The Use of Sawdust and Palm kernel Shell as Substitute for Fine and Coarse Aggregates in Concrete Construction in Developing Countries

Usman, N. D.
Idusuyi, F. I.
Department of Civil Engineering Technology, Federal Polytechnic, Bauchi, Nigeria

Ojo, E. B.
Research Department, Nigerian Building and Road Research Institute, Abuja

Simon, B.
Department of Building, Federal Polytechnic, Bauchi, Nigeria

ABSTRACT
This study examined the use of the locally available building materials such as sawdust and palm kernel shell as possible substitutes for fine and coarse aggregate in concrete. The physical properties such as specific gravity, Bulk density, Absorption test and sieve analysis test of these local materials were examined. The materials were batched by volume for the production of concrete and slump test were done on concrete to compare and control the water content. Four sets of concrete were casted (cement: sawdust: granite, cement: sand: granite, cement: sand; palm kernel shell and cement: sawdust: palm kernel shell) into cubes of size 150 x 150 x 150 using a mix ratio 1:2: 4 and 1:3:6.The concrete cubes were cured by sprinkling method for different time duration (7, 14, 21, and 28 days). The compressive strength tests were carried on the concrete. Compressive strength result for 1:2:4 and 1:3:6 concrete mixes show an overall reduction in compressive strength in all the mixes containing sawdust and palm kernel shell as compared to normal concrete mix (cement: sand: gravel). Also, there was a progressive reduction in compressive strength with age. Absorption test carried out showed that the rate of water absorbed by sawdust and palm kernel shells are higher compared to sand and gravel respectively. This indicates that the water absorption capacity in both sawdust and palm kernel shells would need to be modified in order to improve its compressive strength and durability. The quality of concrete with palmkernel shells can be improved by breaking into smaller sizes before using the palmkernel shell to produce a well graded sample of various sizes which in turn will help in proper interlock of the particles in concrete mass.

Keywords: *Sawdust, palm kernel shell, concrete, cement*

INTRODUCTION
The high and rising cost of building construction in developing countries has been a source of concern to government and private developers. Concrete is a very good construction material made by mixing cement, coarse aggregate (gravel or crushed stone), fine aggregate (Sand) and water either in designed or prescribed proportions. It is strong in compression and has some resistance to some chemical and biological attack like termites etc. while steel, which is strong in tension, is incorporated in it,

thus becoming "reinforced concrete" a strong and durable material, which can be formed into various sizes and shape. This account for its wide spread use in civil engineering structure such as buildings, dams and so on (Smith, 1989). However, as a result of the daily increase in the cost of concrete material most especially cement, crushed stone (coarse aggregate) and fine aggregate (fine sand). It becomes imperative to introduce and develop available local material. This is what has necessitated the use of sawdust and palm kernel shell as substitute for fine and coarse aggregate in concrete. Building construction has been in existence since the creation of mankind, from the Stone Age to the present use of concrete. In the past, people build house with leaves, tree branches and even grasses.

Recently, however people have changed from one type of building material in a continuing effort to obtain the best possible protection from weather and the environment (Jackson and Plur, 1988). Attempts have also been made by various researchers to reduce the cost of it constituent and hence total construction cost by investigating and ascertaining the usefulness of material which could be classified as local materials. Some of these local materials are agricultural or industrial waste which includes sawdust, palm kernel shell, pulverized fuel ash, slag, fly ash, coconut shells among others which are produced from milling stations, thermal power station, waste treatment plant and so on (Fernandez, 2007). As a result of the increase in the cost of construction materials, especially cement, crushed stone (coarse aggregate), fine sand (fine aggregate); there is the need to investigate the use of alternate building materials which are locally available. Since most building construction works consist of concrete work; therefore, reduction in cost of concrete production will reduce the cost of building construction. High cost of building material has affected many Nigerians who engage in cutting corners to achieve building production leading to failure in the buildings. It is therefore necessary to use alternative available local material for concrete production. The aim of this study, therefore, is to examine the use of locally available construction materials (such as sawdust and palm kernel shell) as substitutes for fine and coarse aggregate in concrete. Concrete is a construction material which consists of the mixture of fine, coarse aggregate, cement which proportionally mixed with certain percentage of water. The importance of concrete as construction material is increasing every day. Green concrete is a plastic mass, which can be molded into any desired shape (Gupta and Amit, 2004).

Palm kernel shells as a local material: Palm kernel shells are the crushed outer part of palm kernel nut derived after the extraction of palm oil. Palm kernel shell (PKS) is the hard endocarp of palm kernel fruit that surround the palm seed. It is obtain as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). Palmkernel shell are available in large quantities in palm oil producing areas such as Okiti-pupa, Ode-aye farm settlement, Araromi obu rubber and oil plantations, Irele oil plantations in Ondo State, NIFOR and Okomu farms in Edo State and in reasonable quantities in other towns and villages especially in the southern part of Nigeria (Alagbon, 1994).

Sources, Properties and Uses of Palm Kernel Shell: Many varieties of palm exist, which include Dura, Pisifere and Tenera and they are recognized mainly by the thickness of their shell (endocarp) and fibrous oily part (mesocarp) and the fruits. Dura variety has very thick shell and thin fibrous part only. In the Pisifera variety, the shell is almost absent or very tiny, the bulk of the fruit being fibrous mainly produce little or no kernel. The Tenera variety is the hybrid of dura and pisifera. The thickness of the shell and the fibrous part are of medium size (Nwokolo, 1994). The following are the properties of Palm kernel shell:

i. Kernel shells are black in colour.
ii. They have light weight
iii. They are porous in nature
iv. They are hard

Palm kernel shells are used for the followings:

1. As a good source of fuel for domestic cooking in most area where they occur.
2. They are often dumped as waste products of the oil industry.
3. They are shell is used by the blacksmith and goldsmith to make bellow for melting iron/gold.
4. Palm kernel shell may be used for making terrazzo.
5. They are used as fill materials for filling pot holes in muddy areas in some localities.
6. Like all light weight aggregate, concrete made from shell may be useful for thermal insulation, in the making of pre-stressed concrete (Anthony, 2000).

Sawdust as an aggregate in concrete: Sawdust can be used as alternative substitute for fine aggregate in concrete production. Sawdust should be washed and cleaned before use as concrete constituent because of large amount of bark which can affect setting and hydration of cement. Concrete obtained from sawdust is a mixture of sawdust, gravel with certain percentage of water to entrance the workability and full hydration of the cement which help in bonding of the concrete. Sawdust concrete is light in weight and has satisfactory heat insulation and fire resisting values. Nails can be driven and firmly hold in sawdust concrete compare to other lightweight concrete which nail can also easily drive in but fail to hold (Peatfield, 1982).

According to Olutoge (1995), the flexural strength increased from 1.43 N/mm^2 at 7 days to 2.24 N/mm^2 at 28 days for control slab (i.e. about 57% increment). However, the strength of the 25% replacement by sawdust showed increased in flexural strength from 1.15N/mm^2 at 7 days to 1.67 N/mm^2 at 28days (45% increments). Similarly, the 50% replacement of sawdust showed an increase from 0.89 to 1.12N/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 1.2N/mm^2 at 28days. In term of compressive strength, the 25% replacement slab gave a value of 15.9N/mm^2 which is equivalent to grade 15 concrete which a specified value of 15N/mm^2 for lightweight concrete (BS 8110, 1997).

MATERIALS AND METHOD

The sawdust was sourced from building line at Muda Lawal market in Bauchi, Bauchi State. The sawdust consists of chipping from various hardwoods. It was sun dried and kept in waterproof bags. The sawdust was treated by boiling for five hours and later rinsed with water and sun dried. The palm kernel shells used were obtained from Iwo in Osun State, Nigeria. The shells were put in basket in batches thoroughly flushed with water to remove impurities that could be detrimental to concrete. They were sun dried and kept in waterproof sacks. Palm kernel shells were treated by soaking it in hot water with detergent and washed off the oil content, then rinsed in fresh water and sundried.

The granite (coarse aggregate) used for the study was 12mm diameter in size. It was sourced from a quarry site. Aggregate Abrasion Test carried out was used to determine the abrasive resistance of a coarse aggregate sample. The sample of 20kg, washed and oven dried at 105°C to 110°C was weighed and placed into the abrasion testing machines. The machine was run and rotated at the speed of 30 to 33rpm for 500 revolutions. The sample was discharged after a number of revolutions from the machine and the preliminary separation of the test sample on sieve No.12 (1.7mm). Finer portion were allowed to pass through the sieve, and the passed portion were weighed. The sand (fine aggregate) was sourced from the concrete laboratory, Federal Polytechnic, Bauchi.

It was thoroughly flushed with water to reduce the level of impurities and organic matter and later sun dried. To confirm to the requirements (BS 882, 1982), 1kg of sand was weighted, and the aggregate was air-dried while the sieved were cleaned. The sample was poured into the sieve, which was stacked on each other in descending order of aperture. After fixing the set of sieves on the sieve shaker, it was moved backwards and forwards, sidewards, left and right and circular clockwise and anticlockwise to prevent splashing. The set were dismantled and the weight of the fraction retained on each sieve was obtained. The cement used was ordinary Portland cement. It was obtained or sourced from cement seller in front of Federal Polytechnic, Bauchi. And it conformed to the requirement (BS 12, 1996).

The water used for the study was obtained from the tap inside the concrete laboratory of the institution. The water was clean and free from any visible impurities. It confirmed to BS 3148(1980) requirements.The palm kernel shells were also treated as earlier discussed. Some physical properties of the sawdust and palm kernel shell were examined. Concrete were made from these local materials in four sets.

Set 1: Concrete from cement, sawdust and gravel
Set 2: Concrete from cement, sand and palm kernel shells.
Set 3: Concrete form cement, sawdust and palm kernel shells.
Set 4: Concrete from cement sand and Gravel.

Batching of the four sets of concrete listed above was done by volume. Before it is done, the required quantity of cement, sawdust and palm kernel shell batch (mix proportions) was measured and thoroughly mixed by hand on the floor, using spade.

After these have been mixed, the required quantity of water was added. The combined constituent, were then mixed thoroughly on the floor continuously until a workable, smooth uniform and constituent mixture would be obtained. These are mixed in different mix proportions 1:2:4 and 1:3:6 (cement, sawdust and palm kernel shell). Different mix proportions were casted in different mould to determine the workability of the concrete mix. Many factors affect the workability of concrete among which were the water content, mix proportions, size of aggregate, shape, surface texture grading of aggregate. Presence of admixture like air entraining reduces internal friction and increase workability (Shetty, 1982). The physical properties of the materials used were determined and are presented on tables and graphs using simple percentage for data analysis.

RESULTS AND DISCUSSION

Grain Size Distribution: Grain size distributions of palm kernel shells, sand and granite are presented on tables 1-3. The corresponding gradation curves are also presented in Figures 1-3. The soil is classified (figure 2) as well graded soil according to the unified soil classification system (USCS)(Holtz and Kovacs, 1981). The soil is uniformly graded according to the unified soil classification system (USCS) (Holtz and Kovacs, 1981). All the specific gravity meets the requirement recommended according to IS-2386-part-III-1963 (table 5). The slump value fell within the range of 10-40mm. This shows that the slump and the compacting value fall within specification (0.78 to 1) (Shetty, 1982) (table 6). The slump result has shown a true slump and compacting factor value fall within 0.78 to 1.00 as recommended (Shetty, 1982) (table 7). The results of the slump test carried out were presented with their degree of workability. The result of concrete made with sawdust and palm kernel as a fine and coarse aggregate respectively formed a true slump (29.2cm), this showed that the two materials can be used together in a mix.

Compressive Strength: Tables 8-11 present the compressive strength test results for the different sets of concrete mixed at 1:2:4 at various curing days. Figure 4 shows the plot of compressive strength against age for the different sets of concrete. For Set 1(Cement: Sand: Granite), we see an increase in compresive strength with increase in age as we observe a maximum compressive strength at 28 days. This is the expected trend as compressive strength of concrete increases with the number of curing days (Shetty, 1982). However, we notice an overall reduction in compressive strength in the other sets. Also, there is a noticeable decrease in compressive strength with increase in age of the cubes. Tables 12-15 present compressive strength test results for the different sets at the 1:3:6 mix. Figure 5 shows a similar trend with figure 4. Both figures show that compressive strength of normal concrete (22 N/mm^2) was higher than that of sawdust concrete (5.78 N/mm^2) and palm kernel shell concrete (5.87 N/mm^2). The compressive strength of sawdust concrete was less than that of palm kernel.

Water Absorption Capacity: Tables 16 and 17 present the results of the water absorption capacity test on sawdust and palm kernel shells. From the result of the absorption test, it was observed that the rate of water absorption by sawdust was greater than palmkernel shell. Both palmkernel shell and sawdust have higher rate of absorption than sand and granite which has effect in increasing water cement ratio in any mix of sawdust and palmkernel. However, an increase in water cement ratio reduces the strength of concrete.

Table 1: Size Distribution of Palm kernel Shells

Sieve size(mm)	Retained (kg) material	Passing (kg) weight	% Retained	% Passing
12.50	0.00	400	0	100
9.50	27.00	373.00	6.75	93.25
6.30	200.00	173.00	50.00	43.25
4.75	97.50	75.00	24.38	18.87
2.36	63.00	12.00	15.75	3.12
2.00	4.50	8.00	1.12	2.00
1.18	3.50	4.50	0.88	1.12
060	2.50	2.00	0.620	0.50
0.425	2.00	0.00	0.500	0

Source: Experimentation, 2011

Table 2: Size Distribution of Fine Aggregate (sand)

Sieve No	Weight Retained	Weight Passed	% Retained	% passing
5.000	0.00	1000	0	100
3.150	72.00	928	7.2	92.8
2.000	142.00	786	14.2	78.6
0.800	429.00	357	42.9	35.7
0.400	203.00	154	20.3	15.4
0.315	47.20	106.8	4.72	10.68
0.215	32.40	74.4	3.24	7.44
0.160	29.20	45.2	2.92	4.52
Pan	45.20	0.00	4.52	0.00

Source: Experimentation, 2011

Table 3: Size Distribution of CoarseAggregate (Granite)

Sieve No	Weight Retained (kg)	Weight Passed (kg)	% Retained	% passing
14	0	1000	0	100
12.5	798	202	79.8	20.2
10.0	78	124	7.8	12.4
8.0	68	56	6.8	5.6
5.0	24	32	2.4	3.2
3.15	17	15	1.7	1.5
2.0	15	00	1.5	0.0
Pan	00	00	00	00

Source: Experimentation, 2011

Table 4: Bulk Density Test of fine coarse aggregate

Sample no.	Vol. of cylinder (cm^3) a	Cylin & water (cm^3) b	Vol. of water (cm^3) c	Sample & Cylinder (g) d	Weight of sample (g) e	Bulk Density g/cm^3	Specific Gravity (GS)	Void Ratio (%)
C/A 2000ml	500	2800	2300	3881	3375	1.47	2.65	44.53
F/A 1000ml	250	1400	1150	2148	1900	1.65	2.57	35.8
Mixed 2000ml	500	2800	2300	4226	3750	1.62	2.61	37.92

Source: Experimentation, 2011

Table 5: Specific Density of sampled materials

Sample	Specific Density
Sawdust	0.77
Palm kernel Shell	1.62
Sand	2.57
Gravel (Coarse aggregate)	2.67

Source: IS-2386-PART-III-1963

Table 6: Slump and Compacting Factor of Concrete (1:2:4mixes)

Type of Concrete	Slump (cm)	Compacting factor
Cement: Sand: Gravel	29	0.90
Cement:Sand: palm kernel shell	28.7	0.85
Cement: Sawdust: Gravel	28.9	0.87
Cement: Sawdust: palm kernel shell	29.2	0.88

Source: Experimentation, 2011

Table 7: Slump and Compacting Factor (1:3:6 mixes)

Type of Concrete	Slump (cm)	Compacting factor
Cement: sand: Gravel	29.7	0.81
Cement:Sand: Palmkernel	28.7	0.78
Cement:Sawdust :Gravel	28.8	0.79
Cement: Sawdust: palm kernel shell	29.1	0.80

Source: Experimentation, 2011

Table 8: Compressive Strength Test Result for Set 1at 1:2:4 mix

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
A1	8.65	8.7	2/09/2011	7 day	2.58	355	15.8
A2	8.60	8.65	9/09/2011	14 days	2.56	455	20.2
A3	8.60	8.67	16/09/2011	21 days	2.57	475	21.1
A4	8.70	8.75	23/09/2011	28 days		495	22

Source: Experimentation, 2011

Table 9: Compressive strength tests for Set 2 (Cement: Sand: Palmkernelshell) at 1:2:4 mix

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
B1	6.0	6.2	9/09/11	7days	1.84	155	6.89
B2	6.0	6.1	16/09/11	14 days	1.81	140	6.22
B3	6.0	6.0	23/09/11	21 days	1.78	135	6
B4	6.1	6.1	30/09/11	21days	1.81	132	5.87

Source: Experimentation, 2011

Table 10: Compressive strength tests for Set 3 (Cement: Sawdust: Granite) at 1:2:4 mix

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
C1	7.4	7.2	16/09/11	7 days	2.13	180	8
C2	7.4	7.1	23/09/11	14 days	2.10	170	7.56
C3	7.3	7.0	30/09/11	21 days	2.07	154	6.84
C4	7.35	7.0	07/10/11	28 days	2.07	130	5.78

Source: Experimentation, 2011

Table 11: Compressive Strength test for Set 4(Cement: Sawdust: Palmkernelshell) at 1:2:4

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
D1	4.3	4.1	23/9/11	7 days	1.21	30	1.33
D2	4.4	4.1	30/9/11	14 days	1.21	21	0.93
D3	4.3	3.9	7/10/11	21 days	1.16	10	0.44
D4	4.4	4.0	14/10/11	28 days	1.19	0	0.00

Source: Experimentation, 2011

Table 12: Compressive Strength Resultfor Set 1 at 1:3:6 Mix

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
A11	8.00	8.12	8/9/11	7 days	2.41	320	14.22
A21	7.90	8.05	15/9/11	14 days	2.39	425	18.89
A31	8.00	8.1	22/9/11	21 days	2.40	450	20
A31	8.10	8.15	29/9/11	28 days	2.42	475	21.11

Source: Experimentation, 2011

Table 13: Compressive Strength test forConcrete Set 2(Cement:Sand: Palmkernel Shell) at 1:3:6

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
B11	5.8	6.0	9/9/11	7 days	1.78	135	6.00
B21	6.0	6.1	16/9/11	14 days	1.81	120	5.33
B31	5.9	5.9	23/9/11	21 days	1.75	105	4.67
B41	5.9	6.0	30/9/11	28 days	1.78	90	4.00

Source: Experimentation, 2011

Table 14: Compressive Strength test forConcrete Set3(Cement, Sawdust and Granite) at 1:3:6

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
C11	7.0	6.85	16/9/11	7 days	2.03	155	6.89
C21	7.1	6.90	23/9/11	14 days	2.04	140	6.22
C31	7.1	6.88	30/9/11	21 days	2.04	125	5.56
C41	7.0	6.8	07/10/11	28 days	2.02	113	5.02

Source: Experimentation, 2011

Table 15: Compressive Strength test forConcrete Set4(Cement, Sawdust and Palm kernel shell) at 1:3:6

Cube mark	Initial weight of cube (kg)	Weight before crushing (kg)	Tested Date	Crushing day	Density of cubes	Crushing load (kn) g/cm³	Comp. strength (N/min)
D11	4.1	3.9	23/9/11	7 days	1.16	25	1.11
D21	4.1	3.8	30/9/11	14 days	1.13	10	0.44
D31	4.2	3.8	7/10/11	21 days	1.13	2	0.09
D41	4.0	3.7	14/10/11	28 days	1.10	0	0.00

Source: Experimentation, 2011

Table 16: Water Absorption Capacity of Sawdust

Sample %	Initial weight (g)	Weight After 6 hour	Weight After 12 hour	Weight After 24 hour	Water Absorption capacity %	Average
A	4.58	5.02	5.80	5.79	26.4	
B	4.62	5.14	6.20	6.21	34.4	31.8
C	5.02	5.51	6.78	6.75	34.5	

Source: Experimentation, 2011

Table 17: Water Absorption Capacity of Palmkernel Shell

Sample %	Initial weight (g)	Weight After 6 hour	Weight After 12 hour	Weight After 24 hour	Water Absorption capacity %	Average
A	10.52	11.02	11.98	12.00	14.1	
B	10.45	10.96	11.86	11.82	13.1	13.1
C	11.20	11.89	12.50	12.54	12.0	

Source: Experimentation, 2011

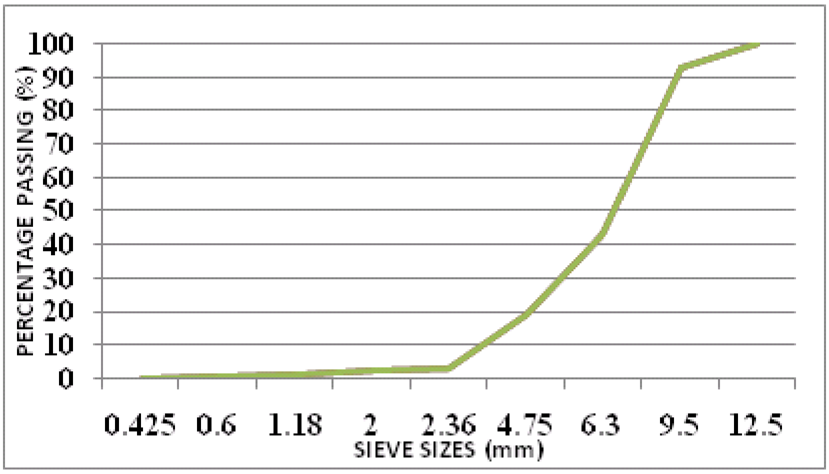

Figure 1: Palm Kernel Grading Curve

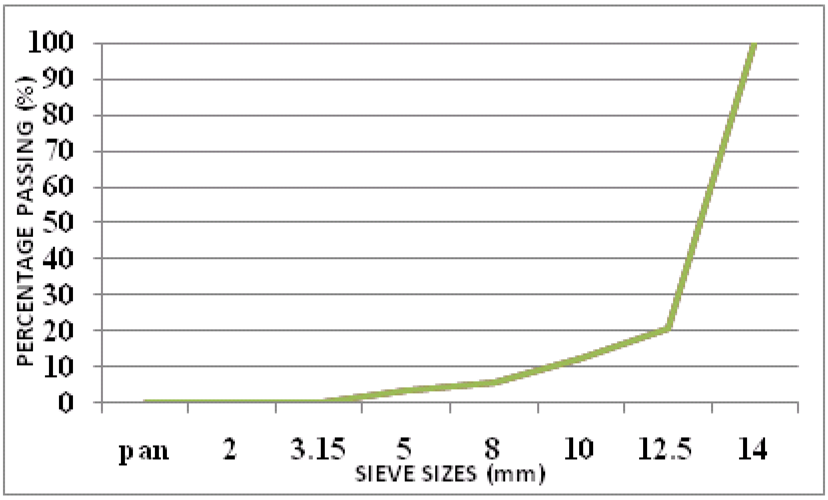

Figure 2: Fine Aggregate (sand) grading curve

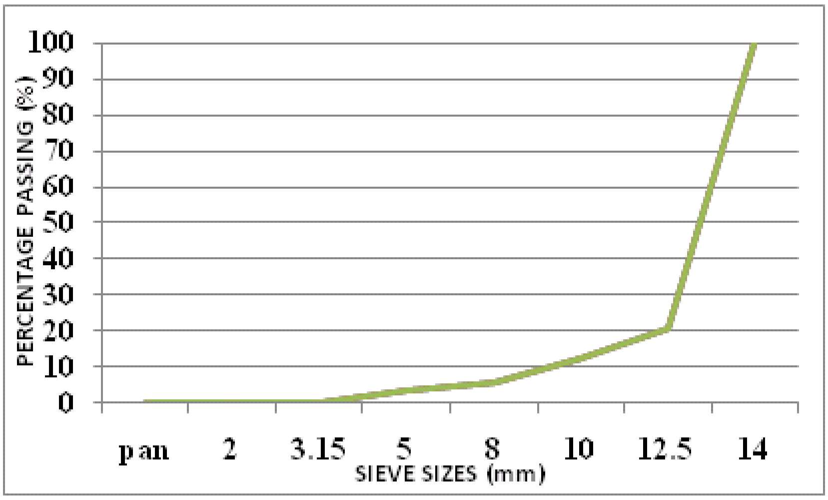

Figure 3: Grading curve for Coarse aggregate

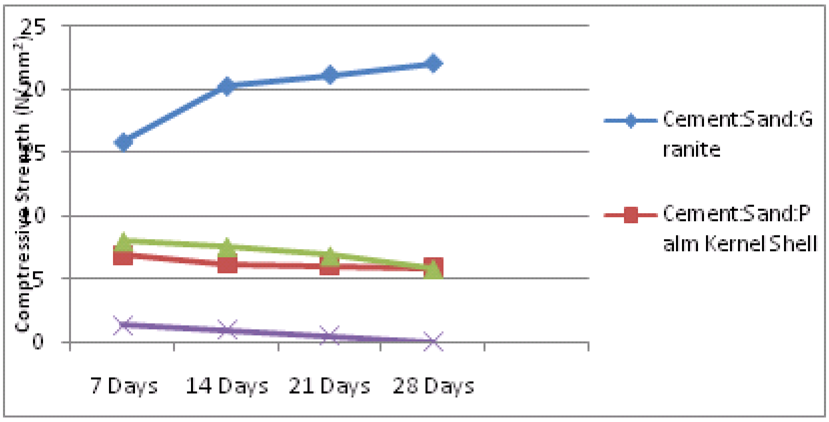

Figure 4: Effect of Replacement of Sand and Granite with Sawdust and Palm Kernel Shell on Compressive Strength of 1:2:4 Mix

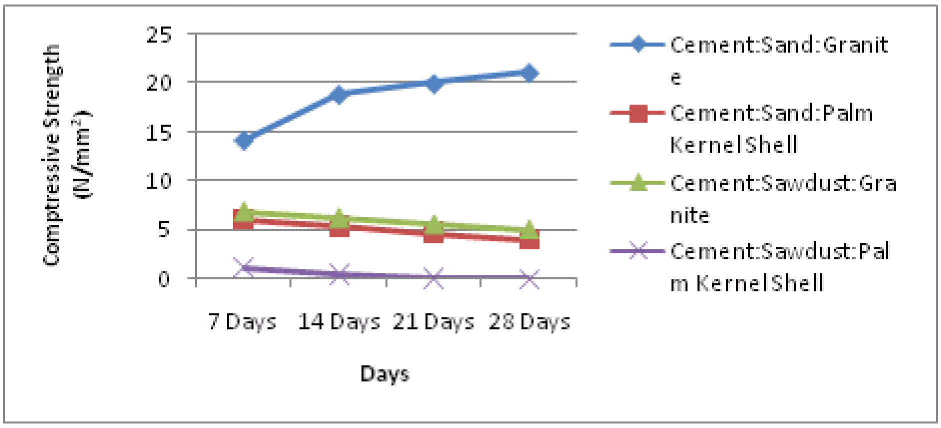

Figure5: Effect of Replacement of Sand and Granite with Sawdust and Palm Kernel Shell on Compressive Strength of 1:3:6 Mix

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to investigate the use of locally available materials (sawdust and palm kernel shells) as substitutes for fine and coarse aggregates in concrete with the overall aim of reducing the cost of construction. Four sets of concrete (cement: sand: gravel, cement: sawdust:granite, cement: sand: palm kernel shells and cement: saw dust: palm kernel shells) were mixed at 1:2:4 and 1:3:6. Various tests were carried out and from the result it was observed that the reduction in strength of concrete with palm kernel shells as a coarse aggregate was due to factors such as porosity, the size and flaky shape of the palmkernel shell which prevent proper bonding between the concrete. The reduction in strength of concrete with sawdust as fine aggregate was due to its higher rate of water absorption because the higher the water contents in concrete, the lower the strength of the concrete. Optimum replacement of both sawdust and palmkernel shell with sand and granite was found to be 25%

beyond the limit, which did not meet the code requirement forstrength BS 1881 part 4 (1970). Organic materials were subjected to deterioration overtime hence, sawdust and palmkernel shell concrete application should bemaintained and be replaced where necessary. To avoid ingress of water, a protective coat of water proofing agent like zycoil should be applied to block existing pores. Based on the findings from this study, the following recommendations are made:

1. It is recommended that a steam washing of the material and pre-treatment with inert chemical be carried out before using them as aggregate rather than ordinary flushing done in the study.
2. The quality of concrete with palmkernel shells can be improved by breaking into smaller sizes before using the palmkernel shell to produce a well graded sample of various sizes which in turn will help in proper interlock of the particles in concrete mass.
3. Due to the porous nature of the sawdust and palmkernel shells, it is recommended that concrete with those materials should not be used in water logged areas to prevent the ingress of water which reduced the strength of concrete
4. Sawdust and palmkernel shell concrete are recommended for use in the following areas for heat insulation e.g. roof, wall, for sound insulation, for screed, for partition wall and panel walls in framed structure and also for aesthetic reasons.
5. Reinforcement should be introduced to sawdust and palm kernel shell concrete to increase the compressive strength of the concrete.

REFERENCES

Alagbon, B. D. (1994), Assessment of kernelshells as suitable aggregate in Concrete and laterite blocks. Final Year Project submitted to Federal University of Technology, Akure.

Anthony, B. J. (2000). Physical Modeling in Geotechnics. PhD Thesis, Virginia Polytechnic Institute and State University. *http:/www.geotechlinks.com/gin.php*

British Standard Code of Practice (1973). BS 882 part 2, course and fine aggregate from natural sources: British standard institution, London.

British standard code of practice (1980). Bs 3148, test for water for making Concrete: London: British standard institution.

British Standard Code of Practice (1997). *BS 8110 part 1, the structural use of concrete.* London: British standard institution.

Fernandez, H. (2007). Partial replacement of sand with fly ash. International Conference-fly ash utilization and disposal in India by CBIP Pp 45-54 *http://lejpt .academic direct.org Accessed no 14th August 2012.*

Gupta, B.L and **Amit, G.** (2004). *Concrete Technology* (Third Edition). New Delhi: Standard Publishers.

Holtz, R. D. and Kovacs, W. D. (1981). Introduction to Geotechnical Engineering, Published by Prentice Hall. *http:/www.amazon.com/introduction-Geotechnical.Engineering*

Jackson, N. and **Plur, R. K.** (1988). *Civil Engineering materials* (Third Edition). London: ELBS/ Macmillan.

Nwokolo, T. U. (1994). Investigation study on palmkernel shells as light weight aggregate. Final Year Project submitted to Civil Engineering Department, University of Benin, Benin.

Olutoge, F. A. (1995). A study of sawdust, palmkernel shell and rice husk ash as full/partial replacement for sand, Granite and cement in concrete. M.Sc Project submitted to University of Lagos, Nigeria.

Peatfield, A. E. (1982). *Practical concreting* (revised edition). Bungay: English University Press Limited, Great Britian.

Shetty, M. S. (1982). Concrete Technology: Theory and Practice. *S. Chand http:/ www.sapnaonline.com/index.php? Accessed no 14th August 2012*

Smith, M. J. (1989). *Soil Mechanic* (Second Edition). London.: The English Language Book Society, MacDonald and Evans Ltd.

www.canadiangeographic.calmagazine/5005/ in depth. Asp) and http://en Wikipedia.org/wiki/ sawdust. *Accessed no 14th August 2012*