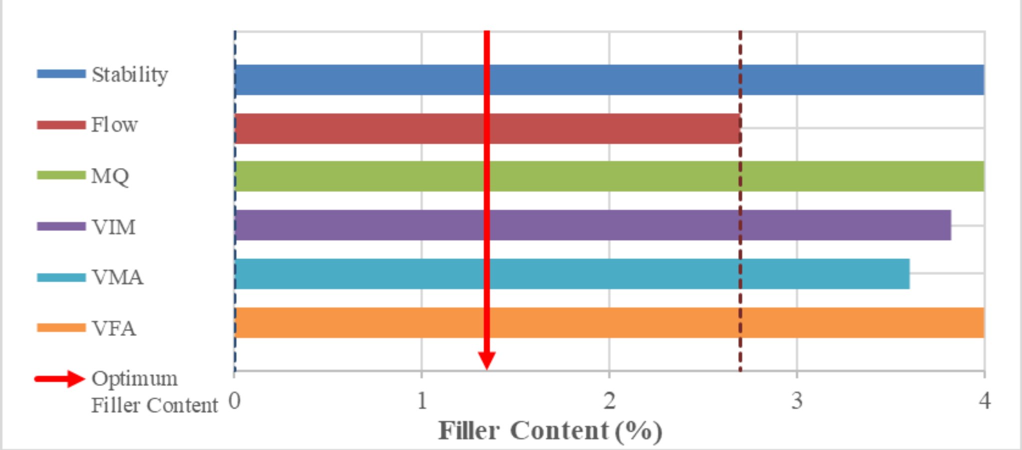


Figure 9. Graph Showing the Relationship between Filler Content and Marshall Parameters

From the graph illustrating the correlation between different filler content variations and Marshall parameters, the optimal filler content is determined to be 1.35%. The Marshall test results conducted with this filler content percentage have demonstrated compliance with the Marshall parameter specification. This indicates that the inclusion of fly ash as a filler has a positive impact on the HRS-WC asphalt mixture.

Effect of Adding Fly Ash as a Filler to Asphalt Mixtures

To find out the effect of adding coal fly ash as a filler, a comparison of each Marshall parameter can be carried out between the asphalt mixture without using filler and the asphalt mixture using the optimum filler, namely 1.35 % of the total weight of the aggregate. The Marshall parameter results without using filler have been obtained from existing data, namely the use of filler is 0%. Meanwhile, the Marshall parameter results for varying the optimum fly ash filler content of 1.35% were obtained using a polynomial equation or a linear regression equation from the graphical results of each Marshall parameter for determining the optimum filler content. A recapitulation of the comparison of Marshall parameters between 0% fly ash filler content and optimum fly ash filler content of 1.35% is shown in table 11 as follows:

Table 11. Marshall Parameter Comparison Results

Masrhall Parameters	Spesification	Unit	Filler Content 0%	Filler Content 1,35%	Percentage %	Information
VIM	3-5	%	4,68	4,14	-11,54	Reduction
VMA	Min. 17	%	18,29	17,84	-2,46	Reduction
VFA	Min. 68	%	74,45	76,84	3,21	Increase
Stability	Min. 600	kg	2040,46	2125,78	4,18	Increase
Flow	Min. 3	mm	3,40	3,26	-4,12	Reduction
Marshall Quotient (MQ)	Min. 250	mg/mm	600,24	673,18	12,15	Increase

According to Table 10, adding fly ash filler to the HRS-WC asphalt concrete mixture resulted in an 11.54% decrease in VIM, indicating that the filler helps fill cavities and makes the pavement layer watertight. The VMA value decreased by 2.46% as the filler filled the voids between aggregates. The VFA value increased by 3.21%, enhancing the asphalt's ability to cover granular cavities. Stability increased by 4.18%, showing that the filler provides a strong binding between particles. The flow value decreased by 4.12%, and the Marshall Quotient (MQ) increased by 12.15%, indicating that the mixture became stiffer and less prone to deformation under load.

Conclusion

Based on the results of Marshall characteristic testing with variations in planned asphalt content of 5,9%, 6,9% and 7,9% in the Lataston HRS-WC mixture, it shows that the optimum asphalt content (KAO) is 7,5%. Marshall parameter testing results at a KAO value of 7,5% have met the 2018 General Bina Marga Specifications (Revision 2) with a stability value of 2040,46 kg, flow of 3,40 mm, Marshall Quotient (MQ) of 600,24 kg/ mm, VIM were 4,68%, VMA were 18,29%, and VFA were 74,45%.

Based on the results of Marshall characteristic testing with variations in filler content of 0%, 1%, 2%, 3% and 4% in Lataston HRS-WC, it shows that the optimum filler content is 1.35%. Based on the calculation of Marshall characteristics at optimum filler content using polynomial equations and linear regression equations, the values for each Marshall parameter were obtained with a stability value of 2125,78 kg, flow of 3,26 mm, Marshall Quotient (MQ) of 673,18 kg/mm, VIM were 4,14%, VMA were 17,84%, and VFA were 76,84%. The test results have met the requirements in accordance with the specification.

Adding fly ash as a filler to the HRS-WC asphalt mixture alters its characteristics. Overall, the inclusion of fly ash enhances the mixture's stability, durability, and stiffness. This happens because fine fly ash particles fill empty spaces in the mixture, increase density, reduce the number of air voids, and can bind the asphalt mixture. However, fly ash can also reduce the flow value of the asphalt mixture to make it stiffer. Stiffer asphalt mixes are less susceptible to plastic deformation under load, reducing the risk of rutting or grooves in the road surface. Applying fly ash as a filler at optimal levels enhances the qualities of the HRS-WC asphalt mixture for road pavement. Nevertheless, excessive use of fly ash can compromise these characteristics by rendering the mixture overly rigid and diminishing the pavement's flexibility, which is crucial for ensuring durability and flexibility in HRS-WC asphalt mixtures.

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