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RESEARCH ARTICLE

Investigating the Utilization of Ground Palm Kernel Shells for Partial Replacement of Cement in Concrete Using Nondestructive Method

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ABSTRACT

The objective of this research is to investigate the utilization of palm kernel shells in ground form (GPK) for partial replacement of ordinary Portland cement (OPC) in concrete by investigating its optimal strength using nondestructive ultrasonic pulse velocity method for both cubic and cylindrical concrete test specimen. In all a total of 135 cubes and 66 cylinders of concrete were prepared. The dimension of the cubic concrete specimens was 150 × 150 × 150 mm and that of the cylindrical specimens were 110 mm and 500 mm diameter and length respectively. The mix design of the GPK shells used as a partial replacement for OPC ranged between 0% and 50% by weight of cement using mix ratio of 1:2:4 with water to cement ratio of 0.8. The concrete specimens were test at curing periods of 7 days, 28 days and 60 days for the cubes and 7 days and 28 days for the cylinders. Based on the results and the analysis done, it was generally observed in all cases that, as the mix ratio is increased, the ultrasonic pulse velocity, modulus of elasticity and the density decreased and as the curing period increased, these values increased across all the mix ratios. The ultrasonic pulse velocity and the density of the specimens shows that concretes containing GPK "fuel" shells has higher values than those containing GPK ordinary shells. Generally, the density, ultrasonic pulse velocity and the modulus of elasticity of concrete containing GPK shells decrease as the replacement percentage increase.

Keywords: Concrete, Density, Ground Palm Kernel Shells, Modulus of elasticity, Nondestructive testing, Replacement Percentages, Ultrasonic Pulse Velocity

1 Introduction

Concrete, which is made from cement, has been the ultimate material for construction. It is therefore an indisputable fact that concrete is the most indispensable material that is used in infrastructure development throughout the world [1]. It is a material consisting of a hard, chemically inert particulate substance, known as an aggregate (sand and crushed stones) that is bonded together by a binding medium or paste (cement and water) [2]. The use of cement for concrete has long been the basis for development of society for generations. However, cement manufacturing process is technology intensive. The extraction of the raw material causes serious environmental problems by damaging the landscape and most of these raw materials become scarce. Recent events in major urban centers in Africa have shown that, the problem of waste management has become a monster, which has bedeviled most efforts by professionals of city, states and federal authorities. These wastes are due to industrial, agricultural, municipal, and other activities. The increasing need worldwide for sustainable development and preservation of the environment has led to development of new materials using waste materials and by-products of numerous industrial processes [3].

Disposal of solid industrial and agricultural wastes through burning results in environmental degradation. This can be minimized by utilizing the wastes for other purposes. This will help overcome waste disposal problems. As a result, the past decade has witnessed many researches that have been carried out for the utilization of such waste in the building industry to partially replace some construction materials especially concrete.

Recent developments have seen some of the components of concrete, partially substituted by the use of agro-based wastes which are economically and environmentally friendly. Typically, among these are rice husk, coconut shell and fibre, guinea corn husk, corn cob, groundnut shells, sugar cane husks, palm oil fuel ash, palm kernel shells and fibre and saw dust. The utilization of waste materials from the palm oil industry in the built industry has seen received much attention mostly as aggregates by using the bunch, the husk, the shells or the fibre. The studies of the effect by the researchers on the use of the ground palm kernel (GPK) shells as partial replacement of cement in order to determine the effectiveness of their use in concrete is not much investigated. The very few works found investigated mechanical properties such as compressive, tensile and flexural strengths on concrete mostly using destructive methods. Research works of such nature includes the works of Olowe and Adebayo [4], Fadele, and Ata [5], Premalatha et al [6], and Ukpaka and Okochi [7].

As part of efforts to make efficient use of GPK shells, this study was conducted to investigate the influences and potential of the partial replacement of cement by GPK shells on the density and strength of concrete as well as to assess the suitability of GPK shells concrete as a structural material using nondestructive testing (NDT) method. So far, no research on GPK shells using NDT method have been reported. Therefore, in this research, ultrasonic pulse velocity (UPV) of NDT method is chosen since this method allows the density, modulus of elasticity and homogeneity of the material to be monitored and provide information about the strength and the existence of internal flaws and defects. It also decreases the cost of the product by reducing scrap and conserving materials, labour and energy [8].

2 Materials and Methods

2.1 Materials

The materials employed in this study are the following: cement, aggregates, ground palm kernel shells. The cement used was the locally made Diamond Brand Portland limestone cement from Aflao in the Volta region. In this work an expanded coarse aggregate with irregular shape and wide variety of sizes were used. This was due to unavailability of regular and close size aggregates on the market at the time the aggregates were needed for the work. The maximum size was found to be 64 mm and the minimum size was 9 mm. The fine aggregate used was taken from a sand winning site at Kasoa in the Central region. The palm kernel shells were collected from a palm kernel mill located at Agbogba near Madina, a suburb of Accra in the Greater Accra region of Ghana. They were washed and dried at ambient temperature of an average of 30 °C for one week. Some of the shells were subjected to incomplete combustion using the methodology for the production of charcoal: they were covered with leaves and soil, set alight and allowed to smoulder for about 3 days. As a result of this process, the shells turned black, lightweight and brittle. These shells are referred to, in this work, as “fuel shells” and the shells not subjected to this process of incomplete combustion are the ordinary shells. The “fuel shells” and the ordinary shells were ground to fine powder in a grinding mill. The water used was obtained from the source that is available for everyday use in houses (i.e., “tap water).

2.2 Specimen Preparation

In the preparation of the concrete specimens the masses of aggregates (fine and coarse) and water were kept constant while those of Portland cement and ground palm kernel shells were varied. The mixing ratio used was 1: 2: 4 (cement: sand: stone, by weight). The weight of the aggregates (fine and coarse) was 2.67 kg and 5.34 kg for the cubic and 4.0 kg and 8.0 kg for the cylindrical. The ground palm kernel shells replacement percentages were 0%, 20%, 30%, 40%, 50% and 60% with the water-to-cementitious ratio kept at 0.8. The various

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components (sand, stone and cement and/or ground palm kernel shells) were thoroughly mixed on a platform. Water was then measured and poured on the dry mixture. The concrete mix was turned over again and again until a homogeneous mix was obtained. The concrete mix was placed in moulds and compacted. Additional compaction was achieved for the cubic moulds by means of a vibrating compactor. The required surface appearance of the specimens was achieved by leveling and smoothing to the level of the mould. In all a total of 135 cubes and 66 cylinders of concrete were prepared in accordance with BS 1881: Part 127 [9]. The dimension of the cubic concrete specimens was 150 × 150 × 150 mm and that of the cylindrical specimens were 110 mm and 500 mm diameter and length respectively. The curing periods were 7 days, 28 days and 60 days for the cubes and 7 days and 28 days for the cylinders. The mix design for the test specimens are as shown in Table 1.

2.3 Test Procedure

The densities of the concrete specimen were carried in accordance with test standards ASTM C642–09 [10] for the cubes and ISO 4013 [11] for the cylinders. For determination of the ultrasonic pulse velocity, the Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT) was used. To conduct the test, the surfaces of all the specimens were cleaned using a clean dry cloth and rough surfaces were scraped in order to make them smooth and the faces of the transducers were smeared slightly with grease and pressed against the opposite sides of the concrete specimen in accordance with ASTM C597 [12].

3 Results and Discussion

3.1 Density Test

The data obtained from the density test of the cubic and cylindrical concrete specimens at various GPK shells replacement percentages are shown in Tables 2 and 3 respectively.

Table 1: *Concrete Test Specimen Mix Design*

GPK Shells **Replacement Ratio** (%)	**0%**	**20%**	**30%**	**40%**	**50%**	**60%**
Cubic Specimen						
Weight of GPK Shells (kg)	0.00	0.27	0.40	0.53	0.67	0.80
Weight of Cement (kg)	1.33	1.07	0.93	0.80	0.67	0.53
Total Weight of Material (kg)	1.33	1.34	1.33	1.33	1.34	1.33
Cylindrical Specimen						
Weight of GPK Shells (kg)	0.00	0.40	0.60	0.80	1.00	1.20
Weight of Cement (kg)	2.00	1.60	1.40	1.20	1.00	0.80
Total Weight of Material (kg)	2.00	2.00	2.00	2.00	2.00	2.00

Table 2: *Density of Cubic Concrete Specimen at Various Curing Days*

Replacement Percentages	**Density (kg/m^3)**					
	7 days		**28 days**		**60 days**	
	Ordinary Shells	**Fuel Shells**	**Ordinary Shells**	**Fuel Shells**	**Ordinary Shells**	**Fuel Shells**
0%	2354.57	2354.57	2443.46	2443.46	2454.32	2454.32
20%	2281.48	2307.65	2342.72	2353.09	2358.02	2374.81
30%	2231.11	2233.09	2255.80	2270.12	2267.16	2285.43
40%	2198.52	2227.16	2217.78	2248.89	2227.65	2262.72
50%	2160.00	2221.73	2178.77	2230.12	2189.14	2239.51
60%	2140.25	2189.14	2157.04	2202.47	2164.44	2205.43

Table 3: *Density of Cylindrical Concrete Specimen at Various Curing Days*

Replacement Percentages	Density (kg/m³)			
	7 days		28 days	
	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells
0%	2327.67	2327.67	2391.85	2391.85
20%	2249.46	2270.15	2291.54	2312.23
30%	2217.19	2246.30	2259.28	2288.39
40%	2198.60	2221.05	2228.06	2250.51
50%	2140.74	2162.83	2158.97	2194.75
60%	2072.00	2107.07	2099.35	2138.63

The effect of replacement of GPK shells on density of the specimens are graphically represented in figures 1 to 4. Figure 1 and 2 shows the effects of replacement of GPK ordinary shells and GPK "fuel" shells of the cubic and figure 3 and 4 the effects of the cylindrical concrete specimens respectively. The result shows that the density of concrete samples decreased with increasing percentage of GPK shells and increased with curing age (i.e. the more the ash contents in the concrete, the lower the density) for all replacement mix ratios investigated.

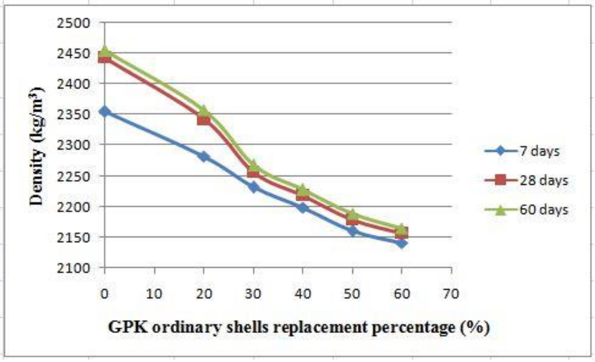

Figure 1: *Density of cubic specimen containing GPK ordinary shells at various percentages*

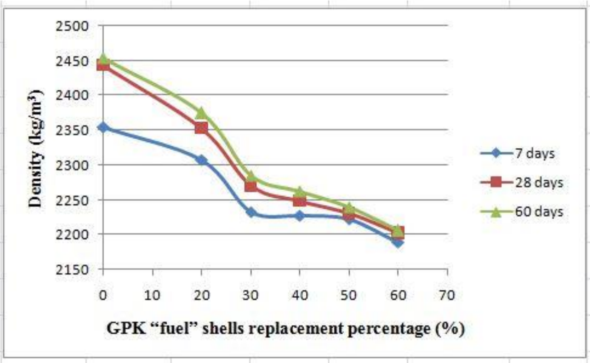

Figure 2: *Density of cubic specimen containing GPK "fuel" shells at various percentages*

For the cubic concrete specimens containing GPK ordinary shells (figure 1), when cured at 7 days, the test result of the density of concrete ranges from 2140.25 - 2281.48 kg/m³ as against 2354.57 kg/m³ for the control. The density of the 20%, 30%, 40%, 50% and 60% replacement are 96.90%, 94.76%, 93.37%, 91.74% and 90.90% that of the control at 7 days curing respectively. The effect of GPK ordinary shells on density was slightly less compare with the control samples.

The 28-days curing density obtained were higher than the 7-days density. The result ranges from 2157.04 - 2342.72 kg/m³ as against 2443.46 kg/m³ for the control. The density of the respective replacement ratios are 95.877%, 92.32%, 90.76%, 89.18% and 88.28% that of the control. Similarly, the 60-days curing density obtained were higher than the 28-days density. The result ranges from 2164.44 - 2358.02 kg/m³ as against 2454.32 kg/m³ for the control and the density of the replacement ratios of 20%, 30%, 40%, 50% and 60% are 96.08%, 92.37%, 90.76%, 89.20% and 88.19% that of the control. The density for the highest replacement GPK ordinary shells of 60% was reduced by less than 10%, 11.7% and 11.8% for the 7 days, 28-days and 60-days respectively when compare with value of the control concrete.

For the cubic concrete specimens containing GPK "fuel" shells (figure 2), similar trend was observed. The 60-days curing density obtained were higher than the 28-days density and the 28-days curing density higher than the 7-days density. When cured at 7 days, the result of the density of concrete ranges from 2189.14 - 2307.65 kg/m³ as against 2354.57 kg/m³ and the

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density of all the various replacement ratios are 98.01%, 94.84%, 94.59%, 94.36% and 92.97% that of the control. The 28-days curing density obtained ranges from 2202.47 - 2353.09 kg/m³ as against 2443.46 kg/m³ for the control. The density of all the various replacement ratios are 96.30%, 92.91%, 92.04%, 91.27% and 90.14% that of the control. At the 60-days curing, the result ranges from 2205.43 - 2374.81 kg/m³ as against 2454.32 kg/m³ for the control and the density of the replacement ratios are 96.76%, 93.12%, 92.19%, 91.25% and 89.86% that of the control. The effect of GPK "fuel" shells for the highest replacement ratio on density was found to reduce by at most 7.0%, 9.86% and 10.1% for the 7-days, 28-days and 60-days respectively when compare with value of the control concrete. For the cylindrical concrete, there was also a decrease in density between the control and the rest of the mix ratios for both the GPK ordinary shells (figure 3) and the GPK "fuel" shells concretes cured at 7 and 28-days (figure 4).

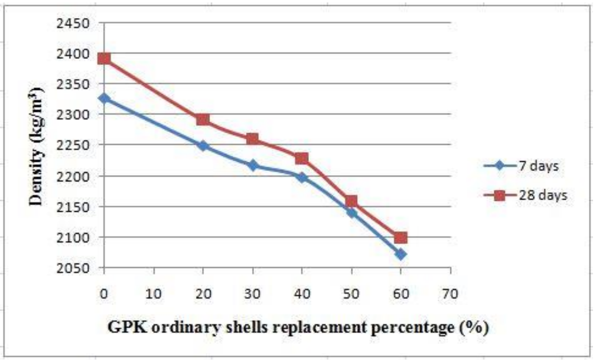

Figure 3: *Density of cylindrical specimen containing GPK ordinary shells at various percentages*

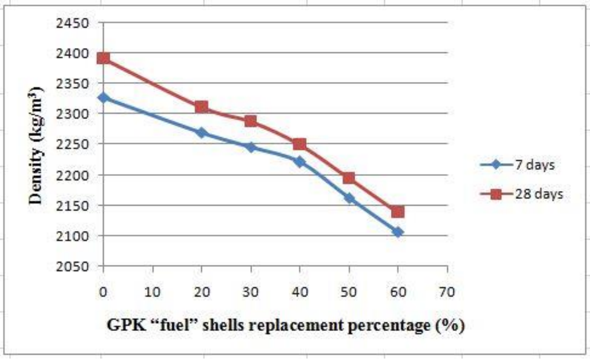

Figure 4: *Density of cylindrical specimen containing GPK "fuel" shells at various percentages*

When cured at 7 days, the test result of the density of the GPK ordinary shells cylindrical concrete (figure 3), ranges from 2072.00 - 2249.46 kg/m³ as against 2327.67 kg/m³ for the control. The density of the 20%, 30%, 40%, 50% and 60% replacement are 96.64%, 95.25%, 94.45%, 91.97% and 89.02% that of the control respectively. The 28-days curing density obtained ranges from 2099.35- 2291.54 kg/m³ as against 2391.85 kg/m³ for the control. The density of all the various replacement ratios are 95.81%, 94.46%, 93.15%, 90.26% and 87.77% that of the control.

For the cylindrical concrete specimens containing GPK "fuel" shells (figure 4), similar trend was observed. The 28-days curing density obtained were higher than the 7-days density. When cured at 7 days, the result of the density of concrete ranges from 2107.07 - 2270.15 kg/m³ as against 2327.67 kg/m³ and the density of all the various replacement ratios are 97.53%, 96.50%, 95.42%, 92.92% and 90.52% that of the control. The 28-days curing density obtained ranges from 2138.63 - 2312.23 kg/m³ as against 2391.85 kg/m³ for the control. The density of all the various replacement ratios are 96.67%, 95.67%, 94.09%, 91.76% and 89.41% that of the control.

The effect of GPK ordinary shells for the highest replacement ratio of the cylindrical specimen on density was found to reduce by at most 10.98% and 12.23% and that of the GPK "fuel shells" was 9.48% and 10.59% for the 7-days and 28-days respectively when compared with value of the control concrete.

Replacement of cement by equal mass of GPK shells leads to a decrease in the density of both the cubic and the cylindrical concrete specimens with reference to the control. However, as curing period is increased, the density of the specimens increased. The decrease in density due to partial replacement of OPC is attributed to the higher density of cement than the GPK shells. The increase in density as curing period increase is also attributed to the filling of voids or pores in the concrete specimen. The density of the cubic specimen is higher than that of the cylindrical for concrete specimens containing both ordinary shells and "fuel" shells. This is because additional compaction was achieved for the cubic moulds by means of a vibrating compactor which was not possible with the cylindrical moulds. Additionally, the density of the GPK "fuel" shells concrete specimens was found to be higher than that of GPK ordinary shells specimen since the true density of GPK "fuel" shells in powdered form is denser than the GPK ordinary shells. Conventional concrete, normally used in pavements, buildings, and other structures, has a density in the range of 1750 to 2400 kg/m^3 at 28 days curing period [13] [14]. The concrete specimens of the cubic and the cylindrical containing both GPK ordinary shells and "fuel" shells at all the curing ages fall within this range and are classified as lightweight concrete according to Newman and Choo [15]. This implies that all the concrete specimens satisfy the minimum density requirement for structural purposes as is also reported by Olutoge [16].

3.2 Ultrasonic Pulse Velocity Test

The data obtained from the ultrasonic pulse velocity test of the cubic and cylindrical concrete specimens at various GPK shells replacement percentages are shown in Tables 4 and 5 respectively.

Table 4: *Ultrasonic Pulse Velocity of Cubic Concrete Specimen at Various Curing Days*

Replacement Percentages	Ultrasonic Pulse Velocity (m/s)					
	7 days		28 days		60 days	
	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells
0%	3843.17	3843.17	4335.67	4371.00	4494.67	4494.67
20%	3120.33	3173.33	3816.67	4072.33	3976.00	4166.33
30%	3082.00	3107.67	3574.33	3694.33	3702.67	3823.00
40%	2656.67	2882.67	3150.67	3335.67	3340.67	3531.67
50%	2202.33	2616.83	2712.67	3162.33	3104.00	3272.33
60%	1886.00	2393.83	2391.00	2839.67	2671.33	2925.33

Table 5: *Ultrasonic Pulse Velocity of Cylindrical Concrete Specimen at Various Curing Days*

Replacement Percentages	Ultrasonic Pulse Velocity (m/s)			
	7 days		28 days	
	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells
0%	3223.67	3223.67	3976.33	3976.33
20%	2843.00	3005.67	3516.00	3674.33
30%	2592.33	2715.67	3321.33	3438.33
40%	2380.00	2502.67	2834.33	3255.00
50%	2014.33	2293.00	2610.00	2778.00
60%	1400.33	1821.00	2279.67	2431.00

The effect of replacement of GPK shells on ultrasonic pulse velocity of the specimens are graphically represented in figures 5 to 8. Figure 5 and 6 shows the effects of replacement of GPK ordinary shells and GPK "fuel" shells of the cubic specimens and figures 7 and 8 that of the cylindrical respectively. The result shows that the ultrasonic pulse velocity of concrete samples decreased with increasing percentage of GPK shells. The decrease becomes more significant when the replacement percentages are increased. However, prolonging the curing time obviously increases the ultrasonic pulse velocity of concrete slightly.

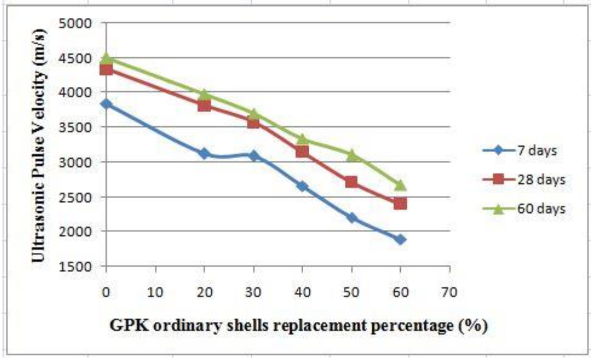

Figure 5: *Ultrasonic pulse velocity of cubic specimen containing GPK ordinary shells at various percentages*

For the cubic concrete specimens containing GPK ordinary shells (figure 5), when cured at 7 days, the test result of the ultrasonic pulse velocity of concrete ranges from 1886.00 - 3120.33 m/s as against 3843.17 m/s for the control. The ultrasonic pulse velocity of these concretes decreases to 81.19%, 80.19%, 69.13%, 57.31% and 49.07% at various replacement percentages with reference to the control mix. At 28 days of curing, the ultrasonic pulse velocity for the control increased to 4335.67 m/s. This shows an increment of 12.8%. The test result ranges from 2391.00 - 3816.67 m/s for the various replacement percentages respectively. The decrease in the ultrasonic pulse velocity was 88.03%, 82.44%, 72.67%, 62.57% and 55.15% that of the control for the various replacement percentages. Between the controls of 28-day and 60-day curing periods, there was a difference of 159 m/s in the pulse velocity which corresponds to only 3.67%. The test result ranges from 2671.33 - 3976.00 m/s for the various replacement percentages respectively as against 4494.67 m/s for the control. The ultrasonic pulse velocity decreases to 88.46%, 82.38%, 74.33%, 69.06% and 59.43% that of the control for the various replacement percentages.

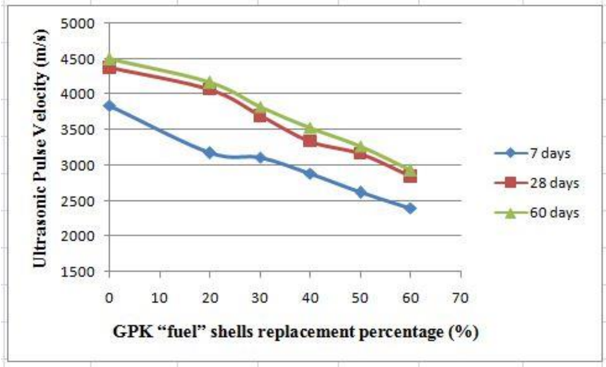

Figure 6: *Ultrasonic pulse velocity of cubic specimen containing GPK "fuel" shells at various percentages*

Considering the cubic concrete specimens containing GPK "fuel" shells (figure 6), the trend is the same as that of the GPK ordinary shells concrete specimens. The ultrasonic pulse velocity result ranges from 2393.83 - 3173.33 m/s for the various replacement percentages. The ultrasonic pulse velocity values correspond to 82.57%, 80.86%, 75.01%, 68.09% and 62.29% of the control mix. At 28 days, the result ranges from 2839.67 - 4072.33 m/s and the decrease in the ultrasonic pulse velocity was 93.93%, 85.21%, 76.94%, 72.94% and 65.50% that of the control for the various replacement percentages respectively. At 60-days, the result ranges from 2925.33 - 4166.33 m/s and the decrease in the ultrasonic pulse velocity was 92.69%, 85.06%, 78.57%, 72.80% and 65.08% that of the control for the various replacement percentages respectively.

For the cylindrical concrete specimens, the graphical representation of the ultrasonic pulse velocity results for the GPK ordinary shells and GPK "fuel" shells can be observed from figure 7 and 8 respectively. The ultrasonic pulse velocity for the GPK ordinary shells (figure 7) at 7 days curing period was found to be 3223.67 m/s for the control and vary from 1400.33 m/s to 2843.00 m/s by varying the replacement ratio of the GPK ordinary shells. The ultrasonic pulse velocity of these concretes was found to decrease to 88.19%, 80.42%, 73.83%, 62.49% and 43.44% at various replacement percentages with reference to the control mix. At 28-day curing period, the ultrasonic pulse velocity for the control was increased from 3223.67 m/s to 3976.33 m/s. The ultrasonic pulse velocity values are observed to vary from 2431.00 m/s to 3674.33 m/s when the GPK ordinary shells replacement percentages were varied. The decrease corresponds to 92.4%, 86.47%, 81.86%, 69.86% and 61.14% of the control for the various replacement percentages.

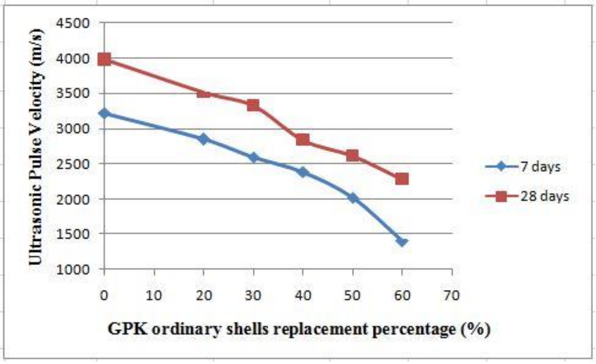

Figure 7: *Ultrasonic pulse velocity of cylindrical specimen containing GPK ordinary shells at various percentages*

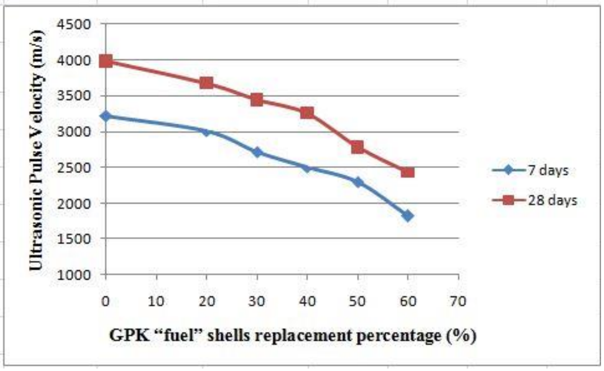

Figure 8: *Ultrasonic pulse velocity of cylindrical specimen containing GPK "fuel" shells at various percentages*

For the cylindrical concrete specimens containing GPK "fuel" shells (figure 8) cured at 7 days, the ultrasonic pulse velocity result ranges from 1821 m/s to 3005.67m/s as against 3223.67 m/s for the control. When the GPK "fuel" shells were varied, the decrease in ultrasonic pulse velocity corresponds to 93.24%, 84.24%, 77.63%, 71.13% and 56.48% of the control for the various replacement percentages. At 28-day curing period, the ultrasonic pulse velocity values vary from 3223.67 m/s to 3976.33 m/s when the GPK ordinary shells replacement percentages were varied. The decrease corresponds to 92.4%, 86.47%, 81.86%, 69.86% and 61.14% of the control for the various replacement percentages.

Similarly, replacement of cement by equal mass of GPK shells leads to a decrease in the ultrasonic pulse velocity of both the cubic and the cylindrical concrete specimens with reference to the control. However, as curing period is increased, the ultrasonic pulse velocity of the specimens increased. The ultrasonic pulse velocity of the cubic specimen is higher than that of the cylindrical for concrete specimens containing both ordinary shells and "fuel" shells. This is because additional compaction was achieved for the cubic moulds by means of a vibrating compactor which was not possible with the cylindrical moulds. The additional compaction in the cubic moulds possibly reduces voids in the concrete specimens. Also, the ultrasonic pulse velocity of the GPK "fuel" shells concrete specimens was found to be higher than that of GPK ordinary shells specimen since the true density of GPK "fuel" shells in powdered form is denser and so less porous than the GPK ordinary shells. The decrease in velocity of the concrete specimens with GPK shells prepared reveals that, porosity and air content increases with the decrease in cement content. Similarly, the degree of compaction affects the volume of voids in concrete comparing the cubic and the cylindrical specimens. Additionally, because the density of GPK shells is lower than that of cement, concrete made with GPK shells has lower than that of cement. For the same reason, concrete made with GPK shells has a higher porosity and absorption and so also is the concrete made with GPK ordinary shells more porous than GPK "fuel" shells.

For quality grading of concrete, the standard for classification is such that, for ultrasonic pulse velocity greater than 4.5 km/s, the concrete is excellent. Other classifications are, between 3.5 km/s to 4.5 km/s, good; between 3.0 km/s to 3.5 km/s, satisfactory; between 2.0 km/s and 3.0 km/s, doubtful and less than 2.0km/s, poor [17]. Classifying the concretes at 28 days curing age,

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the cubic specimens with GPK ordinary shells replacement percentage of 20% is classified as good, 30% and 40% classified as satisfactory, and 50% and 60% is classified as doubtful or poor. For the concrete specimens with GPK "fuel" shells, 20% and 30% is classified as good, 40% and 50% classified as satisfactory, and only the 60% as doubtful. For the cylindrical specimens, the 20% is classified as good, 30% GPK ordinary shells and 30% and 40% GPK "fuel" shells classified as satisfactory, and the rest classified as doubtful. All specimens degraded from "good", to "doubtful", but non fall within the "poor" category in terms of quality.

3.3 Modulus of Elasticity Test

Figure 9, 10, 11 and 12 shows the representative results of the modulus of elasticity. The result obtained from the cubic concrete (Table 6) has been graphically represented in figures 9 and 10 for GPK ordinary shells and GPK "fuel" shells respectively.

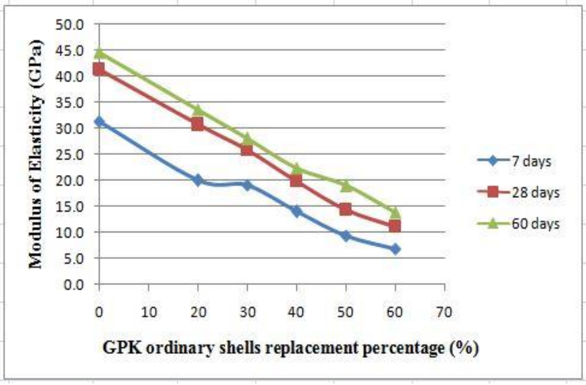

Figure 9: *Modulus of elasticity of cubic specimen containing GPK ordinary shells at various percentages*

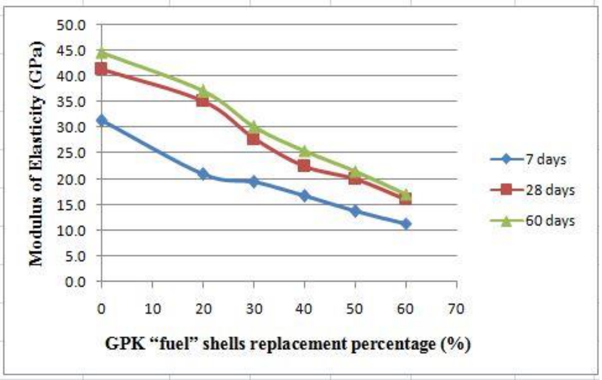

Figure 10: *Modulus of elasticity of cubic specimen containing GPK "fuel" shells at various percentages*

The modulus of elasticity for the GPK ordinary shells (figure 9) at 7 days curing period was found to be 31.30 GPa for the control and vary from 6.85 GPa to 20.0 GPa by varying the replacement ratio of the GPK ordinary shells. The modulus of elasticity of these concretes was found to decrease to 63.9%, 60.93%, 44.63%, 30.13% and 21.89% at various replacement percentages with reference to the control mix. At 28-day curing period, the modulus of elasticity for the control increased to 41.35 GPa. This shows an increment of approximately 32.11%. At this curing age the modulus of elasticity varies from 11.10 GPa to 30.72 GPa when the GPK ordinary shells replacement percentages were varied. The decrease corresponds to 74.29%, 62.73%, 47.93%, 34.9% and 26.6% of the control for the various replacement percentages. As the curing periods increased from 28-day to 60 days, the modulus of elasticity for the control increased to 44.63 GPa with a difference of 3.28 GPa which corresponds to 7.9%. The test result for the various replacement percentages ranges from 13.91 GPa to 33.56 GPa. The percentage decrease in the modulus of elasticity with respect to the control for the various replacement percentages was 75.2%, 62.9%, 50.15%, 42.55% and 31.17% respectively.

Considering the cubic concrete specimens containing GPK "fuel" shells (figure 10), the trend is the same as that of the GPK ordinary shells concrete specimens. The modulus of elasticity results for the 7 days curing period ranges from 11.29 GPa to 20.92 GPa for the various replacement percentages. The values correspond to 66.84%, 62.01%, 53.23%, 43.77% and 36.07% of the control mix. At 28 days, the result ranges from 16.00 GPa to 35.12 GPa and the decrease in the modulus of elasticity was 84.93%, 67.45%, 54.46%, 48.54% and 38.69% that of the control for the various replacement percentages respectively. At 60-days, the result ranges from 17.00 GPa to 37.10 GPa and the decrease in the modulus of elasticity was 83.13%, 67.38%, 56.96%, 48.35% and 38.09% that of the control for the various replacement percentages respectively.

Table 6: *Modulus of elasticity of Cubic Concrete Specimen at Various Curing Days*

Replacement Percentages	Modulus of Elasticity (GPa)					
	7 days		28 days		60 days	
	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells
0%	31.30	31.30	41.35	41.35	44.63	44.63
20%	20.00	20.92	30.72	35.12	33.56	37.10
30%	19.07	19.41	25.94	27.89	27.98	30.07
40%	13.97	16.66	19.82	22.52	22.38	25.42
50%	9.43	13.70	14.43	20.07	18.99	21.58
60%	6.85	11.29	11.10	16.00	13.91	17.00

The modulus of elasticity results obtained from the cylindrical specimen's measurement (Table 7) has been graphically represented in figures 11 and 12 for GPK ordinary shells and GPK "fuel" shells respectively.

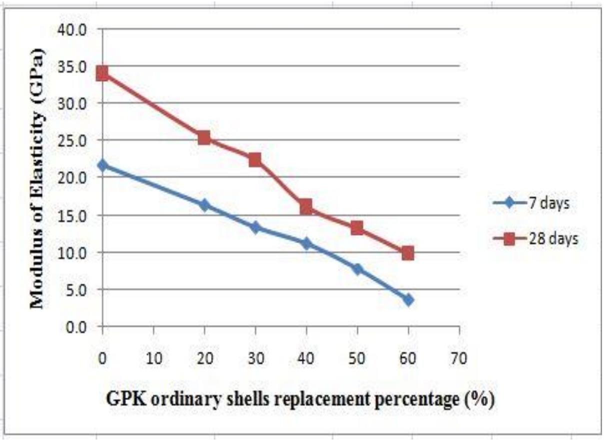

Figure 11: *Modulus of elasticity of cylindrical specimen containing GPK ordinary shells at various percentages*

The modulus of elasticity of the control specimen for the GPK ordinary shells (figure 11) at 7 days of curing was 18.04 GPa. As the mix ratio is increased, the modulus of elasticity decreased and vary from 3.66 GPa to 16.36 GPa. The decrease was found to be 75.15%, 61.6%, 51.49%, 35.97% and 16.81% at the various replacement percentages with reference to the control mix. At 28-day curing period, the modulus of elasticity for the control was increased to 34.04 GPa and vary from 9.82 GPa to 25.50 GPa when the GPK ordinary shells replacement percentages were varied. The decrease observed as a result of the various replacement percentages corresponds to 74.91%, 65.89%, 47.33%, 38.92% and 28.85% of the control. Considering the cubic concrete specimens containing GPK "fuel" shells (figure 12), the trend is the same as that of the GPK ordinary shells concrete specimens.

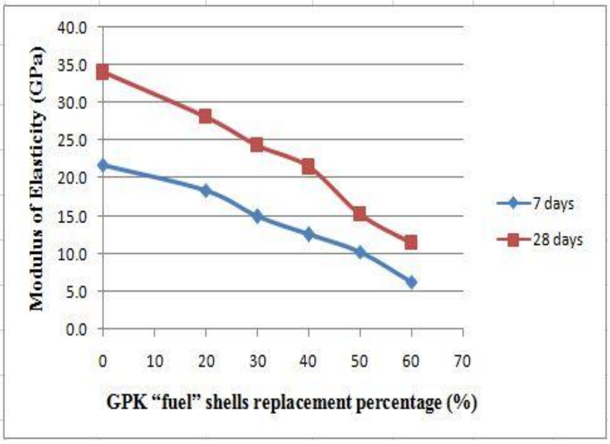

Figure 12: *Modulus of elasticity of cylindrical specimen containing GPK "fuel" shells at various percentages*

The modulus of elasticity results for the 7 days curing period ranges from 6.30 GPa to 18.46 GPa for the various replacement percentages. The decrease in the modulus of elasticity values as the replacement percentages were varied correspond to 84.8%, 68.49%, 57.51%, 46.99% and 28.947% of the control mix. At 28 days, the result ranges from 11.38 GPa to 28.10 GPa and the decrease in the modulus of elasticity was 82.55%, 71.53%, 63.04%, 44.77% and 33.43% that of the control for the various replacement percentages respectively.

Table 7: *Modulus of elasticity of Cylindrical Concrete Specimen at Various Curing Days*

Replacement Percentages	Modulus of Elasticity (GPa)			
	7 days		28 days	
	Ordinary Shells	Fuel Shells	Ordinary Shells	Fuel Shells
0%	21.77	21.77	34.04	34.04
20%	16.36	18.46	25.50	28.10
30%	13.41	14.91	22.43	24.35
40%	11.21	12.52	16.11	21.46
50%	7.83	10.23	13.25	15.24
60%	3.66	6.30	9.82	11.38

Like the density and the ultrasonic pulse velocity, as the curing period increased, the modulus of elasticity increased across all the mix ratios and as curing period is increased, the ultrasonic pulse velocity of the specimens increased. Comparison of the modulus of elasticity of GPK ordinary shells with that of GPK "fuel" shells at all ages and mixed ratios, the "fuel" shells was found to have significantly higher modulus of elasticity. The modulus of elasticity of lightweight concrete generally ranges from 6.89 to 20.68 GPa and that of normal-weight concrete is between 13.79 and 41.37 GPa [18]. Based on the classification of Merritt and Ricketts [18] using the 28 days curing age, all the concrete specimens fall within the lightweight range (6.89 to 20.68 GPa). Interestingly, the cubic concrete specimens of the control mix whose density falls within the normal-weight concrete classification, has the modulus of elasticity also falling within the same normal-weight class (41.37 GPa).

4 Conclusions

From the results and the analysis done, it was observed that as the mix ratio is increased, the density, ultrasonic pulse velocity and modulus of elasticity decreased and as the curing period increased, these values increased across all the mix ratios. The density, ultrasonic pulse velocity and modulus of elasticity of the "fuel" shells specimen are higher than that of the ordinary shells. Based on the above findings, 30% of the GPK "fuel" shells and 20% of GPK ordinary shells could be used for partial replacement of OPC in concrete for pavements, buildings, and other lightweight structural concrete. The use of GPK shells for partial replacement of OPC of 20% can decreases the cost of the concrete product by the reduction of cement. It will also reduce environmental pollution due to dumping of such agro-based waste thereby conserving materials, labour and energy.

5 Declarations

5.1 Acknowledgment

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5.2 Competing Interests

The authors declared that no conflict of interest exist in this publication

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References

[1] S. Keerthinarayana and R. Srinivasan, "Study on Strength and Durability of Concrete by Partial Replacement of Fine Aggregate Using Crushed Spent Fire Bricks," *Directory of Open Access Journals*, LVI (LX) (2), pp. 51-64, 2010.

[2] N. S. Martys, "Survey of Concrete Transport Properties and Their Measurement," *National Institute of Standards and Technology*, Gaithersburg, 1995.

[3] D. Johnston, "AAFA International Product Safety and Sustainability Conference," *29 Corporate Sustainability Programme*, American Efird Inc., China, April 2011.

[4] K. O. Olowe and V. B. Adebayo, "Investigation on Palm Kernel Ash as Partial Cement Replacement in High Strength Concrete," *SSRG International Journal of Civil Engineering (SSRG-IJCE)*, vol. 2, no. 4, pp. 45, April 2015.

[5] O. A Fadele and O. Ata, "Compressive Strength of Concrete Containing Palm Kernel Shell Ash," *American Journal of Engineering Research (AJER)*, vol. 5, no. 12, pp. 32-36, 2016.

[6] P. Premalatha, K. R. Vinodh, L. C. Anto and R. Nithiya, "Properties of Palm Ash Concrete," *International Journal of Engineering Science Invention*, vol. 5, no. 8, pp. 29-32, August 2016.

[7] C. P. Ukpaka and G. I. Okochi, "Production of Cement from Mixture of Palm Kernel and Periwinkle Shell," *Indian Journal of Engineering*, vol. 15, pp. 166-179, 2018.

[8] IAEA, "Basic Principles of Non-Destructive Testing (NDT)," *Training Guidelines In Non-Destructive Testing Techniques: Manual For Visual Testing At Level 2*, VIENNA, IAEA-TCS-54, ISSN 1018-5518, Austria, pp.1, 2013.

[9] British Standards, "BS 1881: Part 127, Method of verifying the Performance of concrete cube compression Machine using the cube test," *Testing Concrete*, British Standards Institution, London, 1990.

[10] ASTM C642–09, "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete," American Concrete Institute.

[11] ISO 4013-1978(E), Concrete-Determination of flexural strength of test specimen, International Organization for Standardization, Switzerland, August 1978.

[12] ASTM C597-09, "Standard Test Method for Pulse Velocity Through Concrete", American Concrete Institute, 2009.

[13] R. Dorf, *Engineering Handbook*. New York: CRC Press, 1996.

[14] S. H. Kosmatka, B. Karkhoff and W. C. Panarese, *Design and Control of Concrete Mixture*, 14th ed. Portland Cement Association, Skokie Illinois, USA, 2003.

[15] J. Newman and B. S. Choo, "Elasticity, Shrinkage, Creep And Thermal Movement," *Advanced Concrete Technology-Concrete Properties*, Elsevier Butterworth Heinemann, Great Britain, pp. 7/2-3, 2003.

[16] F. A. Olutoge, H. A. Quadri, O. S. Olafusi, "Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete," *ETASR - Engineering, Technology & Applied Science Research*, vol. 2, no. 6, pp. 315-319, 2012.

[17] V. M. Malhotra and N. J. Carino, "The Ultrasonic Pulse Velocity Method," *Handbook on Nondestructive Testing of Concrete*, 2nd ed. CRC Press, New York, USA, 2004.

[18] F. S. Merritt and J. T. Ricketts, " Building Materials," *Building Design And Construction Handbook*, 6th ed, McGraw-Hill Companies, Inc., United States of America, pp. 4.23, 2001.