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Application of Alternative Filler in Asphalt Mixture: An Overview from Indonesia Perspective

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Abstract. A good quality and proper quantity of filler material is one of the significant factors in producing asphalt mixture. Many studies have been highlighted waste material as an alternative filler to improve asphalt mixture performance. Hence, this paper reviewed the performance of asphalt mixture using rice husk ash (RHA) as filler in terms of the Marshall properties. It shows that 6% RHA by weight of total aggregate was commonly used and depicted better in Marshall properties than the others. This study also found that the RHA can be used to replace up to 100% of the conventional filler. Even though, higher RHA content could significantly reduce the stability yet it still within the acceptable range and could be applied at medium traffic load road. In return, the higher the RHA content the more waste material can be utilized for road construction. Thus, minimized the usage natural source materials.

1. Introduction

Flexible pavement constructed with four layers namely surface course, base course, subbase and subgrade. While, surface course constructed in two layers which are wearing course (WC) and binder course (BC). Proper asphalt mixture design of WC and BC courses is needed to provide a good pavement performance throughout its service life. Improper design and quantity are one of the crucial issues that leads to increasing air void, causing permanent deformation and reducing its performance. In general, asphalt mixture consists of asphalt, coarse aggregate, fine aggregate and filler. Asphalt mixtures is a well graded mixture containing coarse aggregate (50-65%), fine aggregate and filler (35-50%), asphalt (5-8%) of total mass of aggregate [20]. Filler is the component that are dry, free from lumps and passing sieve no 200 (75 Micron). Commonly, materials used as filler are Portland cement, lime ash or fly ash [1]. Among them, filler is one of the most important components of asphalt concrete. It plays a significant role on the properties of asphalt mixtures. Properly designed and constructed surfaces of this general type are capable of carrying almost unlimited volumes of passenger, mixed, or truck traffic, provided only that they are supported by adequate foundation structures. The majority of these surfaces might be expected to have an economic life of 20 years or more[21]. Filler is one of the factors that influenced the asphalt mixture by increasing the density and minimising the mixture's permeability. Filler also affects the elasticity of the mixture and its sensitivity to water [2]. Production of asphalt mixture involves large quantity of natural sources materials and including filler. In order to provide possible alternative for filler, many potential materials have been studied by researchers and one of them is rice husk ash (RHA). It is the result of burning the waste of rice husks.

Since 90% of global production of rice is form Asian countries such as China, India, Indonesia, Bangladesh, Vietnam and Thailand, abundant of rice husk waste can be collected for research purposes.

As in other countries, Indonesia has also conducted studies on the use of RHA in road construction for the past 20 years. Hence, this paper aimed to review the usage of RHA as a filler in asphalt mixture based on the study conducted in Indonesia.

2. Material and Laboratory Test

2.1. Filler
Filler content affects the process of mixing, spreading and compaction of asphalt mixture. In addition to its size which must be relatively fine, the filler material must have certain properties such as cementitious properties when exposed to water and high adhesion with other aggregates. Among the materials that have cementation properties when exposed to water and are widely used as filler materials are rock ash, fly ash, gypsum, Portland cement (PC) and tiles ash. Previous studies also proved that rice husk ash (RHA) is believed to have good properties as a compactor filler because it has cementation properties, in addition to its relatively small grain size. Besides, the abundance of rice husk has given advantage to be used as alternative filler where the cost is cheaper and easier to obtain.

2.2. Rice Husk Ash (RHA)
Rice husk or grain skin is waste from rice milling process where husk is the second largest part after rice. Milling process produced about 65% rice and 20% rice husk [3]. While rice husk ash (RHA) as shown in Figure 1 is the result of burning the rice husk. It is the 15 % of combustion waste from rice husks, which are usually used as fuel in burning raw bricks.

Figure 1. Rice husk ash.

Rice husk is composed of a network of cellulose fibres that contain high silica content in the form of tough fibres. Based on previous studies, RHA consist of high content of silica (SiO_2) element with a range of 72.29% to 96.7% [1-2,4-6]. High temperature in the combustion process changed the silica structure, affecting the level of pozzolan activity and the smoothness of ash grains. This pozzolan contains cementitious properties when mixed with water [2]. The other chemical composition of rice husk ash was shown in Table 1. While, in term of specific gravity, Rosyidi et al. [7] found that rice hulk ash filler shows lower specific gravity with 0.947 than fly ash filler (as shown in Table 2).

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Table 1. Composition of RHA.

Components	Percentage (%)				
	[1]	[2]	[4]	[5]	[6]
SiO_2	86.89	96.7	92.99	96.7	72.28
$Al2O_3$	1.58	1.01	0.18	1.01	0.37
Fe_2O_3	0.48	0.05	0.43	0.05	0.32
CaO	1.99	0.49	1.03	0.49	0.65
K_2O	5.35	0.91	0.72	0.91	-
Na_2O	0.82	0.26	0.02	0.26	-
MgO	1.29	0.22	0.35	0.22	-
TiO_2	-	0.16	-	0.16	-
P_2O_5	-	0.01	-	0.01	-
MnO	-	0.19	-	0.15	-
SO_3	0.71	-	-	-	-
Water Content	0.52	-	-	-	-

Table 2. Specific Gravity filler [7]

Specific Gravity	Value	Unit
Rice Husk Ash	0.947	g/cm3
Fly Ash	2.688	g/cm3

2.3. Mixture Design & Laboratory Test

In general, there are three layers of asphalt mixture used in flexible pavement in Indonesia. The layers are wearing course (AC-WC), binder course (AC-BC) and base course (AC-Base). The gradation limits used by previous studies complied to Bina Marga published in 2014 [8]. The gradation limits are shown in Table 3. While, amount of filler used is varied based on the respective studies (as shown in Table 4).

Table 3. Gradation limit for asphalt mixture [8].

Sieve size (mm)	Percentage by weight passing	
	AC-WC	AC-BC
37.5	-	-
25	-	100
19	100	90-100
12.5	90-100	75-90
9.5	77-90	66-82
4.75	53-69	46-64
2.36	33-53	30-49
1.18	21-40	18-38
0.6	14-30	12-28
0.3	9-22	7-20
0.15	6-15	5-13
0.075	4-9	4-8

Table 4. Amount of filler for asphalt mixture.

Previous study	Filler Percentage	
	RHA	dust
Syahputra et al. [1]	6	-
Akbar and Wesli [4]	6	-
	-	6
Ismardani and Kasan [5]	1.5	4.5
	6	-
Basuki et al. [9]	6	-
Ferdiana [10]	4	2
Asparini and Sulistiono [11]	6	-
Maulana and Empung [12]	2	4
Ridwan and Nadia [13]	7	-

All mixtures were prepared based on the Marshall mix method and complied the specifications published in Bina Marga 2014 (as shown in Table 5) [8].

Table 5. Marshall properties [7].

Properties	Unit	AC	Modified AC
Density	g/cm^3	2	2
Air voids in mix (VTM)	%	3-5	3-5
Voids in mineral aggregate (VMA)	%	15	15
Voids in aggregate filled with bitumen (VFA)	%	65	65
Stability	N	8000	10000
Flow	mm	2-4	4
Marshall Quotient (Stiffness)	N/mm	2500	3000
Residual Stability	%	90	90

3. Marshall Properties

Recent study conducted by Saepudin [14] in 2021 showed the Marshall parameters using RHA as filler with 6% of optimum binder content (OBC), as presented in Table 6. The data shows that the increase of RHA percentage, increases stability and Marshall quotient but starts to decrease at percentage 7%. The highest stability and Marshall quotient were recorded by 6.5% of rice hulk ash with 9964 N and 2880 N/mm, respectively, followed by 6.0, 5.5, 5.0 and 7.0 %. Only at 6.5% RHA content, all Marshall properties requirement are met. Thus, 6.5% shows the optimum amount of RHA content for the mixture. The reason behind the deviation in optimum binder content (OBC) for RHA be connected to the fact that controls the change in air voids in the mixtures.

Table 6. Marshall Properties using RHA as filler [14].

Mixture requirement	Percentage of rice hulk ash content (%)									
	5.0		5.5		6.0		6.5		7.0	
Stability (N)	8591	✓	9709	✓	9787	✓	9964	✓	9335	✓
Flow (mm)	2.92	✓	3.30	✓	3.00	✓	3.46	✓	3.74	✓
Marshall quotient (N/mm)	2942	✓	2942	✓	3262	✓	2880	✓	2496	✓
VIM (%)	7.56	✗	6.34	✗	5.06	✗	3.65	✓	2.68	✗
VFA (%)	56	✗	65	✓	70	✓	80	✓	85	✗
OBC	6.0%									

Study by Saepudin [14] was compared with other previous studies to observe any trend in Marshall properties due to varied content of RHA. The properties are Stability, Flow, VTM/VIM, Marshall Quotient and Residual Stability. Results of each property are depicts in Figure 2 to Figure 6. The RHA content used in previous study is from 1.5% to 7% with typical RHA content of 6% was used. In general, no consistent trend can be concluded based on the previous results. From the figure, lower RHA content shows an increasing on the stability (MS) value compared to higher RHA content. For instance, the MS of the mixture with RHA containing 1.5% and 2% are increased to 18kN and 16kN respectively compared to the mixture with RHA containing 6%, 6.5% and 7% are decreased to 8kN, 9kN, 9.5kN and 8.5kN. However, an increase in RHA content will reduce the stability value but still within the acceptable range outline by the specification. This trend is consistent with the finding by Rosyidi et. al, [7] where low specific gravity of RHA could be one of the factor contribute to lower stability value. Furthermore, low specific gravity mixture still applicable at the medium traffic load area. This improvement in Marshall stability for RHA mixtures can be attributed to the irregular particles of RHA [15] that may enhance the shear strength and stiffness of the modified binder.

In the case of flow values, most of the prepared mix lies between the specified limit of 2-4mm [16]. Also, the voids in mineral aggregate (VMA) and voids filled with bitumen (VFB) values did not cross the specified limits. From Figure 3, most of the percentage of RHA content used as filler in asphalt mixtures lies between the specified limit which are 3.8mm, 3.3mm, 2.4mm, 4mm, 2mm and 3.3mm except for some cases from the previous study that shows the flow values exceed 4mm. The flow value reflects the plasticity and flexibility properties of asphalt mixtures. Marshall Samples corresponding to the deformation of the load are broken, which represents a measure of the flow and also the value of mixing and flow with the value of internal friction. Flow has a linear inverse relationship with internal friction [17-18].

As it is known, increment in bitumen content slowly decreases the air void and all the studied fillers follow the said pattern individually. However, with increment in filler percentage, the air void in the mixture having RHA continuously is increasing respective to same bitumen content for all the filler percentages as shown in Figure 4. This phenomenon may be occurred due to the presence of more fine particles of RHA in the mixture pushes the coarse aggregates. As a result, the coarse aggregates suspend in the fine particles. All the alternative fillers like RHA nearly follow the same path as HL except 7% RHA content, where air void values are more than that of 5% maximum specified value (Figure 4). This trend may be credited to the fact that RHA, due to its high SSA and porous structure, has a propensity to absorb bitumen binder, making the bitumen film on aggregate thicker, which efficiently reduced the air voids of the mixture [19].

Furthermore, the change in Marshall Quotient (MQ) values may explain the nature of the obtained Marshall test results effortlessly. Marshall quotient (MQ) is defined as the proportion of stability (kN) to flow (mm), and as a hint of the stiffness of mixtures. It is well accepted that the MQ is a quantifier of the materials' resistance to shear stresses, permanent deformation, and hence rutting. The outcome of all the different RHA content on MQ values is shown in Figure 5. As a whole, the MQ values for 6% of RHA shows an increasing values which are 4.5 kN/mm and 3.6kN/mm, respectively. Nevertheless, with more added in filler quantity for RHA mixes, the MQ values gradually escalate and surpass the maximum permissible specified limit of MQ of 5 kN/mm [16]. For this reason, despite having the lowest OBC among all the mixtures, more than 6% RHA should not be used for field application. The increasing tendency in MQ values may be accredited to the fact that the higher concentration of studied waste fillers absorbs the light constituent of bitumen which upsurge the viscosity and stiffness of bituminous binder. This improves the adhesion between mastic and aggregates and boosts the overall ability of the HMA to bear loads.

Last but not least, Residual Marshall stability is another index used for evaluating the water stability of an asphalt mixture (Figure 6). Large residual Marshall stability value indicates good water stability [22]. With the addition of RHA, the residual stability of the asphalt mixture was improved. It can be seen as in Figure 6 that the statistical results show that the residual Marshall stability of the asphalt mixtures was significantly showing high values for high RHA content in asphalt mixtures.

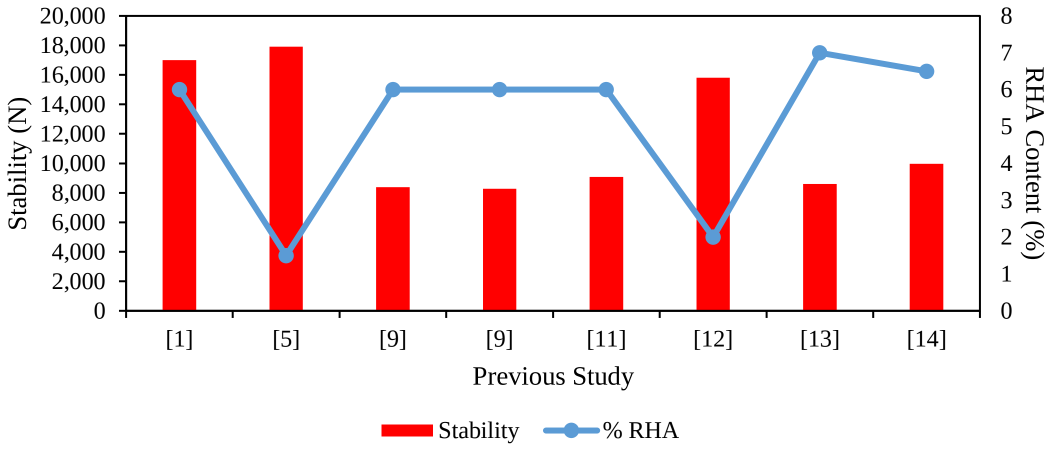

Figure 2. Marshall Stability with different RHA content from previous studies.

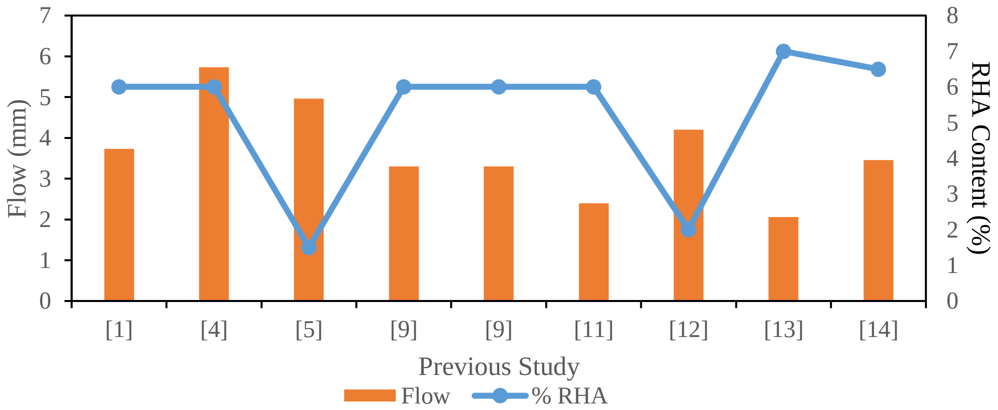

Figure 3. Flow with different RHA content from previous studies.

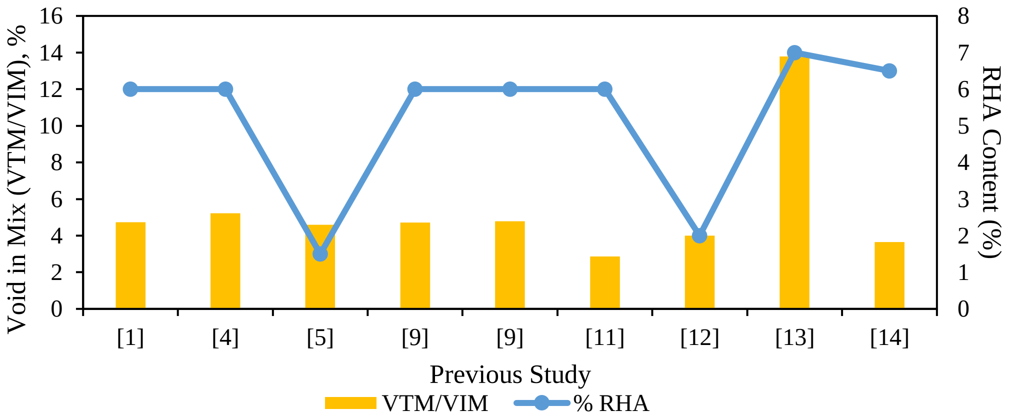

Figure 4. Void in mix (VIM / VTM) with different RHA content from previous studies.

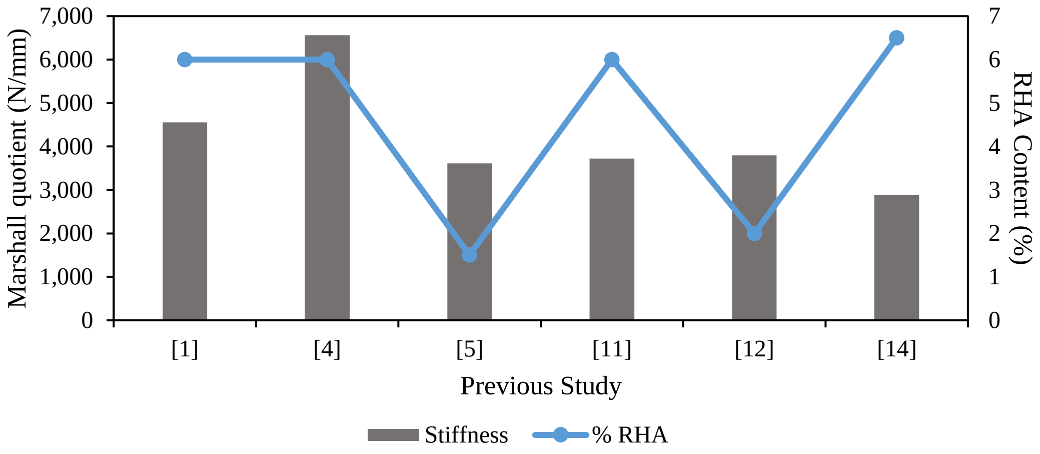

Figure 5. Marshall quotient with different RHA content from previous studies.

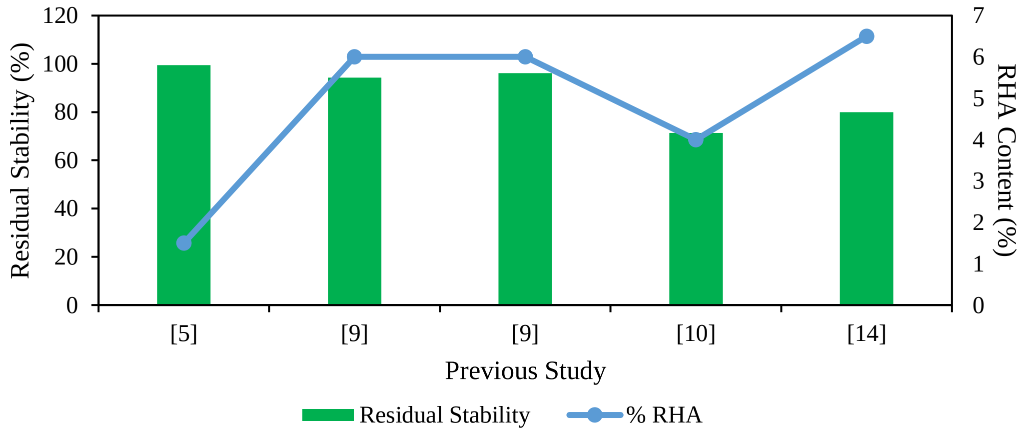

Figure 6. Residual stability with different RHA content from previous studies.

4. Conclusion

Application of rice husk ash (RHA) as a filler in asphalt mixture showed comparable performance than conventional filler. In contrast, higher RHA content could significantly reduce the stability yet still within the acceptable range. The higher the RHA content the more waste material could be utilized for road construction. Thus, minimized the usage natural sources materials.

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