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EVALUATION OF THE APPROPRIATENESS OF SUGERCANE BAGASSE ASH (SCBA) AS FILLER IN ASPHALT PAVEMENT RECYCLING TECHNIQUE

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ABSTRACT

The continuous industrial and agro-based activities world wild have lead to daily generation of wastes with impeding disposal issues raising much concern. Safe disposal of large quantities of daily generated Agro- based wastes in Nigeria has been a night mere. Most of the final wastes from the agro-byproducts only find their ways as landfills, which not only degrade the valuable land

Introduction

Over the past decades, the problem of waste management and control be it industrial, agricultural or even domestic wastes have globally threatened the environment. With increasing and rapid development in the industrial and agricultural sectors, huge amount of wastes have been generated from these sectors of which their disposal has constituted a serious environmental issue. This is because most final wastes from these sectors find their ways as landfills, which not only degrade the valuable land area but also constitute a hazard such as

area but also a hazard such as pollution of the environment. Construction experts in the industry have developed techniques of utilizing these materials for stabilization or modification of construction materials such as soil among others for road based construction, recycling of Reclaimed Asphalt Pavement (RAP) and its modification to meet design specifications, etc. This has lead to the quest for a laboratory based investigations on the suitability of Sugarcane Bagasse Ash as filler in Hot-mix asphalt recycling of RAP. Preliminary tests are conducted on RAP and the results are compared with the specification requirements for pavement mix design of road works. Marshall Stability Hot-mix asphalt design method was employed to test the performance indices of the blended materials for their known engineering properties. The oxide composition test and sieve analysis on sugarcane bagasse Ash showed that, the material can be used as filler, and was adjudged to be pozzolanic since over 80% of SCBA passes No. 200 sieve which satisfied the fineness requirement of filler with at least 65% pass No. 200 sieve, having combined weight of S_iO_2, Al_2O_3, Fe_2O_3 being 76.7 % by weight which is higher than minimum requirement of 70% for a pozzolanic material. At 70% RAP, 30% fresh aggregate and the addition of SCBA at 3% of the total combined weight of aggregate (RAP + fresh aggregate), a good design mix was obtained, and also considered as the most cost effective combination.

Keywords: RAP, Sugarcane, bagasse ash, recycling, filler, hot-mix asphalt, Pavement,

pollution of the environment. Enormous social, economic and environmental benefits of industrial wastes, such as blast furnace slag, coal fly ash, silica fume, etc, which has been successfully used in cementitious materials, cannot be over emphasized.

Presently, agricultural and forestry residues are mainly used as biomass fuel of which the resulting bottom ash or fume ash is the final waste that has generated wide research interest. Researches has revealed that many different kinds of biomass ash such as rice husk ash , palm oil fuel ash, elephant grass ash , sugar cane bagasse ash , corn cob ash, wood waste ash , bamboo stem ash , cattle manure ash , and paper mill ash, can be used as supplementary cementitious materials,(**Qing Xu et`al, 2018**)

During road maintenance and rehabilitation in highway construction, recycling what are being considered as a waste material has often played vital role. Deteriorated asphalt pavement is one of such materials being reclaimed and recycled where it is incorporated into asphalt paving mix by means of hot or cold recycling; and also used as an aggregate in base, sub-base and sub-grade for roads.

This research tends to investigate the possible application of sugarcane bagasse ash (SBA) from sugarcane bagasse, readily available agro-based waste material as filler in RAP recycling and it examine the use of sugarcane bagasse ash as filler in RAP, in hot-mix asphalt design (HMA).

Sugarcane bagasses form a large quantity of agro-based waste materials in almost every part of the world including the West African region with its accompanying disposal enigma. Also, cost of pavement production is on the increase and construction materials are becoming highly scarce, but with innovative techniques being deployed in utilizing locally available, environmentally friendly, cost effective industrial and/or agro-based waste materials, it is appropriate that modification and improvement of construction materials be stepped up incorporating the ash (SCBA) from Sugarcane bagasses.

To tackle the above problems, this research work is aimed at evaluating the appropriateness of Sugarcane Bagasse Ash (SBA) as Filler in recycled asphalt pavement. This was achieved through some specific objectives as, determination of chemical (oxide) composition of the sugarcane bagasse ash, conducting the Particle size distribution of RAP/fresh aggregate and sugarcane bagasse ash in accordance with BS 1377, 1990;

and AASHTO T 27, determination of the suitability of RAP for Reuse in Pavement by comparing the test results with general Specifications for Roads and Bridges, Federal Ministry of Works and Housing (F.M.O.W & H.), and to establish the best possible combination of RAP, Fresh Aggregate and SCBA that produces best asphalt concrete mix design..

Both bitumen and aggregates in RAP are non-renewable resources and while asphalt pavement deteriorates with age, any asphalt pavement can be restored to its original or near original consistency by the process of recycling, which is usually achieved by blending RAP with fresh aggregate, bitumen and rejuvenating agent.

The recycling of existing asphalt pavement materials produces new pavements with appreciable savings in material, cost, and energy, and at the same time, mixtures containing reclaimed asphalt pavement (RAP) have been found to perform equally as virgin mixtures hence, the reclaimed asphalt pavement (RAP) is one of the most recycled materials in the world. (Ahmed & Abdulla, 2015). Removal and reuse of asphalt layer of existing pavement is termed as RAP; while full depth reclamation (FDR) is defined as removal and reuse of hot mix asphalt layer and entire base course. RAP can be reused immediately at sites. (Brajesh 2015)

Mineral Filler

A filler is a very finely ground material of about the same fineness as Portland cement, which, due to its physical properties, has a beneficial effect on some properties of concrete, such as density, workability, permeability, etc. (Neville 2011). Mineral filler consists of very fine, inert mineral matter that is added to the hot mix asphalt to improve the density and strength of the mixture. Filler is generally selected based on its ability to increase the stiffness of the binder mastic or improve adhesion between the binders and aggregate (Road Note 19). The amount of filler as a standard is 7% - 14% of the total weight of material for wearing course of road pavement. Typical mineral filler completely

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passes a 0.060 mm (No.30) sieve with at least 65 percent of the particles passing the 0.075 mm (No. 200) sieve. Mineral fillers in bituminous mix serve the purposes of mortar or mastic with the binder that contributes to improve stiffening of the mix; behaves as mineral aggregates and hence contributes to the contact points between individual aggregate particles.

In the recycling process, additive/filler material is applied. Some of the commonly used mineral fillers in bituminous pavement mix are stone dust, slag dust, hydrated lime, cement, fly ash and loess. These filler materials are not readily available at affordable cost. However, lots of research efforts have gone into waste materials in the construction industry exploring for alternatives at affordable cost. Such materials include industrial, domestic and agro-based waste (Abarshi, 1988; Raheem *et al*, 2010). Among the agro-based wastes is Sugarcane Bagasse Ash (SBA),an agro-based waste product, which is available in abundance in sub-Saharan Africa.Penki et`al (2016), in a study stated that coarse aggregates contribution to the stability of a bituminous paving mixture is mostly due to interlocking and frictional resistance of adjacent particles, while the contribution of fines or sand to stability failure function is filling of voids between coarse aggregates, and mineral filler is often seen as a void filling agent. David et`al (2016) in a research stated that Bagasse-ash is suitable as a filler based on testing with a variety of Bagasse-ash and cement content. Also, the use of Bagasse-ash as filler can both reduce the needs of cement filler and provide a fairly high economic value in addition to overcoming the existing waste. Murana& Sani (2015), study the effect of partial replacement of cement with bagasse ash in hot mix asphalt and revealed that the cement/bagasse ash mixes exhibits satisfactory trend results with an average bitumen content, while stability increases with decrease in bagasse content. In conclusion, it was stated that bagasse ash as a partial replacement for cement will help in solving environmental problems of bagasse waste disposal experienced in urban areas; thus help in achieving the phrase "waste to wealth`

The chemical composition of some agro-based wastes contained lot of silica (SiO_2) and ASTM C618 – 7 specifies that materials with a combined weight of silica, alumina and ferrous oxides of 70% and above be characterized as pozzolanic (Raheem, *et al,* 2010).

MATERIALS AND METHODS

Materials used are the Hot-Mix Asphalt (HMA) main components made of, asphalt cement and aggregate from fresh and RAP materials as well as sugarcane bagasse ash (SBA) as filler material.The reclaimed asphalt pavement material used was obtained from a scarified discarded pavement surface of a road around GIWA along Funtua – Zaria road. The reclaimed asphalt pavement which was pulverized manually was supplied by a vendor after the site was identified.

The fresh aggregate used in this research work was obtained from a quarry of Mother Cat Limited Quarry, a civil engineering construction company located along Gusau Talata Mafara road. The aggregate was supplied in various sizes (all-in aggregate) after identification of the site. The bitumen was supplied from the asphalt plant of Mother Cat Limited located as mentioned above. It is 60/70 grade cutback bitumen which is the commonly used bitumen in road construction for medium traffic.The Sugarcane Bagasse Ash was sourced locally and burnt in the open atmosphere. The ash, after complete burning, was collected, sealed up and transported to the laboratory. It was then ground and sieved through the British Standard No. 200 sieve. The material passing the sieve is then mixed with RAP and fresh aggregate using trial and error method of blending and partial replacement was adopted. The required ratios of the specimen for the necessary tests was 100% RAP & 0% fresh aggregate, 80% RAP & 20% fresh aggregate, 70% RAP & 30% fresh

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aggregate, 60% RAP & 40% fresh aggregate, 50% RAP & 50% fresh aggregate.

Investigation was conducted on Briquettes prepared by reconstituting RAP with the addition of fresh aggregate, Sugarcane Bagasse Ash (filler) and bitumen.

The equipment used in this research which were hired include; digital camera and hand-held GPS device.

The chemical analysis of the oxide composition of sugarcane bagasse was performed in the laboratory by subjecting the material to X- Ray Fluorescence test. X-ray Fluorescence (XRF) which is a non-destructive analytical technique used to determine the elemental composition of materials was used in this research to obtain the oxide composition of the mineral fillers.

Marshal Stability test method was used to determine the optimum bitumen content and for evaluating SCBA specimen in order to achieve the optimum bagasse ash replacement for mineral filler. Bitumen (60/70 grade cutback) was tested for the following physical properties; flash and fire point, ductility, and penetration, specific gravity and softening point.

The Physical and mechanical properties of aggregate was also conducted, Particle size distribution of materials which includes, SCBA, fresh aggregates, and reclaimed asphalt pavement (RAP) was conducted using sieve analysis test method in the laboratory.

The SCBA was sieved through sieve size of (0.63 – 0.075) mm arranged in descending order of size, while the fresh aggregates and RAP were sieved through sieve size of (22.0 – 0.075) mm also arranged in descending order of size. Other Tests conducted on materials based on standard specifications include initial and final setting time of cement using vicat apparatus,

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RESULTS AND DISCUSSION

CHEMICAL (OXIDE) COMPOSITION OF (SCBA)

Table 4.3Chemical Composition of Sugarcane Bagasse Ash (SCBA)

Components	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Carbon
Weight %	62.22	5.83	8.64	7.81	2.76	1.56	7.66	11.03

Composition by weight in SCBA of $SiO_2 + Al_2O_3 + Fe_2O_3 = 76.7\% > 70\%$. The desirable properties of mineral filler in terms of fineness and pozzolanic characteristics were met with the sugarcane bagasse Ash (SCBA) since the percentage passing sieve No. 200 of 82.4% is greater than 65% - 70% specification. In addition to its fineness, SCBA is adjudged pozzolanic (combined weight of S_iO_2, Al_2O_3, Fe_2O_3) is76.7 % by weight which is higher than minimum requirement 70% for a material to be pozzolanic(Raheem, et al, 2010), thus capable in providing strength requirement (stiffness) as that of ordinary Portland cement (OPC). With the above qualities, SCBA can be used as filler in hot mix design of asphalt pavement.

Marshall stability and Flow

Bitumen content (%)	Average Flow (mm)	Corrected stability (KN)
4.0	3.69	5.40
4.5	3.72	5.79
5.0	4.02	5.76
5.5	4.0	4.69
6.0	4.48	4.14

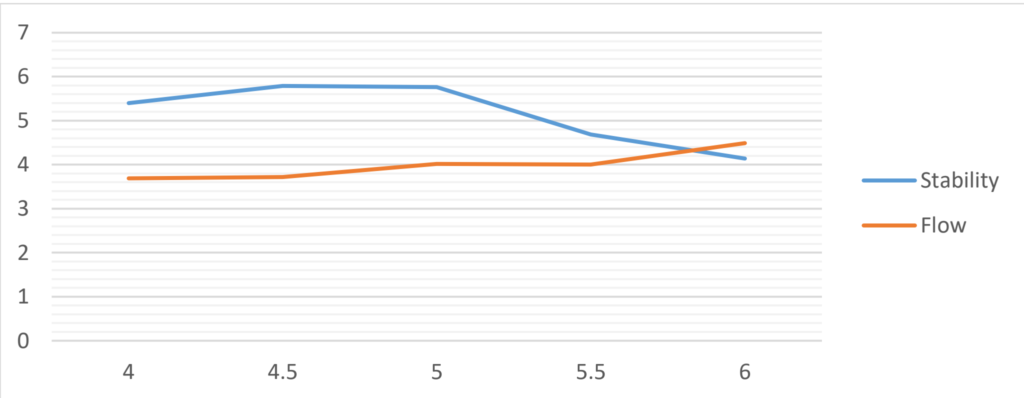

Figure 1: Stability and Flow plotted against bitumen content

Standard specification

Test	Standard specification
Stability (KN)	Not less than 3.5KN (> 3.5KN)
Flow (mm)	2mm – 6mm

The results of the Marshall Stability and flow tests satisfies the standard requirements

RESULTS OF BITUMEN TESTS

Flash and Fire Point

Tests	Obtained Results (°c)	Standard Specification (°c)
Flash point	266	232 (min)
Fire point	286	-

The flash and fire point results are within the allowable limit specified by standard hence, the bitumen sample is suitable for the purpose it is designed.

Ductility

The result of the ductility test obtained was108.2cm which is higher than the minimum of 100cm specification by standard.

Penetration

Test points	Sample 1: penetration(mm)	Sample 2: penetration (mm)
Point 1	66	57
Point 2	69	86
Point 3	68	67
Average	67.7	70

The penetration values of samples 1 and 2 as depicted in the table above are 67.7mm and 70.0mm respectively. 69mm obtained as the average penetration grade, implies that the bitumen has a penetration grade of 60/70 and is suitable for use in HMA in accordance with NGSRB, 2016 specification.

Specific gravity

Test points	Test 1	Test 2	Test 3
Av. Specific gravity	1.04	1.05	1.03

The average specific gravity of 1.04 is within the range of (1.01 – 1.06) for 60/70 grade cut back specified in the Nigerian General Specification for Road and Bridges (NGSRB, 2016) hence, is suitable for use in the HMA.

PARTICLE SIZE DISTRIBUTION

The result of the Particle size distribution tests for the sugarcane bagasse ash (SBA) and RAP/fresh aggregate in accordance with BS 1377, 1990; and AASHTO T 27 are presented in Table 4.1 and Table 4.2 respectively.

Table 4.1: Particle size distribution for sugarcane bagasse Ash (SBA)

Sieve Size (mm)	Percentage passing (%)
0.63	100
0.60	100
0.43	99.03
0.315	98.22
0.30	98.1
0.15	93.2
0.075	82.4

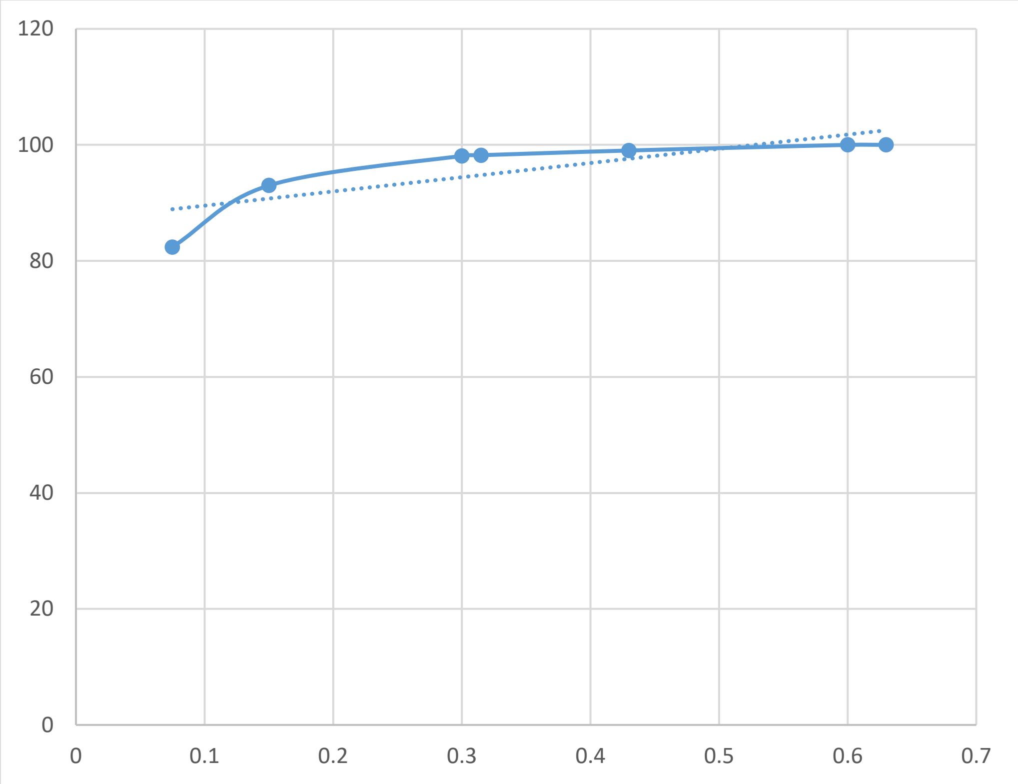

Figure 2: particle size distribution of SCBA

Table 4.2:Particle Size Distribution for RAP and Fresh Aggregates

Sieve size (mm)	Percentage Passing (%)	
	RAP	Fresh Aggregate
22.0	-	100
19.0	100	98.9
12.5	85.6	83.1
9.5	71.2	73.0
6.3	53.7	58.9
2.36	32.8	42.4
1.18	23.1	34.3
0.60	9.4	28.1
0.30	5.8	19.6
0.15	1.9	9.8
0.075	0.7	6.2

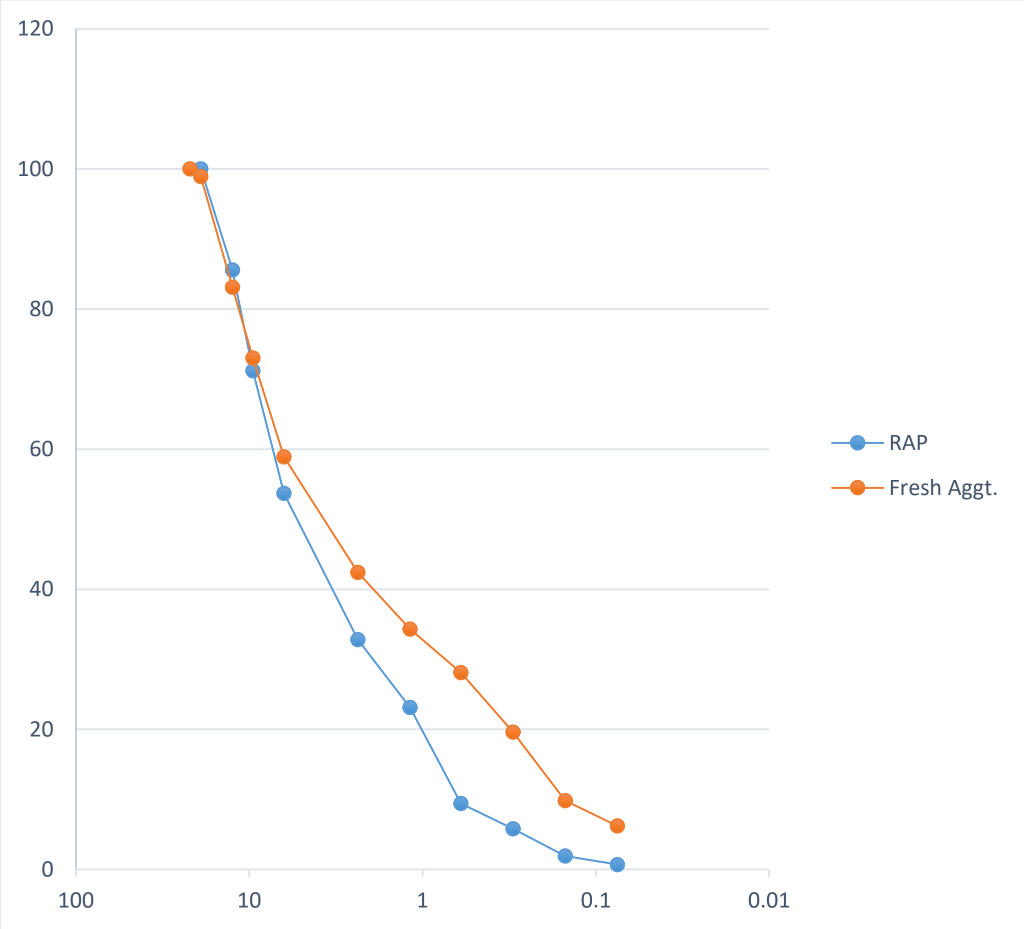

Figure 3: particle size distribution of RAP and fresh aggregate

Figures 2 & 3above demonstrates the graphical representation of the particle size distribution of sugarcane bagasse, reclaimed asphalt pavement (RAP) and fresh aggregate respectively as presented in tables 4. 1 and 4. 2 above.

SUITABILITY OF RAP FOR REUSE IN PAVEMENT

The test results of RAP and fresh aggregate particle size distribution as compared with the Nigeria general specification for roads and bridges 1997 "Federal ministry of works and housing (F.M.O.W & H)" is presented in table 4.3, while the RAP particle size distribution trying to fit within the envelope of the upper and lower limits of the specification is represented graphically in figure 4.

Table 4.4: Particle Size Distribution for RAP and fresh aggregate Compared with Specification

Sieve Size (mm)	Percentage Passing		Specification (F.M.O.W.)
	RAP	Fresh Aggregate	
25	-	100	-
19.00	100	98.9	100
12.50	85.6	83.1	85 – 100
9.50	71.2	73.0	75 – 92
6.30	53.7	58.9	65 – 82
2.36	32.8	42.4	50 – 65
1.18	23.1	34.3	36 – 51
0.60	9.4	28.1	26 – 40
0.30	5.8	19.6	18 – 30
0.15	1.9	9.8	13 – 24
0.075	0.7	6.2	7 – 14

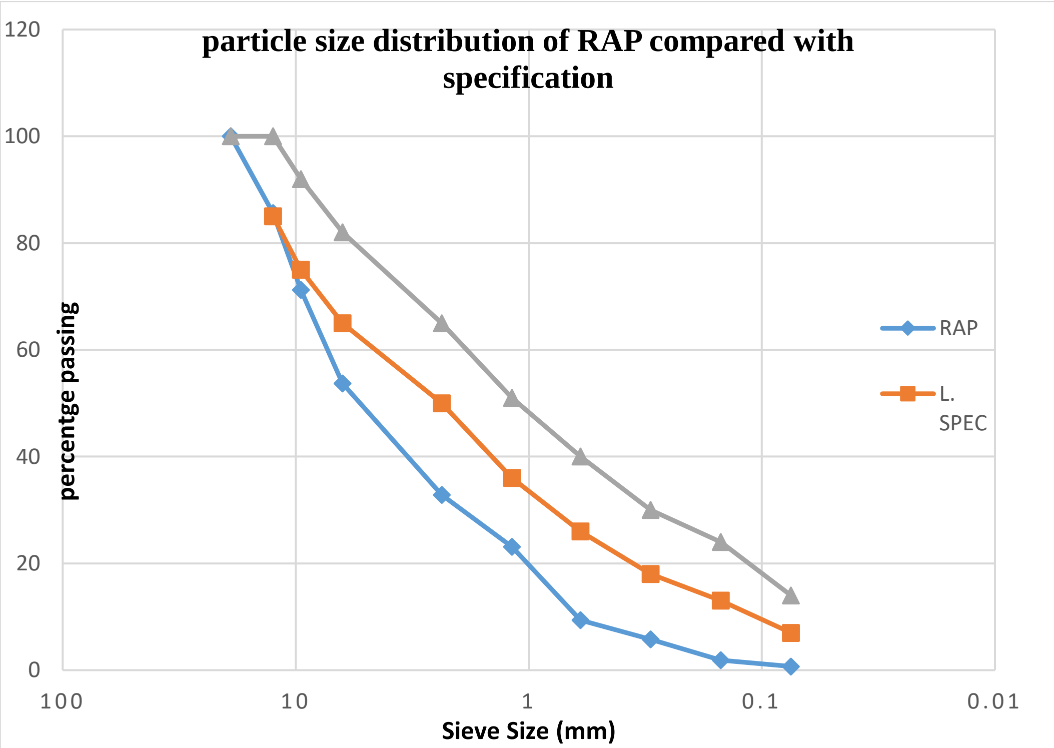

Figure 4: Particles size distribution for RAP compared with specification.

It is clear from table4.5 and Fig 1 that RAP did not fit in to F.M.O.W. &H gradation envelope. Thus, RAP gradation requires a boost from both fresh aggregates and Filler materials in order to be appropriate for production of pavement bituminous mixes.

BLENDED OF AGGREGATES.

The reclaimed asphalt pavement (RAP) material was reconstituted by the addition of fresh aggregate and SCBA (filler) employing the trial and error method of proportioning. A typical comparative table between the gradation of the combined materials with specifications (F.M.O.W, Nigeria) is shown in Table 4.6 below.

Table 4.5: Samples of different composition of RAP and Natural aggregate

Sample Ref. No.	Detail of Composition
A1	100% RAP + 0% Natural aggregate
A2	80% RAP + 20% Natural aggregate
A3	70% RAP + 30% Natural aggregate
A4	60% RAP + 40% Natural aggregate
A5	50% RAP + 50% Natural aggregate

Table 4.6: Comparison of Blended Aggregates gradation with specification

S/No.	Sieve Size	Percentage of Filler Content (%)					Specification of FMOW&H
		0.5	1.5	2.0	2.5	3.0	
1	19.000	100.000	100.000	100.000	100.000	100.000	100
2	12.500	99.810	99.810	99. 810	99. 810	99. 810	85 – 100
3	9.500	89.800	89. 800	89. 800	89.800	89. 800	75 – 92

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4	6.300	76.770	76.770	76. 770	76. 770	76. 770	65 – 82
5	2.360	64.360	64. 360	64. 360	64. 360	64. 360	50 – 65
6	1.180	41.470	41. 470	41. 470	41. 470	41. 470	36 – 51
7	0.600	32.950	32. 950	32. 950	32. 950	32. 950	26 – 40
8	0.300	24.119	24. 119	24. 119	24. 119	24. 119	18 – 30
9	0.150	16.306	16.251	16.238	16.216	16.204	13 – 24
10	0.075	6.916	6.784	6.718	6.652	7.832	7 – 14

The preliminary test results in this research indicated the aggregate in the RAP has to be built up with fresh aggregate because its gradation falls outside the specification envelope. Bitumen content in the RAP was rather very viscous thereby indicating oxidation. The physical and mechanical properties of RAP have passed the minimum requirements for mix design. Sieve analysis on sugarcane bagasse Ash showed that, the material can be used as filler since over 80% of SCBA passes No. 200 sieve which satisfied the fineness requirement of filler which states that at least 65% must pass No. 200 sieve. Furthermore, SCBA is adjudged to be pozzolanic, it can therefore be used as filler to provide the stiffening strength requirement like cement.

Table 4.7 Test results of filler and aggregate in Comparison with standard specifications

S/No.	Properties	Code specifications	Test Results
1	Specific gravity (SCBA)	2.85	2.847
2	Specific gravity (fine aggregate)	2.60 – 2.90	2.68
3	Specific gravity (coarse aggregate)	2.60 – 2.90	2.63
4	Aggregate impact Value (C A)	< 30%	22.37

The properties of the materials studied here meet the requirement of the standard specifications as compared in the table above.

4.8 Test on cement

S/No.	Properties	Code Specifications	Test Result
1	Initial setting time	> 45mins.	59 Mins.
2	Final setting time	< 10hrs.	3hrs, 15mins
3	Specific gravity	3.15	2.67

CONCLUSION AND RECOMMENDATIONS

This paper presents a laboratory based study that was conducted to evaluate the performance of asphalt concrete mix design using sugarcane bagasse ash (SCBA) as filler in hot mix recycled asphalt pavement (RAP) and to establish the best possible combination of RAP, Fresh Aggregate and SCBA that meet the Nigerian specifications for Hot-mix asphalt design.

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