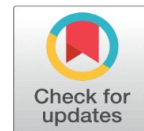# EFFECTS OF USING PALM KERNEL SHELL AND SPIKELET FIBERS AS COARSE AGGREGATE FOR LIGHTWEIGHT CONCRETE

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ABSTRACT

Agricultural and Industrial wastes have created waste management and pollution problems. The replacement of conventional ingredients in concrete production would reduce construction cost and proper waste management. The percentages of spikelet fibers in the composites were 0%, 0.25%, 0.5%, 0.75% and 1%. Concrete cubes and rectangular bricks of sizes 150mm x 150mm x 150mm and 40mm x 40mm x 160mm respectively with different percentages of spikelet fibers cured and tested after 7 and 28 days. The flexural strength, compressive strength, Density, slump workability, rate of water absorption and grain size were analyzed. It results that palm kernel shells were well graded and a good replacement for conventional aggregates. The density and compressive strength after 28 days curing was within the range 1645 to 1749kg/m3 and 15.35 to 19.21kg/m3 respectively. It was observed that slump workability reduced while compressive strength, water absorption, density and flexural strength increases proportionately with fiber contents.

Keywords: Palm Kernel Shell, Spikelet Fibers, Mechanical Properties, Light Weight Aggregate

1. INTRODUCTION

The explosive expansion of plantations in many oil-producing countries has generated enormous amounts of waste creating vital problems in replanting operation and serious environmental concern. The cultivation and production of palm oil are highly done in the tropical and sub-tropical zone of the world. In Cameroon the C.D.C, SOCAPALM, PAMOL, subgroups and individuals cultivate and produced palm oil Ngando et al. (2011). Palm kernel shell (Pks) and empty fruit bunch spikelet fibers (EFB-SF) is derived from oil palm tree (elaeis guinesis) an economically valuable tree, which is native to West Africa and widespread throughout the tropics. They are a major part of the solid waste stream from the processing of oil palm. Alengaram et al. (2013), Priatna and Kuprianov (2015) The fresh fruit bunch of palm tree contains empty fruit bunches and kernel fruit. The separation of fruit from its bunches in process of producing palm oil, leaves empty fruit bunch as waste. The kernel fruit produces kernel shells and kernel fibres as waste. During the cultivation of fresh fruit bunch, the palm fronds are also left in the plantation as waste products. Waste from oil palm cultivation and production are the empty fruit bunches, the kernel shells, kernel fibres and the palm frond fiber. Yakum et al. (2015) In Cameroon, about 3110296 tons of oil palm fruits are

produced per annum predominantly within the coastal areas (FAOSTAT) (2017) and is in a rapid increase posing a threat to the environmental if their disposal mismanaged and poorly handled as it is the case is many African countries. Apart from using these oil palm mill residues as replacement for coarse aggregate in concrete they can also be used as local fuel for domestic cooking, co-firing agents for boilers, strength enhances in earth blocks just to name a few Teoh (2002).

The main objective of this study is to utilise palm kernel shells/spikelet fibres to replace coarse aggregate in light weight concrete with a complete replacement of gravel with palm kernel shells and 0%, 0.25%, 0.5%, 0.75% and 1% spikelet fibres replacement after which comparative analysis will be carried out with concrete cubes of the same dimension to ascertain the reliability of palm kernel shells/spikelet fibres for construction proposes without jeopardizing strength.

2. MATERIALS AND METHODS

The following materials were used for this study:
- local river sand, (fine aggregate of 5mm)
- limestone Portland cement
- palm kernel shell (coarse aggregate of 12mm)
- empty fruit bunch fibres (spikelet fibres)
- water

## 2.1. PREPARATION OF PALM KERNEL SHELLS AND SPIKELET FIBRES

Palm kernel shells were obtained from a local palm oil processing industry in a local oil mill producer in the Ngoketunia division North-west Region of Cameroon. The kernel shell was then grind using grinding machine of three-phase asynchorous motor with a speed of 1440rpm with different particles size (sieve size 14mm) obtained using different machine's sieves as presented on Figure 1 below.
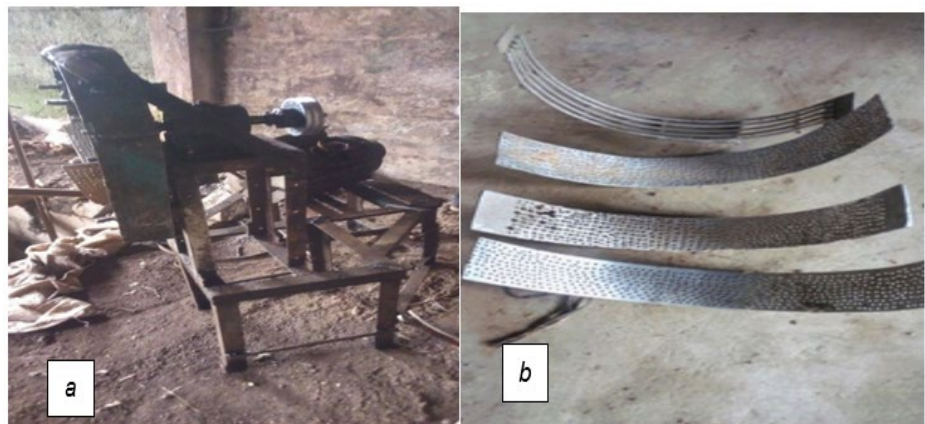
Figure 1 (a) Crushing machine (b), Machines sieves

After grinding, Preparation of the kernel shell was done first by soaking them for 24 hours in detergent after which they were washed and rinsed thoroughly in order to ensure the removal of oil and other impurities. After which the palm kernel shells were sun dried. This pre-treatment is necessary to remove impurities such as oil coatings and mud particles. The palm kernel shells were then sun-dried in open space after which they were subjected to particle distribution using a mechanical

sieve shaker for 5 minutes. After sun drying the palm kernel shell, particle sizes ranging from 5-15mm thickness were selected by the help of a grain size analysis in order to achieve better workability and strength properties.
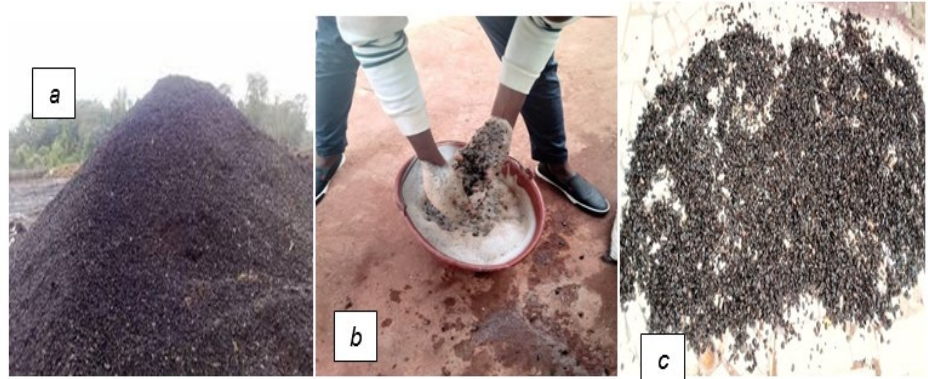
Figure 2 Pre-treatment of palm kernel shell. (a) Crushed pks, (b) Washing of pks, (c) Sun drying of pks

Empty fruit bunches were obtained from an oil mill of a local oil mill producer in the Ngoketunia division precisely in Bambalang. Spikelets were shredded manually by the help of a cutlass. The fibers were then extracted manually by removal of fibres from its matrix without the use of any chemicals and machines, simply by identification and manually removing them. Obtained fibers were further pretreated using 1% NAOH to remove all impurities Ming (2015). It is to be noted that this method carried out is stressful and takes a lot of time due to the piercing nature of the spikelets from the empty fruit bunch.
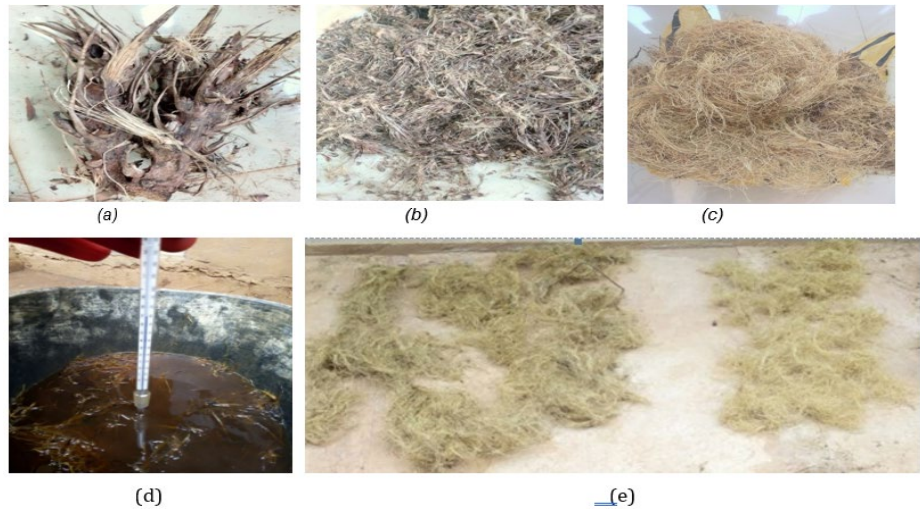
Figure 3 Manually extracted spikelet fibers from EFB (a) Shredded spikelet (b) Obtained spikelet fibers(c) Soaked fibers in NAOH (d) Drying of washed fibers

2.2. FINE AGGREGATE (RIVER SAND)

Naturally occurring clean River Sand also called fine aggregate used in this research were sourced from a sand supplier Northwest region

Figure 4 Naturally occuring sand

2.3. THE GRAIN SIZE ANALYSIS OF SAND AND PALM KERNEL SHELL

This test permits us to be able to know the different sizes of grains that make up the sand and palm kernel shell. This was conducted with the help of grain size analysis apparatus ASTM (2003). Procedure for sand and palm kernel shell

1) The sample were weighed (1 000 g for sand and washed sun-dried palm kernel shell).
2) After weighing the sieves were Arranged in an ascending order from the bottom to the top, to make sure that the seat at the bottom is in position to collect the fine elements.
3) Followed by the Pouring of the aggregates on the topmost sieve.
4) Prior to pouring, the lids were covered in order to avoid the dispersion of dust.
5) The series of sieves were mounted the on the agitator and agitate for 30 seconds.
6) After agitation the machine was Stopped and left to settle for 2 minutes in order to allow the suspended particles decent.
7) This was followed by the Removal of the sieves one by one, agitating each again progressively using the hands and weighing each accumulated grain.
8) After determination of accumulated grain, the percentages of the entire sample passing in each of the sieves were calculated using the following relations.
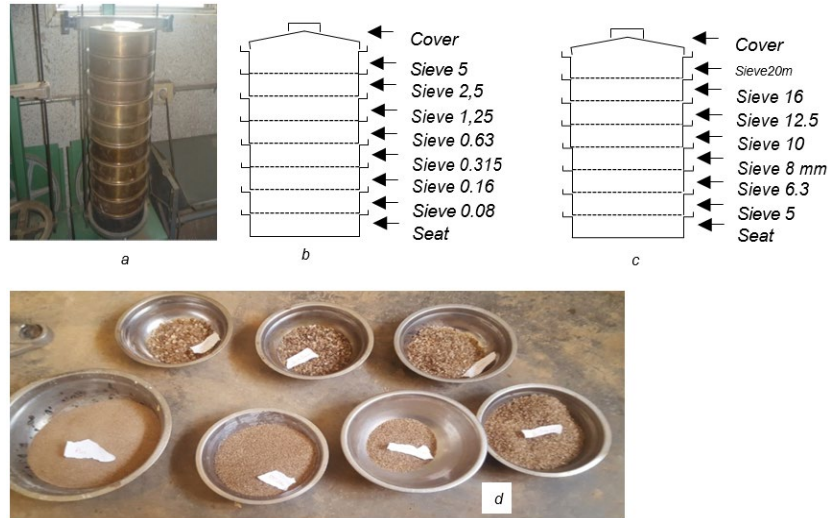
1) Percentage cumulated of grain on each siev $\qquad$ $Y_1 = \frac{X1}{Ws} \times 100$ (1)
2) Xi = total weight of the refusal (g)
3) Ws = Total weight of the sample
4) Percentage of the cumulated passing $Z_1 = 100 - Y_i$ (2)
5) The results are consigned in a table which enables you thereafter to plot the grading curve

Figure 5 (a) Grain size Sieve (b) Sieves 0.08mm to 5mm (c) Sieves 5mm to 16mm (d) Different size grades of sand

2.4. MIXTURE PROPORTIONS

The following specimen composition were being used as tabulated in Table 1

Table 1 Sample composition

samples	Cement (%)	Sand (%)	Spikelet Fibres (%)	PKS (%)
(NC)	20%	27%	0%	53% (coarse aggregate)
0% SF	20%	27%	0%	53%
0.25% SF	20%	26.75%	0,25%	53%
0,5% SF	20%	26.5%	0.50%	53%
0.75% SF	20%	26.25%	0.75%	53%
1% SF	20%	26%	1%	53%

2.5. SLUMP TEST

A concrete is said to be workable if it can be easily mixed, placed, compacted and finished. A workable concrete should not show any segregation or bleeding. Slump text was also conducted with the help of an apparatus ASTM (2003)

Procedure:

1) We started by cleaning the internal surface of the mould thoroughly and place it on a smooth horizontal, rigid and non-absorbent surf ace, such as of a metal plate.

2) W/C ratio of 0.5 to 0.6 and design mix of proportion about 1:1.5:3 (it is presumed that a mix is designed already for the test) was Considered followed by Weighing the quantity of cement, sand, aggregate and water correctly. Mix thoroughly. Use this freshly prepared mixture for the test.

3) After thorough mixing the mould was filled to about one fourth of its height with concrete. While filling, the mould was held firmly in position

4) Tamping of the layer with the round end of the tamping rod with 25 strokes disturbing the strokes uniformly over the cross section followed subsequently.

5) After tamping, the mould was further filled in three layers each time by 1/4th, height and tamping evenly each layer as above. After completion of

rodding of the topmost layer, the mixture was strike with a trowel or tamping bar, level with the top of mould.

6) The moulds were lifted vertically slowly and remove it.
7) The concrete subsided and the Measurement of the height of the specimen of concrete after subsidence determined.

The slump of concrete is the subsidence, i.e., difference in original height and height up to the topmost point of the subsided concrete in millimeters. it is to be noted that the fibers were cut at a length of 4cm in order to acquire better physical and strength properties Abessolo et al. (2020).

Figure 6 (a) Dry samples, (b) Slump cone (c) Samples from the cone

2.6. CASTING, CURING AND TESTING OF SAMPLES

The molds were oiled internally to cast the concrete samples. Specimens of standard dimensions (cubes 150mmx150mmx150mm) were cast for compressive strength determinations and prismatic specimens of (40mm x 40mm x 160mm) were cast for flexural strength. All the specimens were cured for a period of 7 and 28 days before test. Each mixture had 10 samples and the total samples manufactured were 100 each.

Based on the mixture proportion the concrete mix for (NC) 0% SF, 0.25% SF, 0, 5% SF, 0.75% SF, 1% SF were produced and subjected to test to determine the strength of each mix

Figure 7 oiling of molds

Figure 8 Molded Samples

At the required test age, the cubes were removed from the curing tank, wiped off from grit and tested

2.7. COMPRESSION CHARACTERIZATION OF SAMPLES FOR 7 AND 28 DAYS

The compressive test was conducted on all the composite samples with the help of compressive machine, RMU serial 121288 with the capacity of 150KN at the laboratory of civil engineering in Government Technical High School BAMENDA. An increasing compressive load was applied by the hydraulic machine press on the specimen until failure occurred to obtain the maximum compressive load. The specimen dimension was taken before the testing. ACI (2003), Kengoh et al. (2021) The testing was carried out for 7 days, and 28 days specimen after curing
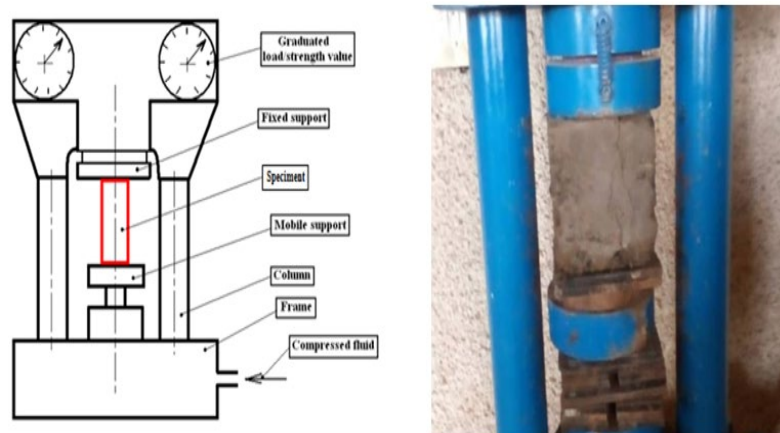
The compressive strength was calculated from the maximum load recorded before failure, by.

Compressive strength $= \frac{Fc}{A}$ $\qquad$ (3)

Where:

Fc: force measured from the compression test machine in N

A: area of the composite specimen in mm2

Figure 9 Compressive strength testing

2.8. FLEXURAL TEST

The test was conducted considering the 3-point ASTM standard using RMU machine serial 1461288. The maximum stresses absorbed were noted and recorded

Figure 10 Flexural testing machine

2.9. WATER ABSORPTION TEST

The determinations of water absorption (WA) were performed. The samples were dried in an oven with the temperature of 105∘C ± 5∘C for 24hours. Water absorption tests were conducted by immersing the specimens in the distill water bath at room temperature for different time durations. After every 1 hours, the specimens were taken out from water and the surfaces were dried using a clean dry cloth. The specimens were reweighed to the nearest 0.001g within 1 min of removing them from the water. The

specimens were weighed regularly. The water absorption rate of each specimen was calculated by the weight difference. The calculations were done as follows:

$$Water\ absorption\ \% = \frac{(weight\ of\ wet\ sample - weight\ of\ dry\ sample)\ X\ 100}{weight\ of\ dry\ sample} \quad (4)$$

3. RESULTS AND DISCUSSION
3.1. SAND GRAIN SIZE ANALYSIS

The particle size analysis of the sand and palm kernel shell used were recorded in the following tables below

Table 2 Presentation of the results of the grain size analysis of the sand

			Origin of sand: riverbanks Mass of dry s ample: 1000g	
Sizes of sieves	Retained	Cumulative retained		Cumulative passing
In (mm)	In (g)	In (g)	In (%)	In (%)
5	16.7	0 16.7	1.67	98.33
2.5	100	116.7	55 11.67	88.33
1.25	413.3	530	53	47
0.63	346.7	876.7	87.67	12.33

0.315	70	946.7	94.67	5.33
0.16	30	976.7	97.67	2.33
0.08	20	996.7	99.67	0.33
Fines mass		3.3g		
Fines %		0.33%		
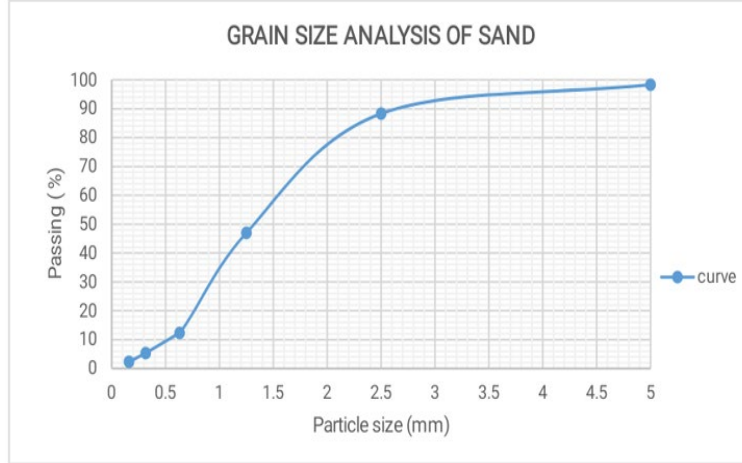
Figure 11 Granulometric curve of analysis of sand

From the grading curve, the values D10, D30, D60 enable us to calculate the coefficient of uniformity of HAZEN (CU) and the coefficient of curvature (Cc), we have:

D10= 0.5
D30= 1
D60= 1.6
Consequent

$$Cu = \frac{D60\%}{D10\%} = \frac{1.6}{0.5} = 3.2 \qquad (5)$$

$$Cc = \frac{(D30\%)2}{D10\% \times D60\%} + \frac{(1)2}{0.5 \times 1.6} = 1.25 \qquad (6)$$

Fineness modulus

It is the sum of refusal (expressed as a percentage weight) in sieves having the sequence numbers or dimensions of the following sieves:

$$Mf = \frac{Sum\ of\ refusal\ cumulated\ in\ the\ sieves\ expressed\ as\ a\ percentage}{100} \qquad (7)$$

- 1.2 < Mf < 2.2: sand having a majority of fine element, which requires an increase in the proportioning of water; facility of setting with the probable detriment of resistances.

- 2.2 < Mf < 2.8: satisfactory workability, good resistance, risks of segregation limited, good natural aggregate for concrete.

- 2.8 < Mf < 3.2: coarse sand (insufficiency of fine elements), raised resistance, significant risk of segregation, worse workability.

Below are the various sieves percentages for grain size analysis of sand:

$$Mf= \frac{98.33+88.33+47+12.33+5.33+2.33+0.33}{100}$$

Mf= 2.53

Table 3 Presentation of the results of the grain size analysis of palm kernel shell				
			Origin of palm kernel shell: Mass of dry sample: 3000g	
Sizes of sieves	Retained	Cumulative retained		Cumulative passing
In (mm)	In (g)	In (g)	In (%)	In (%)
20	0	0	0	100
16	0	0	550	100
14	39.3	39.3	3.93	96.07
10	308.7	348	34.8	65.18
6.3	522.7	870.7	87.07	12.93
5	67.3	937.9	93.79	6.21
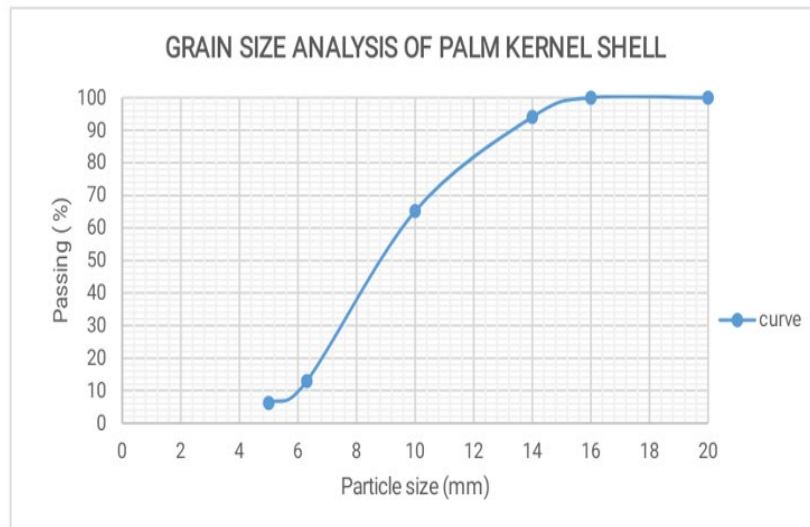
Figure 12 Granulometric curve of analysis of palm kernel shell

Using the grading curve, the values D10, D30, D60 enable us to calculate the coefficient of uniformity of HAZEN (CU) and the coefficient of curvature (Cc), we have:

D10= 6.0
D30= 7.0
D60= 9.0

$$Cu = \frac{D60\%}{D10\%} = \frac{9}{7} = 1.28 \qquad (8)$$

$$Cc = 1 + \frac{(D30\%)2}{D10\% X D60\%} = \frac{(7)2}{6.0X9} = 0.907 \qquad (9)$$

$$Mf = \frac{100+100+96.07+65.18+12.93+6.21}{100}$$

Mf = 3.80

The results showed that fineness modulus of sand mf= 2,53 and for PKS Mf = 3.15 which falls within the ranges of 2.2 to 2.8 and 2.8 to 3.2 ASTM (2003) and also satisfied the requirements of BS EN 12620 :1(2007) for sand and Coarse Aggregate to be used for concrete production. Coefficient of uniformity of HAZEN (CU) and the coefficient of curvature (Cc) were recorded: C_U = 3.2, C_c = 1.25 for sand and C_U = 2.16, Cc=1.2 For PKS. From the results the aggregate can be classified as well graded on have CC value between 1 and 3 in uniformity with requirements of ASTM (2003) hence it can be concluded that the sand and PKS used in this study are well graded and suitable.

3.2. SLUMP TEST

The results of the slump test carried out to determine workability are presented in the table below

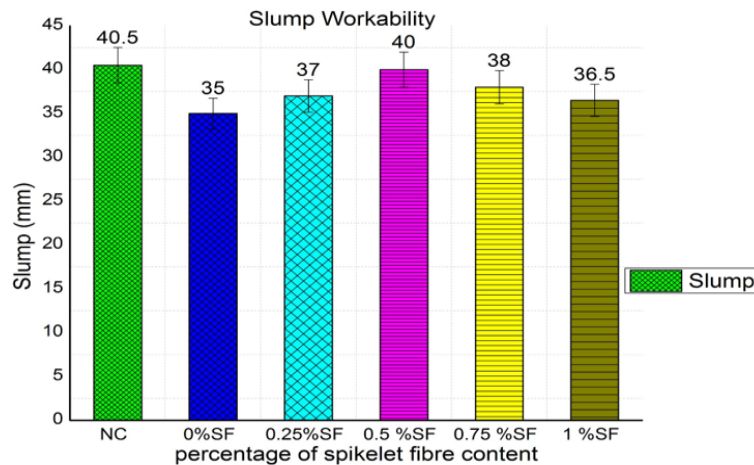| Table 4 slump test values for different mix proportion		
Samples	% Of fibres	Slump, mm
(NC)	Normal concrete slump	45.5
0%SF	0%	35
0.25%SF	0.25%	37
0.5%SF	0.50%	40
0.75%SF	0.75%	38
1%SF	1 %	36.5

Figure 13 consistency of fresh concrete measured by slump

According to the slump test values obtained, it was clearly shown that the slump rate decreases after Coarse Aggregate is changed to palm kernel Shell and continuous to increase since the input of fibres increases the compatibility rate. After 0.5% increase in fibre content the slump starts to decrease this is due to the fact as fibres increase the matrix element sand is reduced making it to be less compactible leading to lower slump rate. Several researchers had the same conclusion in their various work Mehta and Monteiro (2006), Mannan and Ganapathy (2002). Hence, one can conclude from our slump values obtained that the sample proportions are workable and can be used as lightweight concrete.

3.3. DENSITY

The density of the various samples is expressed in the table below
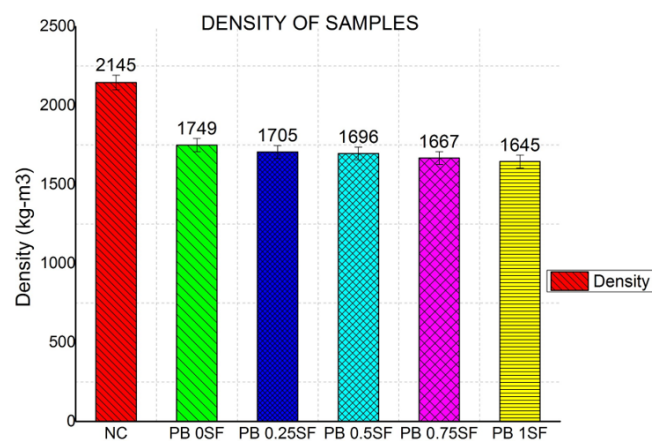
Figure 14 Relationship between density and PKS/SF replacement

According to the observations from the Figure 14 above the mean values of the specimen's density where $\rho 1 = 2145$ k g /m3; ρ 2 = 1749kg/m3; ρ 3 = 1705kg/m3 ; $\rho 4 = 1696$ kg/m3 ; $\rho 5 = 1667$ kg/m3 ; $\rho 6 = 1645$ kg/m3. it was observed That prior to the change from Coarse Aggregate to palm kernel Shell the Density continue to decrease even with increase in fibre content. This is expected as fibres and palm kernel shells have low density, and therefore increase of its content with the reduction of sand content, which is heavier, will invariably decrease the density of the concrete.

The density of the normal concrete is in the order of 2304-2420 kg m-3, while the lightweight concrete has density ranging from 1490 to 2042 kg/m3.it showed an average density of 1692 kg/m3 for the palm kernel shell concrete samples and 2145 kg/m3for normal weight concrete at 28 days. These results show that palm kernel shell concrete samples are about 21% lower in density than the normal weight concrete. Conversely, the range for density of structural lightweight concrete is 1440 kg m-3 to 1850kg m-3 ACI (1999) The density of 1645 to 1749 kg m-3 recorded for the various samples at curing age of 28 days falls within the range for structural lightweight concrete and suggests that palm kernel shell and spikelet fibers can be used to obtained structural lightweight concrete concurring with Mannan and Ganapathy (2002),Itam et al. (2016),Neville (2000)

3.4. WATER ABSORPTION TEST

Table 5 Summary of Water Absorption Rate of samples

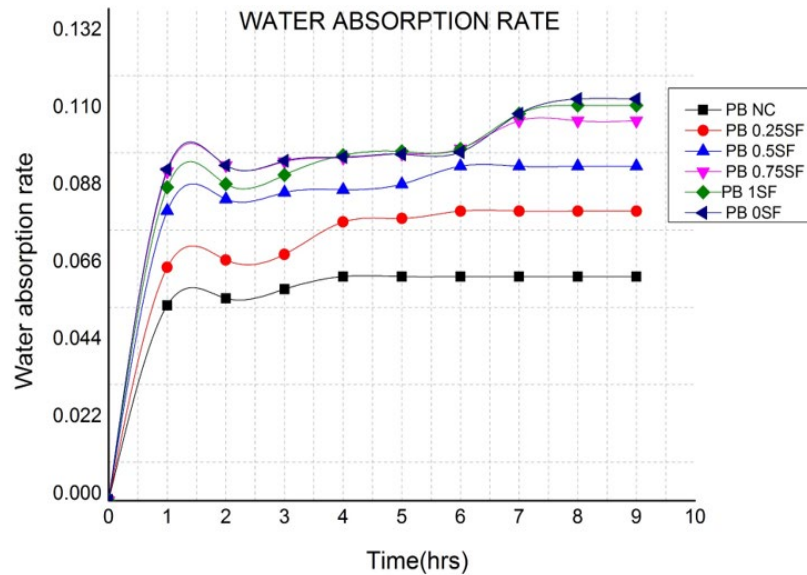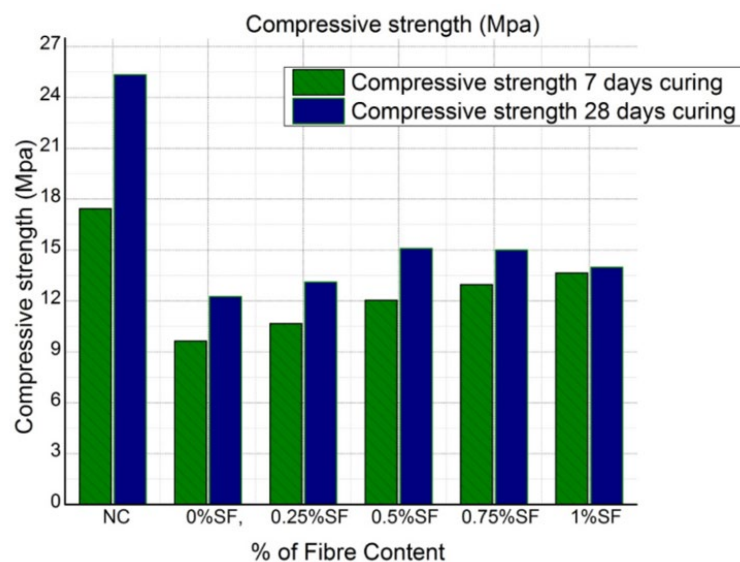| Samples	sample fibre content	Water absorption rate	Percentage of water absorbed
S1	PB (NC)	0.0638	6.38
S2	PB 0SF,	0.0824	8.24
S3	PB 0.25SF,	0.0952	9.52
S4	PB 0.5SF,	0.1081	10.81
S5	PB 0.75SF,	0.1125	11.25
S6	PB 1SF,	0.1143	11.43

Figure 15 Water Absorption Test Results

The figure above presents the summary of the water absorption test results of concrete. From this test, it was observed that the rate of water absorption increased after the change of coarse aggregate (gravel) to palm kernel shell and continue to increase as the fibre content increases. This implies that the rate of absorption of the bricks is dependent on the level of porosity created by the change to PKS and the capability of the fiber to absorption water. Also, from the tests carried out on all the bricks all the absorptive capacities of the PKS/Spikelet fiber concrete- composite fell between 6.38-11.43%, which is specified as okay by ACI (1999) stating that the absorption of lightweight aggregate ranges between 5 to 20 percent by mass of dry aggregate after 24 hours of absorption. Other researchers like Abdul et al. (2001),Achukwu et al. (2015) also concur with the water absorption test results which states that the inclusion of PKS and fibres in concrete increases the water absorption as well as the porosity thus resulting to higher amount of mixing water during concrete production.

3.5. COMPRESSIVE STRENGTH

Values for compressive strength of concrete cubes were summarized as follows

Table 6 Change in Compressive strength Due to aging

| Samples	Compressive strength 7 days	Compressive strength 28 days	Change in Compressive strength Due to age
S1	17.43	25.34	7.91
S2	9.65	12.26	2.61
S3	10.67	13.11	2.44
S4	12.05	15.09	3.04
S5	12.96	15.01	2.05
S6	13.65	13.98	0.33

Figure 16 Compressive strength of different mixture proportions of pavements blocks after 7 and 28 days of curing

From figure above the 28 days compressive strength values of all the percentage replacements PB (NC) PB 0SF, PB 0.25SF, PB 0.5SF, PB 0.75SF, PB 1SF, with spikelet fibers are 25.34, 12.26, 13.11, 15.09 and

15.01, 13.98 Mpa respectively. This demonstrates the huge influence the amount and type of coarse aggregate used in the production of concrete has on the compressive strength of the corresponding concrete.it is also observed that after complete replacement of coarse aggregate with palm kernel shell the value of the compressive strength reduced drastically but where further improved by the addition of spikelet fibers. According to Itam et al. (2016) palm kernel shell can be termed as lightweight aggregate as it has low specific gravity in the range of 1.17-1.6.According to FIP Manual, (1983) some of the codes of practice stipulate minimum strength of lightweight concrete as 15MPa.The classification of structural lightweight concrete is based on a minimum strength according to ASTM (2004) the 28- days compressive strength should not be less than 17 N mm-2 hence we can conclude that the samples falls with the range except for 0%, fiber replacement.

3.6. FLEXURAL TEST

50 samples tested for flexural. It is observed that due to the change from gravel (coarse aggregate) to palm kernel shell the flexural strength dropped. Prior to the input of spikelet fibers the strength kept rising right up to 0.5SF. this could be attributed to the fact the addition of fibres enhances the resistance to fracture of the samples Yakum et al. (2018) it is to be noted that from 0.5SF flexural strength decreases.it was also observed that unreinforced samples exhibited sudden failure in all instances. This tires to findings of other researchers Yakum et al. (2018),Vodounon et al. (2018) stating that the drop of flexural strength after a certain percentage of fibre content could be attributed to various factors such as fibre-to-fibre interaction voids and dispersion problems
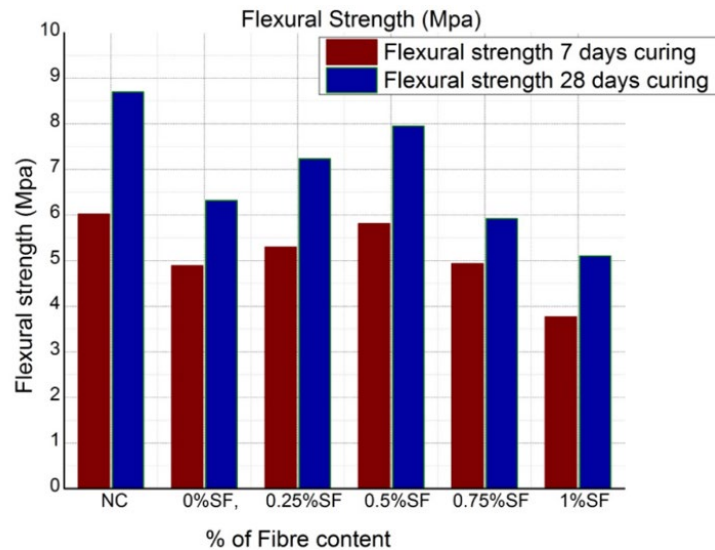
Figure 17 Flexural strength of different mixture proportions of pavements blocks after 7 and 28 days of Curing

4. CONCLUSION

The following conclusions were drawn from this study:

1) It was shown that using palm kernel shell and spikelet fibres as coarse aggregate for pavement bricks realisation had comparable strength properties and structural behaviour to normal weight concrete pavements. However, it was noticed that palm kernel shell-spikelet fibre concrete pavements showed superior performance compared to normal weight concrete composite with respect to cracking; normal gavel concrete composites cracked explosively unlike gradual cracks observed with samples cubes that had palm kernel shell and spikelet fibres. This could be attributed to the compactness of the composites due to the availability of fibres.

2) The density of the palm kernel shell and spikelet fibres concrete obtained ranged from 1645 kg/m3 to 2145 kg/m3 which fall within acceptable limits for lightweight concrete. They were found to be about 21% lower compared to normal weight concrete. Thus, it can be concluded that palm kernel shell and spikelet fibres composites have advantage in both strength and density.

3) The compressive strengths obtained for the palm kernel shell and spikelet fibre composites at 28 days curing ranged from 12.26Mpa to 25.34 Mpa, which met the compressive strength requirements with reference to previous research findings that the compressive strength of palm kernel shell composites ranges from 5 to 25 Mpa based on mix design. Kengoh et al. (2021) The research also revealed that the physical and mechanical properties of palm kernel shell and spikelet fibers aggregate are satisfactory for the production of structural composites. Ezeudu et al. (2021)

4) The workability of the concrete for the mix ratios decreased with the increase in Percentage of palm kernel shell and spikelet fibres replacement due to low density and poor bonding between PKS and fine aggregates in concrete mix.

5) The water absorption capacity of the composites increased with the increase in percentage of palm kernel shell and spikelet fibres replacement for both mix ratios.

ACKNOWLEDGMENTS

NOMENCLATURE

Yi: Percentage cumulated of grain on each sieve
Xi: Total weight of the refusal (g)
Ws: Total weight of the sample
Zi: Percentage of the cumulated passing
Fc: Force measured from the compression test machine in N
A: Area of the composite specimen in mm2
CU: coefficient of uniformity of HAZEN Cc: coefficient of curvature
Mf: Fineness modulus
$\rho 1$:   density.

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