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INVESTIGATIONS ON SAWDUST AND PALM KERNEL SHELLS AS AGGREGATE REPLACEMENT

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ABSTRACT

The high and rising costs of building construction in developing countries have been a source of concern to government and private developers. This study investigated the use of saw dust and palm kernel shells (PKS) as replacement for fine and coarse aggregates in reinforced concrete slabs. Reinforced concrete slabs measuring 800 x 300 x 75mm were cast. Sawdust and PKS were used to replace both fine and coarse aggregates from 0% to 100% in steps of 25%. Flexural strengths were evaluated at 7, 14 and 28 days and compressive strengths were evaluated at 28 days. Increase in percentage of sawdust or palm kernel shells in concrete slabs led to a corresponding reduction in both flexural and compressive strength values. It is seen that at a low replacement value of 25% sawdust and PKS can produce lightweight reinforced concrete slabs which could be used where low stress is required at reduced cost. A weight reduction of 14.5% and 17.9% was achieved for sawdust and PKS replacement slabs respectively. It is also seen that the reduction in cost up to 7.43% can be achieved for every cubic meter of slab production with use of sawdust or palm kernel shell.

Keywords: sawdust, palm kernel shell, concrete slab, flexural strength, aggregates.

INTRODUCTION

The construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries. There arises the need for engineering consideration of the use of cheaper and locally available materials to meet desired need enhance self efficiency, and lead to an overall reduction in construction cost for sustainable development.

Attempts have equally been made by various researchers to reduce the cost of its constituents and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include sawdust, pulverized fuel ash palm kernel shells, slag, fly ash etc which are produced from milling stations, thermal power station, waste treatment plants etc. The utility of fly ash as partial replacement in concrete mixes is on the rise. The quantity of fly ash produced from power plants in India is approximately 105 millions tonnes each year (Fernandez, 2007). The percentage of its utilization is currently less than 13%.

Fernandez investigated the use of fly ash as replacement for fine aggregates in concrete and discovered that the compressive, tensile and flexural strength increase initially and reach a maximum value at 52%for both 7 and 28 days.

Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes. Timber is one of the oldest structural materials used by man. Temples and monuments built several years ago, which still remain in excellent condition show the durability and usefulness of timber (Kullkarni, 2005). Clean Sawdust without a large amount of bark has proved to be satisfactory. This does not introduce a high content of organic material that may upset the reactions of hydration (Neville, 2000)

Palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). PKS is light and therefore ideal for substitution as aggregate in the production of light weight concrete.

Olutoge (1995) in his investigations into the physical properties of rice husk ash, sawdust and palm kernel shell found their bulk densities to be 530kg/m^3, 614kg/m^3 and 740kg/m^3 respectively. He concluded that these materials had properties which resembled those of lightweight concrete materials.

Olanipekun (2006) investigated the properties of coconut shells (CCS) and palm kernel shells (PKS) as coarse aggregates in concrete. The CCS were crushed and substituted for conventional coarse aggregates in gradations of 0%, 25%, 50%, 75% and 100%. Two mix ratios (1:1:2) and (1:2:4) were used respectively. He noted that the compressive strength of the concrete decreased as the percentage of the shells increased in the two mix ratios. However, concrete obtained from CCS exhibited a higher compressive strength than PKS concrete in the two proportions. His results also indicated a 30% and 42% cost reduction for concrete produced from coconut shells and palm kernel shells respectively. He concluded that coconut shells were more suitable than palm kernel shells when used as substitute for conventional aggregates in concrete production.

The present study aims to investigate the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregates in the production of reinforced concrete slabs. Having carried out a brief examination of the background to this study it will be re- stated that this investigation will adopt a “waste to wealth" policy as the study materials presently have little or no economic value with disposal problems being faced by the producers. Thus, this investigation will not only solve the disposal problem but will also ascertain their suitability as replacement for both fine and coarse aggregates in production of reinforced concrete slabs and hence enhance their economic value.

MATERIALS AND METHODS

Materials

Sawdust

The sawdust was sourced from planks and furniture markets in Lagos, Nigeria. The sawdust consisted of chippings from various hardwoods. It was sun dried and kept in waterproof bags

Palm kernel shells (PKS): The PKS used were obtained from Odo-ota, in Nigeria. The shells were put in a basket in batches and thoroughly flushed with water to remove impurities that could be detrimental to concrete. They were sun dried and kept in waterproof sacks.

Granite

The granite (coarse aggregate) used for the study was 12mm size. It was sourced from a quarry on Lagos-Ibadan expressway in Nigeria.

Sand

The sand was sourced from Ikorodu in Lagos, Nigeria. It was thoroughly flushed with water to reduce the level of impurities and organic matter and later sun dried. It conformed to the requirements of BS 882(1982)

Cement

The cement used was ordinary Portland cements. It was sourced from Lagos, Nigeria and conformed to the requirements of BS 12(1996).

Water

The water used for the study was obtained from a borehole. The water was clean and free from any visible impurities. It conformed to BS3148 (1980) requirements.

Steel reinforcement

The reinforcements of size 10mm diameter was sourced in Lagos, Nigeria. The reinforcements were cut into sizes 250mm (main bar at 175mm c/c) and 750mm (distribution bar at 250mm c/c). They were arranged to form a mesh which was used to reinforce the samples.

Batching and mixing of materials

Batching of materials was done by weight. The percentage replacements of aggregates by sawdust and palm kernel shell were 0%, 25%, 50%, 75% and 100%.This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other sample.

Details of mixes

Calculations for the masses of constituents were carried out for a target concrete strength of 20N/mm^2 and have been presented in Tables 1 and 2.

Table-1. Masses of constitutions for sawdust replacement for one batch.

Sawdust replacement (%)	**Mass of Concrete** (kg)			
	Cement	**Sawdust**	**Sand**	**Granite**
0	6.170	-	12.340	24.690
25	6.170	3.085	9.255	24.690
50	6.170	6.170	6.170	24.690
75	6.170	9.255	3.085	24.690
100	6.170	12.340	-	24.690

Table-2. Masses of constitutions for palm kernel shell replacement for one batch.

Sawdust replacement (%)	**Mass of concrete** (kg)			
	Cement	**Sand**	**PKS**	**Granite**
0	6.170	12.340	-	24.690
25	6.170	12.340	6.1725	18.5175
50	6.170	12.340	12.345	12.345
75	6.170	12.340	18.5175	6.1725
100	6.170	12.340	24.690	-

Casting of samples

The size of formwork adopted was 800 x 300 x 75mm. The concrete was mixed, placed and compacted in three layers. Steel reinforcement was placed on top of the first layer which served as cover to the reinforcement. The samples were demolded after 24 hrs and kept in a curing tank for 7,14and 28 days as required.

Testing of samples

All tests were carried out at the Lagos state materials testing laboratory along Lagos-Ibadan expressway, Lagos. Reinforcement samples (3nos, 10mm diameter and 350mm length each) were tested using Techno test universal testing machine. The steel was placed in between the gripping teeth and the knob tightened before the load was applied. The load was increased until fracture. The fracture load was noted.

The flexural test on RC slab was carried out with the automatic techno test flexural machine. The sample was weighed before being put in the flexural machine. The load was applied and increased until failure. The machine automatically stops when failure occurs, and then displays the load and the flexural strength was evaluated. Part of the slab was cut off, shaped, measured and placed on the machine Load was then applied until failure and the crushing load was noted. The compressive strength of each sample was determined as follows;

Compressive strength = Crushing load (N) /Effective Area (mm^2)

RESULTS AND DISSCUSIONS

Results of tensile strength test of reinforcements

The results obtained from the tensile test of reinforcement sample are given in Table-3. The reinforcements test was satisfactory. The strength was above the minimum of 410N/mm^2 specified by 8110.

Table-3. Tensile test results for 10mm diameter high yield reinforcement.

Bar size (mm)	**Yield**		**ultimate**		**Elongation** (%)
10	**Load** (tons)	**Stress** (N/mm^2)	**Load** (tons)	**Stress** (N/mm^2)	
10	3.74	469.64	4.84	609.26	14.5
10	3.85	488.68	4.87	609.71	14.55
10	3.71	471.53	4.75	602.92	13.54
Average		476.62		607.30	14.20

Results of RC slab flexural and compressive strength test

Results from flexural and compressive strength tests on samples are shown in Tables 4 and 5 and Figures 1 and 2.

Table-4. Flexural and compressive strength of slabs with various percentage of sawdust.

% Sawdust	**7 days**		**14 days**		**28 days**		
	Weight (kg)	**Flexural strength** (N/mm^2)	**Weight** (kg)	**Flexural strength** (N/mm^2)	**Weight** (kg)	**Flexural strength** (N/mm^2)	**Comp. strength** (N/mm^2)
0	40.95	1.43	41.10	1.96	41.10	2.24	21.6
25	33.15	1.15	34.90	1.39	35.15	1.67	15.9
50	32.65	0.89	30.16	1.01	27.50	1.12	10.3
75	32.20	0.54	26.85	0.68	27.30	0.81	8.0
100	20.35	0.39	19.40	0.51	18.25	0.55	6.1

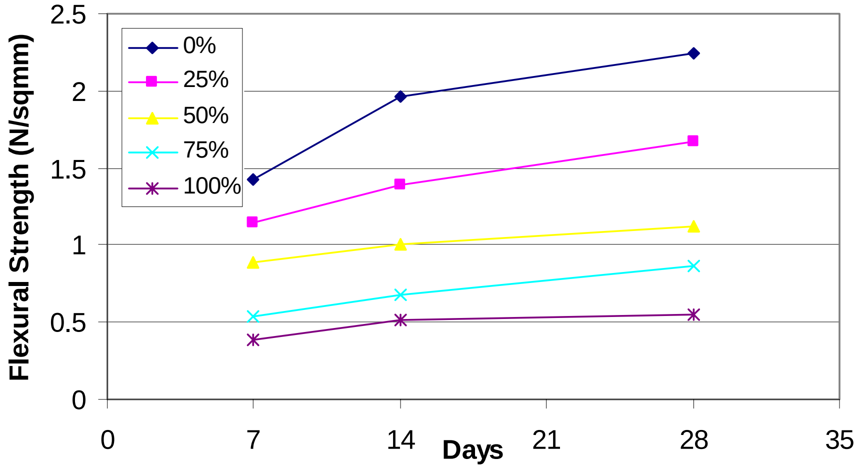

Figure-1. Effect of replacement of sand with sawdust on flexural strength.

Table-5. Flexural and compressive strength of slabs with various percentages of palm kernel shells.

% PKS	7 days		14 days		28 days		
	Weight (kg)	**Flexural strength** (N/mm^2)	**Weight** (kg)	**Flexural strength** (N/mm^2)	**Weight** (kg)	**Flexural strength** (N/mm^2)	**Comp. strength** (N/mm^2)
0	40.95	1.43	40.80	1.96	41.10	2.24	21.6
25	32.66	1.19	35.41	1.35	33.75	1.75	15.9
50	31.44	1.11	30.16	1.18	31.73	1.19	10.9
75	29.22	0.80	27.55	0.81	30.63	0.87	8.5
100	28.01	0.68	26.87	0.70	28.93	0.75	7.2

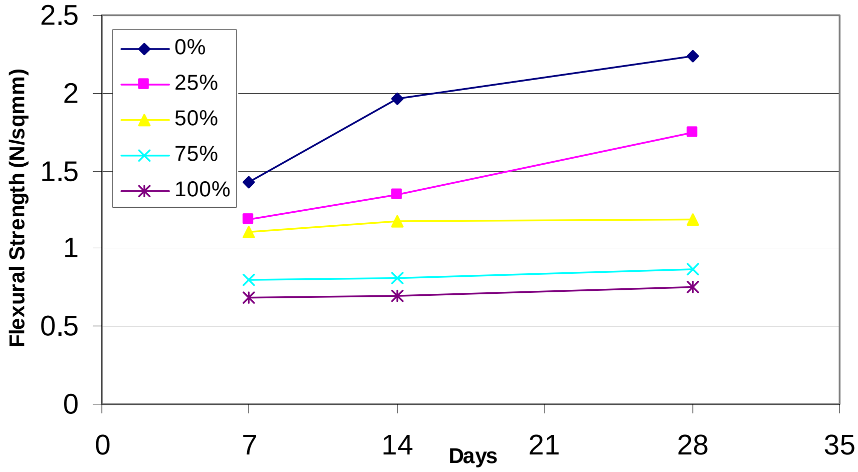

Figure-2. Effect of replacement of granite with palm kernel shells on flexural strength.

Effect of replacement of sand with saw dust

It is seen from Table-4. That for control slab, the flexural strength increased from 1.43 N/mm^2 at 7 days to 2.24 N/mm^2 at 28 days (i.e. about 57% increment). However, the strength of the 25% replacements by sawdust showed increased in flexural strength from 1.15N/mm^2 at 7 days to 1.67 N/mm^2 at 28 days (45% increment).

Similarly, the 50% replacements of saw dust showed an increase from 0.89 to 1.12 N/mm^2 between 7 and 28 days. According to BS 1881, part 4 (1970), a grade 15 concrete should have acquired a flexural strength of 1.2 N/mm^2 at 28 days. Based on the above and the results obtained, only the 25% replacements sample satisfactorily meets the criteria. Table-6 shows recommended grades of concrete as per BS 8110 (1997).

Table-6. Recommended grade of concrete (BS8110, 1997).

Grade	Characteristics strength	Concrete class
7 10	7.0 10.0	Plain concrete
15	15	Reinforced concrete with lightweight aggregate
20 25	20.0 25.0	Reinforced concrete with dense aggregate
30	30.0	Concrete with post tensioned tendous
40 50 60	40.0 50.0 60.0	Concrete with pre tensioned tendous

With respect to the compressive strength (Table-4), 0% replacement gave a value of 21.6 N/mm^2. This was above the specified value of 20N/mm^2 for grade 20 concrete (BS 8110, 1997). The 25% replacement sample gave a value of 15.9N/mm^2, which was equivalent to grade 15 concrete that has a value of 15N/mm^2 specified for light weight concrete. It could also be observed that the weight of the slab reduced from 41.1kg for o% replacement to 35.15 kg for 25% replacement at 28 days, which is about 15% reduction in weight

Effect of replacement of granite with palm kernel shells on concrete

A similar behaviour to that of sawdust replacements slabs was observed for palm kernel shell replacement concrete (Table-5). At 25% palm kernel shell replacements, the flexural strength increased from 1.19N/mm^2 at 7 days to 1.75 N/mm^2 at 28 days (47% increment). The strength of the 50% sample increased from 1.11N/mm^2 at 7 days to 1.19N/mm^2 at 28 days (7%). The 25% replacements slab was also observed to have met BS 1881 part 4 (1970) requirement for lightweight concrete. The 50% replacements slab also gave promising results but further investigations will be required to make a final assessment

In terms of compressive strength, the 25% replacement slab gave a value of 15.9N/mm^2 which is equivalent to grade 15 concrete which has a specified value of 15N/mm^2 for lightweight concrete. At 50% replacement however the compressive strength was 10.89N/mm$^{2.}$ This belonged to the class of grade 10 concrete categorized as plain concrete

COST ANALYSIS

This analysis is based on a unit of concrete(1.0m^3) made from conventional materials and a modified concrete made by substituting materials with 25% of fine aggregate and 25% of coarse aggregates using sawdust and palm kernel shells respectively. Table-7 shows the unit price of materials. Proportion of materials for mix 1:2:4 and the cost of production for both type of concrete is given in Table-8 a and b.

Table-7. Unit price of materials.

S. No.	Material	Price (US $)	Market unit	Volume (m^3)	Unit price per m^3
01	Cement	150	Bag	0.035	428.57
02	Granite	300	Tonne	0.60	50.10
03	Sand	250	Tonne	0.88	28.57
04	Water				10.0
05	Sawdust	Waste material			0
06	Palm kernel shells	Waste material			0
07	Workmanship				15.00
08	Overhead cost				15.00

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Table-8. Cost of production 1 m^3 concrete.

(a): Concrete without sawdust and kernel shells

S. No.	Material	Required volume (m^3)	Unit price per m^3	Amount (US $)
01	Cement	0.287	428.57	123.00
02	Granite	0.99	50.10	49.60
03	Sand	0.53	28.57	15.14
04	Water	0.168	10.0	1.68
05	Sawdust	0	0	0
06	Palm kernel shells	0	0	0
07	Workman ship		15.00	15.00
08	Overhead cost		15.00	15.00
	Total cost of production for 1.0M^3			**219.42**

(b): Concrete with 25% sawdust

S. No.	Material	Required volume (m^3)	Unit Price per m^3	Amount (US $)
01	Cement	0.287	428.57	123.00
02	Granite	0.99	50.10	49.60
03	Sand	0.398	28.57	11.36
04	Water	0.168	10.0	1.68
05	Sawdust	0.133	0	0
06	Workman ship		15.00	15.00
07	Overhead cost		15.00	15.00
	Total cost of production for 1.0M^3			**215.64**

(c): Concrete with 25% palm kernel shells

S. N	Material	Required volume (m^3)	Unit price per m^3	Amount (US $)
01	Cement	0.287	428.57	123.00
02	granite	0.74	50.10	37.07
03	Sand	0.398	28.57	11.36
04	Water	0.168	10.0	1.68
05	Palm kernel shells	0.25	0	0
06	Workman ship		15.00	15.00
07	Overhead cost		15.00	15.00
	Total cost of production for 1.0M^3			**203.11**

Savings per cubic meter of concrete = 219.42-203.11 = 16.31 US $
Percentage savings = (16.31/219.42)*100 = 7.43%

CONCLUSIONS AND RECOMMENDATIONS

From the results of the tests carried out, the following conclusions and recommendations can be made:

- A possibility exists for the partial replacement of sand and granite with sawdust and palm kernel shell in the production of lightweight concrete slabs;
- Optimum replacement of both sawdust and palm kernel shell with sand and granite has been found to be 25%. Beyond this limit, the slab produced did not meet code requirements for strength as per BS 1881 Part 4 (1970);
- With 25% sawdust and palm kernel shell substitution, a cost reduction of 7.43% was achieved for every cubic metre of concrete produced;
- Notwithstanding promising results, sawdust and palm kernel shell concrete are recommended for non-structural purposes e.g. roadside kerb construction;
- To avoid ingress of water, a protective coat of waterproofing agents like zycosil should be applied to block existing pores; and
- Organic materials are subject to deterioration over time hence sawdust and palm kernel shell concrete applications should be regularly maintained and replaced when necessary.

Based on the above, the following recommendations are made for further studies.

- It is recommended that steam washing of the materials and pre-treatment with inert chemicals be carried out before using them as aggregates rather than ordinary flushing done in the study;
- Effect of admixtures and permeability of concrete made with various percentage replacements should be studied;
- Similar studies are recommended for beam sections to ascertain the flexural behaviour of lightweight concrete made with these materials;
- .Replacement of Sawdust or Palm kernel shell by volume adjustment is recommended in order to achieve higher strength of material concrete; and
- Durability studies of reinforced concrete slabs made with sawdust and palm kernel shell should be carried out.

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