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Analysis of the Mechanical Properties of Sand-Palm Kernel Shell Portland cement Based Masonry Blocks

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Abstract: **The research examines the properties of sandcrete and sand-PkS masonry blocks in an attempt to compare the properties of sandcrete masonry blocks and sand-PKS masonry blocks acceptable standards. Block samples were batched by volume in mix ratios of 1:4, 1:5 and 1:6 respectively. The percentage palm kernel shell replacement adopted for each and every mix ratio varies from 0%, 20%, 40% and 50%. Curing was done for 28days and samples were tested to determine bulk and wet density, water absorption, porosity, compressive strength and flexural strength. It was observed that all percentage PKS replacement in mix ratio 1:4,1:5 and1:6 exceeded the minimum bulk density limit of 1920kg/m^3 specified for normal weight masonry blocks in BS 2028(7) for individual blocks except 50% PKS replacement in mix ratio 1:5 and 1:6. Water absorption value were lower than the maximum limit recommended (240kg/m^3) in ASTM (C140) for all mix ratios examined and at all percentage PKS replacement except in mix ratio 1:6 at 50% replacement. Porosity values increased from 0% to 50% in all the mix ratios. Standard organisation of Nigeria 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. Only the compressive strength of 1:5 mix at 50% PKS replacement and 1:6 mix at 40% & 50% PKS replacement did not meet the specification of load-bearing and non-load bearing block. The specific gravity of sand is twice that of PKS. There was a decrease in flexural strength as the percentage PKS replacement increased from 0% to 50% across all the mix ratios. Masonry blocks with sand replaced with PKS are suitable for load bearing and non-load bearing walls and can also be used for low income housing.**

Keywords: **Bulk density, Compressive Strength, Flexural Strength, Masonry blocks, Palm kernel shell, Specific gravity, Water absorption, Wet density.**

I. INTRODUCTION

Shelter is a basic necessity to man after food and water. Sandcrete blocks account for 60% of walling material used in most building in Nigeria and Africa in general. Other walling materials in use includes plywood, stones, glass, aluminium, bricks, steel, reinforced plastics, fibre etc.

Sandcrete blocks can be defined as materials made of coarse natural sand or crushed rock dust mixed with cement in certain proportion and water, and moderately compacted into shapes (Seeley, 1993). On moulding they set, harden and attain adequate shapes. NIS 87(2004) defines sandcrete blocks as composite materials made up of cement, sand and water and moulded into different shapes and sizes. Sandcrete blocks may be either lightweight or dense (Seeley, 1993). Light blocks are non-load bearing while dense are load bearing. They are made from a cement /sand mix usually 1 part of cement to 6 or 8 part of sand (1:6 or 1:8) with water/cement ratio of between 50 and 75% (B.S. 3921:1969).

Sandcrete blocks are used throughout Nigeria, in most African countries and Asia. Until perhaps a few years ago, these blocks were manufactured in many parts of Nigeria without reference to any specifications either to suit local building materials or for good quality work. The situation in Nigeria has since changed as the Standards Organization of Nigeria now has specifications for both the manufacture and use of these blocks in Nigeria (Oyekan, 2008).

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They could be used as external walls or partition walls. The later (150mm thick blocks) is usually non-load bearing (Mohamed and Anwar, 2014).

The physical properties of sandcrete blocks include strength, durability, fire resistance and thermal insulation. The compressive strength of sandcrete blocks is a measure of its resistance to axial load. BS 2028(1968) recommends 3.45N/mm^2 for mean strength and 2.59N/mm^2 for the lowest individual strength. The federal Ministry of works recommends 2.1N/mm^2 for mean strength and 1.7N/mm^2 for the lowest individual strength.

B.S. 2028 (1968) gives specification for precast concrete blocks which describes solid, hollow and cellular blocks: Table 1.1. It further stated that the total width of cavities measured at right angles to the face of the blocks as laid in a wall must not exceed 65 percent of the block thickness. Table 1.2 gives the dimensions for the three types of blocks described in the British Standard.

The standard (BS 2028) (1968) describes type A blocks as dense (having a density of not less than 1500 kg/m3) and include the strongest blocks the use of which is permitted in all positions. Types B and C blocks are lightweight concretes having densities less than 1500 kg/m3 made with lightweight aggregate or aerated cement with or without fine aggregate.

The high cost of constituent materials of both sandcrete and concrete has led to non-realization of adequate housing in both urban and rural dwellings. The high cost of materials is the reason manufacturers result to sharp and under hand practices in production of sandcrete blocks.

There has been a call by Nigerian government for sourcing and development of alternative non-conventional local construction materials in the construction industry to cut down the cost of construction. Alternatives to cement and/or sand are good for the social and economic development of the construction industry in general and building construction industry in particular.

In order to reduce production cost and to also improve the Engineering properties of sandcrete blocks, there is the need to completely replace or to partially replace sand with Agricultural waste. Palm kernel shells, by-product of agro-processing from oil palm are being increasingly used as substitutes for aggregate in concrete. The Palm kernel shell ashes are also being used as partial replacement for cement in concrete. The availability of Palm Kernel Shell and the need for environmental sustainability and also finding alternative use for waste and to reduce cost of blocks which will in turn satisfy the shelter needs of man is the main reason for this work using grinded Palm Kernel Shell as replacement for sand in block production.

Table 1.1: Specification for precast concrete blocks

Type	Void percent of total volume
Solid;	Up to 25 percent
Hollow; Large holes or cavities Pass through the block.	More than 25 percent but less than 50 percent
Cellular; Large holes or Cavities with one bed, face Closed (usually laid uppermost).	More than 25 percent but less than 50 percent

Source: B.S 2028(1968)

Table 1.2: Dimensions for the three types of blocks in British Standard.

Type	To bond with B 7mm bricks Size Specified for manufacture (mm)	Sizes dimensionally conditioned on the nominal 102mm basis. Size Specified for manufacture (mm)
A Length	448	397 or 499
Height	143 or 219	194 or 295
Thickness	51, 64, 76, 102,152 or 219	76, 92,102,143,178 or 194
B Length	448	397,499 or 600
Height	219	194 or 295
Thickness	76, 89, 102, 152, 203, or 219	76, 92, 102,143,178 or 194
C Length	448	397,499 or 600
Height	219	194 or 295
Thickness	51 or 64	51 or 64

Source: B.S 2028(1968)

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Palm kernel shell was partially a waste in the 1990s and early 2000 as more than 350,000 tons were available for sale (oyejobi et al, 2012). The PKS had been a little known then for its potential usage on a large scale especially in concrete work (Mohammad, 2007). Beyond 2000, research into utilization of Palm Kernel Shell as light weight concrete and other uses had received a big boost. Palm kernel shells (PKS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram, et al, 2010). The Palm Oil Plant (Elais Guinensis), considering its three different varieties Durà, Pesipherà and Tenerà, produces an edible fruit similar to an apricot which has a nut inside. During the crude palm oil process the fruit's flesh is melted through a steaming treatment. The residual nuts are further mechanically crushed to extract the seeds or kernels. The Palm Kernel Shells (PKS) is a virgin biomass with a high calorific value, typically about 3,800 Kcal/kg (ASTM, 1978). Oil Palm trees grow in the coastal belt in Nigeria which varies in depth from 100 to 150 miles and a riverine belt which follows the valleys of the Niger and Benue for a distance of about 450 miles from the sea. The main palm oil producing states include Ogun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers (Oyejobi et al 2012).

Mohd et al (2008) reported the density of palm kernel shell to be in the range of 1700 to 2500kg/m^3.Generally when the density of concrete is lower than 2000kg/m^3, it is categorized as light weight concrete (Oyejobi,2012).

Palm kernel shells in the past had been used solely as fuelling material at home and for industries. For some time now, the Nigerian government has been clamouring for the use of local materials in the construction industry to cut down cost of construction. There has therefore been a greater call for the sourcing and development of alternative, non-conventional local construction materials.

This need to develop alternative, non-conventional local construction materials is the main aim of this research work.

2. MATERIALS AND METHODS

Steel moulds were fabricated and Sand-PKS blocks were produced at different mix ratios and sand replacement. Blocks were cured for 28 days. Blocks were capped and the mechanical properties were determined.

2.1 Materials:

2.1.1 Sand:

The Sand used in the production of blocks was obtained from flowing stream at Appleton road in the University of Ibadan. It was sun dried and free from unwanted materials. The Sand was thereafter sieved through sieve size 2.36mm and sand passing through this sieve size was used to produce blocks.

2.1.2 Palm kernel shell (PKS):

The PKS used was obtained from a local palm oil mill at Oje market in Ibadan Oyo state and was already in cracked form. The shell was soaked in water for 24 hours and washed to remove dirt and organic materials present. Thereafter, it was sun dried and grinded in milling plant to between 1mm-4mm size.

2.1.3 Cement:

The Ordinary Portland cement used for the experiment was Elephant brand produced by West African Cement Company, Ewekoro in Ogun State sourced from retail cement outlet in Ibadan Oyo State.

2.1.4 Water:

Water used for production of PKS-Sand blocks was obtained from bored hole at Egboga building, faculty of technology, University of Ibadan. The water was observed to be colourless, odourless, tasteless and free from impurities.

2.1.5 Mould:

Plate 2.2 shows hollow Steel moulds (3 number) of dimension 230mm by 110mm by 110mm each fabricated using checker plate was adopted for this work. The hollow is of dimension 70mm by 110mm each. The surface area of mould and masonry unit is 15,500mm^2, the volume of the mould and masonry block is 1.705 $\times 10^{-3}$ mm^3. The moulds are lubricated with black oil to facilitate easy removal of block samples.

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2.2 Methods:

2.2.1 Production of sand-pks and sandcrete block:

Three mix ratios used to produce Sand-PKS blocks samples and Sandcrete blocks (Control) samples is shown in table 2.1.

Table 2.1: Mix proportion and percentage replacement of Sand with PKS

Mix proportion	Percentage Replacement of Sand with PKS			
1:4	0%	20%	40%	50%
1:5	0%	20%	40%	50%
1:6	0%	20%	40%	50%

Batching was done by volume using a plastic cylindrical container. In the manufacture of these blocks, hand mixing using hand trowel (plate 2.1) was employed and the materials were turned over a number of times until an even colour and consistency was attained.

Water-Cement ratio of 0.55 was employed throughout the block production process.

Steel face cover capable of transferring compaction load was fabricated alongside the mould. The mould was filled in three layers and twenty five blows was applied per layer using 150mm by 150mm by 150mm concrete cube shown in plate 2.3. The final layer was then rammed into the mould compacted and smoothened off with circular steel face tool.

After removal from the mould, the blocks were arranged in separate rows to set for 24 hours to set (Plate 2.4) and kept wet by curing in water tank for 28 days.

All samples were capped (plate 2.5) with 10mm cement mortar after 28 days. Capping was done on both sides of the block. The cement mortar used for capping was of mix ratio 1:2.

Plate 2.2: Steel Moulds

Plate 2.3: Concrete Cube Compactor

Plate 2.4: Drying Block Samples

Plate 2.5: Capping Blocks with Cement Mortar

Plate 2.1: Mixing Aggregates

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2.2.2 Compressive strength of sand-pks and sandcrete blocks:

Capped samples totalling thirty six numbers for Sand-PKS blocks and twelve numbers for Sandcrete blocks (Control Samples) were crushed to determine their compressive strength after twenty eight days. All samples were tested using ELE 1500KN digital machine (Plate 2.6).To obtain the compressive strength, the loads recorded was divided by the effective surface area of the block. The effective surface area of the block is given by the total surface area of the blocks minus the area of the hollow. The area was calculated as 15,500mm^2. Hence, Compressive strength was calculated.

2.2.3 Flexural strength of sand-pks and sandcrete blocks:

A total of thirty six samples were tested for flexural strength using OKH-600 (plate 2.7) Digital display universal testing machine owned by the Department of Agricultural Engineering, University of Ibadan. Three samples were tested for each mix and the average taken as the flexural strength for the mix.

The three point load system was used and the flexural strength determined using the relationship below:

$$F_L = \frac{3Fa}{2Bb^2}$$

Where F_L is the Flexural Strength

F is the Failure Load

a is the Span of the Beam

b is the Width of the Beam

d is the depth of the Beam

Plate 2.6: Compression Test on Block Samples

Plate 2.7: Flexural Test on Block Samples

3. RESULTS AND DISCUSSION

3.1 Results of Compressive Strength Test:

Table 3.1 shows the results of compressive strength performed on Sandcrete blocks and Sand-PKS blocks.

Table 3.1: Compressive Strength of Sandcrete and Sand-PKS Masonry Blocks

Percentage Replacement (%)	Comp. Strength 1:4 (N/mm^2)	Comp. Strength 1:5 (N/mm^2)	Comp. Strength 1:6 (N/mm^2)
0	5.54	4.98	4.60
20	4.91	3.54	2.33
40	3.13	2.24	1.76
50	2.31	1.14	0.76

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3.2 Results of Flexural Strength Test:

The results of flexural strength is presented in table 4.8(a-c) for sandcrete and sand-pks blocks.

Table 3.2: Compressive Strength of Sandcrete and Sand-PKS Masonry Blocks

Percentage Replacement (%)	Flexural Strength 1:4 (N/mm^2)	Flexural Strength 1:5 (N/mm^2)	Flexural Strength 1:6 (N/mm^2)
0	2.11	1.89	1.75
20	1.86	1.31	1.17
40	1.60	1.20	1.09
50	1.19	1.08	0.74

3.3 Discussion of Results:

The compressive strength of blocks for mix ratio 1:4, 1:5 and 1:6 at 0%, 20% 40% and 50% PKS replacement is plotted in the chart shown in figure 3.1.

Standard organization of Nigeria, a regulatory authority responsible for quality control of sandcrete blocks samples production in Nigeria specified a compressive strength value range of $2.5N/mm^2$ to $3.45N/mm^2$,for a load bearing wall and the value range of $1.8N/mm^2$ and $2.5N/mm^2$ for non-load bearing walls.

Going by standard organisation of Nigeria specification, only 40% and 50% PKS replacement at mix ratio 1:6 and 50% PKS replacement at mix ratio 1:5 respectively did not meet both non-load bearing and load-bearing blocks specification.

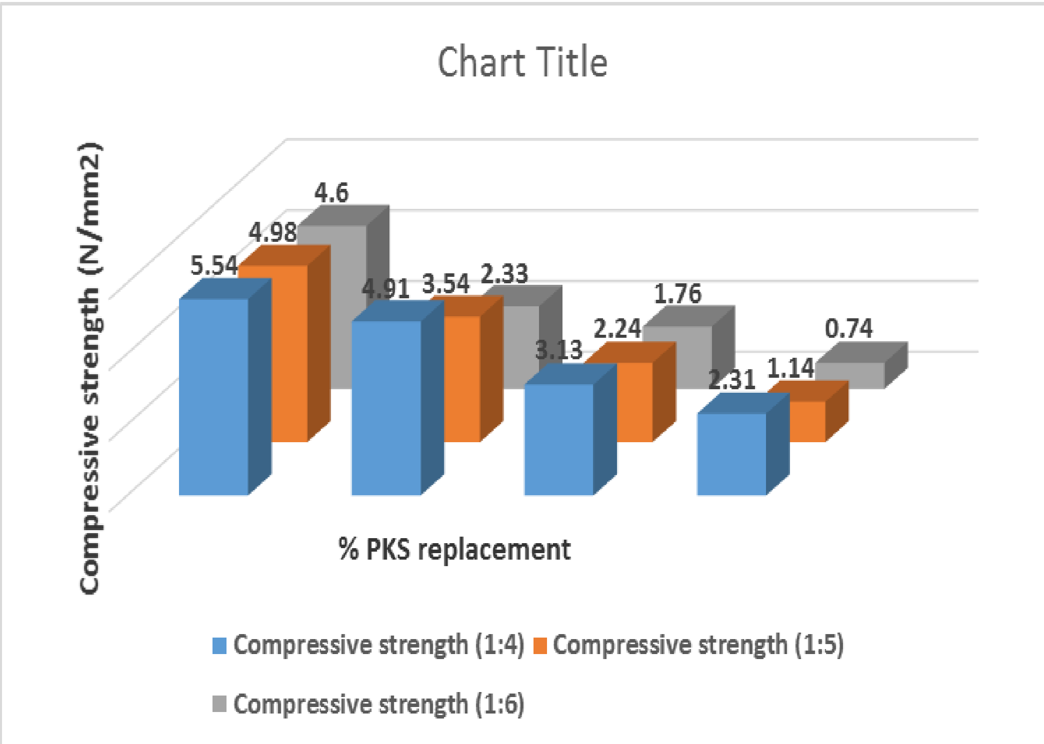

Fig 3.1: Compressive Strength of Blocks against PKS Replacement for Mix 1:4, 1:5 and 1:6

The combined graph of flexural strength to percentage PKS replacement for mix ratio 1:4, 1:5 and 1:6 at 0%, 20%, 40% and 50% PKS replacement is shown in figure 3.2.There is apparent reduction in flexural strength across all mix ratios as percentage PKS replacements increases.

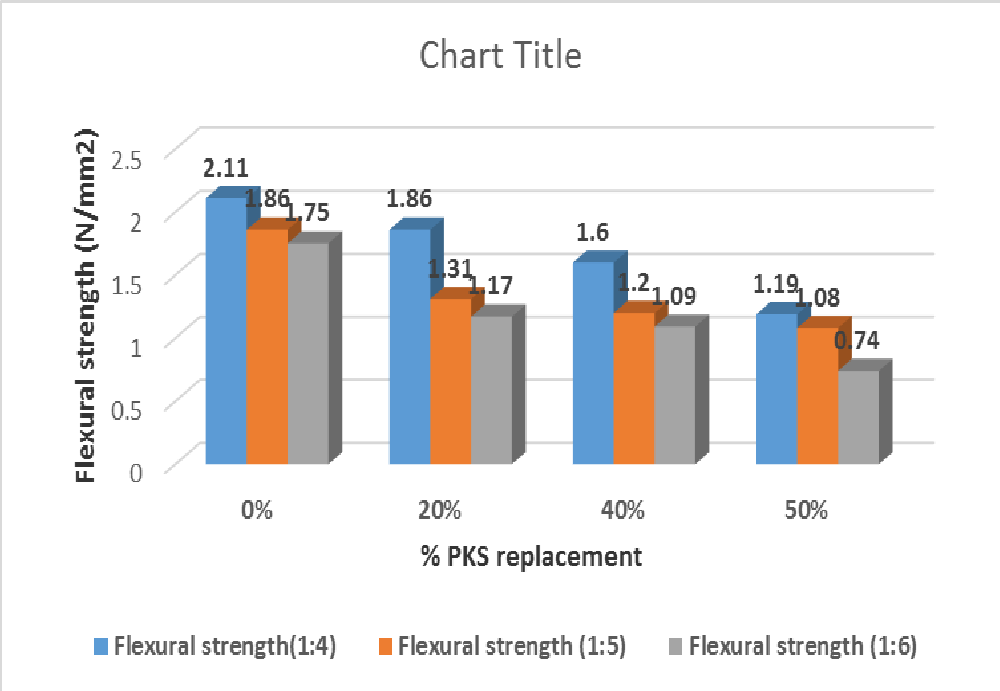

Fig 3.2: Flexural strength of blocks against percentage PKS replacement for mix 1:4, 1:5 and 1:6

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion:

Standard organisation of Nigeria 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. Only the compressive strength of 1:5 mix at 50% PKS replacement and 1:6 mix at 40%& 50% PKS replacement did not meet the specification of load-bearing and non-load bearing block.

It was also observed that there was decrease in flexural strength as the percentage PKS replacement increases from 0% to 50% across all the mix ratios.

4.2 Recommendations:

From this research work, 20% replacement at 1:4 mix ratio is recommended for block production for low cost housing.

Improved compaction, proper curing method and selection of appropriate materials should be enforced by the standard organisation of Nigeria (SON).

Palm kernel shell has been discovered to have lignin (53.4%) which react negatively with ordinary Portland cement. Further research work is recommended on the removal of lignin from palm kernel which would then improve its performance either as a replacement for sand in block production or as a coarse aggregate in concrete.

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