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ANALYSIS OF MARSHALL CHARACTERISTICS WITH ARECA NUT ASH FILLER SUBSTITUTE MATERIAL IN AC-WC CONCRETE ASPHALT MIXTURE

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ABSTRACT

Asphalt is a primary material used in road construction, and improving pavement quality requires environmentally friendly alternative materials. Areca husk ash, which contains high levels of cellulose and silica, has the potential to enhance asphalt mixture performance. This study was conducted to determine the effect of using areca husk ash as a filler substitute in AC-WC mixtures. The Marshall test method was applied with filler substitution variations of areca husk ash to stone dust at 0%, 20%, 40%, 60%, 80%, and 100%, as well as asphalt content ranging from 4.5% to 6.5%. The test results showed that all mixture variations were still within the limits of the 2024 Bina Marga specifications. The optimum asphalt content (OAC) tended to decrease as the proportion of areca husk ash increased, with the highest value obtained at 20% substitution (6%). Thus, areca husk ash can serve as a partial filler substitute without reducing AC-WC quality, although its use should be limited to maintain the stability and performance of the mixture in accordance with technical standards.

Keywords: AC-WC, areca palm fiber, asphalt, Marshall characteristics

1. INTRODUCTION

Asphalt is the main material in highway construction that functions as aggregate binders and cavity fillers to form flexible pavement. However, its use in large quantities is less efficient so alternative materials are needed that can improve the performance of the mixture while reducing dependence on pure asphalt. One of the materials that has the potential to be used is ash from burning areca nut nut ash.

Areca nut is a palm plant that is widely found in Indonesia, but its nut ash waste is often not used and is only burned. In fact, areca nut nut ash contains cellulose, silica, and pectin with high levels of cellulose (70.2%) and 6.02% ash which has the potential to increase the strength and durability of paved mixtures (Hasanuddin et al., 2019). The use of areca nut nut ash ash is not only economically valuable, but also supports the reduction of agricultural waste and the principles of sustainable development.

In road construction, AC-WC mixtures require fillers to fill the interaggregate cavities, improve stability, and reduce air cavities. Areca nut nut ash ash has the potential to be an alternative filler, so Marshall testing was carried out to assess its effect on the stability, flow, air cavity, and density of the mixture.

2. THEORETICAL FOUNDATION

Pavement Layer

The surface course serves to withstand the load of traffic, channel pressure to the lower layer, and protect it from water. This layer must also be safe for vehicles with a rough enough texture to prevent damage such as rutting, corrugation, and cracking. Based on their nature, the surface layer is divided into non-structural (burda, burtu, latasir, buras, latasbum, lataston/HRS) and structural (lapen, latasbug, laston/AC) (Sari, 2021).

Aggregate is the main component of the pavement layer with a ratio of 90%-95% aggregate based on weight percentage or 75%-85% aggregate by volume. A good quality aggregate is needed for a surface layer that directly bears the load of traffic and spreads to the layer below it (Gazalie, 2017).

Fillers can be in the form of various materials such as limestone, dolomite dust, portland cement, fly ash, dust from high furnaces, and other nonplastic minerals. This fine material must pass through a sieve No. 200 with a size of 0.075 mm. The main role of fillers is to increase the viscosity of asphalt while reducing the sensitivity of the mixture to temperature changes (Gunarto, 2019).

Asphalt is a hydrocarbon material that has adhesive properties, is black-brown, and shows viscoelastic characteristics. The source of asphalt can come from nature or petroleum processing. Asphalt or bitumen is a viscous liquid consisting of hydrocarbon compounds with relatively small amounts of sulfur, oxygen, and chlorine (Utami et al., 2020).

Hard asphalt or cement asphalt is physically a solid material at room temperature and has thermoplastic properties. This means that asphalt will melt when heated to a certain temperature, then harden again when the temperature drops. The asphalt content in the pavement mixture usually ranges from 4–10% of the total weight of the mixture, or around 10–15% (Sukirman, 2016).

Areca Nut Husk

So far, the use of areca nut plants is generally limited to the seeds for medicine, cosmetics, or dyes, while the fruit fibers are only waste that is often burned. In fact, areca nut fiber contains cellulose, ash, and water so it has the potential to be used, one of which is as a raw material for briquettes to replace oil (Hasanuddin et al., 2019).

Areca nut nut ash ash has a silica content of 29.17–45.43% which is the dominant component, so it has the potential to be used as an alternative source of silica in the synthesis of glass-ceramics and supports environmentally friendly management of agricultural waste. Thus, areca nut nut ash ash can be categorized as a sustainable alternative silica material that contributes to the development of environmentally friendly construction materials (Anuar et al., 2021).

The use of areca nut ash as a filler in the AC-BC mixture is able to increase stability up to 50% variation with an average of 3569.23 kg, but at higher levels the stability tends to decrease even though it still meets the standard. The highest flow parameter is obtained at 25% at 4.5 mm and continues to decrease to 1.8 mm at 100%, indicating that the mixture is getting stiffer. This condition is in line with an increase in Marshall Quotient (MQ) to 2082.32 kg/mm at 100%, which can reduce flexibility and trigger cracking. Therefore, the optimum level of areca nut ash as a filler is in the range of 25–50% (Utami et al., 2020).

Asphalt Mix

Hot asphalt mixture is a combination of aggregate and asphalt mixed at a certain temperature, so that the entire aggregate surface is evenly coated with asphalt (Apriyanto, 2018).

Asphalt concrete mixture is a combination of aggregate and asphalt that is designed to meet technical specifications. Material characteristics are determined by physical properties such as specific gravity, absorption, gradation, as well as asphalt properties such as penetration and viscosity. In Indonesia, mixed design is generally carried out using an empirical method using the Marshall test (Sukirman, 2016).

3. METHOD

The Marshall test method is used based on the 2024 Bina Marga General Specification on AC-WC mixtures with asphalt content of 4.5%–6.5%. Variations are

carried out through substitution of areca nut ash filler against rock dust by 0%, 20%, 40%, 60%, 80%, and 100%. All materials used have been tested according to SNI and meet technical specifications, with the parameters analyzed including stability, flow, VIM, VMA, VFB, density, and Marshall Quotient.

4. RESULTS AND DISCUSSION

Mixed Design Analysis

The design of the AC-WC mixture in this study was carried out by trial *and error method* adjusted to applicable technical standards. The aggregate composition is set at 12% for 1–2 coarse aggregates, 45% for 1–1 coarse aggregates, 40% for fine aggregates (rock ash), and 3% for rock dust fillers. The results of the calculation and preparation of proportions are then compared with the gradation provisions in the 2024 General Specification of Highways, and a combined gradation curve is obtained that is fully within the required limits. Furthermore, the mixture was tested with a variation in asphalt content of 4.5% to 6.5% and betel nut ash filler substitution of 0%, 20%, 40%, 60%, 80%, and 100%. Thus, the mixed design used in this study has met the technical requirements as the basis for the manufacture of test specimens and the determination of the optimum asphalt level through Marshall testing which can be seen in Table 1

Table 1 Lataston AC-WC Mix Design

No. Aggregate Sieve		Aggregate 1-2 (%)	Aggregate 1-1 (%)	Stone Ash (%)	Filler (%)	Combined Aggregate	Aggregate Specification
Inch	mm						
¾	19.100	100	100.00	100	100	100	100
⅜	9.520	6.51	89.42	100	100	84.02	77-90
No. 4	4.750	0.23	40.97	99.56	100	61.28	53-69
No. 8	2.360	0.17	7.47	87.06	100	41.20	33-53
No. 16	1.180	0.14	2.11	66.66	100	30.63	21-40
No. 30	0.600	0.07	0.85	50.60	100	23.63	14-30
No. 50	0.300	0.04	0.40	35.71	100	17.47	9-22
No. 100	0.150	0.02	0.25	20.87	100	11.46	6-15
No. 200	0.075	0.02	0.08	7.5	100	6.04	4-9

Test Specimen Processing

The determination of the optimum asphalt level (KAO) was carried out in the range of 4.5%–6.5% according to the 2024 Highway Specifications. The KAO value is determined based on the results of the Marshall test which shows that the mixture meets the requirements. The test includes AC-WC without and with areca nut ash substitution to see the difference in characteristics. Furthermore, the total weight of the mixture is

arranged based on the proportions of aggregate and asphalt and adjusted to the mold capacity. The results of the KAO determination for each nut ash ash variety are shown in Table 2.

Table 2 Recapitulation of Optimum Asphalt Yield

variation	mixture proportions		KAO (%)
	SP	DB	
	%		
1	100	0	5,55
2	80	20	5,63
3	60	40	5,74
4	40	60	5,90
5	20	80	6,00
6	0	100	6,11

It can be seen in Table 2 that the greater the percentage of areca nut nut ash ash, the value of the optimum asphalt content (KAO) tends to decrease. The asphalt content in the SP variation is 100% lower than the SP 0%. This is influenced by the smaller specific gravity of areca nut nut ash ash, so that the need for asphalt to coat the aggregate is also reduced. This condition shows that the use of areca nut nut ash ash can reduce the need for asphalt while utilizing organic waste as an alternative filler.

Marshall Test Results

Marshall testing was carried out to determine the characteristics of the AC-WC mixture with a variety of areca nut ash fillers. The parameters tested included stability, flow, Marshall Quotient (MQ), Void in Mix (VIM), Void in Mineral Aggregate (VMA), Void Filled Bitumen (VFB), and density. The test results of each parameter are presented in the form of a table and analyzed in accordance with the provisions of the 2024 Highway Specification.

1. Stability

The stability of the AC-WC mixture with areca nut nut ash ash showed the highest value at 6% SP 80% asphalt content of 1432.56 kg, while the lowest value at 4.5% SP 80% was 1072.22 kg, as can be seen in Table 3.

Table 3 Stability Values with Variations of Areca Nut ash Mixture

Mixed Variations		Stabilty				
		Aspalt Rate				
SP	DB	4.5	5	5.5	6	6.5
(%)						
100	0	1290.958	1562.304	1397.575	1338.537	1307.080
80	20	1312.863	1583.936	1489.595	1375.534	1283.988
60	40	1242.42	1611.30	1404.71	1348.09	1179.95
40	60	1093.651	1452.632	1410.579	1329.460	1201.367
20	80	1072.28	1223.87	1230.83	1217.29	997.99
0	100	1181.024	1461.666	1607.377	1598.012	1297.393

2. *Flow*

The mixed flow is in the range of 2.72–4.60 mm, with the largest value at 4.5% SP 100% and the smallest at 6.5% SP 80%, as can be seen in Table 4.

Table 4 Flow Values with Variations of Areca Nut ash Mixture

Mixed Variations		Flow				
SP	DB	Asphalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	2.76	3.05	3.57	3.76	5.17
80	20	4.69	4.00	3.61	3.97	4.58
60	40	3.51	4.19	4.00	3.93	4.81
40	60	3.63	4.11	4.00	3.84	4.72
20	80	3.25	3.46	3.14	3.62	3.83
0	100	3.76	3.63	3.84	3.94	4.00

3. *Marshall Quotient* (MQ)

MQ values vary between 309.5–379.5 kg/mm, with highest yields at 6% SP 80% and lowest at 4.5% SP 60%, as can be seen in Table 5.

Table 5 MQ Values with Variations of Areca Nut ash Mixture

Mixed Variations		MQ (kg/mm)				
SP	DB	Aspalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	469.116	512.302	392.504	357.466	253.504
80	20	280.337	394.899	412.793	346.131	282.317
60	40	354.198	384.777	350.619	343.804	245.377
40	60	301.651	355.045	352.752	346.857	255.034
20	80	332.56	354.14	393.51	337.75	263.37
0	100	315.527	403.617	419.073	406.772	324.597

4. *Void In Mix* (VIM)

The percentage of VIM was recorded between 3.5–4.8%, with the highest value at 4.5% SP 0% and the lowest at 5.5% SP 80%, as can be seen in Table 6

Table 6 VIM Values with Variations of Areca Nut ash Mixture

Mixed Variations		*VIM*				
SP	DB	Asphalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	6.82	5.64	4.47	3.49	3.19
80	20	6.97	5.83	4.70	3.51	2.76
60	40	6.89	5.56	4.83	4.04	4.02
40	60	7.21	6.08	4.49	4.06	4.41
20	80	7.45	6.30	4.89	3.93	4.37
0	100	7.22	6.33	5.18	4.71	4.42

5. *Void In Mineral Aggregate* (VMA)

The VMA value is in the range of 15.2–17.8%, with the highest value at 4.5% SP 0% and the lowest at 5.5% SP 80%, as can be seen in Table 7.

Table 7 VMA Values with Mixed Variations of Areca Nut ash

Mixed Variations		*VMA*				
SP	DB	Asphalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	15.04	15.02	15.02	15.19	15.97
80	20	15.20	15.22	15.25	15.25	15.63
60	40	15.14	15.00	15.39	15.74	16.76
40	60	15.46	15.49	15.13	15.79	17.13
20	80	15.70	15.72	15.51	15.71	17.13
0	100	15.51	15.77	15.79	16.43	17.21

6. *Void Filled Bitumen* (VFB)

The VFB shows a range of 72–82%, with the highest values at 5.5% SP 80% and the lowest at 4.5% SP 0%, as can be seen in Table 8.

Table 8 Values of VFB with Mixed Variations of Areca Nut ash

Mixed Variations		*VFB*				
SP	DB	Asphalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	54.66	62.47	70.22	77.05	80.03
80	20	54.17	61.68	69.26	76.96	82.38
60	40	54.73	62.96	68.72	74.39	76.14
40	60	53.52	60.77	70.41	74.34	74.43
20	80	52.58	59.91	68.48	74.98	74.55
0	100	53.50	59.85	67.23	71.32	74.32

7. *Density*

The density of the mixture ranges from 2,285–2,305 gr/cc, with the highest density at 6% SP 20% and lowest at 6.5% SP 100%, as can be seen in Table 9.

Table 9 Density Value with Variations of Areca Nut ash Mixture

Mixed Variations		Density				
SP	DB	Asphalt Rate				
(%)		4.5	5	5.5	6	6.5
100	0	2.26	2.27	2.28	2.29	2.28
80	20	2.26	2.27	2.28	2.30	2.30
60	40	2.27	2.29	2.29	2.29	2.27
40	60	2.27	2.28	2.30	2.30	2.27
20	80	2.27	2.28	2.30	2.30	2.28
0	100	2.28	2.29	2.30	2.29	2.28

DISCUSSION

Once all Marshall parameters have been analyzed, the next stage is the determination of the optimum asphalt content (KAO) for each mixture variation. The recapitulation of the Marshall test results on each mixture variation with areca nut ash can be seen in Table 10

Table 10 Recapitulation of Marshall Characteristic Results in KAO

Mixed Varitations (%)		Limit of Asphalt Content (%)	KAO (%)	Characetistics of Marshall						
SP	DB			Stability (Kg)	*Flow* (mm)	VIM (%)	VMA (%)	VFB (%)	MQ (Kg/mm)	*Density*
100	0	5.2 - 5.9	5.55	1368.06	3.66	3.98	15.11	73.64	375.0	2.290
80	20	5.35 - 5.9	5.63	1432.56	3.79	4.11	15.25	73.11	379.5	2.290
60	40	5.33 - 6.15	5.74	1376.40	3.96	4.43	15.75	71.55	347.2	2.290
40	60	5.33 - 6.5	5.9	1370.02	3.92	4.28	15.46	72.37	349.8	2.300
20	80	5.5 - 6.5	6	1217.29	3.62	3.93	15.71	74.98	337.8	2.305
0	100	5.72 - 6.5	6.11	1447.70	3.97	4.57	16.82	72.82	365.7	2.288
Spec.				> 800	2 - 4	3 - 5	> 15	65 - 75	-	-

The test results show that all variations of the AC-WC mixture with areca nut ash filler still meet the 2024 Bina Marga Specifications. The value of KAO decreases as the proportion of areca nut filler increases due to the difference in specific gravity with stone dust. Substitutions up to 80% are capable of providing good Marshall characteristics, with the highest stability at 80% (1432.56 kg) and the best density at 20% (2,305 gr/cc). At 100% areca nut nut ash ash, the quality of the mixture tends to decrease. Overall, areca nut nut ash ash can be used as an alternative to environmentally friendly fillers in AC-WC mixtures with optimal proportions between 20%–80%.

5. CONCLUSION

Based on the results of the research on the mixture of AC-WC mixture with areca nut ash as a replacement filler, it was concluded that areca nut nut ash ash as a filler affects the characteristics of Marshall in the AC-WC mixture. The best conditions are obtained

in the substitution of 20% with a 6% KAO because it is able to maintain the balance of stability, flow, VIM, VMA, VFB, MQ, and density. However, there are several combinations that do not meet the specifications of Bina Marga 2024, namely asphalt content of 4.5% with areca nut nut ash ash of 69–89%, asphalt content of 5% with 37–79%, asphalt content of 5.5% with 0–19%, asphalt content of 6% with 68–100%, and asphalt content of 6.5% with 27–100%, so its use needs to be limited.

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