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Determination of Compressive Strength of Sandcrete Block Containing Laterite and Ground Palm Kernel Shell (GPKS)

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ABSTRACT: This research examines the properties of Sandcrete, Sand-GPKS, Sand-Laterite and Sand-GPKS-Laterite blocks in an attempt to compare them with the acceptable standards. Block samples were batched by mass in mix ratio of 1:6. The percentage replacement adopted for replacement of sand with Ground Palm Kernel Shell (GPKS) were 5%, 10%, 15%, 20% and 25%; for sand with Laterite were 5%, 10%, 15%, 20% and 25%. This gave rise to a total of 19 mix ratios. A total of 171 blocks were produced, this comprises 9 blocks for each mix ratio. The mixtures were compacted manually. Curing was done by sprinkling water on the specimens for 7, 14 and 28 days respectively and the samples were tested to determine weight, density and compressive strength. It was observed that density and compressive strength decreased and increased respectively as curing age increased, but both reduced as the percentage replacement level increased. At 28th day curing age, the maximum average density and compressive strength of the sandcrete block (control), were 1641kg/m^3 and 2.64N/mm^2 respectively. For Sand-GPKS blend blocks, the maximum 28th day's average density and compressive strength recorded were 1473 kg/m^3 and 1.14 N/mm^2 respectively. For Sand-Laterite blend blocks, the maximum 28th day's average density and compressive strength recorded were 1587 kg/m^3 and 2.49 N/mm^{2}respectively. For Sand-GPKS-Laterite blend blocks, the result showed that the maximum 28th day's average density was 1438kg/m^3 for 10% Laterite and 5% GPKS sand replacement, while the maximum compressive strength recorded was 1.18 N/mm^2 for 5% Laterite and 5% GPKS sand replacement. According to BS 2028 (1968), blocks with density greater than 1500kg/m^3 are classified as type A blocks (dense block) and blocks with density less than 1500kg/m^3 are classified as type B (light weight block). According to the 28th day average density result, all except the control sandcrete block and block with up to 20% sand replacement with laterite were all type B (light weight block). Nigeria Industrial Standard stipulate the compressive strength of 1.8-2.5N/mm^2 for non-load bearing block and 2.5-3.45 N/mm^2 for load-bearing block. Only the compressive strength of the control block met the specification of load-bearing while the percentage replacement of laterite from 5% to 20% met the specification for non-load bearing block. Masonry blocks with sand replaced with laterite up to 20% are suitable for non-load bearing walls and can also be used for low cost building construction.

KEYWORDS: compressive strength, sandcrete, blocks, laterite, Ground Palm Kernel Shell (GPKS)

I. INTRODUCTION

According to NIS 87:2004, sandcrete block is define as a composite material made up of cement, sand and water usually at a mix ratio 1:6 of cement and sharp sand respectively with minimum of water mixture and in some cases admixture, moulded into different sizes and dried naturally. According to them, they are masonry units which when used in its normal aspect exceeds the length or width or heights specified for bricks. It is widely used in Nigeria as walling units and over 90% of houses in Nigeria are being constructed of sandcrete blocks [1]. This makes sandcrete blocks a very important material in building construction. The versatility, strength and durability of cement are of utmost priority over other constituent materials. The cost of sandcrete production is relatively high due to the manufacture of its main constituent i.e. ordinary Portland cement and sand [1]. It then becomes necessary to look for ways to cut down conventional material costs. One of the suggestions in the forefront has been the sourcing,

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development and use of readily available local materials suitable for the production of any component of a building [2], [3].

The prospect of GPKS and Laterite as an alternative to the conventional sand sounds strange and promising. However, there uses as a building materials are not common in most part of the world including Nigeria [4]. Effort to produce affordable houses which will cause less environmental stresses and make construction affordable and sustainable has necessitated research to the use of alternative materials. Such materials, according to [5] should be locally available and can replace conventional ones used in construction. Furthermore, the materials should be cheap, readily available and contribute to stress reduction on the environment.

To overcome or minimize these problems, there have been efforts by Governments at various levels carrying out the policy of direct intervention into the provision of shelter by building low cost housing units. [6], stated that in many developing and underdeveloped countries in Asia and Africa, the research on the use of industrial waste materials such as oil palm kernel shell (OPKS) from palm oil production is envisaged. Consequently, the quest for alternative cheaper materials and utilization of industrial waste and by-product materials in infrastructure development is proven economically viable when environmental factors are considered and these materials meet appropriate performance specifications and standards. [7]concluded that 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.

[8] indicated that the requirement for vegetable oil is constantly increasing; hence more cultivation of oil palm is forecast in the future. Consequently, the production of palm oil result on waste by products such as Palm Kernel Shell (PKS), Palm Kernel Fibre (PKF), Palm Oil Mill Effluent (POME) and Empty Fruits Bunches (EFB). Stockpiling these wastes have created storage problem to the factories as large quantities of them are produced every day.

Similarly, Lateritic soil has been one of the major building materials in Nigeria for a long time. The main reason is because it is readily available and the cost of procuring it is very low. Lateritic soil has other advantages which make it potentially a very good and appropriate material for construction, especially for the construction of rural structures in the developing countries. These advantages include non-requirement of specialized skilled labour for the production of laterized blocks and for its use in the construction of structures. Laterized concrete structures are known to have potentially sufficient strength compared with those of normal concrete. In Nigeria, lateritic soil abounds locally and its use is mainly limited to Civil engineering works like road construction and land fill operations but it is less utilised in the building industry except in filling works. Because of the abundance of lateritic soils and its readily availability, its optimum use in building production could positively affect the cost of buildings which can lead to the production of more affordable housing units. However, because laterites and lateritic soil have no sufficient technical data, it is not yet a generally accepted building constructional material and this contributes to its limited application in building block production [9].

The problem of good standard place of living and inadequate housing in Nigeria is highly related on the high and increasing cost of sandcrete block. The cost of component materials of the sandcrete block contributes majorly to this high cost hence the need to find alternative local materials for their construction works which can be cheaper and better in some properties is very important.

Furthermore, [8] indicated that the requirement for vegetable oil is constantly increasing; hence more cultivation of oil palm is forecast in the future. Consequently, the production of palm oil result on waste by products such as Palm Kernel Shell (PKS), Palm Kernel Fibre (PKF), etc.Stockpiling these wastes have created storage problem to the factories as large quantities of them are produced every day. Similarly, these wastes are mostly stockpile in open fields and have negative impact on the environment. In addition to this, there is great negative impact on the environment due to the exploitation of the conventional fine aggregate, sand at the quarry site. Hence, having a way to convert this waste to usefulness will have a long way to help checkmate the environmental degradation.The main objective of this study is to determination of compressive strength of sandcrete block containing Laterite and Ground Palm Kernel Shell (GPKS).

II. MATERIALS

The materials to be used for this work include:

Ordinary Portland Cement

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

Dangote brand of Ordinary Portland cement, conforming to the requirements of BS 12:1978 with moisture content of 0.003 and specific gravity of 3.15, was purchased from a cement dealer at Eziobodo within FUTO community in Owerriwest, Imo state, Nigeria and was stored in a dry place prior to use for all the tests.

Water

Clean potable water free from foreign materials from a borehole supply and conforming to the specification of BS EN 1008: (2002) was used for both specimen preparations and curing.

River Sand

Sharp river sand was obtained from Otamiri, a nearby river along the Umuchima/Ihiagwa axis within FUTO community in Owerriwest, Imo State, Nigeria. The sand was spread and exposed to the atmosphere for about 7 days to remove excess moisture in the particles which will greatly affect the result of the finished specimen.

Ground Palm Kernel Shell (GPKS)

Palm Kernel Shell was obtained from Rocha Palm Plantation in Avu town in Owerri west, Imo State, Nigeria. It will be crushed/grinded to fine aggregate size and sieved with sieve size corresponding to fine aggregate (sand). Palm kernel shell passing sieve No 8 (4.75mm) was collected.

Laterite

Laterite was obtained from the borrow pit located in Okigwe, Imo State, Nigeria. The laterite was sieved with sieve size corresponding to size of fine aggregate (sand). The Laterite passing sieve No 8 (4.75mm) was collected.

PHYSICAL PROPERTY TESTS

(a) Sieve Analysis

Sieve analysis is a laboratory method used to determine the grain size distribution of aggregates. The sieve analysis was carried out in accordance with the steps prescribed in BS 812, Part 103.1-1990. A stack of sieves was arranged with larger sieve sizes placed above the smaller ones. The sieve analyses was performed on river sand, GroundPalm kernel shell and laterite to determine the particle size gradation respectively. The samples collected were all dried for seven days before conducting the sieve analyses. The stack of sieves were subjected to vibration for about 10 to 15 minutes by the mechanical shaker to induce the action of sorting the materials through the different sieves depending on the material particle size. The particles passing through the 150µm sieve were collected in a clean dry pan. After shaking, the particle retaining in each sieve were weighed and the necessary computations were done. The results of the sieve analysis are shown in Table 2 through Table 5

(b) Specific Gravity

The specific gravity Sand, GPKS and Laterite was done in accordance to BS 812-2: 1995. The results of the specific gravity of Sand, GPKS and Laterite are shown in Tables 6, 7 and 8.

CHEMICAL PROPERTY TEST

Chemical analyses done at PRODA in Enugu was conducted on the cement to determine its chemical compositions in accordance to USEPA 6200 (2007). Loss on ignition was determined in accordance to BS EN 196 -2 (1995). Laterite and GPKS chemical compositions were determined in order to know their various chemical oxide's components. The results of the chemical test is shown in Table 10

PROPERTIES OF BLOCKS DETERMINED IN THE LABORATORY.

The characteristic test on block which are density test and compressive test were determined after the production of block work had been done.

Production of Block

The field work was on the production of the sandcrete blocks. The blocks to be tested for their densities and compressive strengths were moulded using the ratios already estimated. The blocks were produced using the locally manufactured mould which produces only one block at a time. Batching of the materials was done by mass using a weighing balance of 50kg capacity. Solid blocks of dimension 450 x 225 x 225 mm was moulded. Mixing of the constituents was done manually using shovels. First, the sand and the cement were mixed to a constant and uniform colour. Palm Kernel Shell and laterite, which were ground and sieved, were added and the whole process of mixing continued until a uniform colour was achieved. Water was finally added and the mixing continued until the colour of the paste was uniform. The mixture was then loaded into the mould where it was compacted by raising and dropping the loaded mould. The mould was then filled to the top, compacted and levelled using a tamping rod, and

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

finally, demoulded immediately. A total of 171 sandcrete blocks with partial replacement of sand with laterite and GPKS were produced. All 171 blocks were cured for 7, 14 and 28 days by sprinkling them daily with potable water.

Proportioning of the sandcrete block mix

The batching of the materials used for production of the blocks was done by mass

For the purpose of this research work, the following were used:

.Density of Sandcrete Block = 1900kg/m^3; Mix Ratio = 1:6; water/cement ratio (w/c) = 0.5Size of Sandcrete Block = 450 x 225 x 225mm. and volume of Sandcreteblock = 0.0143m^3. The masses of the constituent ingredients of the blocks are shown in Table1

Mix No	Percentage variations (%)			Mix Ratio variations				W/C	Number of Samples	Weight of materials (kg) per block				Total weight of materials (kg)			
	LAT	GPKS	R.S	Cement	R.S	LAT	PKS			Cement	R.S	LAT.	GPKS	Cement	R.S	LAT.	GPKS
1	0	0	100	1	6	0	0	0.5	9	3.88	23.29	0.00	0.00	34.92	209.61	0.00	0.00
2	0	5	95	1	5.7	0	0.3	0.5	9	3.88	22.13	0.00	1.16	34.92	199.13	0.00	10.48
3	0	10	90	1	5.4	0	0.6	0.5	9	3.88	20.96	0.00	2.33	34.92	188.65	0.00	20.96
4	0	15	85	1	5.1	0	0.9	0.5	9	3.88	19.80	0.00	3.49	34.92	178.17	0.00	31.44
5	0	20	80	1	4.8	0	1.2	0.5	9	3.88	18.63	0.00	4.66	34.92	167.69	0.00	41.92
6	0	25	75	1	4.5	0	1.5	0.5	9	3.88	17.47	0.00	5.82	34.92	157.21	0.00	52.40
7	5	0	95	1	5.7	0.3	0	0.5	9	3.88	22.13	1.16	0.00	34.92	199.13	10.48	0.00
8	10	0	90	1	5.4	0.6	0	0.5	9	3.88	20.96	2.33	0.00	34.92	188.65	20.96	0.00
9	15	0	85	1	5.1	0.9	0	0.5	9	3.88	19.80	3.49	0.00	34.92	178.17	31.44	0.00
10	20	0	80	1	4.8	1.2	0	0.5	9	3.88	18.63	4.66	0.00	34.92	167.69	41.92	0.00
11	25	0	75	1	4.5	1.5	0	0.5	9	3.88	17.47	5.82	0.00	34.92	157.21	52.40	0.00
12	5	5	90	1	5.4	0.3	0.3	0.5	9	3.88	20.96	1.16	1.16	34.92	188.65	10.48	10.48
13	5	10	85	1	5.1	0.3	0.6	0.5	9	3.88	19.80	1.16	2.33	34.92	178.17	10.48	20.96
14	10	5	85	1	5.1	0.6	0.3	0.5	9	3.88	19.80	2.33	1.16	34.92	178.17	20.96	10.48
15	15	10	75	1	4.5	0.9	0.6	0.5	9	3.88	17.47	3.49	2.33	34.92	157.21	31.44	20.96
16	10	15	75	1	4.5	0.6	0.9	0.5	9	3.88	17.47	2.33	3.49	34.92	157.21	20.96	31.44
17	20	5	75	1	4.5	1.2	0.3	0.5	9	3.88	17.47	4.66	1.16	34.92	157.21	41.92	10.48
18	5	20	75	1	4.5	0.3	1.2	0.5	9	3.88	17.47	1.16	4.66	34.92	157.21	10.48	41.92
19	10	10	80	1	4.8	0.6	0.6	0.5	9	3.88	18.63	2.33	2.33	34.92	167.69	20.96	20.96

Density Test:

Three blocks from each batch were randomly selected after the 7th, 14th and 28thdays curing age. They were gently wiped with non-absorbent cloth in order to remove any dust or loose matter stuck to them before measuring their dimensions (i.e. length, breadth and thickness). The blocks were weighed and then the densities were calculated after which the average were deduced. The density of the block samples were calculated using Equation (1).

$$\rho = {}^{m}/_{v} \quad (1)$$

Where ρ = density, m = mass and v = volume.

The results of the density of the block sample are shown in Table 11 through Table 19.

Compressive Strength Test.

After the density test, the blocks were crushed after 7, 14 and 28 days of curing using Okhard Machine Tool's WA-1000B digital Universal Testing Machine (UTM). The machine conforms to the requirements of BS EN 12390-4 (2000) and has a testing range of 0 – 1000kN. The solid sandcrete blocks were placed in between two steel plates of 25mm thickness and wide enough as to cover the top and bottom of the blocks. Force was gradually applied through the plates of the testing machine until the blocks failed in compression. The values read off

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

the UTM at failure of block represent the compressive load. The compressive strengths of the blocks were determined by dividing the compressive load with the surface cross-sectional area of the sandcrete block. Three samples each were tested for a particular mix ratio and the average value taken as the compressive strength for the mix.
The Compressive Strength of the block samples were determined using Equation (2).

$$fc = \frac{F}{A} \quad (2)$$

The results of the compressive strength are shown in Table 11 through Table 19

Comparison of the Compressive Strength of Sand-Laterite Blocks and Sand-GPKS Blocks Produced
The blocks produced by partially replacing sand with laterite were compared using their 28th day compressive strength percentage difference with those produced by partially replacing sand with GPKS. The results were obtained using Equation (3).

$$\text{Percentage difference} = \frac{f_{cSL} - fc_{SG}}{f_{cSL}} \times 100 \quad (3)$$

Where f_{csL} is the compressive strength of sand- laterite block, and f_{cSG} is the compressive strength of sand-GPKS block. The results obtained is shown in Table 20

Presentation And Analysis Of Results
The results of the various tests conducted are presented as follows:

Characteristics Test Result on Material
The characteristics test result on material which are of two; the physical and chemical test result, are stated below.

Physical Property Test Result
The results of the physical property tests on Sand, Laterite and GPKS and summary of these results are presented in Table 2 through Table 9, while the gradation curves for Sand, Laterite and GPKS are presented in Figure 1.

Table 2: Particle Size Distribution of Sand

Sieve Size (mm)	Mass Retained (g)	% Mass Retained	Cumulative % retained	Cumulative % passing
4.75	9.33	1.87	1.87	98.13
2.36	24.97	5.00	6.87	93.13
1.18	71.46	14.31	21.19	78.81
0.60	178.42	35.74	56.92	43.08
0.43	120.07	24.05	80.97	19.03
0.30	51.73	10.36	91.34	8.66
0.15	36.85	7.38	98.72	1.28
Pan	6.41	1.28	100.00	0.00
Total	**499.24**		**357.88**	

Finesness modulus = 357.88/100 = 3.58

Table 3: Particle Size Distribution of Laterite

Sieve Size (mm)	Mass Retained (g)	% Mass Retained	Cumulative % retained	Cumulative % passing
2.36	10.65	2.15	2.31	97.69
1.18	52.76	10.65	12.96	87.04

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

0.60	284.13	57.35	70.31	29.69
0.43	80.94	16.34	86.65	13.35
0.30	33.43	6.75	93.39	6.61
0.15	23.31	4.71	98.10	1.90
Pan	9.41	1.90	100.00	0.00
Total	**495.43**		**363.72**	

Finesness modulus = 363.72/100 = 3.64

Table 4: Particle Size Distribution of GPKS

Sieve Size (mm)	**Mass Retained (g)**	**% Mass Retained**	**Cumulative % retained**	**Cumulative % passing**
2.36	160.54	32.17	32.39	67.61
1.18	228.74	45.83	78.21	21.79
0.60	70.53	14.13	92.35	7.65
0.43	12.81	2.57	94.91	5.09
0.30	8.20	1.64	96.56	3.44
0.15	7.23	1.45	98.00	2.00
Pan	9.94	1.99	100.00	0.00
Total	**499.11**		**492.42**	

Finesness modulus = 492.42/100 = 4.92

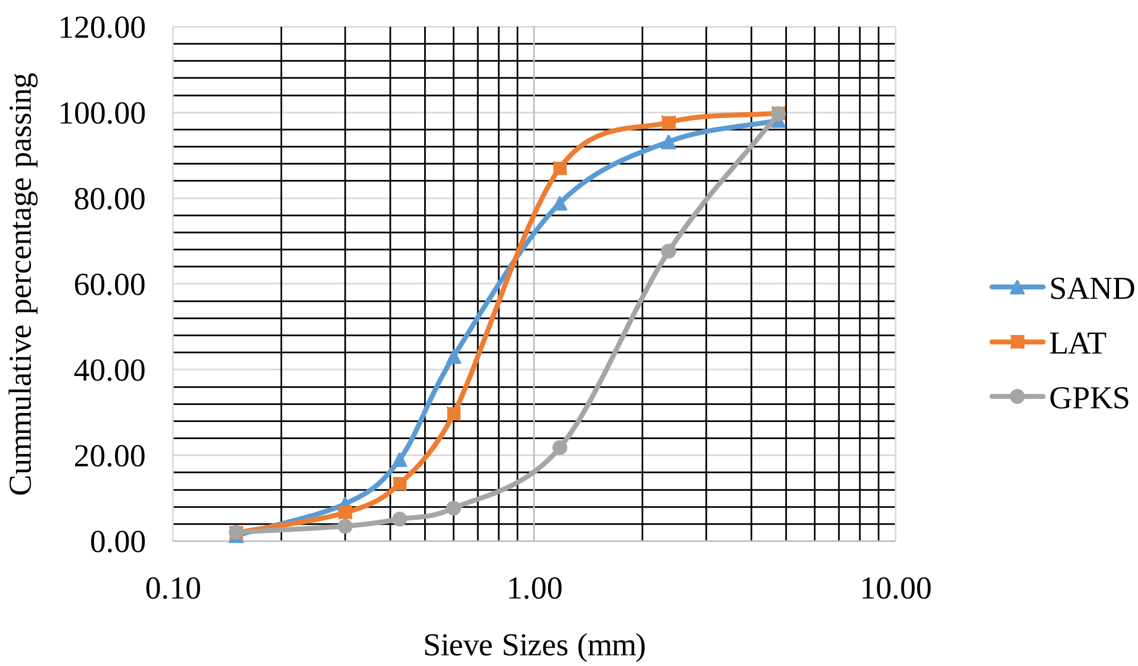

Figure 1: Graph of particle distribution of Sand, Laterite (LAT) and GPKS

Gradation coefficients

From Figure 1, the Coefficient of uniformity, Cu and Coefficient of gradation, Cc were obtained using Equations (4) and (5).

$$Cu = \frac{D_{60}}{D_{10}} \quad (4)$$

$$Cc = \frac{D^2{}_{30}}{D_{60} D_{10}} \quad (5)$$

The results of gradation coefficients of sand, laterite and GPKS are as shown in Table 5

Table 5: Gradation coefficients of sand, laterite and GPKS

Material	**D_{10} (mm)**	**D_{30} (mm)**	**D_{60} (mm)**	**$Cu = \frac{D_{60}}{D_{10}}$**	**$Cc = \frac{D^2{}_{30}}{D_{60}D_{10}}$**
Sand	0.32	0.6	0.80	2.5	1.41
Laterite	0.61	0.8	0.37	0.61	2.91
GPKS	0.70	1.5	2.10	3.00	1.53

Table 6: Specific gravity of sand

Descriptions	**Trial Run**		
	Trial I	**Trial 2**	**Trial 3**
Mass of empty pyncnometer bottle, W1 (g)	149.74	149.74	149.74
Mass of bottle + dry sample, W2 (g)	210.50	213.00	214.50
Mass of bottle + dry sample + water, W3 (g)	684.64	686.70	687.20
Mass of bottle filled with water only, W4 (g)	646.80	646.80	646.80
Mass of dry sample, W5 = [W2-W1], (g)	60.76	63.26	64.76
Mass of water occupying same volume as the sample, W6 = [W4]-[W3-W5], (g)	22.92	23.36	24.36
Specific gravity = W5/W6, (g)	2.65	2.71	2.66
Average Specific Gravity	2.67		

Table 7: Specific gravity of GPKS

Descriptions	**Trial Run**		
	Trial I	**Trial 2**	**Trial 3**
Mass of empty pyncnometer bottle W1, (g)	149.74	149.74	149.74
Mass of bottle + dry sample, W2 (g)	206.00	217.00	203.00
Mass of bottle + dry sample + water, W3 (g)	679.50	685.00	678.20
Mass of bottle filled with water only, W4 (g)	646.80	646.80	646.80
Mass of dry sample, W5 = [W2-W1], (g)	56.26	67.26	53.26
Mass of water occupying same volume as the sample, W6 = [W4]-[W3-W5], (g)	23.56	29.06	21.86

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

Specific gravity = W5/W6	2.39	2.31	2.44
Average Specific Gravity	2.38		

Table 8: Specific gravity of laterite

Descriptions	Trial Run		
	Trial I	**Trial 2**	**Trial 3**
Mass of empty pyncnometer bottle, W1 (g)	149.74	149.74	149.74
Mass of bottle + dry sample, W2 (g)	214.45	214.65	214.50
Mass of bottle + dry sample + water, W3 (g)	686.94	686.70	687.20
Mass of bottle filled with water only, W4 (g)	646.80	646.80	646.80
Mass of dry sample, W5 = [W2]-[W1], (g)	64.71	64.91	64.76
Mass of water occupying same volume as the sample, W6 = [W4]-[W3-W5], (g)	24.57	25.01	24.36
Specific gravity = W5/W6	2.63	2.60	2.66
Average Specific Gravity	2.63		

Table 9: Summary of Physical properties test result of fine aggregates.

Property	River sand	Laterite	GPKS
Specific gravity	2.67	2.63	2.38
Fineness Modulus	3.58	3.64	4.92
Coefficient of uniformity, C_u	2.5	0.61	3
Coefficient of curvature, C_c	1.41	2.91	1.53
Plastic limit		21.69	
Liquid limit		32.20	
Plasticity Index		10.51	

Chemical Property Test Result of Cement, Laterite and GPKS

The results from the chemical property tests for Cement,Laterite and GPKS are presented in Table 10

Table 10: Percentage Concentration of Major Chemical Constituents of Dangote Cement, Laterite and GPKS

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

Oxide compounds	Cement	Laterite (LAT)	GPKS
Calcium oxide (CaO)	64.30	-	8.79
Silica (SiO_2)	21.25	29.10	54.80
Alumina (Al_2O_3)	4.33	20.30	11.4
Iron oxide (Fe_2O_3)	1.85	33.50	0.362
Tin oxide (TiO_2)	0.13	1.30	-
Sodium oxide (Na_2O)	0.17	0.02	-
Potassium oxide (K_2O)	0.71	0.14	6.25
Magnesium (MgO)	1.81	-	6.11
SiO_3	3.70		-
Loss of Ignition	1.5		-

Properties of Blocks Determined in the Laboratory.
The characteristics test results on blocks are presented in Tables 11 through Table19 while their density and compressive strength graphs are presented in Figure 2 through Figure 5.

Table 11: 7th day Compressive Strength values and densities of Sandcrete Blocks Containing GPKS

Mix No		Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	A	24.00	1678.32	1675.99	114	1.79	1.77
	B	24.20	1692.31		109	1.72	
	C	23.70	1657.34		115	1.81	
2	A	21.50	1503.50	1508.16	52	0.82	0.76
	B	21.80	1524.48		51	0.80	
	C	21.40	1496.50		43	0.67	
3	A	19.20	1342.66	1342.66	43	0.67	0.67
	B	19.40	1356.64		38	0.60	
	C	19.00	1328.67		47	0.74	
4	A	18.10	1265.73	1268.07	32	0.50	0.68
	B	18.30	1279.72		48	0.76	
	C	18.00	1258.74		50	0.78	
5	A	16.70	1167.83	1166.67	32	0.50	0.50
	B	16.75	1171.33		45	0.70	
	C	16.60	1160.84		19	0.30	
6	A	16.10	1125.87	1123.54	21	0.33	0.33
	B	15.90	1111.89		22	0.35	
	C	16.20	1132.87		20	0.31	

Table 12: 14th day Compressive Strength Values and densities of Sandcrete Block Containing GPKS

Mix No	Sample	Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

							(N/mm²)
1	A	23.70	1657.34	1655.01	153	2.40	2.38
	B	23.90	1671.33		147	2.30	
	C	23.40	1636.36		155	2.43	
2	A	21.20	1482.52	1487.18	70	1.10	1.03
	B	21.50	1503.50		69	1.08	
	C	21.10	1475.52		57	0.90	
3	A	18.90	1321.68	1321.68	57	0.90	0.90
	B	19.10	1335.66		52	0.81	
	C	18.70	1307.69		63	0.99	
4	A	17.80	1244.76	1247.09	42	0.67	0.68
	B	18.00	1258.74		44	0.68	
	C	17.70	1237.76		45	0.70	
5	A	16.40	1146.85	1145.69	29	0.45	0.45
	B	16.45	1150.35		40	0.63	
	C	16.30	1139.86		17	0.27	
6	A	15.80	1104.90	1102.56	19	0.30	0.29
	B	15.60	1090.91		20	0.31	
	C	15.90	1111.89		17	0.27	

Table 13: 28th day Compressive strength values and densities of Sandcrete Block Containing GPKS

Mix No	**Sample**	**Mass (kg)**	**Density (Kg/m^3)**	**Average Density (Kg/m^3)**	**Compressive Force(KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
1	A	23.5	1643.36	1641.03	170	2.67	2.64
	B	23.7	1657.34		163	2.56	
	C	23.2	1622.38		172	2.7	
2	A	21	1468.53	1473.19	78	1.22	1.14
	B	21.3	1489.51		77	1.2	
	C	20.9	1461.54		64	1	
3	A	18.7	1307.69	1307.69	64	1	1
	B	18.9	1321.68		57	0.9	
	C	18.5	1293.71		70	1.1	
4	A	17.6	1230.77	1233.1	47	0.74	0.76

	B	17.8	1244.76		48	0.76	
	C	17.5	1223.78		50	0.78	
5	A	16.2	1132.87	1131.7	32	0.5	0.5
	B	16.25	1136.36		45	0.7	
	C	16.1	1125.87		19	0.3	
6	A	16.1	1125.87	1088.58	21	0.33	0.32
	B	15.4	1076.92		22	0.34	
	C	15.7	1097.9		19	0.3	

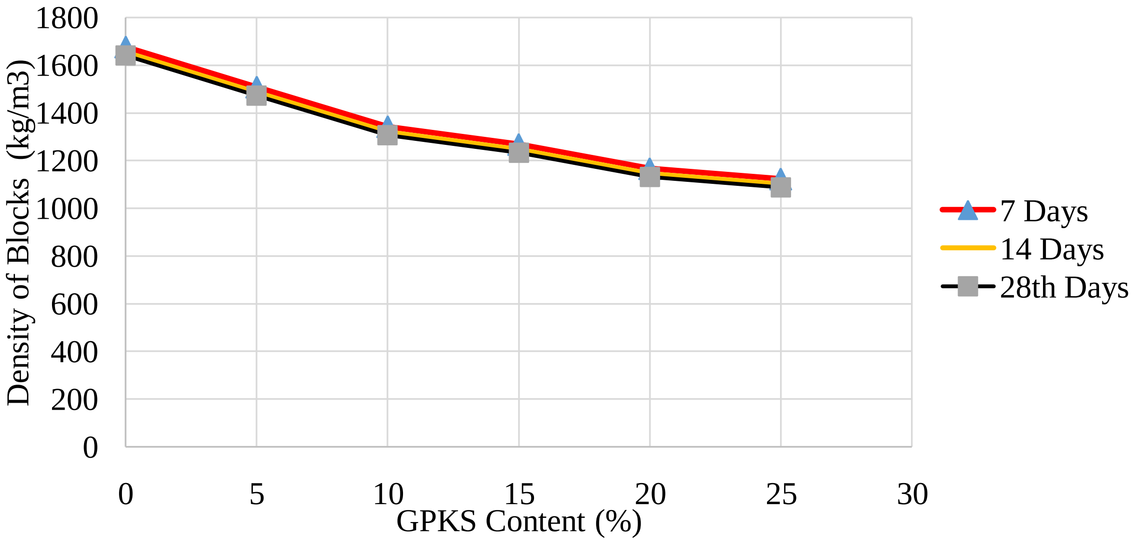

Figure 2. Density of Blocks versus GPKS Content

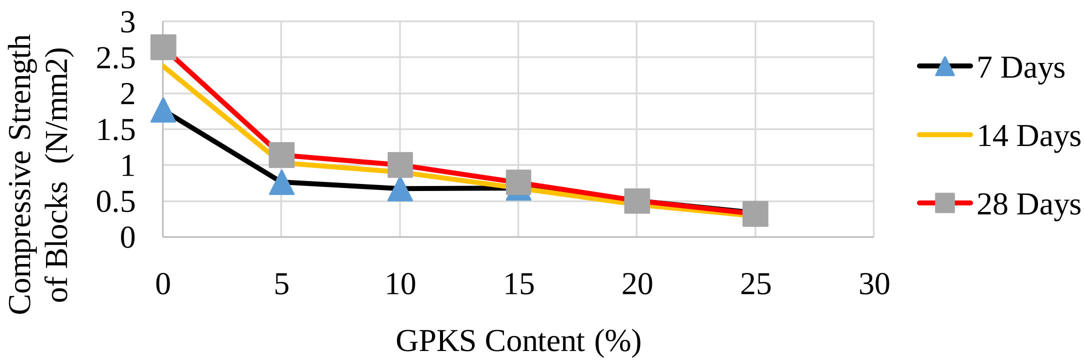

Figure 3. Compressive Strength of Blocks versus GPKS Content

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

Table 14: 7th day Compressive Strength values and densities of Sandcrete Block Containing

Mix No	Sample	Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	A	24.30	1699.30	1706.29	113	1.78	1.76
	B	24.50	1713.29		109	1.70	
	C	24.40	1706.29		115	1.80	
7	A	23.20	1622.38	1622.38	105	1.65	1.66
	B	23.00	1608.39		107	1.67	
	C	23.40	1636.36		105	1.65	
8	A	22.80	1594.41	1620.05	101	1.59	1.60
	B	24.00	1678.32		103	1.61	
	C	22.70	1587.41		102	1.60	
9	A	22.30	1559.44	1558.28	93	1.45	1.44
	B	22.40	1566.43		92	1.44	
	C	22.15	1548.95		91	1.43	
10	A	22.00	1538.46	1540.33	86	1.35	1.35
	B	22.15	1548.95		85	1.34	
	C	21.93	1533.57		87	1.36	
11	A	21.70	1517.48	1519.81	65	1.02	1.04
	B	21.60	1510.49		67	1.05	
	C	21.90	1531.47		66	1.04	

Table 15: 14th Day Compressive Strength values and densitiesof Sandcrete Block Containing Laterite

Mix No	Sample	Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	A	23.70	1657.34	1655.01	153	2.40	2.38
	B	23.90	1671.33		147	2.30	
	C	23.40	1636.36		155	2.43	
7	A	22.90	1601.40	1601.40	142	2.23	2.24
	B	22.70	1587.41		144	2.26	
	C	23.10	1615.38		142	2.23	
8	A	22.50	1573.43	1599.07	137	2.15	2.16
	B	23.70	1657.34		139	2.17	
	C	22.40	1566.43		138	2.16	

9	A	22.00	1538.46	1537.30	125	1.96	1.95
	B	22.10	1545.45		124	1.95	
	C	21.85	1527.97		123	1.93	
10	A	21.70	1517.48	1519.35	116	1.82	1.82
	B	21.85	1527.97		115	1.81	
	C	21.63	1512.59		117	1.84	
11	A	21.40	1496.50	1498.83	88	1.38	1.40
	B	21.30	1489.51		90	1.41	
	C	21.60	1510.49		89	1.40	

Table 16: 28th day Compressive Strength Values and densities of Sandcrete Block Containing Laterite

Mix No	Sample	Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	A	23.50	1643.36	1641.03	170.00	2.67	2.64
	B	23.70	1657.34		163.00	2.56	
	C	23.20	1622.38		172.00	2.70	
7	A	22.70	1587.41	1587.41	158.00	2.48	2.49
	B	22.50	1573.43		160.00	2.51	
	C	22.90	1601.40		158.00	2.48	
8	A	22.30	1559.44	1585.08	152.00	2.38	2.40
	B	23.50	1643.36		154.00	2.42	
	C	22.20	1552.45		153.00	2.40	
9	A	21.80	1524.48	1523.31	139.00	2.18	2.16
	B	21.90	1531.47		138.00	2.16	
	C	21.65	1513.99		137.00	2.15	
10	A	21.50	1503.50	1505.36	129.00	2.02	2.02

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

	B	21.65	1513.99		128.00	2.01	
	C	21.43	1498.60		130.00	2.04	
11	A	21.20	1482.52	1484.85	98.00	1.54	1.55
	B	21.10	1475.52		100.00	1.57	
	C	21.40	1496.50		99.00	1.55	

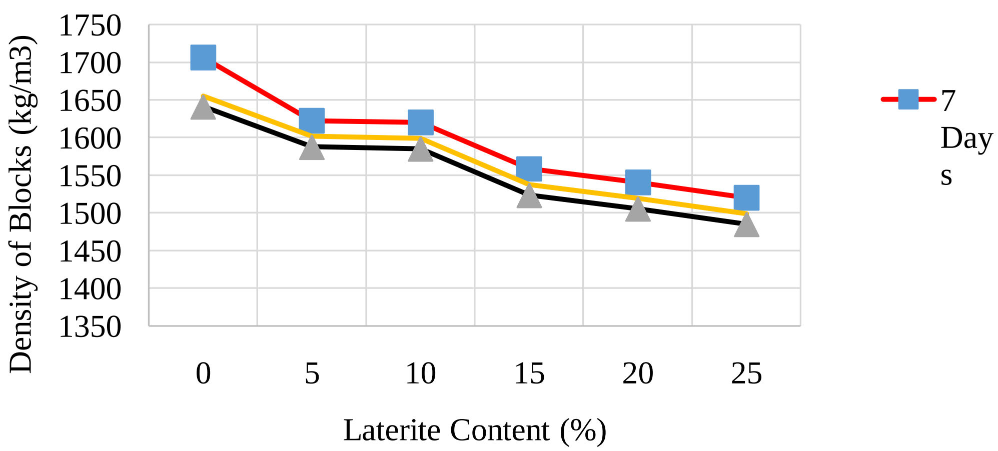

Figure 4. Density of Blocks versus Laterite Content in the block

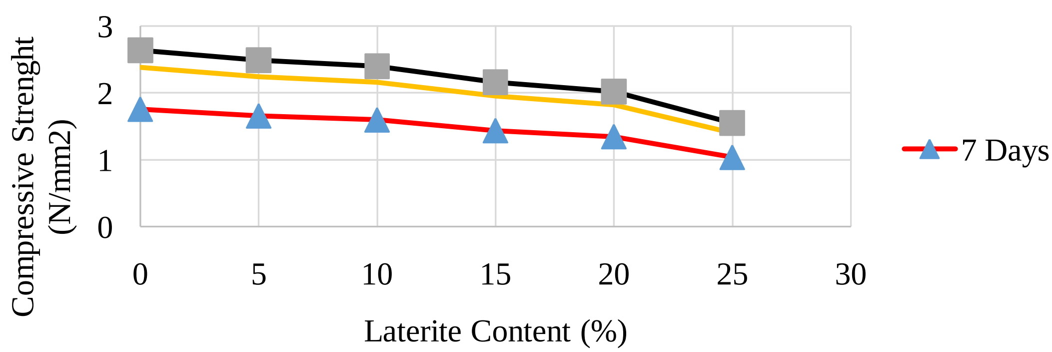

Figure 5. Compressive Strength versus Laterite Content in the block

Table 17: 7th day Compressive Strength values and densities of Sandcrete Block Containing Laterite and GPKS

Mix No	Sample	Mass (kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Compressive Force(KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	A	24.00	1678.32	1675.99	114	1.79	1.77

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

	B	24.20	1692.31		109	1.72	
	C	23.70	1657.34		115	1.81	
12	A	20.70	1447.55	1433.57	50	0.78	0.79
	B	20.50	1433.57		51	0.80	
	C	20.30	1419.58		50	0.79	
13	A	19.90	1391.61	1391.61	47	0.74	0.72
	B	20.10	1405.59		48	0.75	
	C	19.70	1377.62		43	0.67	
14	A	21.10	1475.52	1473.19	50	0.78	0.77
	B	21.20	1482.52		49	0.77	
	C	20.90	1461.54		49	0.76	
15	A	19.00	1328.67	1338.00	37	0.58	0.59
	B	19.60	1370.63		38	0.60	
	C	18.80	1314.69		36	0.57	
16	A	17.80	1244.76	1247.09	31	0.48	0.48
	B	18.00	1258.74		29	0.46	
	C	17.70	1237.76		32	0.50	
17	A	20.10	1405.594	1402.10	49	0.77	0.77
	B	20.15	1409.091		50	0.79	
	C	19.90	1391.608		48	0.76	
18	A	16.90	1181.818	1186.48	28	0.44	0.44
	B	17.20	1202.797		26	0.40	
	C	16.80	1174.825		30	0.47	
19	A	19.20	1342.657	1340.33	39	0.61	0.62
	B	19.00	1328.671		43	0.67	
	C	19.30	1349.65		37	0.58	

Table 18: 14th day Compressive Strength values and densities of Sandcrete Block Containing Laterite and GPKS

Mix No	**Sample**	**Mass (kg)**	**Density (Kg/m^3)**	**Average Density (Kg/m^3)**	**Compressive Force(KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
1	A	23.70	1657.34	1655.01	153	2.40	2.38
	B	23.90	1671.33		147	2.30	
	C	23.40	1636.36		155	2.43	
12	A	20.40	1426.57	1412.59	67	1.05	1.07
	B	20.20	1412.59		69	1.08	
	C	20.00	1398.60		68	1.06	

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

13	A	19.60	1370.63	1370.63	64	1.00	0.97
	B	19.80	1384.62		64	1.01	
	C	19.40	1356.64		57	0.90	
14	A	20.80	1454.55	1452.21	67	1.04	1.04
	B	20.90	1461.54		66	1.04	
	C	20.60	1440.56		65	1.03	
15	A	18.70	1307.69	1317.02	50	0.78	0.79
	B	19.30	1349.65		52	0.81	
	C	18.50	1293.71		49	0.77	
16	A	17.50	1223.78	1226.11	41	0.65	0.65
	B	17.70	1237.76		40	0.62	
	C	17.40	1216.78		42	0.67	
17	A	19.80	1384.615	1381.12	66	1.04	1.04
	B	19.85	1388.112		68	1.06	
	C	19.60	1370.629		65	1.02	
18	A	16.60	1160.839	1165.50	37	0.59	0.59
	B	16.90	1181.818		34	0.54	
	C	16.50	1153.846		40	0.63	
19	A	18.90	1321.678	1319.35	52	0.82	0.83
	B	18.70	1307.692		57	0.90	
	C	19.00	1328.671		50	0.78	

Table 19: 28th day Compressive Strength Values and densities of Sandcrete Block Containing Laterite and GPKS

Mix No	**Sample**	**Mass (kg)**	**Density (Kg/m^3)**	**Average Density (Kg/m^3)**	**Compressive Force(KN)**	**Compressive Strength (N/mm^2)**	**Average Compressive Strength (N/mm^2)**
1	A	23.50	1643.36	1641.03	170	2.67	2.64
	B	23.70	1657.34		163	2.56	
	C	23.20	1622.38		172	2.70	
12	A	20.20	1412.59	1398.60	75	1.17	1.18
	B	20.00	1398.60		77	1.20	
	C	19.80	1384.62		75	1.18	
13	A	19.40	1356.64	1356.64	71	1.11	1.08
	B	19.60	1370.63		71	1.12	
	C	19.20	1342.66		64	1.00	
14	A	20.60	1440.56	1438.23	74	1.16	1.15

	B	20.70	1447.55		73	1.15	
	C	20.40	1426.57		73	1.14	
15	A	18.50	1293.71	1303.03	55	0.87	0.87
	B	19.10	1335.66		57	0.90	
	C	18.30	1279.72		54	0.85	
16	A	17.30	1209.79	1212.12	46	0.72	0.72
	B	17.50	1223.78		44	0.69	
	C	17.20	1202.80		47	0.74	
17	A	19.6	1370.629	1367.13	73	1.15	1.15
	B	19.65	1374.126		75	1.18	
	C	19.4	1356.643		72	1.13	
18	A	16.4	1146.853	1151.52	41	0.65	0.65
	B	16.7	1167.832		38	0.6	
	C	16.3	1139.86		45	0.7	
19	A	18.7	1307.692	1305.36	58	0.91	0.93
	B	18.5	1293.706		64	1	
	C	18.8	1314.685		55	0.87	

Comparison of the Compressive Strength of Sand-Laterite Block and Sand-GPKS Block Produced The comparison of block produced from partial replacement of sand with laterite and that with partial replacement of sand with GPKS is shown in Table 20

Table 20: Comparison of Sand-Laterite block and Sand-GPKS masonry block

Percentage replacement of sand by laterite or sand by GPKS (%)	**Compressive strength of sand-laterite Block (f_{cSL}) N/mm^2**	**Compressive strength of sand-GPKS Block (f_{cSG}) N/mm^2**	**Percentage difference $= \frac{f_{cSL}-f_{cSG}}{f_{cSL}} \times 100$ (%)**
5	2.49	1.14	54.22
10	2.40	1.00	58.33
15	2.16	0.76	64.81
20	2.02	0.5	75.25
25	1.55	0.32	79.35

III. DISCUSSION OF RESULTS

Physical Characteristics of materials used

(a) Gradation of Sand, Laterite and GPKS

The sieve analysis of Sand, Laterite and GPKS showed that both sand, laterite and GPKS fall in Zone II of the grading of fine aggregates as given in NIS: 87 (2004) and BS 882 (1992) and are suitable for making sandcrete block. The fineness modulus were respectively 3.58, 3.64 and 4.92 for Sand, Laterite and GPKS respectively. These values fall in class C, M and C respectively is recommended for fine aggregates in concrete works as recommended by BS 882 (1992).

.The coefficient of uniformity, Cu and the coefficient of gradation, Cc for the sand were respectively 2.5 and 1.41, for laterite were 0.61 and 2.91 while the corresponding values for the GPKS were 3 and 1.53.

The results show that sand, laterite and GPKS have a smaller range of particle sizes and they are all well graded since their coefficient of curvatures, Cc were within the limit in accordance with ASTM D-2487-17

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

(b) Specific Gravity of Sand, Laterite and GPKS

The specific gravity of the Sand, Laterite and GPKS were found to be 2.67, 2.63 and 2.38 respectively. These values are within the normal ranges for the respective materials. Values of specific gravity of laterite and GPKS obtained from literature varies depending on the gradation and the parent rock for laterite while that of the GPKS is dependent on the variety, species and location of the palm fruit. [7]obtained 2.3 as the specific gravity of GPKS. [4] gave a range of 2.55 - 4.6 as specific gravity for laterite suitable for concrete works and the value obtained falls within range.

Chemical Analysis of Cement, Laterite and GPKS

The chemical composition of cement, laterite and GPKS are given in Table 10. The percentage composition of the major compounds in cement namely: CaO, SiO_2, Al_2O_3 and Fe_2O_3 are 64.03%, 21.35%, 4.33% and 1.85% respectively. These values are within the range provided by [11]. The other percentage constituents- SO_3 and loss of ignition are 3.7% and 1.5% respectively. They also fall within the limits given by BS EN 197-2(2000). The chemical composition of laterite shows the percentage composition for the major constituents namely: SiO_2 (29.10%), Al_2O_3 (20.3%), Fe_2O_3 (33.05%). This constituent compounds evident from the chemical analysis confirms the constituent compounds of a typical laterite as explained by [11]. The silica content of the laterite indicates that it can be used for sand replacement in sandcrete works. The degree of laterization as indicated by the silica-Sesquioxides (S-S) ratio and its value is 0.54 (<1.33) which indicates that it is a laterite. The constituent compound from the chemical analysis of GPKS shows the major compounds of GPKS as silica (SiO_2) and Alumina (Al_2O_3). The total percentage of silica present is 54.81% which represents more than half of the constituent compounds and this high percentage of silica content is indicative that the material can be used for sand replacement. The alumina (Al_2O_3) content is 11.4%.

Characteristics Test Results of Blocks.

The characteristic test result of blocks on sand-laterite, sand-GPKS and sand-laterite and GPKS blocks are discussed below.

(i) Effect of Partial Replacement of Sand with Laterite on the Density Property of the Blocks.

The graph shown in Figure 4 illustrates the variation of the density of specimen with different replacement percentage of natural sand by laterite. It was observed that as the curing age increased, there was a decrease in the density of the different batches as laterite fines increases as seen in the graph plotted in Figure 4. Generally, Figure 4 shows a gradual decrease in the densities of the block as the laterite content increases. The highest average density at 28th day of curing was 1641kg/m3 which was recorded by the control sandcrete block (no laterite) whiles those with 5%, 10%, 15%, 20% and 25% replacements recorded an average density of 1587kg/m^3, 1585kg/m^3, 1523kg/m^3, 1505kg/m^3 and 1485kg/m^3 respectively. According to BS 2028 (1968), all except the 25% replacement were dense blocks. Obviously, this signifies that sandcrete block with high amount of laterite fines were less dense than those with only conventional sand. This could be attributed to the lower specific gravity of the laterite fines when compared to that of the natural sand as presented in Tables 8 and 9

(ii) Effect of Partial Replacement of Sand with Laterite on the Compressive Strength Property of the Blocks.

The compressive strength variations at various levels of percentage replacement of sand with laterite are shown in Figure 5. It was also observed that as the curing age increased, there was an increase in the compressive strength of the different batches as seen in the graph plotted in Figure 5. The highest average compressive strength at 28th day of curing was 2.64 N/mm^2 which was recorded by the control sandcrete block (no laterite) while those with 5%, 10%, 15%, 20% and 25% replacements recorded an average compressive strength of 2.49 N/mm^2, 2.40 N/mm^2, 2.16 N/mm^2, 2.02 N/mm^2 and 1.55 N/mm^2 respectively. Test results show that the compressive strength of sandcrete block at 28th day decreases as percentage laterite content increases. This may not be unconnected with the fact that sand contains mainly silica in the form of quartz which is a very hard material, hence the higher compressive strength material end product obtained when it combines with cement in comparison with laterite which contains less of silica. Furthermore, Nigeria Industrial Standard specified compressive strength of 1.8-2.5N/mm^2 as a non-load bearing block, hence only blocks with percentage replacement up to 20% met the standard.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 4 Apr. 2021, pp: 556-576 www.ijaem.net ISSN: 2395-5252

(iii) Effect of Partial Replacement of Sand with GPKS on the Density Property of the Blocks.

The graph shown in Figure 2 illustrates the variation of the density of specimen with different replacement percentage of natural sand by GPKS. It was observed that as the curing age increased, there was a decrease in the density of the different batches as GPKS increases as seen in the graph plotted in Figure 2. Generally, Figure 2 shows a gradual decrease in the densities of the block as the GPKS content increases. The highest density at 28th day of curing was 1641kg/m^3 which was recorded by the control sandcrete block (no GPKS) whiles those with 5%, 10%, 15%, 20% and 25% replacements recorded an average density of 1473kg/m^3, 1308kg/m^3, 1233kg/m^3, 1132kg/m^3 and 1089kg/m^3 respectively. According to BS 2028 (1968), all except the control block were a light weight block. Obviously, this signifies that blocks with high amount of GPKS were less dense than those with only conventional sand. This could be attributed to the lower specific gravity of the laterite fines when compared to that of the natural sand as presented in Tables 6, 7 and 9

(iv) **Effect of Partial Replacement of Sand with GPKS on the Compressive Strength Property of the Blocks**.

The compressive strength variations at various levels of percentage replacement of sand with GPKS are shown in Figure 3. It was observed that as the curing age increase, there was an increase in the compressive strength of the different batches as seen in the graph plotted in Figure 3. The highest average compressive strength at 28th day of curing was 2.64 N/mm^{2}which was recorded by the control sandcrete block (no GPKS) while those with 5%, 10%, 15%, 20% and 25% replacements recorded an average compressive strength of 1.14 N/mm^2, 1.00 N/mm^2, 0.76 N/mm^2, 0.50 N/mm^2 and 0.32 N/mm^2 respectively. Test results show that the compressive strength of sandcrete block at 28th day decreases as percentage GPKS content increases. This could be as a result of the chemical component, lignin (53.4%) in palm kernel which has been discovered to react negatively with Ordinary Portland Cement [12].

It was also observed that the ease of compaction and moulding decreased and thus the time it took to mould one GPKS block increases as the percentage of GPKS content increases. In other words, the more GPKS content in the mix, the more difficult and the longer time it took to mould. This could be as a result of insufficient adhesion between the component materials.

(v) Effect of Partial Replacement of Sand with GPKS and Laterite on the Density Property and compressive strength of the Blocks.

Table 19 illustrates the variation of the density and compressive strength of specimen with different replacement percentage of natural sand by GPKS and laterite. It was observed that as the curing age increases, there was a decrease in the density of the different batches of the mix ratio. The highest density at 28th day of curing was 1641kg/m^3 which was recorded by the control sandcrete block (no GPKS and laterite fines) while the Mix Nos 12, 13, 14, 15, 16, 17, 18 and 19 recorded an average densities of 1399kg/m^3, 1357kg/m^3, 1438kg/m^3, 1303kg/m^3, 1367kg/m^3, 1152kg/m^3 and 1305kg/m^3 respectively. Obviously, this signifies that sandcrete blocks with high amount of GPKS were less dense. Moreover, according to BS 2028 (1968), all except the control block were light weight block.

In addition, it was observed that as the curing age increases, there was an increase in the compressive strength of the different batches. The highest compressive strength at 28th day of curing was 2.64 N/mm^2 which was recorded by the control sandcrete block (no GPKS and laterite) while the for the Mix Nos: 12, 13, 14, 15, 16, 17, 18 and 19 replacements recorded an average compressive strengths of 1.18N/mm^2, 1.08N/mm^2, 1.15N/mm^2, 0.87N/mm^2, 0.72N/mm^2 1.15N/mm^2, 0.65N/mm^2 and 0.93N/mm^2 respectively. Test results show that the compressive strength of sandcrete block at 28th day decreases as percentage GPKS and laterite content increases. This could be as a result of the chemical component, lignin (53.4%) in palm kernel shell which has been discovered to react negatively with ordinary Portland cement [12].

It was also observed that the ease of compaction and moulding decrease and thus the time it took to mould one GPKS and laterite block increases as the percentage of GPKS and laterite content increases. In other words, the more GPKS and laterite content in the mix, the more difficult and the longer time it takes to mould. This could be as a result of insufficient adhesion between the component materials.

Comparison of the Compressive Strength of Sand-Laterite Block and Sand-GPKS Block Produced

From the result shown in Table 22, at 5%, 10%, 15%, 20% and 25%, the percentage difference recorded were 54.22%, 58.33%, 64.81%, 75.25% and 79.35. The result obviously show that the compressive strength of Sand-Laterite block is very high than those of Sand-GPKS block. This great difference among this two blend increases as the percentage replacement increases. The maximum and minimum percentage difference occurred at 25% and 5% replacement. It was observed that the high content of GPKS was actually resulting a drastic decrease in the compressive strength of the block. The change could also be as a result of the chemical component, lignin which increase at the GPKS increases and which act negatively with ordinary Portland cement [12].

IV. CONCLUSIONS

It was observed that the higher the percentage replacement of the conventional fine aggregate, sand with either laterite or GPKS the decrease in the density of the blocks. According to the 28th day average density result, all except the control sandcrete block and block with up to 20% sand replaced with laterite were all type B (light weight block). Moreover, there was a reduction in the compressive strength of the sandcrete blocks produced with increased percentage replacement of the conventional fine aggregate, sand. Nigeria Industrial Standard specified compressive strength of 1.8-2.5N/mm^2 for non-load bearing block and 2.5-3.45 N/mm^2 for load-bearing block. Hence, only the replacement of sand with laterite up to 20% could be used for non-load bearing block.

In addition, from the result in Figure 9, it could be observed that the compressive strengths in Sand-Laterite blocks were higher than compressive strengths of Sand-GPKS blocks.

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