

Effect of Palm Frond Ash as a Substitute Filler on Mixture Characteristics (AC - WC)

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Abstract

The use of palm frond ash as a replacement filler in Asphalt Concrete-Wearing Course (AC-WC) mixtures has been studied to evaluate its effect on the Marshall characteristics of the asphalt mix. This research aims to analyze the effect of using palm frond ash as a filler in Asphalt Concrete-Wearing Course (AC-WC) mixtures. The materials used include aggregates from the Lagadar Quarry and asphalt binder. This study aims to analyze the effect of using palm frond ash as a filler in Asphalt Concrete-Wearing Course (AC-WC) mixtures. The materials used include aggregates from Quarry Lagadar, 60/70 asphalt, and palm frond ash from PTPN Subang. Tests were conducted on the physical properties of the materials and mixtures, including penetration tests, softening point tests, and Marshall tests (Stability, flow, VMA, VIM, and MQ). The results showed that palm frond ash at a concentration of 1.5% was the most effective concentration for Marshall parameters. The mixture composition with varying ash content showed that the Marshall values met the 2018 Bina Marga specifications except for the 2.5% variation.

Keywords: palm frond ash, filler, Asphalt Concrete-Wearing Course (AC-WC), Marshall characteristics, VIM, VFA, Marshall stability, Marshall tests.

1. INTRODUCTION

The use of palm frond ash as a filler in Asphalt Concrete Wearing Course (AC-WC) mixtures for road pavement design is an innovation that has the potential to improve material quality while supporting the management of palm oil industry waste. Palm frond ash, which is a byproduct of palm frond combustion, possesses physical and chemical properties that can enhance shear strength, stability, and resistance to permanent deformation (rutting) in asphalt mixtures. Additionally, the use of palm frond ash can reduce reliance on conventional filler materials, thereby lowering production costs and supporting sustainable development principles by reducing waste accumulation.

By understanding the characteristics and behavior of asphalt mixtures using palm frond ash, it is hoped that useful information can be obtained for designing more efficient and sustainable road pavements. Furthermore, this research can also contribute to the development of environmentally friendly road construction materials.

2. RESEARCH METHODS

2.1 Overview of Research

Materials used in asphalt concrete - wearing course (AC-WC) mixtures must meet specifications and various tests to ensure that they have the expected properties. In this study, material testing was carried out based on the General Specifications of the Directorate General of Highways 2018 Revision 2. Marshall testing was carried out to determine the effect of adding palm frond ash fillers with concentrations of 1,5%, 2%, 2,5% on the resulting value.

2.2 Location and Time of Research

This research was conducted at the Asphalt Mixing Plant Laboratorium PT Anten Asri Perkasa, Bandung City, West Java Province.

This research was conducted from February 2025 to July 2025, with stages ranging from material preparation, testing the characteristics of the AC-WC asphalt constituent mixture, making test objects, Marshall testing and analyzing the research data.

2.3 Research Materials

The materials used in this research include:

- a) The fine aggregate, coarse aggregate, and stone ash used came from the Lagadar area, Bandung Regency, West Java.
- b) The asphalt used was 60/70 penetration asphalt.
- c) The palm frond ash used was flask palm frond ash obtained from palm oil plantation PTPN Subang, West Java.

2.4 Research flow

The research process followed these stages:

- Material testing (aggregate, asphalt, and filler) to verify compliance with Bina Marga standards.
- Preparation of specimens with asphalt contents of 5%, 5.5%, 6%, 6.5%, and 7% to determine optimum asphalt content via Marshall testing.
- Preparation of specimens with palm frond ash content of 1,5%, 2%, 2,5% using the determined optimum asphalt content.
- Evaluation of Marshall characteristics and determination of optimum filler content.

3. RESULTS AND DISCUSSION

3.1 Material Testing Results

a) Results of Physical Testing Of Aggregates

The test results show that the aggregates used in this study have met the 2018 Bina Marga General Specifications for AC-WC mixtures

b) Asphalt Physical Testing Results

Table 2. Asphalt Physical Testing Results

Inspection Type	Inspection Method	Test Result	Speciation		Description
			Minimum	Maximum	
Specific Gravity	SNI 2441:2011	1,030	1	-	Fulfil
Penetration	SNI 2456:2011	60,4 mm	60 mm	70 mm	Fulfil
Softening Point	SNI 2434:2011	50,4 c	48 c	-	Fulfil
Ductility	SNI 2432:2011	135 mm	100 mm	-	Fulfil
Viscosity	SNI 7729:2011	418 cst	300 cst	-	Fulfil
TFOT					
Weight Loss	SNI 7729:2011	0,05%	-	1%	Fulfil
Penetration	SNI 7729:2011	57,2 mm	54 mm	-	Fulfil
Ductility	SNI 7729:2011	120 mm	50 mm	-	Fulfil

Source : (Data Analysis, 2025)

The test results show that the 60/70 penetration asphalt used in this study has met the 2018 Bina Marga General Specifications for AC-WC mixtures.

3.2 Marshall Test Results of Optimum Asphalt

Marshall test results are obtained from making specimens with variations in asphalt content of 5%, 5.5%, 6%, 6.5%, and 7% to obtain the value of Marshall characteristics used for the Optimum Asphalt Content value. Each variation in the percentage of asphalt content made as many as 3 (three) test specimens. The Marshall characteristic values from the Marshall test are shown in the following table.

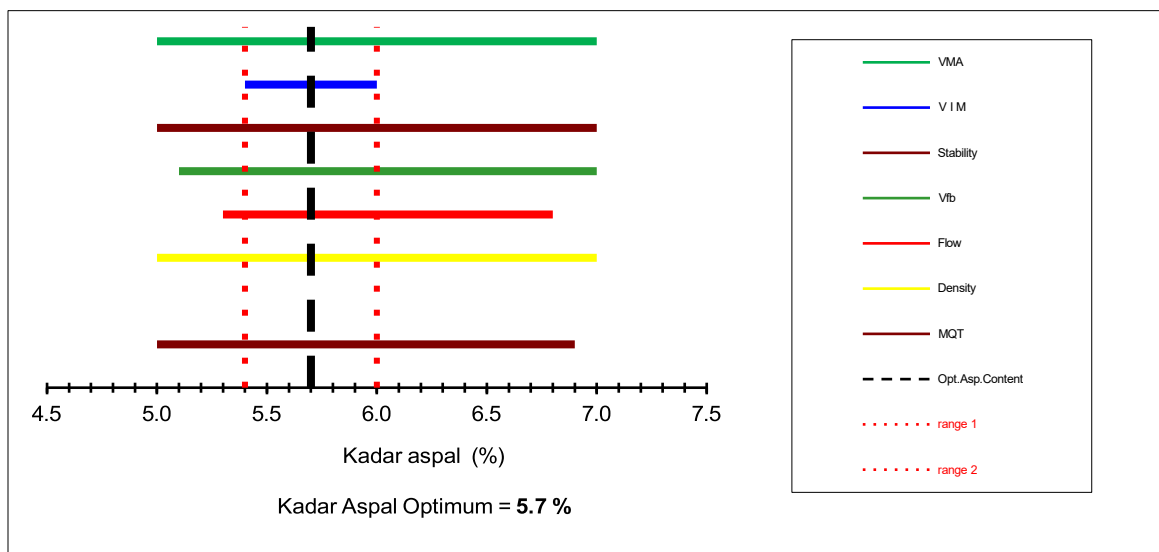


Figure 2. Flow Chart of Research Source : (Data Analysis, 2025)

From the bar graph in Figure 2, it is obtained that the Optimum Asphalt Content that can be taken from Marshall testing is with an asphalt percentage level of 5,7%. So in the mixing of making test objects using palm frond ash filler using a mixture of asphalt content of 5,7% for each filler variation.

3.3 Result of Marshall Testing of Palm frond ash Filler Material

Marshall test results were obtained by making test objects that have been added with palm frond ash filler with variations in filler content of 1,5, 2%, 2,5%. Each variation in the percentage of filler content was made as many as 3 (three) test specimens, so that a total of 15 test specimens were made. The average Marshall parameter values of Marshall tests that have added palm frond ash filler are shown in Table 4 as follows:

Table 4 .Marshall Characteristic Values

Description	UNIT	Grafik KAO	KAO 5.7 %	HASIL TES Penambahan Abu pelepah Sawit			SPEK-SNI 2018 REV-II
				1.5%	2.0%	2.5%	
- Kadar Aspal Optimum	%			5.7			-
- Density	gr/cc	2.281	2.282	2.291	2.288	2.273	-
- VMA	%	15.85	15.79	15.34	15.44	15.94	Min. 15
- VFB	%	75.00	75.85	77.52	76.68	73.56	Min. 65
- VIM	%	4.05	3.82	3.45	3.60	4.22	3.0 - 5.0
- Stability	kg	1090	1007	1080	1137	1177	Min .800
- Flow	mm	2.70	2.86	2.70	2.56	1.94	2.0 - 4.0
- Marshall Quotient	kg/m ²	408	357	402	450	612	Min. 250

Source : (Data Analysis, 2025)

Based on the marshall characteristic value of each palm frond ash filler variation, the variation of palm frond ash content that is used as the Optimum Asphalt Content (KAO) is the variation with 1,5% palm frond ash content. The reason for choosing KAO at 1,5% palm frond ash is based on the values below

1. Highest Stability Value:

At 1,5% palm frond ash content, the Voids and Flow value reached the optimum, which is the highest value

compared to other variations. This indicates the mixture is most capable of withstanding the load before deformation occurs. High stability is important for the road to withstand heavy traffic without premature deterioration.

2. Material Efficiency and Workability:

At 1,5%, the mix was found to be stiff, stable, yet elastic and easy to work with (good workability), making it technically and economically the most ideal choice for road projects.

3.4 Variation of Palm frond ash as Filler and Asphalt Content on Density of Mixture

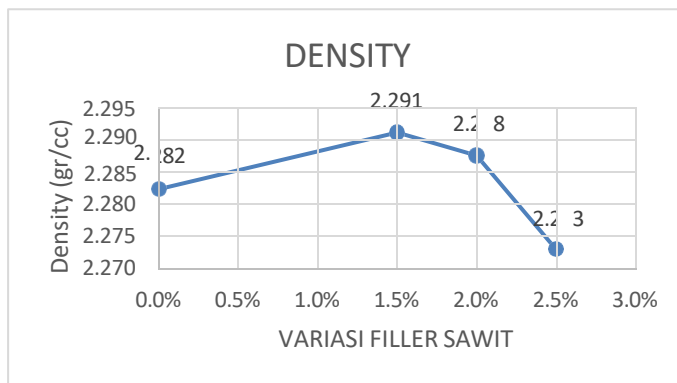


Figure 3. Graph of Density Value Source : (Data Analysis, 2025)

3.5 Variation of Palm frond ash Content as Filler and Asphalt Content on VMA

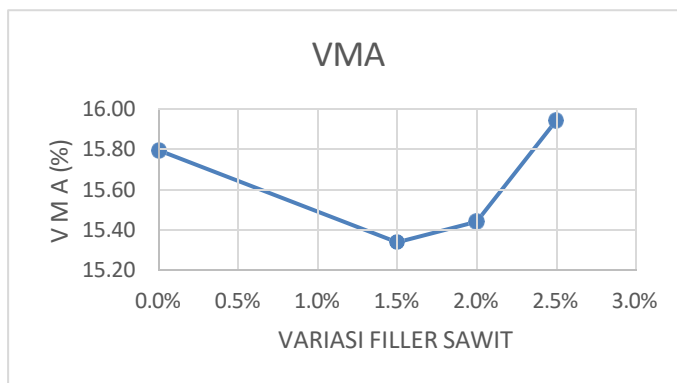


Figure 4. Graph of VMA Value Source : (Data Analysis, 2025)

3.6 Variation of Palm frond ash Content as Filler and Asphalt Content on VIM

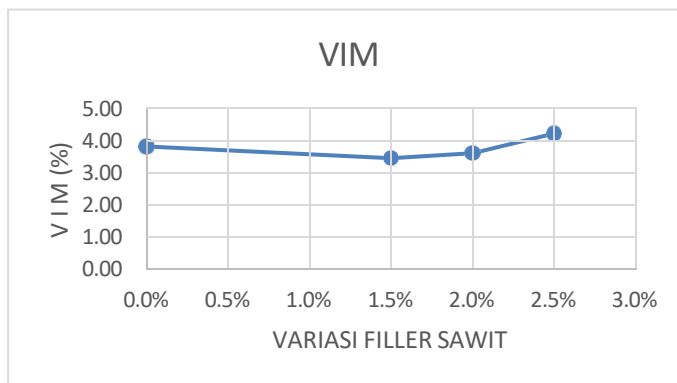


Figure 5. Graph of VIM Value Source : (Data Analysis, 2025)

3.7 Variation of Palm frond ash Content as Filler and Asphalt Content on VFA

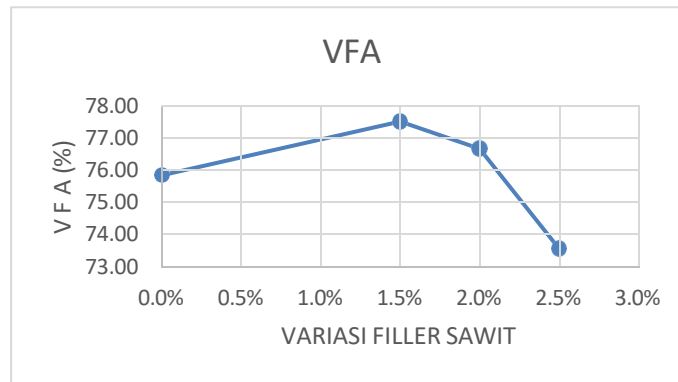


Figure 6. Graph of VFA Value Source : (Data Analysis, 2025)

3.8 Variation of Palm frond ash Content as Filler and Asphalt Content on Stability

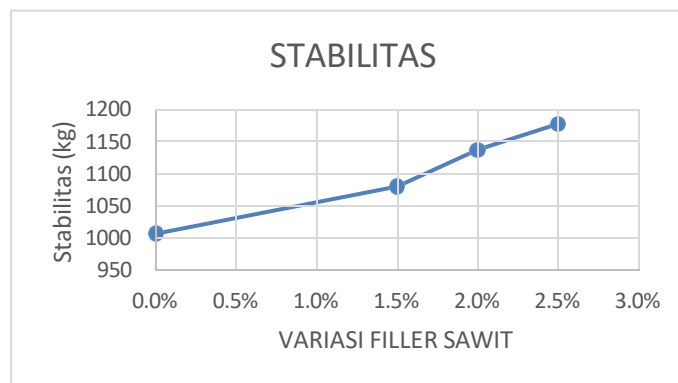


Figure 7. Graph of Stability Value Source : (Data Analysis, 2025)

3.9 Variation of Palm frond ash Content as Filler and Asphalt Content on Flow

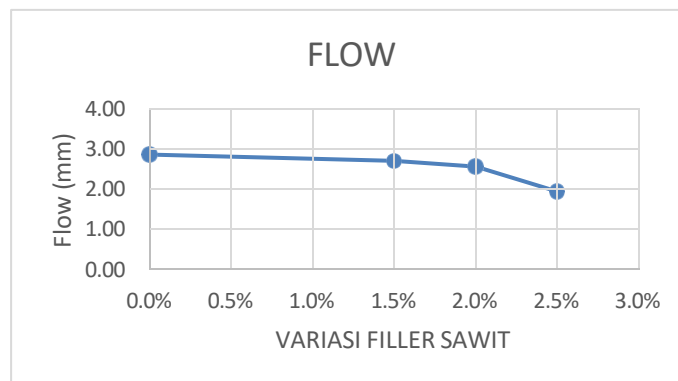


Figure 8. Graph of Flow Value Source : (Data Analysis, 2025)

3.10 Variation of Palm frond ash Content as Filler and Asphalt Content on Marshall Quotient

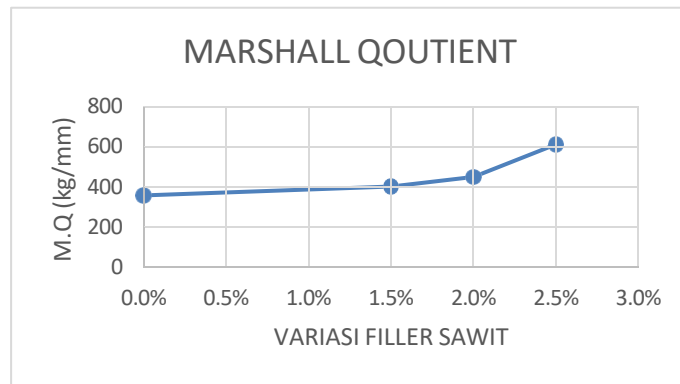


Figure 9. Graph of Flow Marshall Quotient Source : (Data Analysis, 2025)

The results of the research conducted show that palm frond ash filler is one of the relatively good fillers used in pavement construction because the main components of palm frond ash are alkali and silicon dioxide (Fahyuan et al., 2019).

4. CONCLUSION

Based on the research that has been done, several conclusions are obtained including the following:

- 1) Based on the results of Marshall characteristics testing using varying levels of Palm frond ash as filler, obtained:
 - a. Density
 Highest at 1.5% palm frond ash: 2.291 g/cc.
 Density decreases with increasing ash content, indicating that the more ash filler added, the lighter the mixture becomes.
 - b. VMA (Voids in Mineral Aggregate)
 All values meet SNI specifications (min. 15%).
 The highest value at 2.5% ash is 15.94% ⇒ the mixture becomes more porous, but still within acceptable limits.
 - c. VFA (Voids Filled with Asphalt)
 All variations meet the standard (>65%).
 The highest value at 1.5% ash is 77.52%, meaning that the voids in the aggregate are largely filled with asphalt, indicating a denser mixture and resistance to water infiltration.
 - d. VIM (Voids in Mix)
 All variations are within the range of 3.0–5.0%, in accordance with SNI.
 The lowest value at 2.0% ash is 3.45% ⇒ the mixture is dense, with few air voids; the potential for cracking due to expansion/contraction should be noted.
 - e. Stability
 All variations have stability above 800 kg, meeting SNI standards.
 The highest at 2.5% ash is 1177 kg, indicating excellent load-bearing capacity for traffic.
 - f. Flow
 All test results fall within the range of 2.0–4.0 mm, in accordance with standards.
 The lowest value at 2.5% ash (1.94 mm) is slightly below the threshold ⇒ caution is needed as the mixture may become too stiff or brittle.
 - g. Marshall Quotient (MQ)
 MQ is an indicator of the stiffness and deformation resistance of the mixture.
 The highest value at 2.5% ash is 612 kg/mm, far above the minimum requirement of 250 kg/mm ⇒ indicating the mixture is very stiff and resistant to deformation.
- 3) After testing the AC-WC with a mixture of palm frond ash filler, it can be concluded:

- a. The use of palm frond ash filler in AC-WC mixtures provides an increase in stability, Marshall Quotient, and VIM values. These values meet the Marshall requirements according to Bina Marga 2018. However, at higher levels, the mix performance decreased.
- b. Palm frond ash filler results in a stiffer and more deformation stable mix, but should be limited to not exceed the optimum levels to avoid reduced workability and other substandard characteristics.

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