SUITABILITY OF RICE MILL WASTES IN ASPHALTIC CONCRETE

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ABSTRACT

The effects of partially or wholly replacing Quarry Dust (QD) as an asphalt filler with rice mill wastes, Rice Husk Ash (RHA) at 0% - 100% and Rice Husk (RH) at 100% were investigated. From the Marshall Stability test conducted, results showed that, with 5% bitumen content at 10.0% optimum RHA content, the Stability, Flow, Density, Air Void, Void in Mixed Aggregates (VMA) and Voids Filled with Binder (VFB) were found to be 7152N, 4.37mm, 2.294g/cm^3, 6.4%, 17.4%, and 64% respectively. Thus, at 10.0% optimum RHA content, Marshall Stability was found to be adequate for wearing course. Stability results for 100% rice husk (RA) as filler was 3930N at 5% bitumen content, this is adequate for binder course. The Flow, Density, Air Void, VMA and VFB were found to be: 3.65mm, 2.235g/cm^3, 8.8%, 19.9% and 44.2% respectively, which meet the standard requirements for asphaltic pavements. Hence, it was concluded that the investigated rice mill wastes could be used in asphalt pavement courses.

Keyword: Bitumen, Rice Husk Ash, Rice Husk, Quarry Dust, Marshall Stability, Asphalt.

1. INTRODUCTION

In recent times, there has been a global consensus towards adopting best practices that are environmentally friendly and sustainable in virtually every field of endeavour. This is evidenced in increasing advocacy to curb carbon emissions, the fight against deforestation, pollution, public health safety and a host of other initiatives. Consequently, research around using waste products in useful applications has been on the rise. It is against this backdrop that agro-wastes which were previously dumped on land or water bodies causing pollution and contamination (Sargın et al., 2013) are now being harnessed to serve useful purposes.

Rice Husk and Rice Husk Ash are among agro wastes being researched on towards applicability in the construction industry. Rice Husk is an agricultural waste obtained from the milling of rice (Sargın et al., 2013). It accounts for 20% of the about 649.7 million tons of rice produced annually worldwide (Murana and Sani, 2014). When Rice Husk is burnt in ambient atmosphere to any temperature within the range of 225 – 500 degrees Celcius (Banerjee, Barbhuiya and Rajbongshi, 2019), Rice Husk Ash is produced. RH and RHA are pozzolans. Based on their chemical compositions, they form cementitious compounds in reaction with other components in the presence of humidity (Papadakis and Tsimas, 2002). This unique property makes them useful in applications in concrete for building and general construction as well as in asphalt concrete for road pavements. Asphalt concrete comprises aggregates, which serves as the structural skeleton for carrying load, fillers, to fill voids existing between aggregates and a binder, usually bitumen which binds and holds all the constituents of the mix together (Banerjee, Barbhuiya and Rajbongshi, 2019). The filler also plays a critical role of structural integrity as it prevents water penetrating the pavement (Banerjee, Barbhuiya and

Rajbongshi, 2019) and impacts stiffness to the mix. (Al-Hdabi, 2016). Conventional mineral fillers have extensively been used overtime in asphalt concrete mixes. However, with the emerging trend in the need to adopt environmental best practices that are cost effective and sustainable, research around using waste materials as fillers in asphalt concrete have been on the rise.

Al-Hdabi (2016) investigated the use of Rice Husk Ash instead of conventional mineral filler in hot asphalt mixtures. Ordinary Portland Cement Asphalt concrete and Rice Husk Ash (RHA) Asphalt concrete cement was investigated. Samples of the corresponding asphalt concretes were prepared by varying bitumen contents at 0.5% increment by weight. Optimum Bitumen Content (OBC) of 5.5% was adopted for the two types of mixtures. Mechanical, moisture damage and long-term aging were some properties investigated in the two mixtures. The result showed a substantial increase in Marshal stability (65% increase) when conventional filler was replaced with RHA. Also, the RHA mixtures were found to be generally more durable than those of OPC. The study concluded that RHA can be incorporated instead of conventional mineral fillers in asphalt concrete mixtures.

Sargın et al (2013) investigated the usability of RHA in asphalt concrete as mineral filler. Limestone (LS) was the conventional mineral filler used in the study. Asphalt concrete samples using limestone in different proportions of 4,5,6 and 7% as mineral filler and bitumen contents ranging from 3.5% - 6.5%, increasing by 0.5% were produced. Optimum Bitumen Content and filler rate were determined as 4.73% and 5% respectively for the limestone filler. This OBC and filler rate now served as control sample for the partial replacement of RHA with Limestone filler in the rate of 25,50,75 and 100%. The results showed that the best marshal stability was obtained from 50% replacement of LS with RHA.

Jit Banerjee et al (2019) utilized RHA in Hot Mix Asphalt (HMA) by partial replacement with stone dust as conventional filler. HMA samples were initially prepared using 5% stone dust as filler with varying percentages of bitumen in the mix. At the second stage, stone dust was partially replaced by RHA at 1, 2, 3 and 4% weight of total sample and in four different bitumen contents of 4.5, 5, 5.5 and 6%. The result showed that replacing stone dust by 1% RHA gave better marshal stability value as compared to the using only stone dust for every percentage of bitumen considered. At 2% replacement, the marshal stability shows results that are very similar to those in which only stone dust is utilized at every bitumen percentage considered.

Akter and Hossain (2017) assessed the influence of rice husk ash and slag in bitumen paving mixes and compared same with conventional mineral filler (stone dust). Test specimens for each of the investigated filler was prepared in accordance with ASTM standards with varying percentages of bitumen contents. They found that specimens made with non-conventional fillers had satisfactory Marshall Properties which are almost the same as conventional fillers.

In this study, a comparison of the engineering properties of asphaltic concrete using Quarry dust (QD), Rice Husk (RH) and Rice Husk Ash (RHA) were carried out in the first part. In the second part, partial replacement of quarry dust with RHA was investigated.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Aggregates

The coarse aggregate used for the study is crushed granite not exceeding 20mm size. Aggregates were gotten from local construction site. Sieve analysis, specific gravity and Aggregate Impact Value (AIV) tests were carried out for the aggregates used. Figures 1 and 2 show results of sieve analysis on fine and coarse aggregates used in preparing asphalt concrete samples for the investigation. Tables 1 and 2 shows results of specific gravity tests carried out on aggregates and fillers with their comparison to set standards, while Table 3 show the mix proportion adopted for the study.

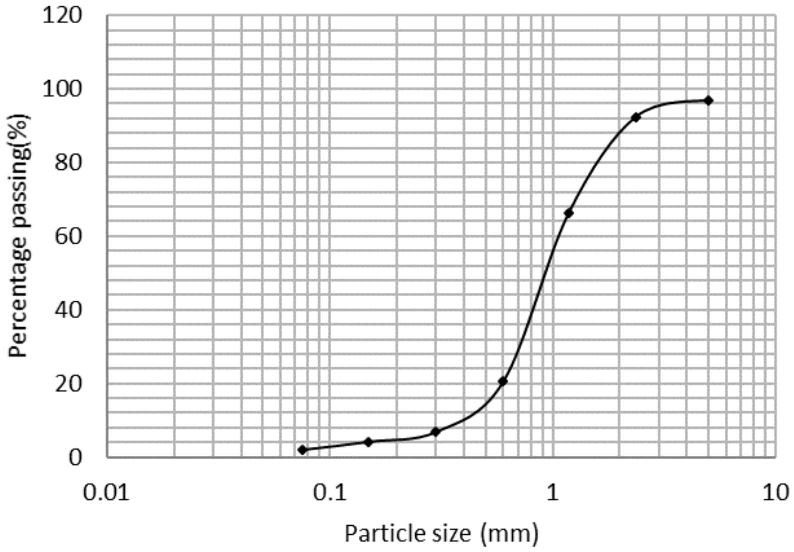

Figure 1: Sieve analysis for fine agg.

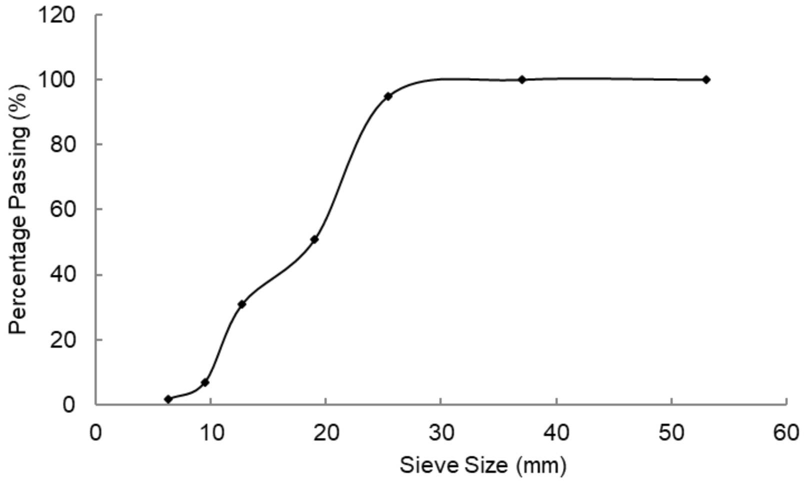

Figure 2: Sieve analysis for coarse agg.

Table 1: Specific Gravity of Aggregates and Fillers

Aggregates	Fine	Coarse	Quarry Dust	Rice Husk	Rice Husk Ash
Specific Gravity	2.65	2.66	2.64	1.89	2.11

Table 2: Comparison of Test Results on Aggregates with Standards.

Property	Unit	Result obtained	Code used	Code specification
AIV	%	19.8	BS EN 12620:2002	<30
Specific gravity (fine)	-	2.65	ASTM C128:2015	2.6-2.9
Specific gravity (course)	-	2.66	ASTM C128:2015	2.6-2.9

Table 3: Mix proportion used

Type	Size in mm	% of constituents
Crushed sand	0 – 2mm	59%
Crushed stone	5 – 10mm	20%
Crushed stone	10 – 15mm	10%
Filler	0 – 0.075mm	5%
Bitumen		6%

2.1.2 Bitumen

Asphalt concrete mixes were prepared using 80 – 100 penetration grade bitumen and having test properties presented in Table 4.

Table 4: Comparison of Physical Characteristics of bitumen with Standard Code.

Test	Standard	Min. Code specifications for 80/100 pen grade	Results obtained
Penetration at 25^{0}C (mm)	3. ASTM D5-2006	80-100	92
Specific gravity at 25^{0}C min	ASTM D70	0.97-1.03	1.02
Flash point (^{0}C) Min	ASTM D92-2018	219	252
Fire point (^{0}C) Min	ASTM D 92-2018	230	275
Ductility at 25^{0}C Min (mm)	ASTM D113-2017	75	103

2.13 Filler

Quarry dust, RH and RHA were the fillers being compared. The filler rates were 5% by weight of the total mix. These materials were sourced locally from quarry sites and rice mills in Cross River State. The RH used were dried, grounded and passed through the 75-micron sieve. Samples passing this sieve were used in the mixture to prepare asphalt concrete. The chemical composition of RHA is as shown in the Table 5.

Table 5: Chemical composition of Rice Husk Ash (RHA)

S/N	Sample	Elements And % Composition						
		Z_nO	SiO_2	CaO	Fe_2O_3	K_2O	M_nO	MgO
1	RHA	0.75	84.55	0.3	0.25	0.69	0.43	0.45

2.2 Experimental Procedure

Asphalt concrete samples were prepared according to procedures set out in relevant standards (ASTM D 1559 and IRC 111) for each of the three different fillers at a rate of 5%. For each filler, samples were prepared in five bitumen content (4%, 4.5%, 5%, 5.5% and 6%). 15 samples were prepared in total and Marshall Stability test conducted to determine the optimum bitumen content. The flow, bulk density, air void, void in mineral aggregate (VMA) and void filled by bitumen (VFB) were determined.

2.2.1 Partial replacement of Quarry dust with Rice Husk Ash

Partial replacement of Quarry dust with RHA at 5%, 10%, 15%, 20%, 50% and 100 % was carried out. Marshall Test samples were first prepared for a control sample containing quarry dust at 5% and an estimated optimum bitumen content of 5%. The optimum bitumen content is the average of the bitumen content with maximum stability, the bitumen content with the maximum bulk density and the median value of the specified percentage air void in the mix, which is 5%. Subsequently, the quantity of quarry dust in the control sample was replaced by RHA corresponding to the percentages stated above in other samples. In each case, all the test parameters determined for the first phase were also obtained.

3. RESULTS AND DISCUSSIONS

The first part of this investigation compares the engineering properties of QD as a conventional filler and two agro waste RH and RHA for use in asphalt concrete. Marshall stability and other test were carried out on asphalt concrete samples prepared using these fillers at a rate of 5% and in varying percentages of bitumen content. Figures 3-7 compares test results of stability, flow, percentage air void, VMA, VFB for the fillers being investigated.

3.1 Marshall Stability

Figure 3 shows the plot of stability against bitumen contents. It could be seen that the stability (maximum load developed during the test) for all the different fillers initially decreases as the bitumen content increases, then begins to increase again from 4.5% bitumen content, peaks at 5% for quarry dust and rice husk and at 5.5% of RHA fillers, then continues to decline with increasing bitumen contents. The results show that QD have a significantly higher MS value (41% and 44% more than RHA and RH respectively) at 5% bitumen content. The stability value obtained at 5% bitumen content for QD was found to have satisfied the minimum requirements of 6672N stipulated for a typical wearing course of a heavy traffic pavement as shown in Table 6. Also, the stability value obtained at 5.0% bitumen content when RH and RHA were used respectively as filler in asphalt mix were found to be adequate for binder course materials only since it satisfies the minimum value of 3336N required for medium traffic as could be seen in Table 7.

3.2 Flow Values

The flow of an asphalt concrete specimen is defined as its deformation at the point when maximum load occurs. From Figure 4, it could be seen that the maximum flow value for QD occurred at 6% bitumen content with a value of 5.4mm, while at 4.5%, RH and RHA had their maximum flow values to be 4.02mm and 5.89mm respectively all of which falls within the range of 2-14mm as specified by standards shown in Table 7. Conventionally, an increase in bitumen content of an asphalt concrete mix will cause a decrease in the percentage of air void in that mix.

3.3 Air Voids.

From Figure 5, the air voids against bitumen content for the three fillers decreased, according to Jaswanth et al (2016) this is required for better strength and service life of the pavement. The percentage of air voids in the mix decreases as the bitumen content increases albeit with a slight increase between the 4.5 – 5% bitumen content region this may be due to the increasing Marshall Quotient or rigidity ratio within these regions indicating higher resistance to permanent deformation at these range of bitumen content.

3.4 Voids in Mineral Aggregates (VMA)

The Voids in Mineral Aggregates (VMA) usually increases with an increase in binder content. From Figure 6, it could be seen that the graph followed the conventional form with a maximum VMA for each of the fillers as 20.4%, 19.9%, and 21% for QD, RH and RHA respectively all of which are greater than the minimum value of 15% for maximum aggregates size of 12.5% used for the mix.

3.5 Voids Filled with Binder (VFB)

Voids Filled with Binder (VFB) from Figure 7 increased with an increase in bitumen content of the samples. The maximum VFB values obtained for each of QD, RH, and RHA was 48.2%, 44.2% and 59% respectively.

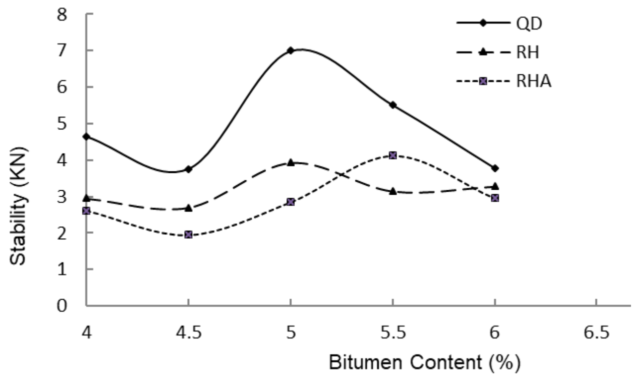

Figure 3: Stability against bitumen content

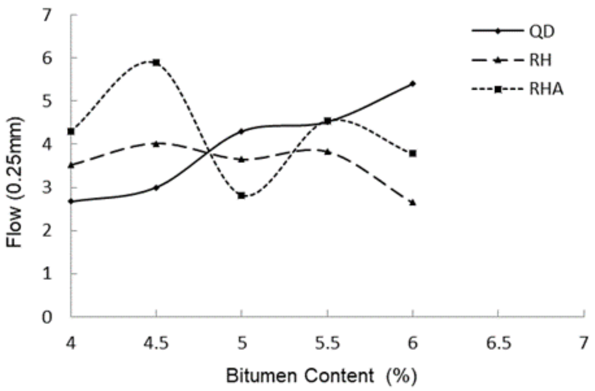

Figure 4: Flow against bitumen content

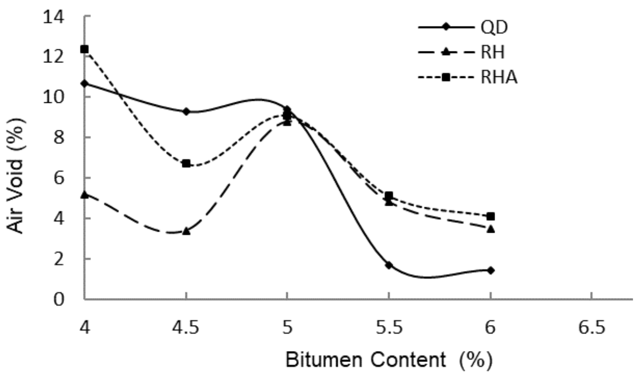

Figure 5: Air Void against bitumen content

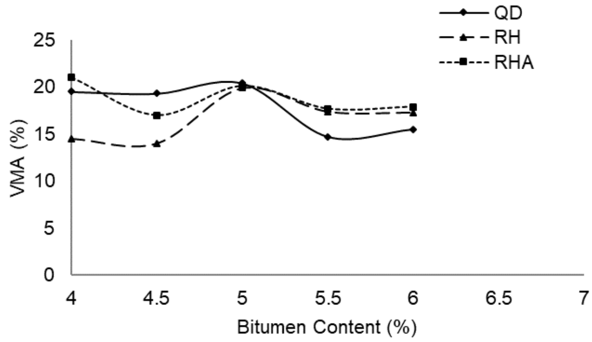

Figure 6: VMA against bitumen content

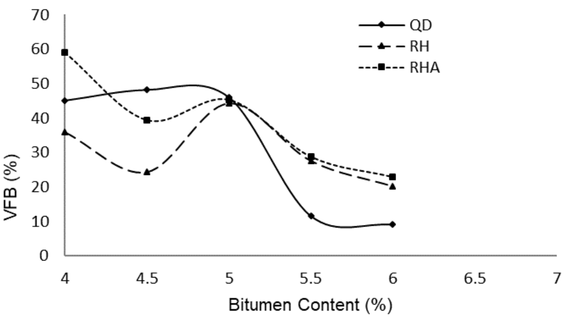

Figure 7: VFB against bitumen content

3.6 Effect of partial replacement of QD with RHA

Results of the effects of partial replacement of quarry dust with rice husk ash are presented in Table 6 and Figures 8-13 for 5%, 10%, 15%, 20%, 50% and 100 % partial replacement of QD with Rice Husk Ash respectively. The results show the effect of partially replacing QD with RHA on the MS, flow and volumetric properties. It could be seen that at 10% partial replacement of QD with RHA, it was found that there was a significant increase in the stability of the mix. A maximum stability of 7152N was obtained, an increase of about 32% compared to the control mix where only QD was used. Also, at 10% RHA replacement, Marshall Quotient (MQ) or rigidity ratio (the ratio of stability to flow value) which indicates the resistance of a mix against permanent deformations was highest (1.64). Therefore, at 10% partial replacement of QD with RHA, the stability of the mix will be satisfactory and can be used for wearing course where heavy traffics are expected. Result from the test also showed that even at 5%, 20%, and 50%

replacement with stability values of 3936N, 4704N and 5664N respectively, the mix obtained can still be used for binder course construction since all has a Marshall stability value greater than that the specified value of 3336N as shown in Table 6.

Table 6: Summary of Marshall analysis for partial replacement of stone dust with RHA.

RHA Content (%)	Stability (KN)	Flow (0.25mm)	Marshal Quotient (KN/mm^2)	Bulk density (g/cm^3)	Air void (%)	VMA (%)	VFB (%)
0	6.836	4.3	1.59	2.221	9.4	20.4	46.1
5	6.936	3.25	1.21	2.351	4.1	15.7	73.9
10	7.152	4.37	1.64	2.294	6.4	17.8	64.5
15	2.688	6	0.45	2.035	17	27.1	37.3
20	4.704	4.89	0.96	2.411	1.6	13.5	88.1
50	5.664	4.69	1.21	2.375	3.1	14.9	79.1
100	2.4	5.18	0.46	2.264	7.6	18.8	59.6

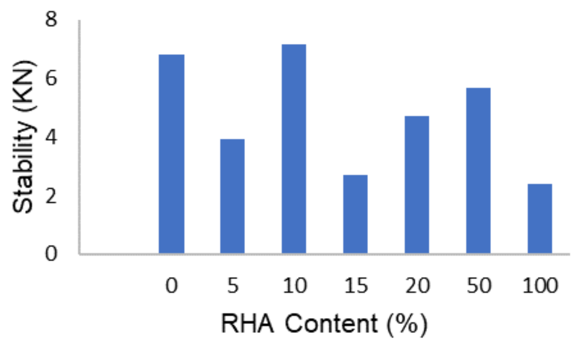

Figure 8: MS vs RHA

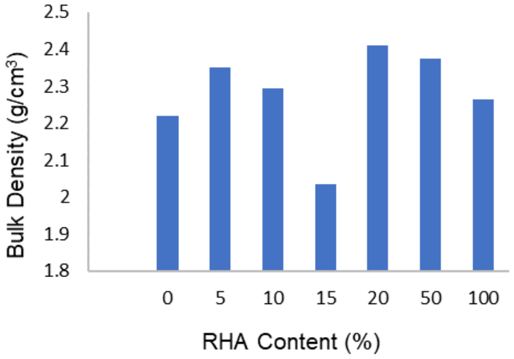

Figure 9: Bulk Density vs RHA content

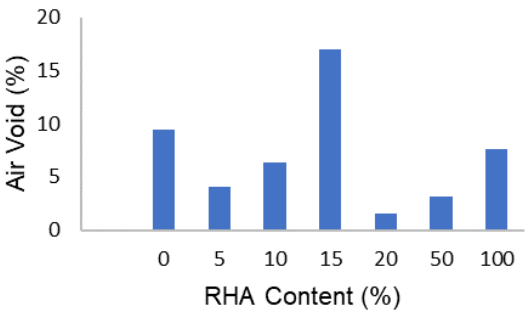

Figure 10: Air Void vs RHA Content

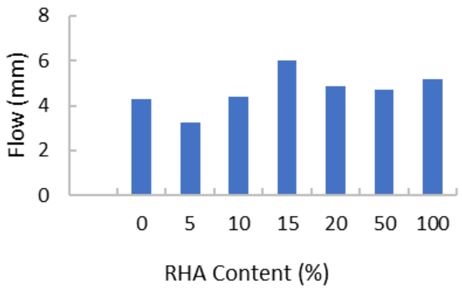

Figure 11: Flow vs RHA content

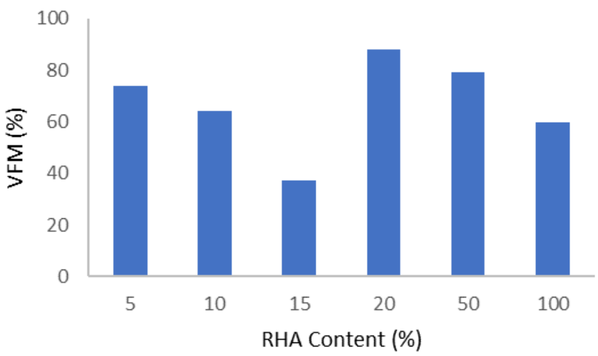

Figure 12: Void Filled with Binder vs RHA Content

Table 7: Typical Marshall Mix Design Criteria (ASTM D 1559)

Description	Base course		Binder course		Wearing course	
	Min.	Max.	Min.	Max.	Min.	Max.
Marshall specimens (ASTM D 1559) No. of comp. blows on each end of specimen	75		75		75	
Stability (N)	2224		3336		6672	
Flow (0.25mm)	2	14	2	14	2	14
VMA (%)	13		14		15	
Air voids (%)	3	8	3	8	4	6
VFB (%)	70		70		70	

4. CONCLUSION

Current trends aimed at reducing negative environmental impacts and encouraging sustainable construction have resulted in ever increasing demands for the use of waste materials in the production of asphalt mixes. The basic objective of this research was to compare the properties of asphalt mix when conventional and agricultural waste material (RH and RHA) are used as fillers in asphalt mixes and a partial replacement of QD with RHA. From the analysis and results obtained from various tests conducted, the following conclusions were reached;

- Rice Husk powder showed much less Marshall stability value when compared with Quarry dust, hence cannot fully replace Quarry dust as filler in asphalt concrete for use road pavements
- RHA also had Marshall Stability less than Quarry dust at the optimum bitumen content thus, cannot fully be used as filler in asphalt concrete mixes.
- At 10% partial replacement of QD with RHA, the specimen obtained was found to have satisfactory Marshall Properties.
- The mix obtained from 100% RH and RHA have stability result that make them suitable for use as filler in binder course at 5% optimum bitumen content.
- Using Rice Husk as fillers in paving mixes partly solves the solid waste disposal problem of the environment.
- Agro-waste products could be used for paving rural and low traffic roads.

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