EFFECT OF GROUND PALM KERNEL SHELL (GPKS) FINES CONTENT ON COMPRESSIVE STRENGTH OF CELLULAR MASONRY BLOCKS

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ABSTRACT

The paper assesses how partial replacement of sand with Ground Palm Kernel Shells (GPKS) affect physical and mechanical properties of masonry units. The mix ratio of 1:8 (cement: sand) was selected for the moulding of the control samples (0% GPKS aggregate replacement content) while a water/cement ratio of 0.50 was used in the study. The fine aggregate (sand) was replaced with GPKS aggregate from 0%, 10%, 20%, 30% and 40%. GPKS cellular masonry units were moulded in five (5) different mix percentages and were cured for 7, 14 and 28 days respectively. Each mix percentage comprises of eighteen (18) cellular masonry units. Two (2) sizes of cellular masonry units were used for the experiment 455mm x 220mm x 150mm and 455mm x 220mm x 125mm. 75mm x 75mm x 75mm cubes were used to determine the water absorption rate of the masonry units. From the result, the water absorption rate was below the maximum 12% acceptable for masonry units tested for 1, 3 and 24 hours according to BS 2656-1:2005. The compressive strength result revealed that the 7 and 28 days compressive strength of 150mm thick cellular masonry units ranges from 4.99N/mm² - 6.25N/mm²; 4.12N/mm² - 5.07N/mm²; 3.49N/mm² - 4.76N/mm²; 1.52N/mm² – 2.16N/mm² and 1.46N/mm² - 2.00N/mm² respectively, while the 7 and 28 days compressive strength of 125mm thick cellular masonry units ranges from 4.41N/mm² - 5.46N/mm²; 2.97N/mm² - 3.88N/mm²; 2.68N/mm² - 3.11N/mm²; 2.06N/mm² – 2.95N/mm² and 1.79N/mm² - 2.35N/mm² respectively for 0%, 10%, 20%, 30% and 40% GPKS aggregate replacement content. The results revealed that the 28 days compressive strength of all the GPKS cellular masonry units were lower than the control sample (0% GPKS aggregate replacement content). The result obtained for 150mm thick and 125mm thick cellular masonry units with 10%, 20% and 10%, 20%, 30% GPKS aggregate mix percentages were higher than the 2.8N/mm² required by BS 6073-1: 1981and 2.5N/mm² required by GS 297-1: 2010. Hence, the compressive strength of all the GPKS aggregate masonry units decreased with the increase of GPKS aggregate replacement percentages as compared to the control samples (0% GPKS). For all the GPKS cellular masonry units, highest strengths occurred at the 28days curing period for all the mix percentages.

Keywords: Cellular Masonry Units, Water absorption, Compressive Strength, GPKS

1.0 Introduction

The growing demand for the use of conventional materials such as sand and quarry dust to produce masonry units for housing development is likely to face shortage due to over exploitation of these natural resource (Dadzie and Yankah, 2015). Presently in Ghana, indiscriminate sand winning adversely effects the livelihood of farming communities due to the depletion of lands for agricultural purposes. Environmental and economic considerations have led to the exploration of agricultural and industrial by-products as a substitute for conventional natural aggregate in concrete. The utilization of agricultural by-products as alternative construction materials is needful for developing countries where the cost of construction is relatively high due to factors such as increase in demand of cement and other building materials, relatively unavailability of natural coarse aggregate in some parts of the country and the high cost of construction materials. Many agricultural by-products which could be used as relevant replacement of conventional aggregates have lighter weights (Eziefula et al, 2017). According to Neville and Brooks (2010) the use of more lightweight concrete in the production of prestressed concrete and high-rise buildings is continuously trending due to the advantages associated with lightweight aggregate over conventional concrete. These advantages include, decreased dead load, lower rate of depletion of natural resources, lower thermal conductivity and reduced construction cost. The palm kernel shell has been identified as one of the agricultural by-products which could serve as a replacement of aggregate in concrete although it has not been entirely exploited as an aggregate in building sustainable structures in Ghana.

In recent decades, the production of palm oil has increased in Southeast Asia and more recently in Africa and Latin America, with an expected further growth (Rival and Levang 2014). Globally, the production of palm oil increased by about 7% from 65 to about 70 million tonnes, with more than 20 million hectares of new oil palm plantations developed across the world. The hard endocarp of palm kernel fruit that surrounds the palm seed is the palm kernel shell which is obtained from crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Eziefula et al, 2017). A large quantity of palm kernel shells are indelible agricultural by-products usually discarded as waste and these shells are produced daily in Ghana. According to the Oil Palm Development Association of Ghana (OPDAG), the country's oil palm industry has the capacity to meet the local demand, indicating that the existing crude palm refineries in Ghana have the combined capacity to refine approximately 615,000 tonnes per annum (OPDAG, 2018). Mo et al (2016) revealed that, stockpiling agricultural by-products in landfills and open dumpsites causes environmental problems such as contamination and pollution. A possible way of solving this problem of waste management is to use the palm kernel shells as alternative aggregate to produce concrete and its products. Although the use of ground palm kernel shell (GPKS) aggregate as a building material is not common in Ghana and other parts of the world, its usage as an alternative to conventional sand in the production of masonry units will reduce environmental degradation and make construction sustainable (Emiero and Oyedepo, 2012). Table 1.1 below shows the annual production details of products and waste from the oil palm industry in Ghana.

Table 1.1 Shows the products and waste from the oil palm industry in Ghana

Product/ waste	Weight in tonnes
Palm oil	615,000.00
Palm kernel	205,000.01
Fiber	439,285.73
Shell	175,714.29
Empty fruit bunches	673,571.45
Pome	820,000.02
Total	**2,928,571.50**

Chandra and Bhise (1994) in their study on solid concrete block masonry scheme indicated that concrete blocks are precast masonry units such as solid, cellular and hollow blocks of different sizes and are used as load and non-load bearing units for masonry walls. Depending on the structural requirements of the masonry units. Cellular blocks are masonry units that have one or more formed holes that do not wholly pass through the masonry unit. The selection of cellular blocks can have significant advantages over solid blocks where weight is a major consideration. Cellular blocks do not require special techniques and can be laid on a full bed of standard or general-purpose mortar for most applications" (Rostam et al, 2016).

Katz and Baum (2006) in their investigation on the effect of high levels of fines content on concrete properties indicated that fine aggregates play a very important role in controlling the properties of fresh concrete. Since they help to improve the cohesiveness, workability of fresh concrete and prevent segregation and bleeding. However, the presence of very fine particles known as "fines" is generally limited for three reasons. These reasons are listed below;

1. Fine particles may lead to reduced workability due to the large surface area that must be wetted. This leads to an increase in the amount of water required to maintain proper workability, this requires increase in cement content to maintain strength.
2. Very fine particles tend to adhere to the surface of lager particles and prevent proper bonding between the cement paste and the aggregate. This normally results in weak aggregate-paste bond that weakens the concrete: and
3. Clay particles, which are smaller than a few microns, undergo significant volume changes when they absorb water and dry out thereafter.

Generally, it is difficult to obtain sand with very low fines content, although its effect on concrete is critical. However, some higher amounts of fines are allowed in manufactured sand, as long as it is free from clay and shale. Therefore, sand as a major constituent to produce masonry units is known to have challenges in future that the construction industry needs to deal with. According to Prusty and Patro (2015), the palm kernel shell is a suitable lightweight aggregate for concrete production because of its properties in terms of size, shape, surface texture, toughness, and hardness. Again, they stated that, the size of a broken palm kernel shell varies according to the the cracking force and its thickness is dependent on the specie. Usually, the thickness of the palm kernel shell ranges from 0.5-8 mm. Palm kernel shell is fairly smooth in texture and its shape may be flaky, irregular, angular, circular, or polygonal depending on the breaking pattern of the nut

(Dhir and Jackson, 1996). Alegaram el al (2008) revealed in their study that, palm kernel shell does not contaminate or leach to produce toxic substances when it is bound in concrete matrix. Hence, they bind easily with cement products, just like the conventional coarse aggregates.

A number of research carried out within the past years on various aspects of palm kernel shell concrete showed palm kernel shell is a suitable coarse aggregate for light weight concrete.(Osei and Jackson; Aslam et al , 2016) However, there is a dearth of literature on the effect of GPKS fines content on cellular masonry unit properties. Therefore, this study delves into the effect of GPKS fines content on cellular masonry unit properties as a result of partial replacement of sand with GPKS aggregate.

2.0 Materials and Method

The object of the study was to assess the effect of Ground Palm Kernel Shell (GPKS) fines content on cellular masonry units properties as a result of partial replacement of sand with Ground Palm Kernel Shell (GPKS) aggregate. The material constituents, batching, moulding of masonry units and curing. In this study of GPKS masonry unit, the fine aggregate (sand) was partially replaced with GPKS aggregate in different percentages for the production. Cellular masonry units are made from a mixture of Ordinary Portland Cement, higher percentage of sand, moderate quarry dust and water, which are left to cure after moulding. The curing process is done directly by sprinkling water on the block for 7, 14 and 28 days.

2.1 Materials

The following materials were used in moulding the GPKS cellular masonry units used in this experimental study.

Sand: Graded river sand from Ada, passing through a British standard sieve. The sand was free from clay, dirt and organic impurities, passing through sieve sizes of 5mm and 75 micrometers was used to prepare the GPKS cellular masonry units.

Ground Palm Kernel Shell (GPKS): PKS used was obtained from local palm kernel community in Obuasi and was already in cracked form. The shells were washed with water and detergent to remove dirt and organic materials present. The shells were then heaped in an open space for air-drying. Then after drying, the PKS was ground by a grounding machine at the Building and Road Research Institute (BRRI), Kumasi. Both sand and GPKS aggregates samples were oven – dried and the particle size distribution was determined.

*Cement***:** Ordinary Portland cement (OPC) was used as the binder for the experiment. A cement produced by Ghana Cement Limited (GHACEM), the major producer of cement in Ghana, which is readily available in every part of the country was used for all the mixes in this study. This cement used satisfy the requirements of British Standard Code (BS EN 197-1:2011).

Water: Water used for the preparation of the cellular masonry units was from Ghana Water Company, which is clean, colourless, odourless and free from impurities. The presence of anti-organic materials can affect the setting and hardening properties of the cellular masonry units produced.

3.0 RESULTS AND DISCUSSION

3.1 PARTICLE SIZE DISTRIBUTION

The result of the grading test performed on both the sand and GPKS aggregates used for the study are plotted in figure 3.1and 3.2 which was carried out at the Department of Urban Roads (Materials laboratory) in Accra. Automatic sieve shaker with British standard series of sieves were used to determine the grading curves (Particle Size distribution) of sand and GPKS aggregates in accordance with BS EN 1015 – 1:1999. The particle size distribution of fine aggregate (sand) and GPKS aggregate are shown graphically in figures 3.1 and 3.2. The particle size distribution of sand and GPKS aggregate were compared to the standard grading of fine aggregates in relation to upper limit and lower limit.

3.1.1 Sand

The analysis of particle size distribution curve of river sand sample obtained from Ada used in masonry unit production is illustrated graphically in figure 3.1, showed a medium grained material in relation to the upper limit and lower limit, since the greater part of the curve falls in the middle of the upper and lower limits of standard grading. The river sand can be termed to be well graded.

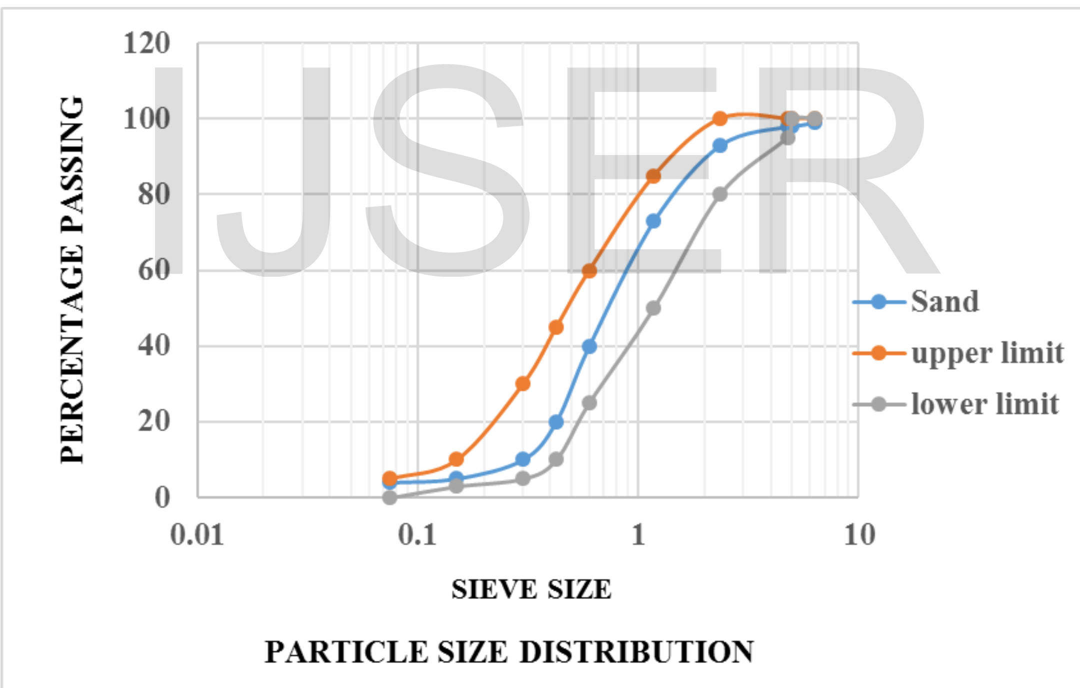

Figure 3.1, Particle Size Distribution of Sand

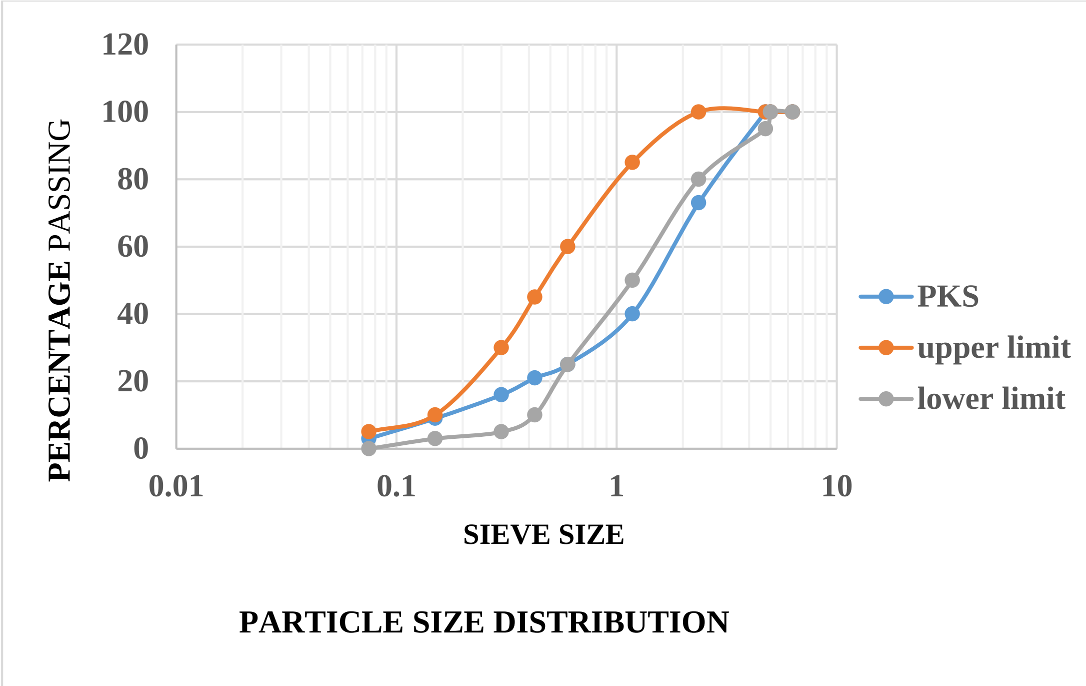

Figure 3.2, Particle Size Distribution of GPKS aggregate

3.1.2 GPKS aggregate

From figure 3.2, the GPKS aggregate particles are finer, as the greater part of the curve falls below the lower limit of standard grading between 2.36mm and 0.6mm. The GPKS aggregate can be described as fine grained. The GPKS aggregate was used with the river sand to mould the cellular masonry units with dimensions 455mm x 220mm x (150, 125) mm.

3.2. EXPERIMENT ON GPKS CELLULAR MASONRY UNITS

3.2.1 Preparation of GPKS Cellular Masonry Unit Samples

In this study, batching of the materials was done by weight using a weighing scale and mixing was done manually using shovel on clean, impervious surface. After mixing, cellular steel moulds of size 455mm x 220mm x 150mm and 455mm x 220mm x 125mm with void area of 15,675mm^2 was used for the preparation of GPKS cellular masonry units. The samples were produced from different mix percentages of 0%, 10%, 20%, 30% and 40% GPKS aggregate. The water cement ratio was set to be 0.45 which was adjusted to improve workability due to increase in GPKS percentages (from 0.45 to 0.60). The GPKS cellular masonry units were produced from cellular masonry unit manufacturing machine attached with vibrator. After moulding, the cellular masonry units were allowed for 24 hours before curing for 7days, 14days and 28 days. Besides, three (3) sample cubes of size 75mm x 75mm x 75mm were prepared to determine the water absorption rate.

3.2.2 Determination of Water Absorption

The water absorption was determined as required in BS EN 1015 – 18. Water absorption test was conducted on the thirty (30) 75mm x75mm x 75mm cubes made from all the GPKS aggregate mix percentages, with three (3) cubes each from 10%, 20%, 30%,40% and cement and sand ratio was prepared as control samples (0% GPKS). After curing period, the samples were oven –dried and subjected to water absorption. The water absorption test was conducted on the masonry unit samples after 28days of curing and oven - dried. Before immersion in water, the weight of the masonry unit samples was determined. The samples were immersed in water for 1, 3 and 24 hours.

3.2.3 Determination of the Compressive Strength of Cellular Masonry Unit Samples

The compressive strength tests were carried out in accordance with BS EN 1015 – 1: 1999. Nine (9) masonry samples were used for compressive strength test with three (3) set at 7, 14 and 28 days age using digital compressive testing machine. The tests were carried out at the Central Materials Laboratory of the Department of Urban Roads in Accra, Ghana. Ninety (90) cellular masonry unit samples were investigated for their strengths.

3.2.4 Computation of compressive strength of the cellular Masonry unit samples

In determining the compressive strength of the cellular masonry units in N/mm^2 the crushing loads recorded were divided by the effective area of the masonry unit. Equation 1 was used in calculating the compressive strength and Equation 2 gives the effective surface area of the cellular masonry unit.

$$\text{Compressive strength} = \frac{\text{Crushing load}}{\text{Effective surface area of unit}} \quad (1)$$

Effective surface area of unit = Total Surface Area of unit – Area of Cellular void (2)

4.0 RESULTS AND DISCUSSION

4.1 WATER ABSORPTION

The twenty-four (24) hours water absorption percentages (%) obtained from masonry units produced with GPKS aggregate exhibited in Table 4.1. The water absorbed at 1, 3 and 24 hours for masonry units with GPKS percentages of 0%, 10%, 20%, 30% and 40% ranges between 6.64% to7.52%; 3.14% to 6.81%; 4.57% to 8.12%; 3.93% to 8.43% and 4.97% to 9.04% respectively. It was observed that the water absorption increases as the percentage replacement of sand with GPKS aggregate increases. The masonry unit with 40% GPKS aggregate was porous with the absorption rate of 9.04% at 24 hours. However, at 1 hour the water absorption rate was (4.79%) due to the finer nature of the GPKS aggregate in the pores of the masonry unit. From the results, all the mix percentages have water absorption levels lower than 12% maximum recommended for masonry unit required by BS 5628-1: 2005.

Table 4.1, Water absorption of GPKS masonry units

GPKS (%)	Dry weight (Before immersion in water) (Kg) 1	2	3	Ave. weight	Wet weight (After 24 hours immersion in water) (Kg) 1	2	3	Ave. weight	Weight of water absorbed (Kg)	Water Absorption Rate (%)
0	0.76	0.75	0.75	**0.753**	0.82	0.80	0.81	**0.810**	0.057	**7.52**
10	0.65	0.63	0.63	**0.637**	0.69	0.68	0.67	**0.680**	0.043	**6.81**
20	0.66	0.66	0.65	**0.657**	0.72	0.71	0.7	**0.710**	0.053	**8.12**
30	0.6	0.6	0.58	**0.593**	0.65	0.64	0.64	**0.643**	0.050	**8.43**
40	0.66	0.61	0.61	**0.627**	0.71	0.68	0.66	**0.683**	0.057	**9.04**

4.2 COMPRESSIVE STRENGTH

Table 4.2, shows the compressive strength results of 150mm thick cellular masonry units while Table 4.3, shows the compressive strength results of 125mm thick cellular masonry units. The test carried out indicated that the compressive strength of GPKS cellular masonry units cured at 7, 14 and 28 days age. The compressive strength of the150mm thick GPKS cellular masonry units at age 7 and 28 days ranged between 4.99N/mm² - 6.25N/mm²; 4.12N/mm² - 5.07N/mm²; 3.49N/mm² - 4.76N/mm²; 1.52N/mm² – 2.16N/mm² and 1.48N/mm² - 2.00N/mm² respectively.

Table 4.2, compressive strength of 150mm thick cellular masonry units

Serial Number	Period of Test (days	GPKS Mix Percentages and Strength (N/mm^2)				
		0	10	20	30	40
1	7	4.99	4.12	3.49	1.52	1.46
2	14	5.80	4.62	4.24	1.81	1.71
3	28	6.25	5.07	4.76	2.16	2.00

Table 4.3, compressive strength of 125mm thick cellular masonry units

Serial Number	**Period of Test (days**	**GPKS Mix Percentages and Strength (N/mm2)**				
		0	**10**	**20**	**30**	**40**
1	7	4.41	2.97	2.68	2.06	1.76
2	14	5.00	3.40	2.79	2.61	2.02
3	28	5.46	3.88	3.11	2.95	2.35

The compressive strength of the125mm thick GPKS cellular masonry units at age 7and 28 days ranges between 4.41N/mm² - 5.46N/mm²; 2.97N/mm² - 3.88N/mm²; 2.68N/mm² - 3.11N/mm²; 2.06N/mm^2 – 2.95N/mm² and 1.76N/mm² - 2.35N/mm² respectively. The values were higher than the specified minimum compressive strength of 2.8 N/mm² and 2.5 N/mm² prescribed by BS 6073 – 1: 1981 and GS 297 – 1: 2010 for load bearing walls for 28 days results. This result can be attributed to the fact that the particle size distribution, water/cement ratio and degree of compaction of all the mix percentages affected the compressive strength. It was also observed that the strength of the GPKS cellular masonry units increases gradually with the curing age.

5.0 CONCLUSION

Based on the experiments performed in this study, the following conclusions were made:

1. The water cement ratio was a determinant in achieving the workability and strength of the GPKS cellular masonry units.

2. The increasing quantity of GPKS aggregate increases the water demand of the mix and this often increased the porosity and water absorption rate of the masonry unit with 40% GPKS aggregate. Generally, porosity, water absorption and capillary action decreased with increasing sand content.
3. The compressive strength of all the GPKS aggregate masonry units decreased with the increase of GPKS aggregate replacement percentages as compared to the control samples (0% GPKS). However, for all the GPKS cellular masonry units, highest strengths occurred at the 28days curing period for all the mix percentages.

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