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EFFECT OF PALM SHELL WASTE AS A FILLER IN AC-WC USING LOCAL AGGREGATE

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Abstract

Not all roads in Mamuju are in good condition. Innovation in road pavement materials is needed to improve the performance of road pavements in these areas by utilizing local natural resources. One of the natural resources in Mamuju is palm oil. The rise in palm oil production in Indonesia generates large amounts of palm shell waste, which can pollute the environment if not properly managed. This study analyzes the characteristics of So'do River aggregate and the effect of using palm shell waste as a filler on Asphalt Concrete – Wearing Course (AC-WC) mixtures. The research method was experimental. The asphalt content used in this study was 6.50%. Cement filler was partially replaced with palm shells waste at 0%, 25%, 50%, 75%, and 100%. Marshall tests were conducted following the 2018 General Bina Marga Specifications Revision 2 to measure stability, flow, VIM, VMA, and VFB. Results indicate that So'do River aggregate meets technical standards, and palm shell waste filler affects AC-WC mixture properties, particularly stability and volumetric parameters. The best stability occurred at a 50% palm shell–50% cement ratio. Some substitution levels still comply with specifications, showing palm shell waste has potential as a sustainable alternative filler in AC-WC mixtures.

Keyword: AC-WC, filler, Marshall test, palm shell waste

INTRODUCTION

Not all roads in Mamuju are in good condition. Roads leading to villages and the interior of Mamuju, for example, are often impassable by regular vehicles, only dirt bikes or four-wheel drive vehicles, making access difficult for health workers and residents. Furthermore, sections of the Trans-Sulawesi Highway in Mamuju (such as the Andi Dai/Tuna area) are often slippery and muddy, especially during rain due to spilled soil from projects or logistics activities. Innovation in road pavement materials is needed to improve the performance of road pavements in these areas by utilizing local natural resources. One of the natural resources in Mamuju is palm oil.

The palm oil industry in Indonesia produces palm shell waste that has the potential to cause environmental problems if not managed properly. Disposal or open burning of this waste can pollute the environment and waste resources. Utilizing palm shell waste as an alternative material in road construction can be a sustainable solution. The road surface layer receives direct traffic loads, requiring a stable mixture with good mechanical characteristics. Improving pavement quality can be done by utilizing local materials such as So'do River aggregate and filler from palm shell waste. This study aims to analyze the characteristics of So'do River aggregate and the effect of palm shell waste as filler on the performance of Asphalt Concrete – Wearing Course (AC-WC) mixtures.

Roads are important infrastructure for people's mobility and distribution of goods, so their quality is very important. [1]. Good road conditions directly affect transportation efficiency and user safety. A common surface layer is Asphalt Concrete – Wearing Course (AC-WC), which bears the burden of traffic and is exposed to environmental conditions.[2]. This layer must be able to withstand vehicle pressure while also being resistant to extreme weather. The AC-WC mixture must be precisely designed to be stable, durable, and resistant to deformation. [3]. Proper design ensures longer pavement life and reduced maintenance costs. Asphalt performance is influenced by the aggregate, asphalt, and filler that form the solid mixture structure. [4].

Filler is a fine material that fills the voids between aggregates, increasing the density and bonding of the mixture. [5]. With the proper filler, the porosity of the mixture can be controlled, reducing surface deformation. Fillers are generally derived from minerals such as cement, lime, or fly ash. [6]. While effective, these materials have certain production costs and environmental impacts. However, the use of conventional fillers continues to increase costs and resource consumption. [7]. This has prompted the search for more economical and environmentally friendly alternative materials. Alternative materials are needed that maintain the quality of the mixture. [8]. The selection of new materials must consider compatibility with asphalt and aggregates. One such material is palm kernel shell waste from the processing industry. [9]. This waste has fine particle characteristics that make it a potential filler. Palm oil production in Indonesia produces solid waste that is often underutilized. [10]. If not utilized, this waste accumulates and causes environmental problems. It is usually burned or dumped, leading to pollution and waste. [11]. Improper waste management also means the loss of valuable resources. Using palm kernel shells as filler can reduce environmental impact and increase the value of waste.[12]. The use of this waste supports sustainable development strategies. As a filler, palm shell waste is expected to improve the stability, density, and durability of the mixture. [13].

However, previous studies have not examined the use of palm shell waste as filler on roads in Mamuju. Previous studies show inconsistent results, where pineapple fiber improves durability[14], the use of palm fiber in AC-WC mixtures reduced the stability of the mixture.[15]. The addition of 2.20% palm fiber to the AC-WC mixture increases stability up to 1,581kg [16] and the remaining marshall stability exceeds 90% [17]. The potential use of conductive-fibre-modified asphalt as a cost-effective smart pavement strategy in tropical regions [18].

Initial experiments indicate that the mechanical properties of the mixture can be improved with this natural filler[19]. Research objective is needed to determine the effect of using palm shells waste in AC-WC. The research results will form the basis for recommendations for field implementation. This will serve as an environmentally friendly and economical alternative material for improving road pavement performance. This step aligns with efforts to reduce the costs and environmental impact of modern road pavements.

The limitations of this study are that the asphalt content used is derived from previous research at 6.5% (considering that the optimum asphalt content has maximum stability value), the use of filler is a ratio of cement and palm shell waste content. This study only analyzes the characteristics of aggregates, asphalt fillers, and Marshall.

RESEARCH METHODS

The aggregate was taken from the So'do River, Mamuju Regency, then tested at the UKI Paulus Makassar Laboratory to ensure its compliance with technical requirements. Figure 1,2,3,4 show material location, aggregate taking process, cement as filler, and palm shell waste. This research approach is experimental, namely focusing on direct material testing to obtain physical and mechanical parameters.

The sieve sizes for AC-WC mixture are sieve sizes of 19 mm (100% pass), 12.5 mm (90-100% pass), 9.5 mm (77-90% pass), 4.75 mm (53-69% pass), 2.36 mm (33-53% pass), 1.18 mm (21-40% pass), 0.600 mm (14-30% pass), 0.300 mm (9-22% pass), 0.150 mm (6-15% pass), and 0.075 mm (4-9% pass).

Figure 1. Material Location


Figure 2. Aggregate Taking Process

Figure 3. Cement

Figure 4. Palm Shell

Physical characteristics of aggregates, namely (strength and durability) abrasion (Los Angeles Test): Measures the resistance of aggregates to breakage/wear (maximum 40% for AC-WC). Soundness: Tests weather resistance using Sodium/Magnesium Sulfate solution. Adhesion to Asphalt: Ensures that asphalt does not easily come off the aggregate surface when exposed to water.

Sieve analysis shape and texture: Determines the grain gradation to fit the design envelope (like the previous AC-WC table). Flatness and Elongation Index: Limits the number of grains that are too thin or long because they are prone to breakage. Plane of Breakage: Ensures coarse aggregates have rough (angular) surfaces to allow for interlocking.

Specific gravity and absorption specific gravity (bulk, apparent, SSD): Required for calculating the volume of voids in the mixture (VMA, VIM). Water absorption: The maximum limit is usually 3%. If it is too high, the aggregate will absorb too much asphalt (wasting costs).

Sand Equivalent (SE): Measures the content of clay or fine dust that can reduce asphalt bonding (minimum 50-60%).Clay clumps: ensures there is no soft material that can crumble.

Sample preparation in Marshall Test, the asphalt and aggregate mixture was heated and mixed. Compaction: The sample was placed in a mold and compacted with a hammer with a certain number of impacts (e.g., 75 times per side for heavy traffic loads). Soaking: The sample was cooled, removed from the mold, and then immersed in a water bath at a temperature of 60ºC for 30-40 minutes. The sample was placed on a Marshall Test Set to test its stability and flow. Marshall testing was carried out on 15 test objects (3 per variation) with gradation according to the 2018 General Highways Specifications Division 6. Figure 5 and 6 show specimen and Marshall testing. The results of this test are used to design the ideal mixture composition thus that the road pavement is resistant to dynamic loads and temperature changes.

Figure 5. Specimen

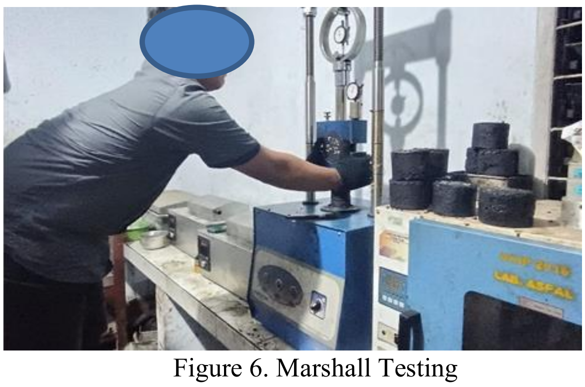

Figure 6. Marshall Testing

RESULTS AND DISCUSSION

Results

Aggregate Characteristics

1. Aggregate abrasion (Los Angeles Abrasion – SNI 2417:2008):

   The wear values for fractions A, B, C, and D are 17.68%, 15.38%, 13.36%, and 10.54%, respectively, all below the maximum limit of 40%, indicating that the aggregate is wear-resistant and meets the requirements[20].

2. Specific gravity and absorption of coarse aggregate (SNI 1969:2016):

   The bulk specific gravity is 2.71, SSD is 2.77, apparent gravity is 2.89, and absorption is 2.40%, all within specifications, so the coarse aggregate can be used[21].

3. Specific gravity and absorption of fine aggregate (SNI 1970:2016):

   The bulk specific gravity is 2.57, SSD is 2.63, and apparent gravity is 2.76, with absorption of 2.78%, indicating that the fine aggregate has good absorption qualities[22].

4. Aggregate sieve analysis

   The percentage of material passing the sieves was within specifications: 100% for 3/4", 92.74% for 1/2", 82.47% for 3/8", 61.73% for No. 4, 48.54% for No. 8, 36.51% for No. 16, 26.29% for No. 30, 17.14% for No. 50, 10.58% for No. 100, 5.61% for No. 200, and 0% for PAN, thus the aggregate gradation met the upper and lower limits for asphalt mixtures[23].

5. Aggregate passed No. 200 sieve (SNI 03-4142-1996)

   A value of 3.41% < the maximum limit of 10%, thus meeting the requirements[24].

6. Fine aggregate silt content (SNI 03-4428-1997)

   The mud content is 3.96%, <5% limit, indicating clean and good fine aggregate[25].

7. Flat and oblong particles

   Flat particles (3/4”, 1/2”, 3/8”, 1/4”) are 7.18%, 6.18%, 9.54%, and 0%, respectively; oblong particles are 3.03%, 3.82%, 9.77%, and 0%, respectively. All are less than 10%, meeting the grain shape requirements[26].

8. Aggregate adhesion to asphalt (SNI 2439:2011)

   Adhesion >95% indicates a very good aggregate-asphalt bond[27].

9. Filler specific gravity check (SNI ASTM C136:2012)

   The filler specific gravity is 2.94 g/cm³, meeting specifications[28].

Asphalt Characteristics

1. Penetration at 25°C (SNI 2456:2011)

   The asphalt penetration value of 65.2 (0.1 mm), within the specification range of 60–70, indicates a balance between stiffness and flexibility[29].

2. Ductility at 25°C (SNI 2432:2011)

The ductility value of 150 cm, exceeding the minimum limit of 100 cm, indicates the asphalt has good tensile strength and is resistant to premature cracking[30].

3. Softening point of asphalt (SNI 2434:2011)

The softening point value was recorded at 50.4°C, exceeding the minimum limit of 48°C, indicating that the asphalt is relatively stable against high temperatures and plastic deformation[31].

4. Flash Point of Asphalt (SNI 2433:2011)

The flash point of asphalt is 280°C, higher than the minimum limit of 232°C, indicating the asphalt's safety during the mixing and compaction process[32].

5. Specific Gravity of Asphalt (SNI 2441:2011)

The specific gravity of asphalt is 1.017g/cm³ > 1.0g/cm³ minimum, making it suitable for use as a binder in asphalt mixtures[33].

6. Weight Loss (TFOT) (SNI 06-2441-1991)

The weight loss percentage is 0.03%, well below the maximum limit of 0.8%, indicating low volatility and resistance of the asphalt to heat aging[34].

7. Penetration at TFOT (SNI 06-2440-1991)

The penetration value after TFOT is 65%, higher than the minimum limit of 54%, resulting in relatively stable asphalt consistency[35].

Filler Characteristics

Test results show that the specific gravity of the palm shell filler is 0.49 (SNI 03-4145:1991 method) [36] . The 2018 General Highways Specifications do not specify a minimum or maximum limit for the specific gravity of the filler.

Mixture Composition

The AC-WC test specimens consisted of coarse and fine aggregates, filler, and asphalt in specific proportions, mixed hot. A total of 15 specimens were used for the Marshall test, and all materials met specifications. Table 1 shows mixture composition.

Table 1. Mixture Composition

Asphalt content (%)	Comparison of cement and palm shells waste	Fine Aggregate (g)	Coarse Aggregate (g)	Cement (g)	Palm shells waste (g)
6.5	100 : 0	626.64	435.84	59.2	0
	75 : 25	626.64	435.84	44.64	14.88
	50 : 50	626.64	435.84	29.76	29.76
	25 : 75	626.64	435.84	14.88	44.64
	0 : 100	626.64	435.84	0	59.2

Stability

The use of palm shell waste filler in the AC-WC mixture (6.50% asphalt content) increases stability up to 50% substitution with a maximum value of 2101.41 kg, then decreases at 75% and 100%. This increase occurs because the filler fills the voids between the aggregates, making the mixture denser and stronger, while too high a substitution reduces the effectiveness of the asphalt. All variations still meet the 2018 General Bina Marga Specifications, with optimum stability at 50% palm shell filler. Figure 7 shows Relationship between Stability and the Proportion of Palm Shell Waste Filler.

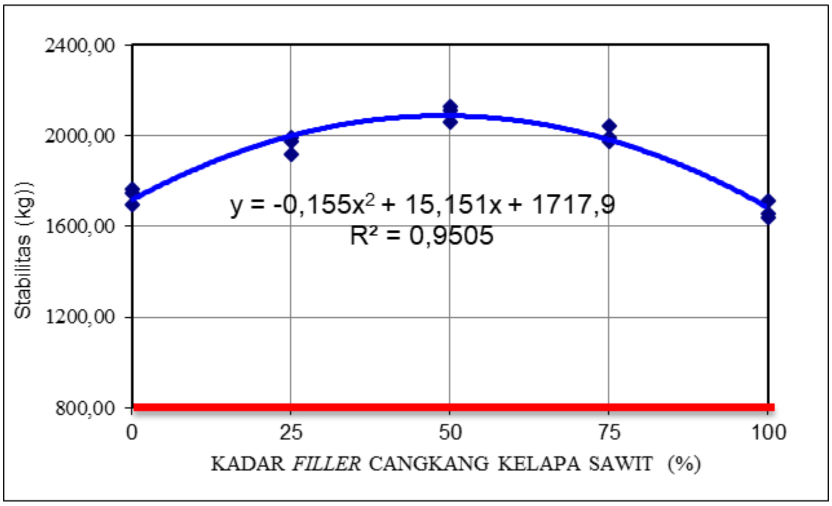

Figure 7. Graph of The Relationship Between Stability and The Proportion of Palm Shell Waste Filler

Flow

Based on the analysis results with a fixed asphalt content of 6.50% and variations in cement filler substitution by palm shell filler, the flow value shows a downward trend from 3.40 mm at 0% content to 3.10 mm at 50% content, then increases to 3.55 mm at 100% content. Although there are changes in the flow value in each variation, all test results still meet the 2018 General Bina Marga Specifications. Figure 8 shows the relationship between flow and palm shell substitution.

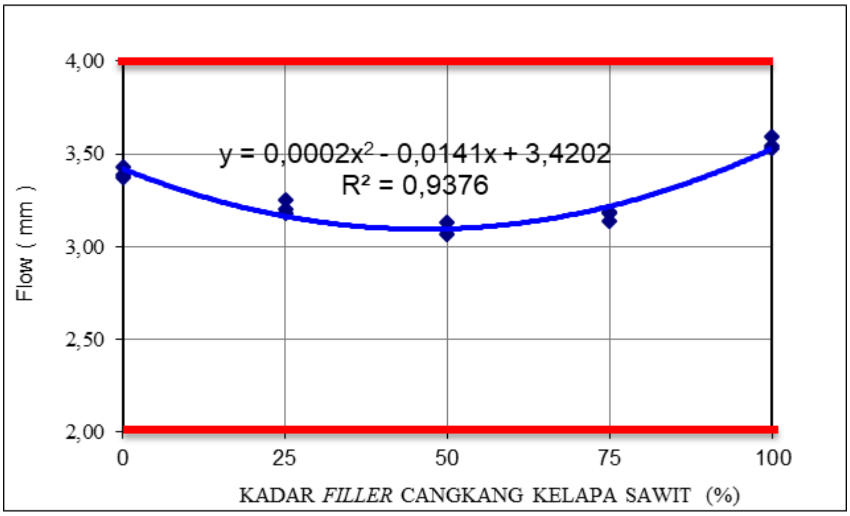

Figure 8. Graph of The Relationship Between flow and palm shell substitution

Void in Mix

Based on the analysis of variations in cement filler substitution with palm shell waste filler, the Void in Mix (VIM) value shows a decreasing trend as the palm shell filler content increases, from 4.86% at 0% to 3.36% at 100%. This decrease indicates that the palm shell waste filler is more effective in filling the voids between aggregates, resulting in a denser mixture. Despite the decrease in the VIM value, all test results still meet the requirements of the 2018 General Highways Specifications. Figure 9 shows the graph of the relationship between VIM and the proportion of palm shell waste as filler.

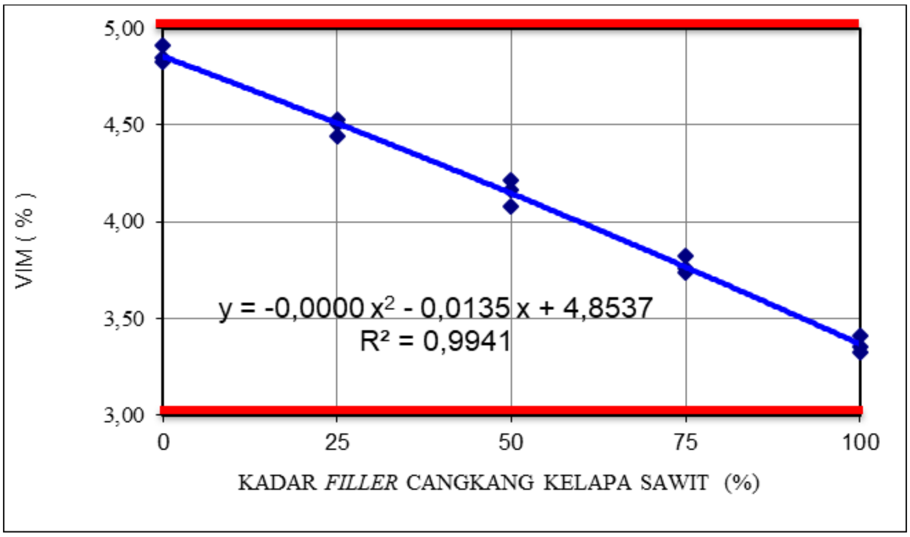

Figure 9. Graph of the Relationship Between VIM and The Proportion of Palm Shell Waste Filler

Void Filled with Asphalt (VMA)

With an asphalt content of 6.50%, the VMA value decreased from 19.06% (0% shell filler) to 18.41% (100% shell filler) because fine particles filled the voids between the aggregates. All values still met the 2018 General Bina Marga Specifications, although excessive substitution can reduce asphalt space and reduce the quality of the mixture bond. Figure 10 shows relationship between VMA and the proportion of palm shell waste filler.

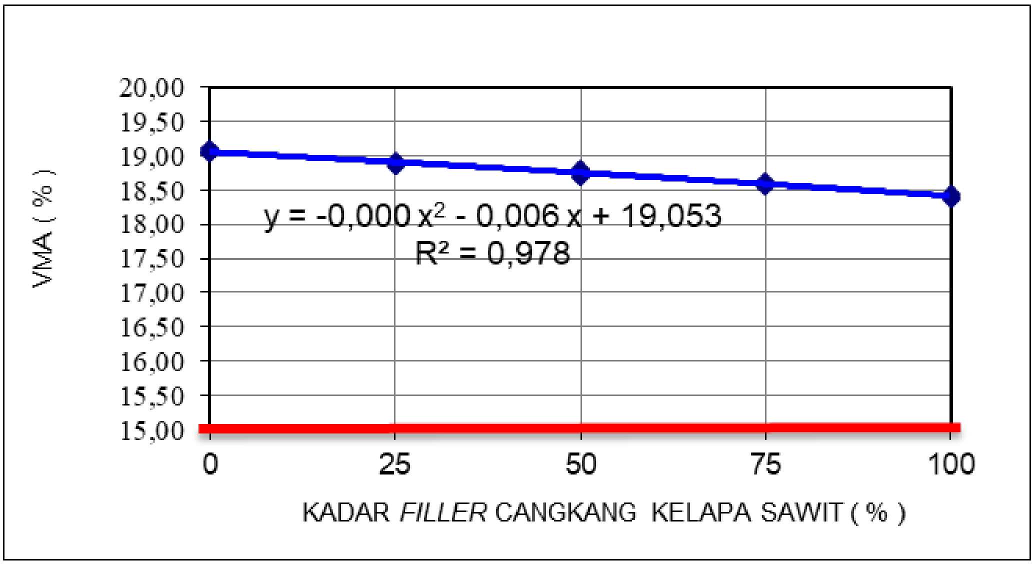

Figure 10. Relationship Between VMA and The Proportion of Palm Shell Waste Filler

Void Filled with Bitumen (VFB)

With an asphalt content of 6.50%, the VFB value increased from 74.50% (0% filler) to 81.73% (100% filler) because the fine particles of palm shell filler filled the voids between the aggregates. All values still met the 2018 General Bina Marga Specifications, indicating that this filler effectively increased the density and binding power of the AC-WC mixture. Figure 11 shows relationship between VFB and the proportion of palm shell waste filler.

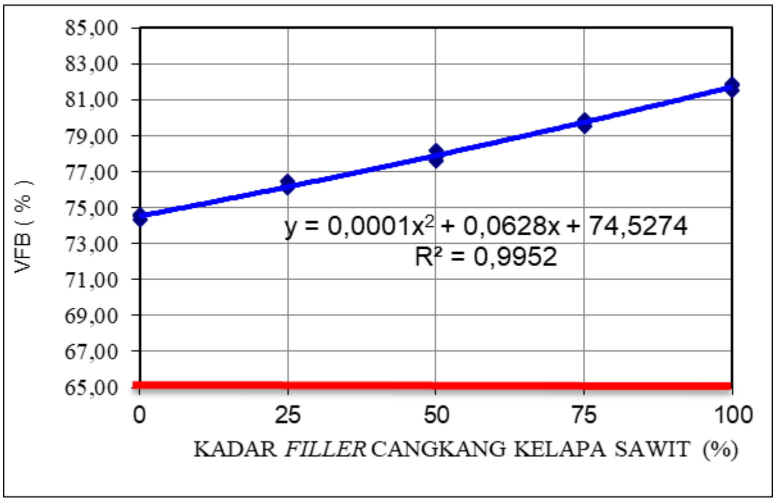

Figure 11. Relationship between VFB and the proportion of palm shell waste filler

DISCUSSION

Overall, neither the use of palm shells as filler nor the use of palm shell content up to 100% meets the minimum stability value requirements for the AC-WC mixture, which is 800 kg. Palm shell waste content up to 50% maximizes the stability value, in this condition the mixture becomes more durable against repeated vehicle loads. However, palm shells waste used above 50% cause the interconnecting between the aggregate, filler, and asphalt to be weaken, and this can cause the mixture to be less dense and cause road damage such as bleeding.

The flow of the AC-WC mixture, whether without or using palm shell waste filler, met the flow range requirements. The flow value decreased by up to 50% when using palm shell filler. This reduced flow in the mixture increased the bond between the road pavement components. Conversely, using palm shell fillers exceeding 50% can cause bleeding, rutting, corrugation, and potholes.

Without the use of filler from palm shell waste, the voids in the mix increased to a maximum. Conversely, using up to 100% reduced the VIM value. However, even using 100% still met specifications. A VIM value exceeding 5% makes compaction difficult, resulting in a stiff mixture, allowing water to easily penetrate, damaging the asphalt bond. A VIM value below 3% causes the mixture to become unstable at high temperatures. The Void in Mix (VIM) value indicates the amount of air voids remaining in the mixture after compaction [37].

The effect of using palm shell waste filler for voids in mineral aggregate meets the minimum specification requirements. However, excessively high VMA values can reduce stability, resulting in reduced resistance to traffic loads. This result is also strengthened by previous research that high VMA values have an effect on stability. [38].

Voids filled with bitumen increase with increasing palm shell waste filler content. However, excessively high VFB values can cause bleeding damage, reduced stability, and over-compacting the mixture. Conversely, excessively low VFB values can cause the pavement to become brittle.

The most ideal combination of cement filler and palm shell waste to create ideal road pavement performance and meet the requirements of AC-WC mixed road pavement specifications is 50:50.

CONCLUSION

The So'do River aggregate and palm shell waste filler have characteristics that meet the 2018 General Bina Marga Specifications, making them suitable for use in AC-WC mixtures. The use of palm shell waste filler has been shown to affect the stability of the mixture, where the stability value increases with increasing filler content until it reaches an optimum condition of 50%, then decreases at higher levels. However, all variations are still within the required specification limits. This indicates that palm shell waste has the potential to be used as an alternative filler material, while supporting the utilization of local materials and more optimal waste management. For further research, it is recommended to conduct studies on variations in filler content, other types of pavement layers, and field-scale testing to obtain more comprehensive mixture performance data.

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