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FLEXURAL STRENGTH OF PAVING STONES MADE WITH GROUND PALM KERNEL SHELL AS REPLACEMENT OF FINE AGGREGATE

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ABSTRACT

The need for alternative, non-conventional local construction materials has led to the increased use of palm kernel shell (PKS) as partial replacement of coarse and fine aggregates. The use of palm kernel shell as partial replacement for stone dust in the production of paving stones is considered in this study. The research involved determining the impact palm kernel shell (PKS) will have on the flexural strength and split tensile strength of the paving stones produced. The sizes of the palm kernel shell were less than 5mm. Stone dust paving stones (SDPS) were used as control using mix ratios of 1:3, 1:4, 1:5 and 1:6. Particle size distribution, moisture content and bulk density were determined for the stone dust aggregate and palm kernel shell. Concrete paving stones were cast using stone dust and palm kernel shell (PKS) and both were cured for 28 days. Tests were carried out which included flexural strength test, and water absorption test. The results of the tests carried out after 28 days of curing showed that only paving stones made with mix ratio 1:3 gave significant values.

Keywords: Palm Kernel Shell, Paving Stones, Flexural Strength Test, Stone Dust.

I. INTRODUCTION

The gradual depletion of the available natural resources used as building materials and its resulting imbalance in the ecological systems has led to researches been geared towards finding partial or complete alternatives to these resources. In this course, recycled concrete aggregate, crushed clay bricks, low density polyethylene, foundry greensand waste, groundnut husk ash, termitaria dunghill and stone dust has been used as partial replacement for sand as fine aggregates in the production of concrete paving stone [1][2][3]. Based on its availability in the tropical regions, economic strength and similar physical and mechanical properties with stone dust, this research used palm kernel shell as fine aggregate in replacing stone dust in the production of concrete paving stones. This study aims at determining the effect of palm kernel shell on the flexural and split-tensile strengths and its optimum mix ratio for the production of concrete paving stones.

II. LITERATURE REVIEW

Various researches have been carried out on the use of palm kernel shell in lightweight concrete.

In 2014, Willians F.N et al [4] carried out a research on the suitability of palm kernel shell as coarse aggregate in lightweight concrete production. Beams and cubes were casted with total replacement of granite with palm kernel shell (PKS) and an equivalent control was casted to serve as the basis for comparison, a water ratio of 0.65 at a mix ratio of 1:2:4. The beams and cubes were cured for 7, 14, 21 and 28 days. The results showed that the compressive strength and flexural strength increased with age of curing but the compressive strength and flexural strength of the palm kernel shell concrete (PKSC) was less than that of normal weight concrete (NWC). The values showed that it could be used as a lightweight concrete.

Mohammed H. et al [5] carried out an investigation on the use of crushed palm kernel shell as partial replacement of fine aggregate in asphaltic concrete. The asphaltic concrete was prepared with fine aggregate (66%), coarse aggregate (14% - 20mm granite size), quarry dust (6%) and bitumen (6.3%). A partial replacement of 10, 30, 50 and 70% by weight of the fine aggregate by crushed palm kernel shell (PKS) were prepared. The results showed that the sample with 10 and 50% partial replacement of fine aggregate with the palm kernel shell determined properties were within the specifications for asphaltic concrete roads.

There has been notable researches carried out on paving stones and some which are relevant to the project work will be highlighted.

Radhikesh et al [6] studied the use of stone crusher dust as a fine aggregate in concrete for paving stone. It was gotten from the research that the replacement of fine aggregate by crusher dust up to 50% by weight has negligible effect on the reduction in the physical and mechanical properties of the paving blocks. It also saves up to 56% in terms of cost and this will vary based on the distance of the fine aggregate from the construction/manufacturing site.

Opeoluwa Dada and Antonie Mulaba [7] researched on the possible use of foundry greensand waste in making pavers and production of bricks. The conclusion from the study was that foundry greensand waste was best used as a partial replacement for aggregate in paving stone production and also as a replacement for sand in the making of mortar used for brick setting.

In 2010, Kosemani Olajumoke [2] worked on the use of termite mould/termitaria as a replacement for the fine aggregate in the production of interlocking concrete pavers. The result showed that after 28 days of curing a compressive strength of 21.98N/mm^2 was gotten for the uncontaminated sample (without termite mould) while the concrete paver with ratio of termitaria-sand of 5%, 10% and 15% were 19.64N/mm2, 19.01N/mm^2 and 13.61N/mm^2 respectively. As the percentage increases the strength of the concrete pavers decreases.

Chi Sun Poon and Dixon Chan [1] in 2005 researched into the use of recycled concrete aggregate and crushed clay bricks in paving blocks production. In this research it was concluded that the use of crushed clay brick reduced the density, compressive strength and tensile strength of the paving stones. The water absorption of paving blocks with crushed clay bricks were higher than those without it. The paving blocks using 50% crushed clay bricks met the requirement by AS/NZS 4455 and ETWB of Hong Kong (Grade B) for pedestrian areas. Paving blocks (Grade B) with 25% crushed clay brick satisfied the requirement specified by ETWB of Hong Kong for trafficked area.

In Ghana Eric Ababio et al [3] researched on the use of waste low density polyethylene as partial replacement for sand in the production of high strengths concrete pavement bock. It was observed that the density, compressive strength, flexural strength and splitting strength decreased as the polyethylene content increased. It was concluded that if 10% - 50% of the plastic content was used the resulting pavement block would satisfy the requirement for pedestrian walkways, light traffic and heavy traffic situations.

In the research carried out by Euniza Jusli et al [8], sand as fine aggregate was partially replaced with rubber granules with different thickness of block facing layer. The percentages and sizes of the rubber granules were varied. Physical, chemical and mechanical tests were carried out on the doubled layer rubberized concrete paving blocks (DL-RCPBs) with 10, 20, 30 and 40% replacements of rubber granules by weight of aggregate and the blocks were designed with 10mm, 20mm, 30mm and 40mm of facing layer thickness.

III. METHODOLOGY

Materials

The following materials were used:

- Dangote Portland Cement bought from the retail sellers in Ibadan
- Stone dust – this was gotten from a construction site in University of Ibadan
- Palm Kernel Shell (PKS) – This was gotten from Oko in Ibadan and grinded into fine by a grinding mill.
- Water
- Lubricating oil – This was used to lubricate the paving stone formwork before casting the paving stone.

Procedure:

Procedure for Production of Paving Stones

In carrying out this research, trial test was carried out. The trial test was to help determine which set of ratios will be best suited for the experiment. The mix ratio of 1:5 and 1:6 were used to cast the paving stone using only the stone dust and the untreated palm kernel shell (PKS). The paving stone formwork was oiled and then the stone dust was batched (batching was done by volume). The required proportion of cement and water was added. Followed by the mixing of the stone dust and cement into a consistent and workable mixture. This was poured into the formwork and compacted by slightly shaking it sideways at the edges of the formwork which afterwards was left to set. The next day, it was de-molded, weighed and taken to the curing tank – curing was done for 28 days. From the results gotten, the main research was carried out using 1:3 and 1:4 as the mix ratios for the casting of paving stones using stone dust, palm kernel shell (PKS). The same procedure used in the trial was also used in the casting of the 1:3 and 1:4 mix ratios. After curing for 28 days, various tests were carried out on it – flexural strength and the water absorption test.

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IV. MODELING AND ANALYSIS

1. Procedure for Moisture Content Test

$$w = \frac{m_2 - m_3}{m_3 - m_1} x\ 100\%$$

where

m_1 is the mass of the container (in g)

m_2 is the mass of the container and the wet test portion (in g)

m_3 is the mass of the container and the dry test portion (in g)

The container is clean and dried, then weighed to the nearest 0.1g m_1. The sample is then placed in the container and weigh the whole m_2. The container and the test sample is placed in the oven to dry at 105^{0}C for minimum 12 hours. After drying, the container and its content is weighed m_3.

2. Procedure for Flexural Strength Test

The paving stone sample was placed longitudinally and centered on the supporting bearing blocks. The load-applying block was then brought in contact with the upper surface at the centerline between the supports. The load applying block was brought in full contact with the paving stone surface by applying 3.1N preload. Special care was taken to ensure that the paving stone was in uniform contact with the bearing blocks and the load applying block.

The load was applied with a hand pump, and so the paving stone was loaded by applying the load at a rate of one full pump stroke per second. The applied load is about 125N, the full pump stroke was then reduced to about a 12-pump stroke and the one second stroke rate was maintained. The rate of load application for screw power machines, with the moving head operating at 1.3mm per minute when the machine is running idle, is acceptable.

The formula used in calculating the flexural strength is:

$$R = \frac{P\ x\ l}{bd^2}$$

Where R is modulus of rupture in KPa

P is maximum load in KN

l is span length in metres

b is average width in metres

d is average depth in metres.

V. RESULTS AND DISCUSSIONS

Moisture Content Tests:

Table 1 – Moisture Content for Stone Dust and Palm Kernel Shell

	Stone Dust		Palm Kernel Shell (PKS)	
Can No.	A	B	C	D
Weight of can (g)	14.1	13.0	15.4	14.4
Weight of can + wet sample (g)	26.2	28.1	24.9	24
Weight of can + dry sample (g)	26.0	27.8	23.0	22.1
Weight of dry soil (g)	11.9	14.8	7.6	7.7
Weight of water (g)	0.2	0.3	1.9	1.9
Moisture Content (%)	1.7	2.0	25	24.7
Average moisture content	1.85		24.85	

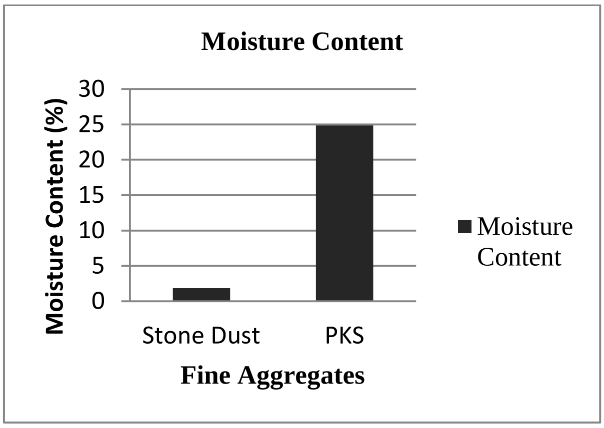

Figure 1: Moisture Content of Stone Dust and Palm Kernel Shell

Bulk Density Test

Table 2 – Bulk Density of Stone Dust and Palm Kernel Shell

	STONE DUST		PALM KERNEL SHELL (PKS)	
Can No.	1	2	3	4
Weight of can (g)	14.7	14.2	14.5	15.1
Height of can (g)	3.6	3.7	3.5	3.4
Diameter of can (cm)	5.0	5.0	5.0	5.3
Radius of can (cm)	2.5	2.5	2.5	2.65
Weight of can + soil (g)	161.7	167.0	78.2	75.1
Weight of soil (g)	147.0	152.8	63.7	60.0
Volume of can (cm^3)	70.66	72.65	68.72	75.01
Bulk density (g/cm^3)	2.08	2.10	0.93	0.80
Average bulk density (g/cm^3)	2.09		0.87	

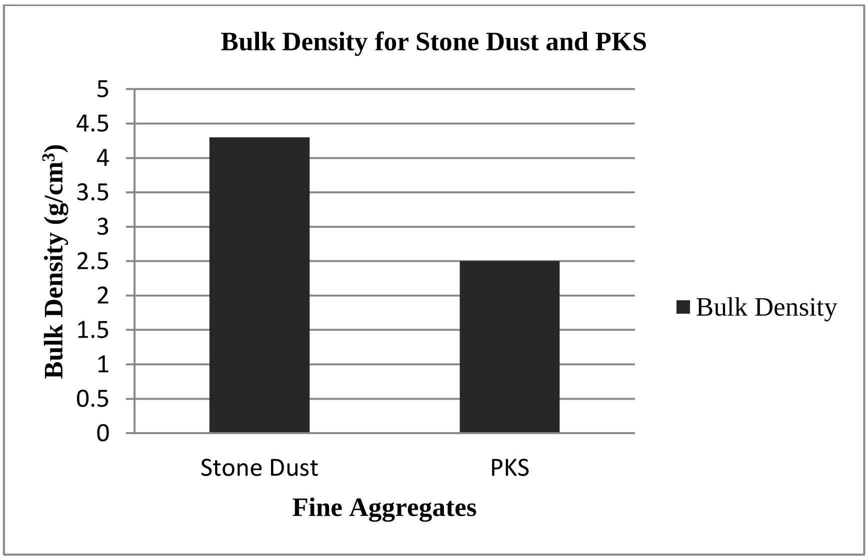

Figure 2: Bulk Density for Stone Dust and Palm Kernel Shell

Particle Size Distribution Data for Palm Kernel Shell (PKS) Sample:

Table 3 – Particle Size Distribution of PKS

Sieve Size	Container+ mass retained (g)	Mass Retained (g)	Weight of empty sieve (g)	% retained	% Passing
6.70mm	459.15	0	459.15	0	100
4.75mm	491.85	3.30	488.55	0.66	99.34
2.36mm	512.10	86.65	425.25	17.33	82.01
1.18mm	587.70	194.25	393.45	38.85	43.16
850µm	424.50	47.30	377.20	9.46	33.70
600µm	390.65	45.40	345.25	9.08	24.62
425µm	375.20	34.35	340.85	6.87	17.75
212µm	282.05	40.90	341.15	8.18	9.57
Pan	488.85		443.6	9.57	0

Particle Size Distribution Data for Dust Sample

Table 4 – Particle Size Distribution For Stone Dust

Sieve Size (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Retained (g)	Mass Retained (g)	% Retained	Cumulative % Retained	% Passing
6.70	464.50	464.50	0.00	0.00	0.00	100.00
4.75	494.50	563.60	69.10	13.82	13.82	86.18
2.36	432.60	567.40	134.80	26.96	40.78	59.22
1.18	397.00	479.30	82.30	16.46	57.24	42.76
0.85	380.10	406.50	26.40	5.28	62.52	37.48
0.6	350.00	384.70	34.70	6.94	69.46	30.54
0.425	390.00	429.90	39.90	7.98	77.44	22.56
0.212	341.50	375.60	34.10	6.82	84.26	15.74
Pan	160.50	239.20	78.70	15.74	100.00	0.00

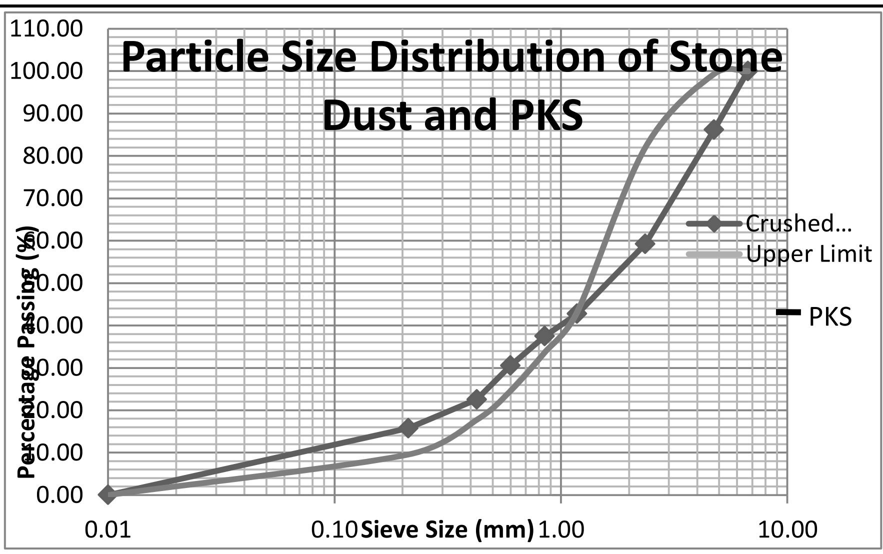

Figure 3 –Particle Size Distribution Chart of Stone Dust and Palm Kernel Shell

Flexural Strength Test Results

Palm Kernel Shell:

Table 5 – Flexural Strength for Palm Kernel Shell Paving Stone

Mix Ratio	Weight	Density (g/cm³)	Load (KN)	Stress (N/mm²)
1:3	1.995	1.327	2.60	1.586
	2.020	1.344	1.30	0.793
	2.010	1.337	2.20	1.342
Average	2.008	1.336	2.03	1.240
1:4	1.945	1.294	----	----
	1.885	1.254	----	----
	1.830	1.218	----	----
Average	1.887	1.255	----	----
1:5	1.905	1.267	----	----
	1.855	1.234	----	----
	1.865	1.241	----	----
Average	1.875	1.247	----	----
1:6	1.715	1.141	----	----
	1.820	1.211	----	----
	1.905	1.206	----	----
Average	1.813		----	----

Stone Dust:

Table 6 – Flexural Strength for Stone Dust Paving Stone

Mix Ratio	Weight	Density	Load (KN)	Stress (N/mm²)
1:3	3.225	2.146	8.90	5.429
	3.340	2.222	7.30	4.453
	3.725	2.478	5.10	3.111
Average	3.430	2.282	7.10	4.331
1:4	3.110	2.069	6.40	3.904
	3.220	2.142	5.70	3.477
	3.450	2.295	6.85	4.178
Average	3.260	2.169	6.32	3.853
1:5	3.295	2.192	5.50	3.355
	3.115	2.073	3.50	2.135
	3.345	2.226	4.35	2.653
Average	3.252	2.163	4.45	2.714

1:6	3.300	2.196	4.20	2.562
	3.285	2.186	2.70	1.647
	3.340	2.222	3.80	2.318
Average	3.308	2.201	3.57	2.176

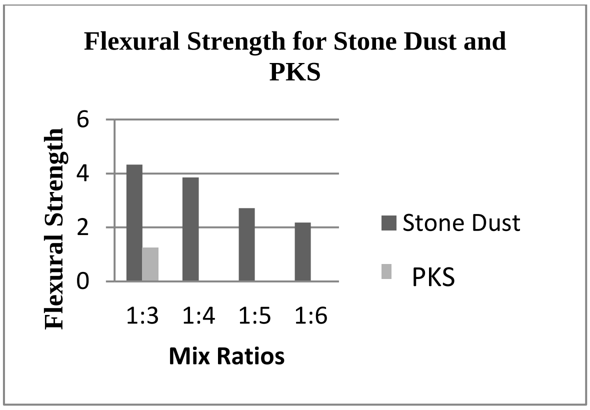

Figure 4 – Flexural Strength for Stone Dust and Palm Kernel Shell

Water Absorption

Water Absorption for Palm Kernel Shell Paving Stone

Table 7 - Water Absorption for Palm Kernel Shell Paving Stone

Mix Ratio	Weight before submerging (kg)	Weight after submerging (kg)	Weight of water absorbed (kg)	Water absorption (%)	Average Water absorption (%)
1:3	1.305	1.395	0.090	6.9	
	1.405	1.490	0.085	6.0	6.3
	1.895	2.010	0.115	6.1	
1:4	1.640	1.765	0.125	7.6	
	1.820	1.960	0.140	7.7	8.0
	1.710	1.860	0.150	8.8	
1:5	0.655	0.735	0.080	12.2	
	0.785	0.885	0.100	12.7	12.3
	0.630	0.705	0.075	11.9	

Water Absorption for Stone Dust Paving Stone

Table 8 - Water Absorption for Palm Kernel Shell Paving Stone

Mix Ratio	Weight before submerging (kg)	Weight after submerging (kg)	Weight of water absorbed (kg)	Water absorption (%)	Average Water absorption (%)
1:3	2.880	2.995	0.115	4.0	
	2.945	3.050	0.105	3.6	3.8

	2.795	2.905	0.11	3.9	
1:4	2.935	3.070	0.135	4.6	
	2.830	2.960	0.13	4.6	5.2
	1.640	1.745	0.105	6.4	
1:5	2.830	2.995	0.165	5.8	
	2.840	3.000	0.160	5.6	5.3
	2.835	2.960	0.125	4.4	
1:6	2.760	2.915	0.155	5.6	
	2.625	2.800	0.175	6.7	5.7
	2.660	2.790	0.130	4.9	

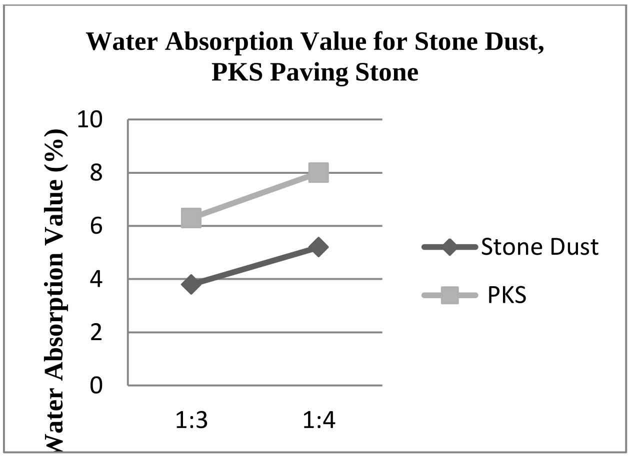

Figure 5 – Water Absorption Value for Stone Dust and Palm Kernel Shell Paving Stones

For the flexural strength test results, it was observed that the values for the stone dust paving stones was consistently higher in all the mix ratios than those gotten from using palm kernel shell and palm kernel shell. However it was observed that the values decreased from 1:3 to 1:6 as shown in figure 4. The values for the stone dust paving stone were the highest for all the mix ratios, for the PKS paving stone, it only gave readings for the mix ratio 1:3.

From the water absorption test, it can be observed that for the PKS, and stone dust paving stones, the values increased as their proportion in the mix increased. This can be seen in Figure 5. Also it was observed that only the mix ratio of 1:3 for PKS paving stone met the standard requirement according to BS EN 1338:2003 which stated that the percentage of water absorption should be less than 7%.

Table 9 - (An Excerpt From Table 3 - CMAA Draft Guide Requirements For Concrete Segmental Paving Units – Ma34 1993)

APPLICATIONS	CHARACTERISTIC FLEXURAL STRENGTH (KN)	BREAKING LOAD (KN)
Residential Pedestrian		
Not around pools	2	
Around pools	2	

Residential Driveway	
Light Traffic	2
Medium Traffic	3
Public Footpaths	
Low volume	3
High volume	3
Pedestrian Malls	3
Roadways	
Minor	3
Local, Collector, Distributor	3
Industrial Pavements	
No containers	4
Containers	4

According to IS 15658: 2006 and CMAA MA34 1993, stone dust paving stone of mix ratios 1:3, 1:4, 1:5 and 1:6 with values of 4.331N/mm^2, 3.853 N/mm^2, 2.714 N/mm^2, 2.176 N/mm^2,can be used for both residential pedestrian, residential driveway(light traffic and medium traffic), public footpaths (low volume and high volume), roadway and industrial pavements. While for palm kernel shell none of the values were suitable.

VI. CONCLUSION

The following are the conclusion gotten from this research work:

- Using palm kernel shell as fine aggregate as replacement for stone dust led to the reduction in the flexural strength as the mix ratios increased.
- None of the mix ratios of palm kernel shell used as fine aggregate in the production of paving stones was suitable.
- Using palm kernel shell as fine aggregate as replacement for stone dust is not viable. This study thereby suggests that the palm kernel shells be treated in further research to test for the feasibility of its use as a replacement for stone dust in the production of paving stones.

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