MARSHALL CHARACTERISTICS WITH THE USE OF CEMENT FILLER AND STONE ASH IN THE MIXTURE ASPHALT CONCRETE WEARING COURSE (AC-WC)

(Case Study: Ogan Ilir Regency Boundary Road-Lubuk Batang STA 26+485 to STA 27+405)

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Abstract

Indonesia is experiencing significant growth in traffic loads, but this is often not balanced by the development of adequate road infrastructure. This phenomenon occurs because the growth of traffic loads is faster than the development of road infrastructure. Excessive traffic loads can cause road damage. When a road has to carry a traffic load that exceeds its planned capacity, damage will occur gradually and impact the quality of the road infrastructure. Asphalt is a dark brown or not thick hydrocarbon compound formed from the elements asphaltenes, resins, and oils. Asphalt in the pavement layer functions as a binding material between the aggregates to form a compact mixture, thus providing the strength of each aggregate. There are various asphalt mixtures, such as hot asphalt mixtures using cement filler and stone ash on the surface layer of the Asphalt Concrete Wearing Course (AC-WC). Therefore, it is necessary to carry out research to determine the Marshall characteristics in the evaluation of hot asphalt mixtures using cement filler and stone ash on the Asphalt Concrete Wearing Course (AC-WC) surface layer, which is adjusted to the 2018 Bina Marga Revision 2 specifications. It was carried out on the district border roads as an object of research. Ogan Ilir – Lubuk Batang and in the PT Laboratory. Komba Mahaka Utama Martapura Ogan Komering Ulu Timur. Marshall test results on the AC-WC mixture using 2 different types of filler, namely cement filler and stone ash filler, and the test results on the research object showed differences in the resulting Marshall characteristics. Still, all results met the requirements of the 2018 Bina Marga general specifications Revision 2.

Keywords: marshall, asphalt content, filler, asphalt concrete wearing course

1. Introduction

Indonesia is experiencing significant growth in traffic loads, but this is often not balanced by the development of adequate road infrastructure. This phenomenon occurs because the growth of traffic loads is faster than the development of road infrastructure. Excessive traffic loads can cause road damage. When a road has to carry a traffic load that exceeds its planned capacity, damage will occur gradually and impact the quality of the road infrastructure. Flexible pavement is an important component in road infrastructure designed to withstand traffic loads and provide users with a safe and comfortable surface. Aggregate is one of the main components of flexible road pavement, and fine aggregate has an important role in flexible road pavement, which often experiences damage, namely the wear layer (AC-WC). AC-WC coating aims to provide smoothness, safety, and comfort for road users and protect the underlying layer from damage due to repeated traffic loads, including the formation of deformation in the form of subsidence, grooves, and grain release. Hot mix asphalt concrete is one type of flexible pavement construction layer. This type of pavement is an even mixture of aggregate and asphalt as a binding material at a certain temperature. To dry the aggregate and obtain a sufficient liquid level from the asphalt so that it is easy to mix it, the two materials must be heated first before mixing.

The characteristics of asphalt concrete are largely influenced by the materials used for the mixture, the gradation of the mixture, and good implementation in the field. In contrast, the strength of asphalt concrete is largely determined by the rocks in the mixing process (composition), which greatly determines the characteristics of the asphalt concrete. Certain materials, both asphalt and aggregate, are used to increase the ability of pavement [1]. Road pavement must be planned properly by applicable standards in Indonesia [2]. Asphalt concrete is one of Indonesia's most widely used types of flexible pavement. This layer comprises coarse aggregate, fine aggregate, and asphalt [3]. This research was done in the Laboratory and the field, as samples were taken on the District Border Road. Ogan Ilir-Lubuk Batang STA 26+485 to STA 27+405). The research aimed to determine the characteristics of Marshall using cement filler and stone ash in the AC-WC mixture. Stone ash is the result of grinding from crushed stone production. Rock ash contains a lot of silica, alumina, alkaline compounds, iron, and lime, although at low levels [4]. Asphalt is a dark brown or not thick hydrocarbon compound formed from the elements asphaltenes, resins, and oils. Asphalt in the pavement layer functions as a binding material between the aggregates to form a compact mixture, thus providing the strength of each aggregate. Apart from being a binding material, asphalt also fills the cavities of aggregate granules and the pores of the aggregate itself. The filler can use stone ash. Filler material must be dry and free from lumps and must be material that passes 75% of sieve number 200 and has non-plastic properties [5]. Marshall test results using AMP stone ash filler PT. Victory Multi Karya meets the specified requirements and can be used [6].

Research conducted by Sartan Nento et al. (2021) using an optimum asphalt content (KAO) of 5.5% from various zeolite stone ash fillers met the specifications of Bina Marga 2010 revision 3 [7]. Research conducted by Muhtar Salim et al. (2021), with the addition of stone ash filler from 1% -3%, the results showed that the stability value, asphalt cavity filled value, and Marshall Quotient value increased along with the stone ash filler content in the HSR-Base mixture [8]. The results of the Marshall test with optimum asphalt content in a mixture of Portland cement filler and stone ash have different values, fulfilling the Marshall property requirements. At the same time, VIM and VFA are the limits [9]. Marshall's test results on the AC-WC mixture using 3 different types of filler, namely cement filler, stone ash, and lime, meet the requirements of the general specifications for Bina Marga 2018 Revision 2 [10]. Budi Winarnao et al. (2020) researched the Marshall method based on stability and flow calculations in the Marshall test using filler with 5 samples that showed results that met the Bina Marga requirements [11].

2. Research Methods

This research was carried out in the Asphalt Laboratory of PT. Komba Mahaka Utama Martapura Ogan Komering Ulu Timur and research objects in the field on the District Border Road. Ogan Ilir-Lubuk Batang STA 26+485-27+405. In this research, the Asphalt Concrete Wearing Course (AC-WC) mixture was used as a mixture; the fine aggregate was taken from AMP PT. Komba Mahaka Utama Ogan Komering Ulu Timur, while the coarse aggregate and stone ash used were natural stone, which was carried out by the crushed stone breaking process from the Asphalt crusher machine. Mixing Plan (AMP) PT. Komba Mahaka Utama. The Asphalt Concrete Wearing Course (AC-WC) mixture fillers are cement and stone ash. The testing stages in this research consist of aggregate testing (coarse, fine, and filler), asphalt testing, and testing of the mixture, namely the Marshall test. Tests were carried out in the laboratory for cement and stone ash fillers, while as a case study, tests were carried out using stone ash filler at several STA 26+485-27+405 sample points. The results of this test are Marshall characteristics, namely Void in the Mix (VIM), Void in the Mineral Aggregate (VMA), Void Filled with Asphalt (VFA), stability, flow, Marshall Quoetion (MQ), and Density. Case studies are taken from several points on the research object, and the results will be taken to The Laboratory for examination so that they can produce marshall data and density data in the field.

3. Results

3.1. Research Results in the Laboratory

The results of the Asphalt Concrete Wearing Course (AC-WC) mixture material examination in this study are presented in the following Table [11] :

Table 1 WC-AC Mixture Inspection Results

Material Type	Mark
Effective Specific Gravity of Fine Aggregate (sand)	2,503 gr/cc
Effective Specific Gravity of Coarse Aggregate Crushed Stone 19.00 mm (3/4") Crushed Stone 9,50 mm (3/8")	2,644 gr/cc 2,613 gr/cc
Effective Specific Gravity of Stone Ash	2,534 gr/cc
Asphalt Specific Gravity	1,033 gr/cc^3
Asphalt Sheet Point	51,8 ºC
Asphalt Flash Point	358 ºC
Asphalt Ductility at temperature 25 ºC	>140
Optimum Asphalt Content in Mixtures AC-WC	5,90 %

Source: *Laboratory Test Results*

Table 2 Composition of Marshall Briquette Mix with Cement Filler

Mix	Mix Percent	Weight (gram)	Cumulative (gram)
Crushed stone 19.00 mm	4,71% ×1200	56,52	56,52
Crushed stone 9,50 mm	45,17%×1200	542,04	598,56
Dust	37,63%×1200	451,56	1050,12
Sand	4,71%×1200	56,52	1106,64
Filler (cement)	1,88%×1200	22,56	1129,20
Optimum Asphalt Content	5,90%×1200	70,80	1200

Source: *Laboratory Test Results*

Table 3 Composition of Marshall Briquette Mixture with Stone Ash Filler

Mix	Mix Percent	Weight (gram)	Cumulative (gram)
Crushed stone 19.00 mm	4,80% ×1200	57,60	57,60
Crushed stone 9,50 mm	45,25%×1200	543,00	600,60
Dust	37,26%×1200	447,12	1047,72
Sand	4,80%×1200	57,60	1105,32
Filler (cement)	1,99%×1200	23,88	1129,20
Optimum Asphalt Content	5,90%×1200	70,80	1200

Source: *Laboratory Test Results*

Table 4 Marshall Test Results

Test Type	Test results			General Specifications 2018 Revision 2
	Cement Filler 1,88%	Stone Ash Filler 1,99%	Stone Ash Filler 1.99% Field Sample	
Optimum Asphalt Content (%)	5,90	5,90	5,90	-
Standard Bulk Density / Content Weight (gr/cc)	2,270	2,250	2,221	-
Percent void to mix (VIM) Standard (%)	4,50	4,80	4,85	3.0 – 5.0
Percent voids to aggregate (VMA) (%)	17,45	17,00	17,29	Min 14
Percent of voids filled with asphalt (VFA) (%)	74,00	71,00	71,94	Min 65
Marshall Stability (kg)	1080	1100	976,10	Min 800
Fatigue/Flow (mm)	3,00	3,60	3,87	2,0 – 4,0

MQ (kg/mm)	360	305	252,44	>250

Source: *Laboratory Test Results*

3.2. Trial Compaction Results

The AC-WC Compaction Trial was carried out at the STA 26+485 – 26+525 location; this compaction trial was carried out with two variations of passing (passing) Tandem Roller and Pneumatic Tire Roller (PTR) to obtain the field density as required. The passing variations (trajectories) are Section I STA 26+485-STA 26+505 R, Tandem, and PTR passing with 10 passes, while Section II STA 26+505-STA-26+525 R passing with 12 passes. The Tandem equipment weighs 8 tons, and the PTR is 12 tons. From the results of this trial, it was found that: Break Down with Tandem Roller 2 passes with a Temperature of $130^{o}C$, Intermediate with PTR 12 passes with a temperature of $115^{o}C$. With loose compaction of 5.3 cm and an average density percentage of 98.47%, the density obtained and the compaction results meet the specified requirements, namely a minimum of 98% [12].

Figure 1 Compaction Test Sampling Process.

Figure 2 Sample Testing Process from Location.

4. Discussion

4.1. Analysis of Optimum Asphalt Content

The asphalt content required in a pavement mixture is the optimum asphalt content, namely an asphalt content that provides the highest stability to the pavement layer where other requirements are met, such as VIM value, Flow, and so on. The optimum asphalt content (KAO) is 5.90% of all fillers used because it meets the requirements of the Marshall test results and other aspects, which can provide an overview of the Trail Compaction test results at the research object.

4.2. Bulk Density Analysis

Density is the weight of the mixture measured per unit volume; density shows the density level of the mixture after it is compacted. Factors that influence density are the quality of the constituent materials, compaction energy, and asphalt content in the mixture. The results of research in the laboratory and the field are shown in the following Figure:

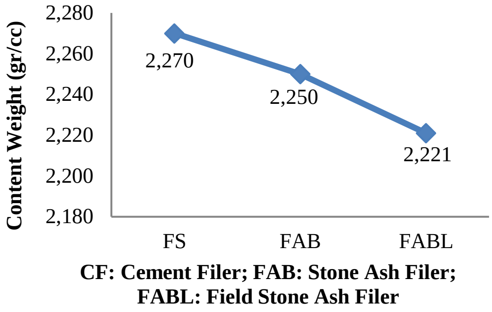

Figure 3 Comparison graph of bulk weight values with Cement Filler, Laboratory Stone Ash Filer, and Field Stone Ash Filer.

Figure 3 for the AC-WC cement filler mixture is the highest value, 2,270 gr/cc. In contrast, there was a decrease for the stone ash filler in laboratory conditions, namely 2,250 gr/cc, and for the stone ash filler from the field location there was a very significant decrease, namely 2,221 gr/cc. For bulk weight, Bina Marga has no special requirements regarding this density, but it greatly influences the volume requirements in the field. The higher the density value, the better the mixture quality will be. This can be explained by the high density of a hot asphalt mixture, the more impenetrable it is to water and air [13].

4.3. VIM Value Analysis

The Void In The Mix (VIM) value, also known as the percentage of voids contained in the total air in the asphalt mixture, influences the life of the pavement layer; the higher the VIM value indicates, the greater the voids in the mixture so that the mixture is vigorous [14]. Suppose the air cavity value in the mixture is small. In that case, it indicates that the mixture is too dense or dense and has high stiffness, which will result in the asphalt surface rising (bleeding) due to compaction by traffic loads and shifting of the asphalt surface (sliding) [15]. The results of the VIM value analysis can be seen in Figure 4 below:

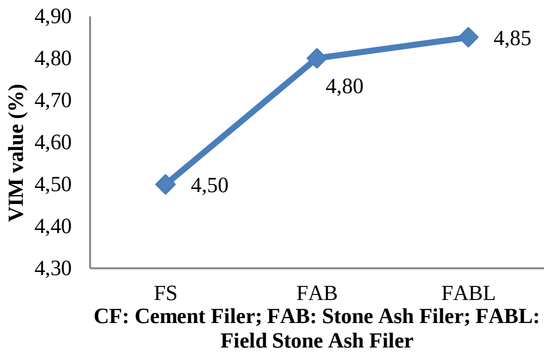

Figure 4 Comparison graph of VIM values with Cement Filler, Laboratory Stone Ash Filer and Field Stone Ash Filer.

The highest VIM value occurred in the stone ash filler from field samples at 4.85%, followed by the laboratory stone ash filler at 4.80%, and the smallest value was in the cement filler at 4.5%. This is because cavities are filled with asphalt evenly, and the compaction process in the field occurs perfectly, causing the asphalt mixture to become dense. If you look at the Bina Marga specifications, the requirements range from 3.0% - 5.0%, which is still in the category of meeting [15].

4.4. VMA Value Analysis

Voids in Mineral Aggregate (VMA) are air voids between aggregates in asphalt mixtures, including air voids and effective asphalt content. The number of pores between aggregate grains in an asphalt mixture is expressed as a percentage. A small amount of air space in the aggregate can limit the asphalt covering the aggregate so that the aggregate is released, making the layer not watertight. Oxidation occurs easily, so the pavement layer is easily damaged [14]. The results of the VMA value analysis can be seen in Figure 5 below:

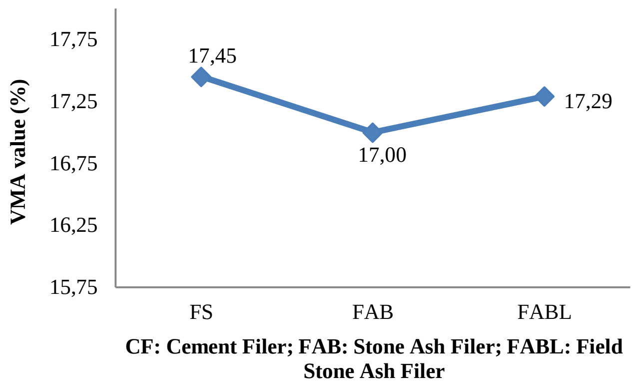

Figure 5 Comparison graph of VMA values with Cement Filler, Laboratory Stone Ash Filer, and Field Stone Ash Filer.

The VIM value of the three fillers used fluctuated, as in Figure 5. The highest VMA value occurred for the cement filler, namely 17.45%, and there was a decrease for the stone ash filler, 17.00%, and increased again for the Lapaangan stone ash filler, amounting to 17.29. %. This is because the cavity filled with asphalt occurs differently between the three fillers. Even though the VMA value fluctuates, in general, it meets the Bina Marga specifications, which require a minimum of 14% [15].

4.5. VFA Value Analysis

Void Filled with Asphalt (VFA) is the percentage of air voids filled with asphalt in the mixture after it has been compacted. The air cavity value filled with asphalt determines the stability, durability, and flexibility of the mixture, which is influenced by aggregate gradation, compaction temperature, asphalt content, asphalt type, and compaction energy [14]. The results of the VMA value analysis can be seen in Figure 6 below:

Figure 6 Comparison graph of VFA values with Cement Filler, Laboratory Stone Ash Filer, and Field Stone Ash Filer.

The VFA value of the three fillers used fluctuated, as in Figure 6. The highest VFA value occurred for the Cement filler, namely 74.00%, and there was a decrease for the stone ash filler, 71.00%, and an increase again for the Fieldstone ash filler, amounting to 71.94. %. This is also influenced by the percentage of voids filled with asphalt; there are also differences. The higher the VFA value, the higher the voids in the mixture filled with asphalt so that the mixture is more impermeable to water and air, but a VFA value that is too high will also cause the asphalt mixture to become blended, but in general it meets Bina Marga specifications which require a minimum of 65% [15].

4.6. Stability Value Analysis

The stability value is the ability of the layer to accept traffic loads without changes in grooves, ruts, waves, and bleeding on the pavement. Things that influence the Asphalt Concrete Wearing Course (AC WC) mixture are friction, interlocking properties, and material shape and are also influenced by aggregate surface texture, aggregate gradation, particle shape, mixture density, and asphalt viscosity [14]. The results of the Stability value analysis can be seen in Figure 7 below:

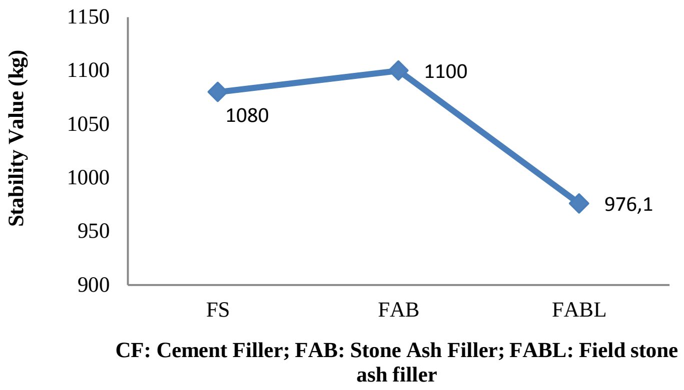

Figure 7 Comparison graph of VFA values with Cement Filler, Laboratory Stone Ash Filer and Field Stone Ash Filer.

The stability value of the three fillers used fluctuated, as in Figure 7. The stability value of the cement filler was 1080 kg, and there was an increase for the stone ash filler, namely 1100 kg, and decreased again for the Lapaangan stone ash filler of 976.10 kg. From the three analysis results with the three fillers used, the highest ability to accept loads is the stone ash filler in the laboratory, while the lowest capability is the fieldstone ash filler, but in general, this stability value meets Bina Marga's specifications, which require a minimum of 800 kg [15].

4.7. Meltdown Value Analysis (Flow)

The yield value (flow) states the amount of deformation or settlement of the compacted mixture, which is due to the large load acting on it, and shows the level of flexibility of a pavement. The melt value is influenced by asphalt factors, asphalt viscosity, gradation, aggregate surface texture, and compaction level [15]. The results of the Stability value analysis can be seen in Figure 8 below:

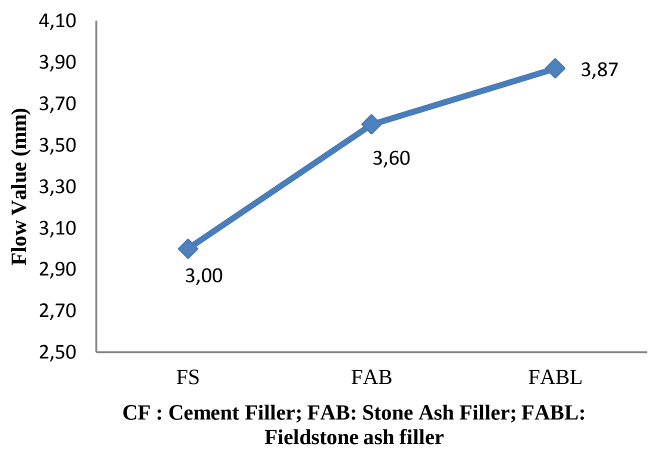

Figure 8 Comparison graph of VFA values with Cement Filler, Laboratory Stone Ash Filer, and Field Stone Ash Filer

The melt value (flow) of the three fillers increased, as in Figure 8. The stability value of the cement filler was 3.00 mm, and there was an increase for the stone ash filler, namely 3.60 mm, and another increase for the Lapaangan stone ash filler by 3.87 mm. The required melt (flow) value is 2.0 to 4.0 [15]. If the melting value is less than 2.0, the mixture will easily crack and flow due to its stiff nature.

4.8. MQ Value Analysis

Marshall Quotient (MQ) is influenced by the quotient between corrected stability and melting value. This quotient value is used as an approximation to the level of stiffness or flexibility of a mixture. The greater the Marshall Quotient quotient value, the stiffer the mixture. The smaller the Marshall Quotient quotient value, the more flexible the mixture. The results of the Stability value analysis can be seen in Figure 9 below:

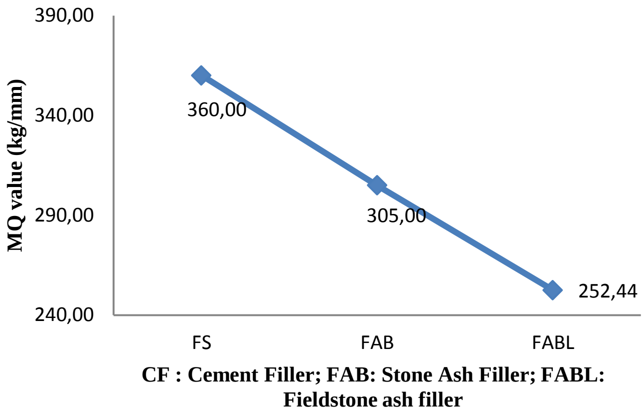

Figure 9 Comparison graph of VFA values with Cement Filler, Laboratory Stone Ash Filer, and Field Stone Ash Filer

The Marshall Quotient (MQ) value of the three fillers used decreased as in Figure 9; the Marshall Quotient (MQ) value for cement filler was 360 kg/mm and decreased for the stone ash filler, namely 305 kg/mm and decreased again for the filler. Lapaangan stone ash was 252.44 kg. The Marshall Quotient (MQ) value is directly proportional to the stability value but inversely proportional to the melting (flow) value. From the three analysis results with the three fillers used, the Marshall Quotient (MQ) value generally meets the Bina Marga specifications requiring greater than 250 kg/mm [15].

5. Conclusion and Recommendation

5.1. Conclusion

From the test results, it can be concluded as follows:

1. Cement filler: KAO is 5.90%, Fill weight is 2.270 gr/cc, VIM is 4.5%, VMA is 17.45%, VFA is 74%, Stability is 1080 kg, flow is 3.00 mm and Marshall Quotient (MQ) is 360 kg/mm.
2. Stone ash filler; KAO is 5.90%, Fill weight is 2,250 gr/cc, VIM is 4.8%, VMA is 17.00%, VFA is 71%, Stability is 1100 kg, flow is 3.60 mm and Marshall Quotient (MQ) is 305 kg/mm.
3. Field stone ash filler; KAO is 5.90%, Fill weight is 2.221 gr/cc, VIM is 4.85%, VMA is 17.29%, VFA is 71.94%, Stability is 976.10 kg, the flow rate is 3, 87 mm and Marshall Quotient (MQ) of 252.44 kg/mm.

5.2. Recommendation

Recommendation that can be conveyed in this research are as follows:

1. Further research can be carried out using various variations in the percentage of different filler levels and using other fillers.
2. In compaction testing in the field, increase the number of sample points to determine changes from various Marshall test results.

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