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Utilization of coconut shell ash as filler for hot mix asphalt containing reclaimed asphalt pavement

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Abstract
This research examined the strength properties of hot mix asphalt (HMA) containing a blend of reclaimed asphalt pavement (RAP) and virgin aggregates with granite dust was replaced with coconut shell ash. Physical test was carried out on the RAP and virgin aggregates. Chemical and geometrical test was done on the coconut shell ash (CSA). All preliminary test conducted in accordance with relevant standards showed adequacy for use in production of HMA. Marshall method of mix design was adopted for the HMA production. Asphalt Institute blending charts was used to determine the quantity of RAP to be incorporated into the mixture. The bitumen content was varied from 4.5 – 7.5% (at intervals of 0.5%). The coconut shell ash was varied from 25% to 100% (at interval of 25%). A maximum stability of 6.8kN was recorded at 5% bitumen content which is a little increment in strength when compared to the maximum stability of 6.7kN obtained at the control. The microstructural analysis of the hot mix asphalt done on the optimum coconut shell ash replacement showed a rough surface texture needed in flexible pavement construction and when comparison is done between the control sample and optimum replacement samples, it shows an improvement in the interlocking arrangement of aggregates resulting in a denser mixture for the modified hot mix asphalt. The study recommends a blend of a 70% RAP and 30% virgin aggregates with 50% coconut shell ash at 5% bitumen content for an improved strength performance of HMA

Keywords: Coconut shell ash, Hot Mix Asphalt, Marshall Stability, Reclaimed Asphalt Pavement, Scanning Electron Microscopy

1. Introduction

Researches carried out worldwide focus on ways of utilizing either industrial or agricultural wastes as useful materials for the road construction, the use of these waste has both economic and environmental benefits. This research involves the utilization of coconut shell ash because of the properties that makes it a suitable construction material while incorporating a high quantity of RAP with varying bitumen content. Coconut shell ash is gotten from burning and calcination of coconut shell which is an agricultural waste that is available in very large quantities in tropical countries of the world (Madakson *et al.,* 2012)**.** The indiscriminate disposal of theses wastes contributes to environment pollution. Hence the need to convert these wastes into useful materials

Study by Hussain and Qiu (2013) shows that replacement of virgin aggregate with reclaimed asphalt pavement can be made up to 10 – 30%, the hot mix asphalt still performs similarly as when the hot mix asphalt is made completely of virgin aggregate. Sadeeq *et al*., (2014) investigated the effect of partially replacing Ordinary Portland Cement (OPC) with rice husk ash (RHA) as mineral filler in asphaltic mixture containing RAP. The results obtained from the experiments showed that the combination of RAP with virgin aggregates and RHA at 70%, 27% and 3% respectively satisfied the design criteria of the design for roads works in Nigeria. However, the indirect tensile strength test conducted on the samples showed that the sample with 25% RHA content had the highest tensile strength while the samples containing OPC had a lower tensile strength. In asphalt concrete, according to Remisova (2015), mineral fillers help to fill voids, improve aggregate and bitumen adhesion, stiffen and toughen the asphalt concrete and accelerate curing of compacted mixtures. Murana and Sani (2014) conducted a study on the partial replacement of cement with rice husk ash in asphalt concrete. The study was laboratory based and consist of various bitumen content 4.5 - 7.5% (at interval 0.5), the OBC was obtained at 5.5% and used in production of hot mix asphalt focusing of partial replacement of cement with rice hush ash from 5 – 25% (at interval of 2.5%). From experimental results obtained, the sample containing 10% rice husk ash satisfied the requirements of Asphalt Institute (1983) criteria for Marshall-stability-flow, VMA and total voids in the mixture.

Studies has shown that the utilization of RAP is sustainable, economically viable and environmentally friendly. However, the practical use of RAP on the field is relatively new in developing countries such as Nigeria and cost of virgin materials quarried from rocks has significantly increased over the years as the virgin aggregates used for road construction are scarce. This paper is aimed to present state-of-of the practice knowledge on the use of higher quantities of RAP in hot mix asphalt while partially or fully incorporating a waste ash as mineral filler. The most challenging part of using RAP in hot mix asphalt is the range set by Asphalt Institute (2014). The objective research is to study on the suitability of coconut shell ash and reclaimed asphalt pavement in hot mix asphalt that suits Nigeria environmenatal conditions and in compliance with Nigerian specifications for roads and bridges requirements.

2 Materials and method

2.1 Materials

The materials used in this study are:

(i) Bitumen (ii) Coarse and Fine Aggregates (iii) Coconut Shell Ash (iv) Granite Dust (v) Reclaimed Asphalt Pavement (RAP). The reclaimed asphalt pavement was sourced from Kaduna-Kano Road construction and quarrying sites. However, the fine, coarse aggregates and bituminous materials was obtained from MotherCAT Construction Company at Palladan, Zaria, Nigeria. The coconut shell used for this research was obtained from Samaru market, incinerated and calcined at a tempreture of 800ºC for 2hours at Department of Industrial Design in Ahmadu Bello University, Zaria, Kaduna State.

2.2 Methods

Test on bitumen are as follows:

(i) Penetration in accordance with ASTM D5/D5M –20 (2020)
(ii) Ductility in accordance with ASTM D113 – 17 (2017)
(iii) Softening point in accordance with ASTM D36/D36-14 (2020)
(iv) Flash and fire point in accordance with ASTM D92 – 18 (2018)
(v) Specific gravity in accordance with ASTM D70 – 18a (2018)
(vi) Solubility in accordance with ASTM D2042-15 (2015)
(vii) Viscosity in accordance with ASTM D4402 (2015)

Test on coarse and fine aggregates are as follows;

(i) Aggregate impact value in accordance with BS 812-112 (1990)
(ii) Aggregate crushing value in accordance with BS 812-110 (1990)
(iii) Elongation index in accordance with ASTM D4791-19 (2019)
(iv) Flakiness index in accordance with BS EN 933-3 (2017)
(v) Specific gravity in accordance with ASTM C127-15 and ASTM C128-15 (2015)
(vi) Sieve analysis (ASTM C136/C136M-19, 2019)

Test on coconut shell ash are as follows

(i) X-Ray fluorescence in accordance with ASTM E1621-13 (2013)
(ii) Sieve analysis in accordance with ASTM C136/C136M-19 (2019)
(iii) Specific gravity in accordance with ASTM D854 – 14 (2014)

Blending of Aggregates

(i) The computation of aggregates in accordance with (FMWH, 2016)
(ii) The Blending of aggregates in accordance with (Asphalt Institute, 2014)

Test on Hot Mix Asphalt

(i) Marshall Stability and Flow Test in accordance with ASTM D6926-20 (2020)
(ii) Scanning Electron Microscopy Test in accordance with ASTM E986-04, (2017)

Table 1: Computation of Different Sizes Aggregates (RAP and Virgin Aggregates)

Sieve Size	**Coarse Aggregate**		**Fine Aggregate**			**Total**
(mm)	**%RAP**	**%VA**	**%RAP**	**%VA**	**%Mineral filler**	
19.05	0	0				0
12.7	16	8.6				24.6
9.52	12.29	7				19.29
6.35	13	4				17
2.36	21.7	5				26.7
1.18			12.5	13		25.5
0.6			9.3	12.3		21.6
0.3			4.4	13.4		17.8
0.15			6.8	9		15.8
0.075			3.01	18.3	15	36.31
Pan			0.07	9.34	85	94.41

Note: RAP = Reclaimed Asphalt Pavement. VA = Virgin Aggregates

Table 2: Blending, Proportioning of Aggregates (RAP and Virgin Aggregates)

Size	**(RAP)**	**(VA)**	**(RAP)**	**(VA)**	**Mineral filler**	**Total**
19.06	0.7×0.00=0.00	0.24×0.00=0				0
12.7	0.7×16.00=11.20	0.24×8.60=2.07				13.27
9.52	0.7×12.29=8.60	0.24×7.00=1.68				10.28
6.35	0.7×13.00=9.10	0.24×4.00=0.96				10.06
2.36	0.7×21.70=15.19	0.24×5.00=1.2				16.39
1.18			0.7×12.5=8.75	0.24×13.00=3.12		11.87
0.6			0.7×9.3=6.51	0.24×12.30=2.96		9.47
0.3			0.7×4.4=3.08	0.24×13.40=3.22		6.3
0.15			0.7×6.8=4.76	0.24×9.00=2.16		6.92
0.075			0.7×3.01=2.11	0.24×18.30=4.39	0.06×15=0.9	7.40
Pan			0.7×1=0.70	0.24×9.34=2.24	0.06×85=5.1	8.04
Total	50		44		6	100

Note: RAP = Reclaimed Asphalt Pavement. VA = Virgin Aggregates

Design of Bitumen Content

Asphalt Institute (2014) was used to estimate Dessign Bitumen Content (DBC) expressed mathematically in equation 1.

$$DBC = 0.035a + 0.04b + Kc + F \qquad \text{Eq. 1}$$

Where a = percentage of aggregate on sieve 2.36mm

b = Percentage of aggregate passing sieve 2.36mm and retained on 0.075µm

c = percentage of mineral aggregate passing sieve 0.075µm

K = 0.18 for instances where 6-10% is passing sieve 0.075µm

F = 0 – 2% of absorption of bitumen (0.7 suggested)

Therefore = $DBC = 0.035(50) + 0.04(44) + 0.18(6) + 0.7 = 5.29\%$ Approximately 5.5%

Asphalt Institute (2014) requires that two extra points be added above and below the DBC at 0.5% interval. In this study two extra points was added below to widen the data points. Thus the reanges of bitumen adopted in this study are 4.5, 5, 5.5, 6, 6.5, 7 and 7.5%

3 Results and discussion

3.1 Results of test on bitumen

The results of the various physical property tests conducted on bitumen are presented in Table 2. The result of the penetration is 65 which is within cthe limit for grade 60/70 penetration grade bitumen, other physical properties test done on the bitumen are softening point (50ºC), ductility (77.7cm), specific gravity (1.02), flash (183ºC), fire point (261ºC), solubility (99.2%) and viscosity(363) are within the range specified by the respective ASTM Standards . therefore the penetration 60/70 bitumen is suitable for the hot mix asphalt since all properties evaluated are within the specifications.

Table 2: Physical Properties of Bitumen with Standard Specifications

S/N	Test Conducted	Unit	Avg. Result	Standard	Remark
1	Penetration	0.1mm	65	60/70	Satisfactory
2	Softening point	ºC	50	48-56	Satisfactory
3	Ductility @ 25ºC	cm	77.7	100 min	Satisfactory
4	Specific gravity	NIL	1.02	1.01-1.06	Satisfactory
5	Flash-point	ºC	183	232 min	Satisfactory
6	Fire-point	ºC	261	NIL	Satisfactory
7	Solubility in C_2S	%	99.2	99 min	Satisfactory
8	Viscosity @ 60 ºC	Secs	363	NIL	Satisfactory

3.2 Results of test on aggregates

The results of the various laboratory tests conducted in this study are presented in Table 3. The values of specific gravities of coarse for RAP and natural aggregate are 2.671 and 2.703 respectively which are within the limits of 2.5 – 3.0, similarly the specific gravity of fine aggregates for the RAP and natural aggregates are 2.580 and 2.61 respectively which are still within the limit of 2.5 – 3.0. The specific gravity of mineral filler for the RAP and natural aggregate are 2.599 and 2.674 respectively which are still within the limits of 2.5 – 3.0 according to the respective ASTM Standards. The flakiness and elongation indices are 28.55% and 35.30% which are within the limits of 35% and 25% as specified by the British Standard. The aggregate crushing value and aggregate impact value are 24.86% and 26.38% which are within the limits of 30% and 35% according to the respective British standard. Also the test results gotten are within the acceptable limit specified by FMPW&H (2016) and hence considered suitable for road construction. Similar results were obtained by Arshad *et al.,* (2017) and Kiruthiha *et al.,* (2015).

Table 3: Physical Properties of Aggregate with Standard Specifications

Properties	RAP	Natural Aggregate	Standard Spec. Min.	Standard Spec. Max.	Remarks
Specific Gravity (Coarse)	2.671	2.703	2.5	3.0	Satisfactory
Specific Gravity (fine)	2.580	2.61	-	-	Satisfactory
Specific gravity (filler)	2.599	2.674			Satisfactory
Flakiness Index (%)	28.55		-	35	Satisfactory
Elongation Index (%)	25.30		-	25	Satisfactory
Aggregate Crushing value (%)	24.86		-	30	Satisfactory
Aggregate Impact value (%)	26.38		-	35	Satisfactory

3.3 Results of particle size distribution test (Sieve analysis)

The aggregate gradation envelope for the particle size distribution is presented in Figure 1. The aggregate gradation envelope shows the result of the combined particle size distribution of the coarse aggregates, fine aggregates and mineral filler, together with the lowest boundary values and the highest boundary value specified by FMPW&H (2016). According Stroup-Gardiner and Wagner (1999) as cited in Sondag *et al.,* (2002) it is advisable to have RAP content as part of the coarse and fine aggregate as it increases the quantity of RAP in the mixture. Particle size distribution of aggregate are examined to ensure that aggregate are well graded as aggregates serve as the skeleton of the mix and help distribute loads and stresses on the pavement. A well graded aggregate ensures that the particles are properly interlocked to reduce moisture ingress in the pavement.

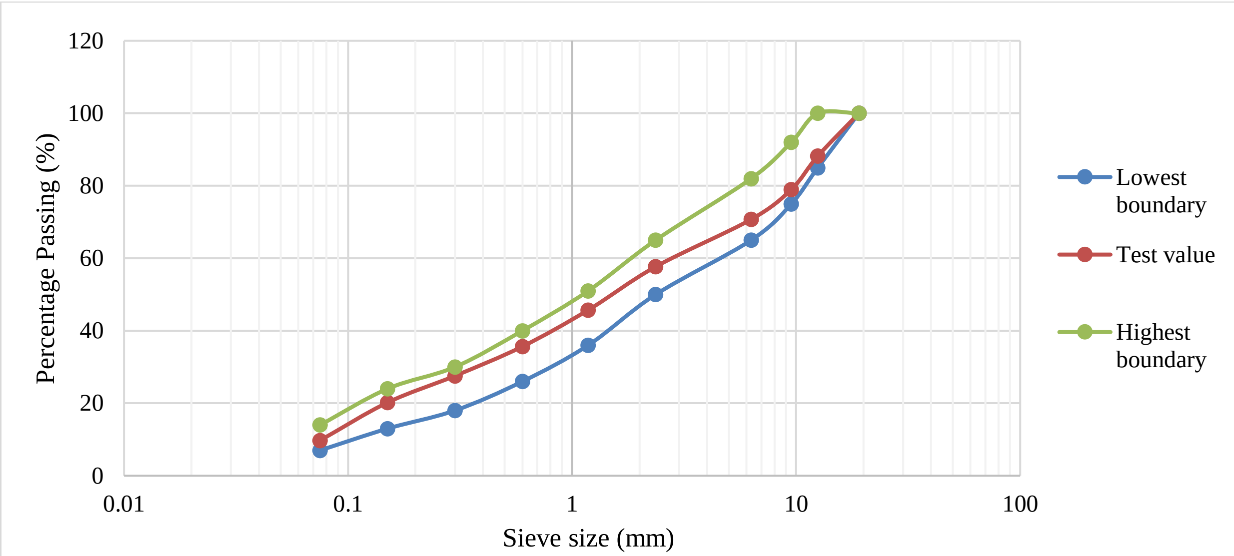


Figure 1: Aggregate Gradation Envelope

3.4 Results of test on Chemical Composition of Coconut Shell Ash

The results of the chemical composition test done on the coconut shell ash is shown in Table 3. X-ray Florescence analysis indicated CaO at 4.416%, SiO_2 at 41.184%, Al_2O_3 at 19.148%, Fe_2O_3 at 12.932, P_2O_5 at 0.32%, MgO at 6.74%, K_2O at 0.698%, Na_2O_3 at 0.75%, SO_3 at 0.66 and LOI at 9.534%. The outcome of the summation of silca oxide, aluminum and iron oxide compositions is greater than 70% ($SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$), these oxide play a key role on the viscosity of bitumen. On the other, quantity of toxic oxides such as phosphate, magnesium, sodium carbonate and sulfur are negligible. This findings showed that the coconut shell ash is suitable for use as filler material in hot mix asphalt. Similar findings were reported by Kumar *et al.,* (2017) and Adeala *et al.,* (2020).

Table 3: Chemical Composition of coconut shell ash

Oxide	CaO	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	MgO	K_2O	Na_2O_3	SO_3	LOI
%Composition	4.416	41.184	19.148	12.932	0.32	6.74	0.698	0.75	0.66	9.534

3.5 Effect of Coconut Shell Ash on Marshall Stability

The variation in Marshall stability values and coconut shell ash with bitumen content is shown in Figure 2. At control (0%) the maximum stability was recorded at 6.7kN corresponding to bitumen content of 6%. For the various percentage of CSA replacement, the maximum stability value of 6.8kN was recorded at 50% CSA replacement, corresponding to 5% bitumen content. It was noticed that further addition of coconut shell ash did not record any significant improvement in the Marshall stability only 1% increase strength was recorded. However, all the stability values met the requirement of FMPW&H (2016) which states a minimum stability values of 3.5kN

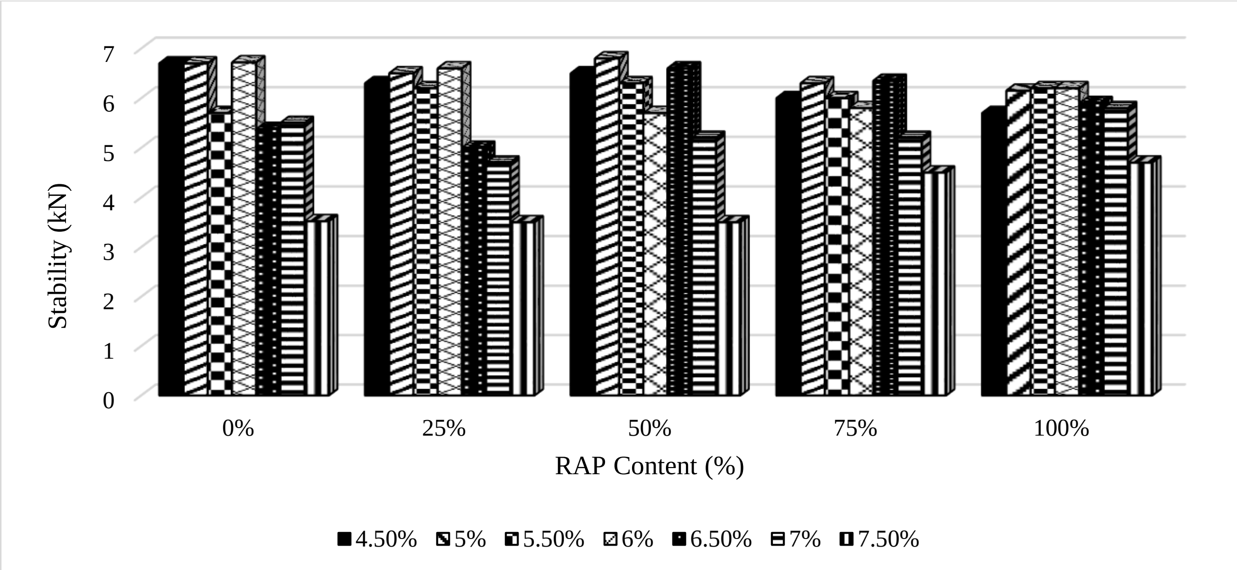


Figure 2. Variation of Stability with Bitumen Content and Coconut Shell Ash

3.6 Effect of Coconut Shell Ash on Marshall Flow

The variation in flow value and coconut shell ash is shown Figure 3. An upward trend in flow value was observed i.e., Flow values for different percentages of coconut shell ash can be said to exhibit a linear or near linear trend line. This increase in flow value could be as a result of combined bitumen contained in the RAP and neat bitumen added during the hot mix asphalt production which increased lubrication in the mixture. However it was observed that all percentages of coconut shell ash replacement at varying bitumen content meet the limit as specified by FMPW&H (2016) for wearing course asphaltic concrete which is set at 2mm-4mm for a wearing course. However flow values for 7% and 7.5% bitumen content did not meet the requirement.

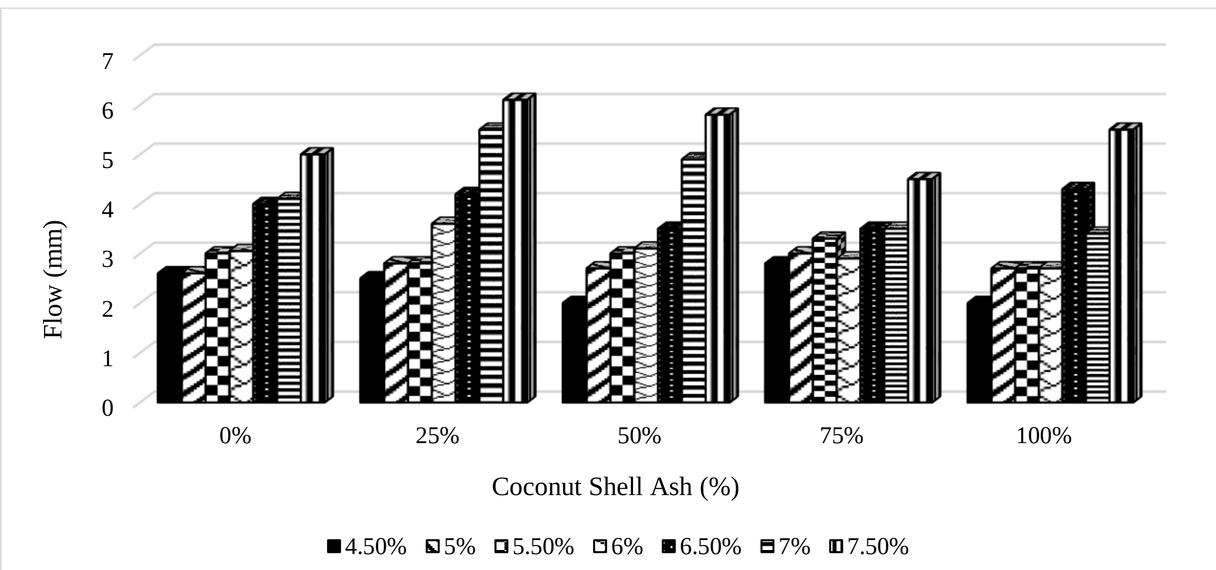


Figure 3. Variation of Flow with Bitumen Content and Coconut Shell Ash

3.7 Effect of Coconut Shell Ash on Unit Weight

The variation in unit weight value and coconut shell ash is shown Figure 4. The Density can be defined as the unit-weight of the asphaltic mixture accomplished via compaction and it is influenced by the specific gravity of aggregates. Volumetric properties of an asphalt mixture is directly related to the unit-weight.

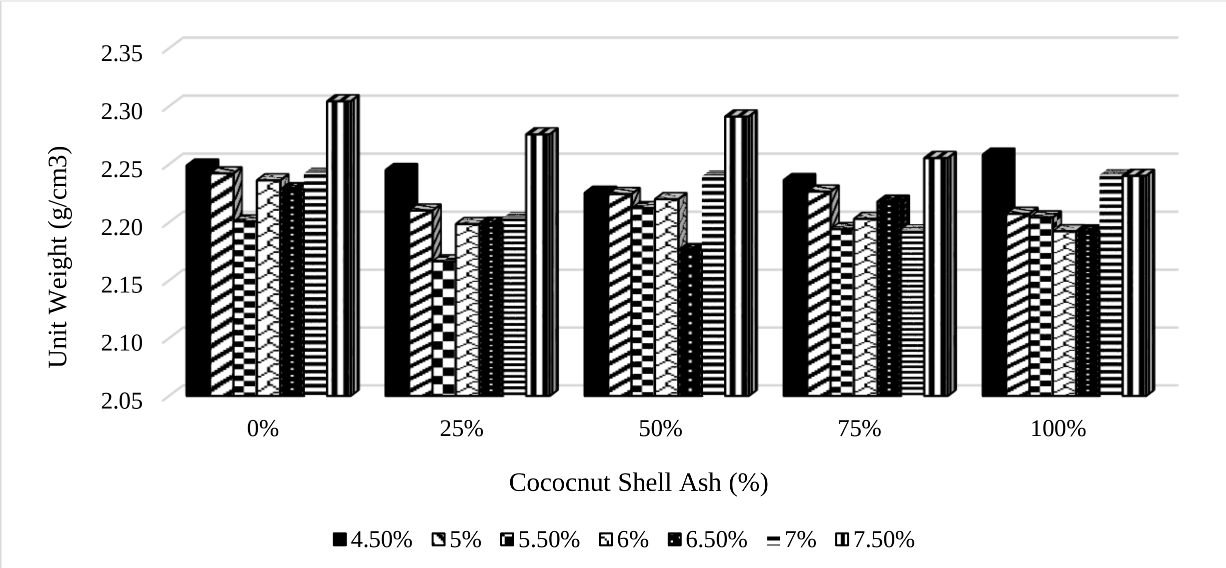


Figure 4. Variation of Unit weight with Bitumen Content and Coconut Shell Ash

3.8 Effect of Coconut Shell Ash on VMA

The variation in VMA value and coconut shell ash is shown Figure 5. It was observed that VMA values increase with increase in bitumen content and then decreases with further addition of bitumen. The main intent of mix design is to obtain a mixture of bitumen and aggregates that have sufficient voids in the mineral aggregates (VMA)

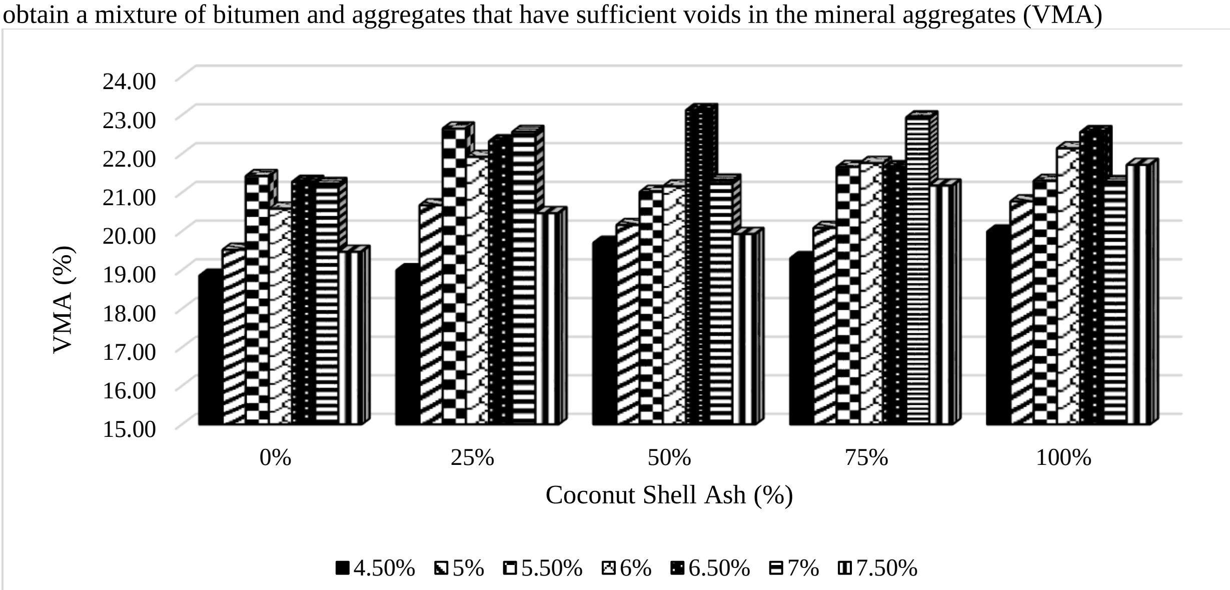


Figure 5. Variation of VMA with Bitumen Content and Coconut Shell Ash

3.9 Effect of Coconut Shell Ash on VFB

The variation in VFB value and coconut shell ash is shown Figure 6. It was generally observed that with increase in bitumen content there is a corresponding increase in VFB across all percentage replacement. The highest VFB was recorded at 7.5% bitumen content across various levels of replacement. This bitumen content met the requirement of FMPW&H (2016) which states that voids filled with bitumen should be within the range of 75 – 82%. Adherence to this requirement is necessary as it reduces the chances of air or water penetrating into the mixture.

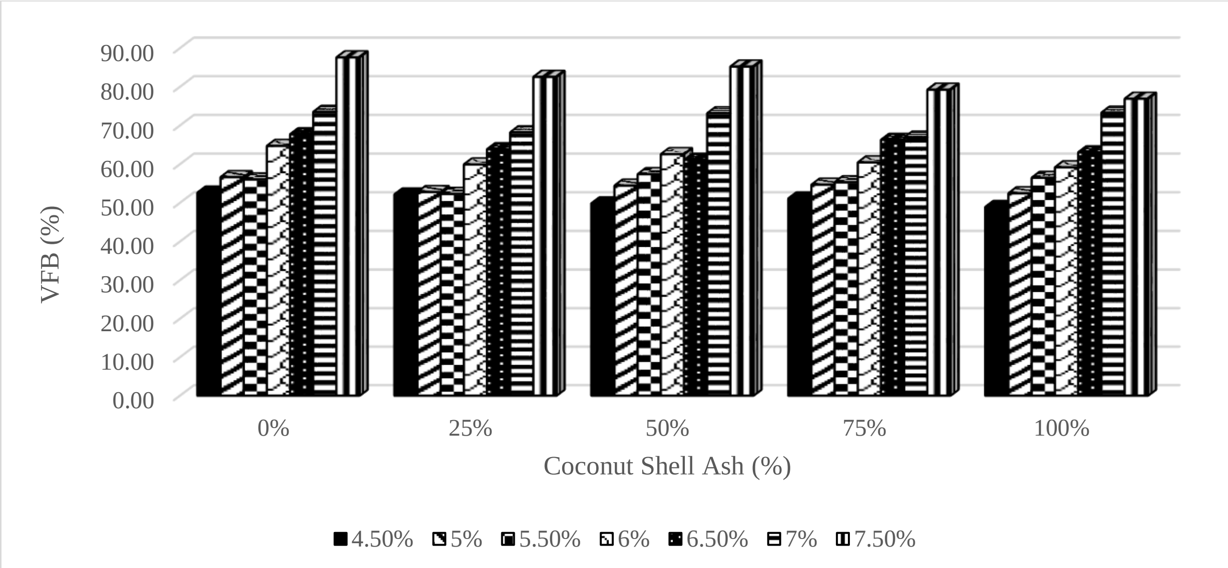


Figure 6. Variation of VFB with Bitumen Content and Coconut Shell Ash

3.10 Effect of Coconut Shell Ash on Pa

The variation in Pa value and coconut shell ash is shown Figure 7. The percent air void showed a continuous decrease in value with continuous increase in bitumen content across all various percentage replacement. The control sample (0%) showed the least percent air void across all bitumen content, while 100% coconut shell ash showed the highest percent air void across all replacement. This can be attributed to the effect of coconut shell ash particles filling voids between the aggregate. It was observed that alone bitumen content of 7.5% across all levels of CSA replacement satisfied the requirement of FMPW&H (2016) which stipulates the vids in total mixture within the range of 3% - 5% for wearing course. It is worthwhile to note that Pa is inversely related to VFB.

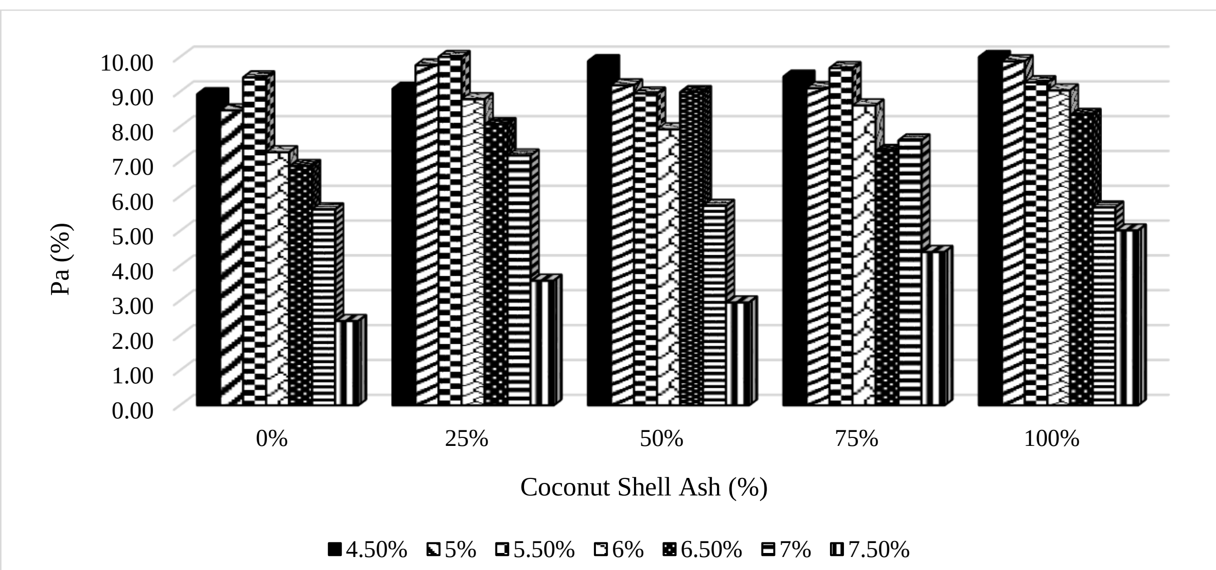
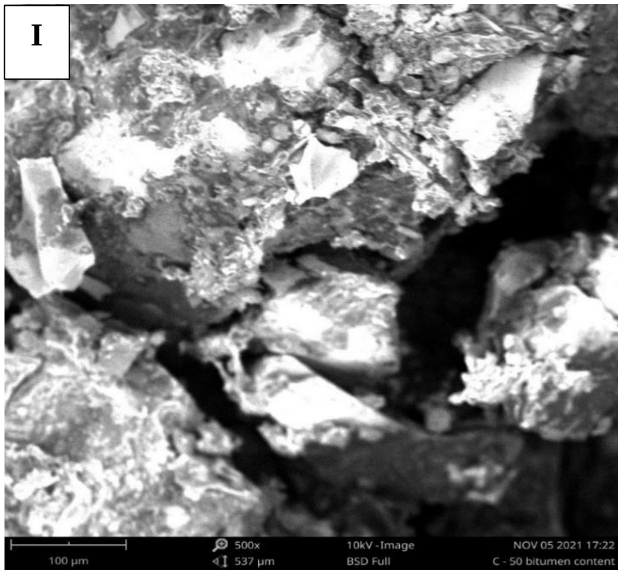


Figure 7. Variation of Pa with Bitumen Content and Coconut Shell Ash

3.11 Microanalysis of Hot Mix Asphalt Sample



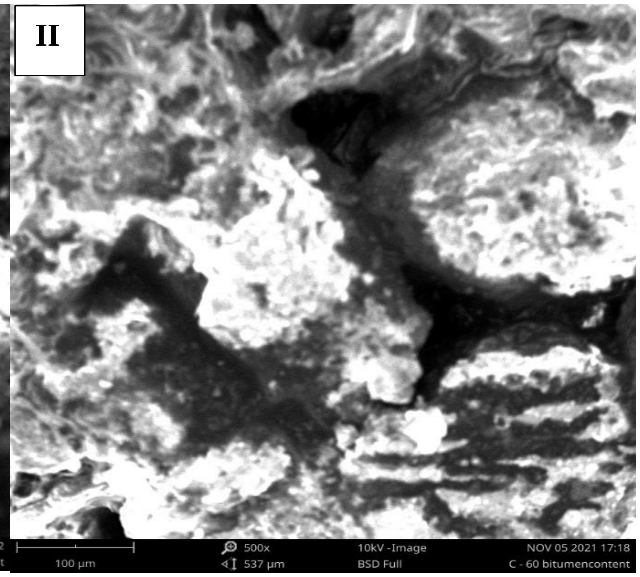


Plate I: Micrograph of control samples at 500x magnification and 537µm scale.
Plate II: Micrograph of modified samples at 500x magnification and 537µm scale.

The micrograph of the control sample (see Plate I) shows a rough texture surface needed for pavement construction; it also shows the interlocking particle arrangements of the mixture. The formation of this kind of matrix shows that a passive (non-reactive) filler like granite did not affect the viscosity of bitumen in order to fill up pores in the mix, this resulting particle arrangements impacts on the strength and durability of the mix. On the other hand, the micrograph for the modified samples with 50% (optimum) coconut shell ash at 5% bitumen content, (see Plate II) also shows a rough texture surface needed for flexible pavement construction, it also indicates the interlocking particle arrangements of the mixture. As seen in the micrograph, the modified briquette shows better particle arrangement with lesser pores between the aggregates, resulting in a denser mix. The dense nature of this mix can be attributed to the reactive nature of the coconut shell ash which impacted on the viscosity of the bitumen allowing it to better coat the aggregates and voids in the compacted mixture. This type of matrix is not unconnected to the increase in the Marshall strength of the hot mix samples.

4 Conclusions

The following are conclusions of this research based on the results obtained:

i. The physical and geometrical properties of Reclaimed Asphalt Pavement (RAP) is analogous to the properties of natural aggregate and within the acceptable limits specified by the Federal Ministry of Power, Works & Housing and therefore can be used in the production of hot mix asphalt.

ii. The sum of oxides of coconut shell ash is greater than 70% (i.e., $SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$), the SO_3 is 0.66 and LOI is 9.534 hence considered good for use in hot mix asphalt.

iii. The use of reclaimed asphalt pavement (RAP) and coconut shell ash as mineral filler showed little increment on strength properties of the hot mix asphalt when the maximum stability at (0%) control with a value of 6.7kN is compared to the maximum stability of 6.8kN recorded at 50% coconut shell ash replacement. However all Marshall stability for the control mixture and the modified mixture prepared with Reclaimed Asphalt Pavement (RAP) and coconut shell ash met the requirement of the Federal Ministry of Power, Works & Housing which states that the minimum of 3.5kN Marshall stability for a hot mix asphalt used for wearing course.

iv. Microstructural analysis using SEM on the hot mix asphalt samples for the modified and unmodified mixes showed an improvement in the interlocking arrangement of the aggregates resulting in denser asphalt concrete.

References

Adeala A.J., Olaoye, J.O., & Adeniji, A.A., 2020. Potential of Coconut Shell Ash as Partial Replacement of Ordinary Portland Cement in Concrete Production**.** *International Journal of Engineering Science Invention.* 9(1). 47-53.

Arshad, A. K., Awang, H., Shaffie, E., Hashim, W. and Abd Rahman, Z. 2017. Performance Evaluation of Hot Mix Asphalt with Different Proportions of RAP Content**.** *E3S Web of Conferences* 1-8

Asphalt Institute. 2014. MS-2 Asphalt Mix Design Method (7 ed.). USA; Asphalt Institute

ASTM C127-15. 2015. *Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM C128-15. 2015. *Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM C136/C136M-19. 2019. *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D113-17. 2017. *Standard Test Method for Ductility of Asphalt Materials* (Vol. 04.03). West Conshohocken, Philadelphia.PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D2042-15. 2015. *Standard Test Method for Solubility of Asphalt Materials in Trichloroethylene.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D36/D36M-14. 2020. *Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)* (Vol. 04.04). West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D4402-15. 2015. *Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D4791-19. 2019. *Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D5/D5M-20. 2020. *Standard Test Method for Penetration of Bituminous Materials.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D6926-20. 2020. *Standard Practice for Preparation of Asphalt Mixture Specimens Using Marshall Apparatus.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D70-18a 2018. *Standard Test Method for Density of Semi-Solid Asphalt Binder (Pycnometer Method),* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D854 – 14 2014. *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM D92-18. 2018. *Standard Test Method for Flash and Fire points by Cleveland Open Cup Tester* (Vol. 05.01). West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM E1621-13. 2013. *Standard Guide for Elemental Analysis by Wavelength Dispersive X-Ray Fluorescence Spectrometry.* West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

ASTM E986-04. 2017, *Standard Practice for Scanning Electron Microscope Beam Size Characterization*, West Conshohocken, PA: American Society for Testing and Materials (ASTM) International. Retrieved from www.astm.org

BS 812-110. 1990. *Testing Aggregates. Methods for Determination of Aggregate Crushing Value (ACV).* London, United Kingdom: British Standard Institution.

BS 812-112. 1990. *Testing Aggregates. Methods for Determination of Aggregate Impact Value (AIV).* London, United Kingdom: British Standard Institution

BS EN 933-3. 2017. *Tests for Geometrical Properties of Aggregates Part 3: Determination of Particle Shape — Flakiness Index* (12th ed.). London, United Kingdom: British Standards Institution (BSI)

FMPW&H. 2016. *General Specifications (Roads and Bridges) Volume II.* Abuja, Nigeria:

Hussain, A and Qiu Yanjun, 2013, *Effect of Reclaimed Asphalt Pavement on the Properties of Asphalt Binders*. The 2nd International Conference on Rehabilitation and Maintenance in Civil Engineering. Procedia Engineering 54, pg 840 – 850

Kiruthiha, K., Loshini, G. and Thivya, M., 2015. Strengthening of Flexible Pavement using Egg Shell as a Filler. *International Journal of Engineering Trends and Technology.* 21(10). 483- 486

Kumar, L., Pandey, K. K., and Khan, S. 2017. Use of Coconut Shell Ash as Aggregates. *International Journal of Research in Engineering and Social Sciences*. 7(2). 15-19

Madakson, P. B., Yawas, D. S., & Apasi, A. 2012. Characterization of Coconut Shell Ash for Potential Utilization in Metal Matrix Composites for Automotive Applications. *International Journal of Engineering Science and Technology*, *4*(3), 1190-1198.

Mohammed, A A., Altlomate A., Al-Zarroug, M. A., Hussain, M. K., and Al-Ramash, S. S. 2019. Performance Evaluation of Hot Mix Asphalt Containing Recycled Concrete Aggregate. *2nd Conference for Engineering Sciences and Technology.* 1-12

Murana, A. A. and Sani, L., 2014. Partial Replacement of Cement with Rice Husk Ash (RHA) as Filler in Asphalt Concrete Design. *Journal of Engineering and Applied Sciences* 10 (2014), 30 – 40, Zaria, Kaduna state.

Norhafizah, M., Ramadhansyah, P. J., Amiera J. S. N., Aqeela M. N., Norhidayah A. H., Hainin, M. R., and Che Norazman C. W. 2016. The Effect of Coconut Shell on Engineering Properties of Porous Asphalt Mixture. *Jurnal Teknologi (Sciences & Engineering).* 7(2). 127–132. doi: 10.11113/jt.v78.9507

Remisova, E. 2015. Study Of Mineral Filler Effect on Asphalt Mixtures Properties. *Bituminous Mixtures and Pavements*, 49-53.

Sadeeq, J. A., Kaura, J. M., Joshua, O., & Rabilu, A. 2014. Recycling of Reclaimed Asphalt Ravement (RAP) with Rice Husk Ash (RHA)/Ordinary Portland Cement (OPC) Blend as Filler. *Jordan Journal of Civil Engineering*, *159*(3269), 1-9.

Sondag, M. S., Chadbourn, B. A., and Drescher, A. 2002. *Investigation of Recycled Asphalt Pavement (RAP) Mixtures*. Minnesota Department of Transportation.

Stroup-Gardiner M. and Wagner, C., 1999. *Use of RAP in Superpave HMA Applications*. Submitted for Publication in Transportation Research Record.