West Africa Built Environment Research (WABER) Conference
10th Anniversary Conference, 5-7 August 2019, Accra, Ghana
Proceedings Edited by Laryea, S. and Essah, E.
ISBN: 978 – 9988 – 2– 6010 – 1
DOI: https://doi.org/10.33796/waberconference2019.82

THE USE OF PALM KERNEL SHELL ASH AS CEMENT REPLACEMENT IN CONCRETE

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The national housing policy of Ghana which was approved by cabinet in 2010, advocate the use of local building materials for the construction of buildings. It is against this background, that in recent years many studies has been conducted to find cheap but useful local building materials to replace the conventional ones which are to some extent expensive. Cement is one of the most important elements in building construction works which is relatively expensive, this research seeks to study the possibility of utilizing palm kernel shell ash (PKSA) as cement replacement in concrete production. The study aimed at finding the chemical composition of PKSA, strength and durability properties of concrete produced from OPC with partial replacement PKSA. The palm kernel shell was burn, sieved and was tested at a chemistry laboratory and then compared with the chemical composition of OPC. The PKSA was used to prepare concrete cubes at replacement levels of 0%, 5%, 10%, 15% and 20%, cured for 28 days. From the study, it was evident that PKSA contains chemicals such as SiO_2 (silicon), Al_2O_3 (aluminium), Fe_2O_3 (iron oxide), CaO (calcium oxide), MgO (magnesium oxide) and K_2O (potassium oxide) which are active ingredient in OPC but are not at the required levels. The PKSA replacement percentage in concrete mix improved workability but water absorption rate was comparatively high. Compressive strength declined as PKSA increases in the mix as well as density. The study showed an inverse correlation between compressive strength and PKSA percentage replacement levels. Following the high water absorption rate of PKSA concrete, it was not recommended for concrete works in waterlog areas. Despites the reduction in strength of PKSA concrete, 5% replacement is recommended for normal concrete works.

Keywords: compressive strength, concrete, PKSA, water absorption

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Appiadu-Boakye, Kennedy, Yeboah, K. Kenneth, Boateng, K. Ransford and Bukari, Mohammed (2019) The use of palm kernel shell ash as cement replacement in concrete In: Laryea, S. and Essah, E. (Eds) Procs West Africa Built Environment Research (WABER) Conference, 5-7 August 2019, Accra, Ghana, 1138-1158

INTRODUCTION

Available data as at 2015 shows that the housing deficit in Ghana is in excess of 1.7 million (Africa Housing Finance Yearbook 2018). The Minister of Water Resources, Works and Housing, on the 15th of October, 2013, with an encounter with Meet-the- Press series in Accra Ghana, stated that, a minimum of 85 thousand housing units is needed annually to address the housing deficit in the country over the next 20 years.

Meanwhile, the cost of cement is on the increase and unaffordable, yet the need for housing and other construction projects that require the use of it keeps growing with increasing population. Data from Building and Road Research Institute (BRRI) shows that cement utilisation in Ghana had increased from 1.8 million tonnes in 2000 to about 3.2 million tonnes in 2011. More than $300 million is spent annually on clinker and cement importation in Ghana, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement.

It is for this reason that the national housing policy which was approved by cabinet in 2010, advocate the use of local building materials for the construction of buildings in Ghana. Following this, many studies have been conducted to find cheap but useful local building materials to replace the conventional ones which are to some extent expensive. One of such enquiry is the use of waste materials and agricultural by-products. Osei and Jackson, (2012) stated that there exists the possibility of replacing coarse aggregates with palm kernel shells in the production of structural concrete. Their study also identified possible cost reduction in replacing granite with palm kernel shells and recommended codification of the use of palm kernel shells as aggregates in concrete. Elinwa and Awari (2001) found that groundnut husk ash could be suitably used as partial replacement of OPC in concrete making. Mehta and Pirtz (2000) investigated the use of rice husk ash to reduce temperature in high strength mass concrete and concluded that RHA is very effective in reducing the temperature of mass concrete compared to OPC concrete. Fynn, Asiedu, Yalley, Zievie and Appiadu-Boakye (2015) investigated the use of cocoa bean shells ash as a stabilizer in soil bricks production. Data from the study showed that the cocoa bean shell ash had a significant effect on the properties of the bricks. The compressive strength of the soil bricks ranged between 4.084N/mm2 and 6.506N/mm2 above the BSI 1985 minimum requirement for masonry units of 2.8N/mm2 with the optimum strength obtained with 20% CBSA. All these studies have confirmed the possibility of some agricultural waste for constructional purpose. However, it could be seen that much have not been done on the usage of palm kernel shell ash (PKSA) as replacement of cement in concrete. This present study seeks to use PKSA as cement replacement in concrete.

LITERATURE REVIEW

Cement extenders

Cement extenders are routine additive used for reducing slurry density and increasing the yield of cement slurry. Replacements reduce the amount of cement required to produce a given volume of set product which results in a greater economy (Shadizadeh et al, 2010).

Different types of cement extenders additives, such as fly ash, blast furnace slag or silica fume are added to a concrete mixture as a replacement material for a portion of the cement present. Such extenders materials are commonly referred to as cement extenders. Most of these additional materials react with some of the components of the cement paste yielding desirable characteristics such as improved strength, workability and better durability (Greensmith, 2005).

Fly ash

Fly ash (FA) is obtained from the ash produced from coal-burning power stations removed by electrostatic precipitators (Addis, 1986). A major part of the dust carried out from the burning of the coal contains a glassy material that is derived from the clay present in the pulverised coal (Bye, 1999). Fly Ash is a fine powder consisting of round, hollow spherical particles that constitute mainly glass and quartz, mullite and calcium oxide.

The fineness of the Fly Ash plays an important role with respect to the reactivity of the material and the workability of the concrete in which it is used. As a general rule, the finer the fly ash, the greater the pozzolanic activity and the better the workability of the concrete mixture. If however, too fine a FA is used in a concrete mixture that already contains a significant proportion of fines, the concrete could lose workability and become sticky.

Advantages and disadvantages of using Fly Ash (FA)

Addis (1986) and Langan et al., (2002) note some of the advantages and disadvantages of using FA as a replacement material in the binder:

- A reduction in the cost of materials and a saving on energy, as less cement is used resulting in a reduction in CO2 emissions
- Better workability and concrete cohesiveness
- A reduction in construction costs as workability is improved
- Reduced water penetration
- Reduced shrinkage
- Reduced heat of hydration
- Reduced cracking tendency
- Slower strength development due to the accompanying pozzolanic activity.

The effects fly ash on concrete properties

The most notable effect of adding FA to a concrete mixture is the reduced water demand and great improvement in workability and flow. This is often the main reason for adding FA to a concrete mixture. According to Bye (1999), this is the result of the absorption of negatively charged particles of silica-alumina glass on the cement grain surfaces. Flow and workability are improved by the mutual repulsion of these negative charges in the paste. The extent of this improvement depends on the fineness and carbon content of the FA and, as mentioned, the finer the material, the greater the effect (Addis, 1986). The carbon content however, has the reverse effect and the more carbon present, the more detrimental the effect on the workability of the concrete.

The hydration of FA cements differs from that of Portland cement with respect to the rate of hydration of the different cement phases, the amount of portlandite formed, the composition of the hydration products and the additional compounds formed as a result of the reactions involving the fly ash itself (Ramachandran et al., 2003). Lower amounts of portlandite are formed in the presence of FA because of the pozzolanic nature of FA and the reaction that occurs between the FA present in the binder and in the lime produced during the PC hydration reactions (Lilkov et al., 1997). Many FA materials however, are unsuitable for use in concrete because of their low pozzolanic activity (Ramachandran et al., 2003).

According to Lilkov et al., (1997), FA has the effect of generally retarding the early stages of hydration and then accelerating the hydration process during the middle and later stages, particularly the hydration of alite present (Langan et al., 2002). This early retardation is because of the slowing of the calcium hydroxide saturation rate in the liquid phase due to the presence of FA. C3A and C4AF also experience the same trend of decelerated hydration in the early stages and accelerated reactions towards the later stages. This has the overall effect of reducing the rate and amount of heat evolved in the concrete during hardening in the presence of FA. According to Addis (1986), the percentage of heat reduction in fly ash cement at twenty-eight days is approximately equal to percentage of FA replacement of PC with respect to the total mass of the binder material.

The composition of the alite and belite hydrates in the paste of a three-day-old FA/PC concrete is very similar to that of a plain PC concrete. The main difference is that the proportions of the hydration products differ (Ramachandran et al., 2003). During the later stages of hydration, the FA reduces the C/S ratio in the CSH gel produced and increases the A/C ratio. The greater the FA content, the greater these effects become.

The condensation of silicate anions with respect to the C3S present is also more rapid when FA is introduced into the concrete mixture.

The presence of FA reduces the amount of CH in the hydration product because of the dilution effect it has during the consumption of calcium hydroxide in the pozzolanic reactions. Initially however, the formation of solid calcium hydroxide from the hydration of C3S is greater than the consumption of CH in the pozzolanic reaction, but eventually the amount of CH present in the hardening paste peaks and then begins to decline (Bye, 1999). The replacement of solid CH with CSH gel in the hardened paste also creates the potential to reduce the permeability of the concrete by modifying the distribution of pore sizes. This can have positive effects on the durability of the concrete since the possible ingress of deleterious foreign materials is reduced due to a reduction in permeability.

The presence of fly ash consequently reduces the magnitude of the main exothermic heat rate peak (peak 3, in figure 2.1) and delays the time at which it occurs (Langan et al., 2002). This delay is greater in the presence of FA with greater calcium content.

Bye (1999) states that with a thirty percent cement replacement with fly ash, the principle peak in heat rate is delayed between three and four hours and the presence of FA depresses the maximum value. The rate of hydration however, is also dependent on the fineness of the FA used and generally, as particle size is decreased the exothermic heat rate peaks as seen in figure 2.1 become sharper and occur sooner in the hydration process (Ramachandran et al., 2003).

If FA is to be used with a view to reducing the heat of hydration, Ramachandran et al. (2003) recommend that high volume (greater than fifty percent binder content) FA cement be used with a low calcium FA because low calcium FA has shown to have the following benefits:

- Low temperature rise
- Adequate early age strength (depending on the w/c ratio)
- Higher later age strengths.

Blast furnace slag

Blast furnace slag is a non-metallic molten by-product formed during the smelting of iron ore. This liquid generally contains siliceous and alluminosilicate impurities from the iron ore and coke involved. The principle oxides found in slag include lime, silica and alumina and hence it is made up of similar chemical compounds to those found in Portland cement, but in different proportions (Bye, 1999). If cooled slowly, slag crystallises and the material possesses little or no cementing properties. If however, it is cooled rapidly to below 800°C the slag forms a granular, glassy material with the hydraulic properties of a cementitious material. This is the type of slag used as a cement replacement material in concrete. The slag is usually ground down into a fine powder, hence the common industry name ground granulated blastfurnace slag (GGBS).

Silica fume

Silica Fume is a by-product from the manufacture of silicon or ferrosilicon alloys by the reduction of silica with carbon in an electric furnace. The gases produced are condensed into an extremely fine powder with a high silica content, hence the term condensed silica fume or CSF. It is a highly active pozzolan and this high reactivity is due to the fineness, high silica content and amorphous nature of the silica (Addis, 1986). Coatings of carbon on the surface of the silica particles however, can greatly reduce the pozzolanic activity of silica fume.

The effect of CSF on concrete properties

When w/c ratio and binder content are kept constant, the most notable effect of CSF on concrete is the dramatic increase in compressive strength over the first 28 days of curing (Lagan et al., 2002). This of course depends on the amount and nature of silica fume present. The increase in strength is also accompanied by a decrease in the permeability of the concrete, aiding in improving the durability characteristics (Addis, 1986).

Other important points to note regarding the effect of CSF on concrete include (Ramachandran et al., 2003):

- The total heat of reaction per unit mass of binder is greater in concretes containing silica fume.
- At all stages during hydration, the Ca(OH)2 content of the concrete is lower in the CSF concretes compared to PC only concretes. This is due to the pozzolanic nature of silica fume.

- In the presence of CSF, the heat rate curves indicate that there is no secondary ettringite or monosulphate produced during hydration.

Blended Cement

Blended cements are currently used in many parts of the world (Bakar, Putrajaya, and Abdulaziz, 2010). Calcium hydroxide [Ca (OH)2] is one of the hydration products of Portland cement and it greatly contributes toward the deterioration of cement composites. When a pozzolan is blended with Portland cement it reacts with the lime to produce additional calcium-silicate-hydrate (C-S-H), which is the main cementing compound. Thus the pozzolanic material reduces the quantity of lime and increases the quantity of C-S-H. Therefore, the cementing quality is enhanced if a pozzolan is blended in suitable quantity with Portland cement (Padney et al., 2003).

Agricultural by-product pozzolans have been used in the manufacture and application of blended cements (Malhotra and Mehta, 2004). Nimityongskul and Daladar (1995) highlighted the potentialities of coconut husk ash, corn cob ash, and peanut shell ash as good pozzolans. Elinwa and Awari (2001) successfully investigated the potentials of groundnut husk ash concrete by partially replacing Ordinary Portland Cement with groundnut husk ash. Adesanya (1996) investigated the properties of blended cement mortar, concrete, and stabilized earth made from OPC and corn cob ash and recommended that corn cob ash can serve as replacement for OPC in the production of cement composites. Dwivedia et al., (2006) successfully investigated the pozzolanicity of bamboo leaf ash. Martirena, Middendorf, and Budelman (1998) found that sugar industry solid wastes such as sugar cane straw ash has pozzolanic activity derived from its high content of amorphous silica. Many other researchers have confirmed rice husk ash a pozzolanic material that can be used to partially replace OPC in making cement composites (Cordeiro, Filho, and Fairbairn, 2009; Habeeb and Fayyadh, 2009; Rukzon, Chindaprasirt, and Mahachai, 2009). A number of researchers have also found good prospects in using blended cements made with sawdust ash (Mehta, 1997; Elinwa, Ejeh, and Mamuda, 2008; and Elinwa and Abdulkadir, 2011). Studies by Chandrasekar et al. (2003) suggest that soil, climatic, and geographical conditions could affect the physical and chemical properties and consequently the pozzolanicity of agricultural by-products.

A study carried out by Fernanda et al. (2008) also showed that, addition of rice husk as cement replacement materials provides additional improvements in compressive and splitting tensile strength and resistance to chloride ion penetration. Thus, rice husk may be utilized as effective mineral addition for designing durable concrete structures. The best content of silica recommended to be added in a volumetric substitution to the Portland cement is 10%. They further observed that the specimens with silica extracted from rice husk showed higher compressive strength values when compared with their equivalent mixture without addition, already at the early ages. The reasons for early compressive strength development of concretes with rice husk are due to fineness, amorphous phase, specific area and degree of reactivity of rice husk.

Pozzolana

The American society of testing materials (ASTM) defines Pozzolans as siliceous or aluminous materials which possess little or no cementitious properties but will, in the presence of moisture, react with lime [Ca(OH)2] at ordinary temperature to form a compound with pozzolanic properties. A pozzolan is a material which, when combined with calcium hydroxide (lime), exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "cement replacement") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete (http://www.aboutcivil.org).

Pozzolanas can be classified as natural and artificial. The basic classification into natural and artificial has no real or engineering purpose (Appiah Boakye, 2012). With respect of economy and performance, it does not matter whether the source is natural or not (Day, 1990). Natural pozzolanas are of two types: the true natural pozzolanas and the pseudo natural pozzolanas.

The true natural pozzolanas are ashes and lavas originating from alkalitrachytic, leucitic, leucotephritic and hauynophric types of magma. These ashes result from explosive eruptive volcanoes and are forced to solidify as a pyroclastic glass (glass fragments formed by rapid quenching of magma produced by volcanic explosions) (Malquori, 1960). In the pseudo natural pozzolanas, the pyroclastic glassy minerals in the original lava have undergone hydrothermal alteration (auto-metamorphism) leading to zeolitization and sometimes argillization (Malquori, 1960, Steopoe, 1964, Kemser, 1964).

Artificial pozzolanas are those materials in which the pozzolanic property is not well developed and hence usually have to undergo pyro-processing before they become pozzolanic (Hammond, 1983). Artificial pozzolanas include materials such as flyash, blast furnace slag, surkhi (burnt clay), siliceous and opaline shales, spent oil shale (used in Sweden to make gas concrete), rice husk ash, burnt sugar cane stalks and bauxite waste (Grane, 1980).

The general term pozzolana is used to designate natural as well as industrial co-products that contain a percentage of vitreous silica. This vitreous (amorphous) silica reacts at ambient temperature with the lime produced by the clinker minerals to form hydrated calcium silicates (C-S-H) (Venuat, 1984, Malhotra, 1987, Malhotra and Mehta, 1996).

Palm Kernel Shell

Palm kernel shell PKS is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). PKS is light and therefore ideal for substitution as aggregate in the production of light weight concrete. Olutoge (1995) in his investigations into the physical properties of palm kernel shell found it density to be 740kg/m3. He concluded that this material has properties which resembled those of light weight concrete materials.

Palm kernel shell is an industrial waste and it’s available in large quantities especially in palm oil producing areas. Palm kernel shells have very low ash (about 3% weight - ASTM D3174-02, 2002) and sulphur (about 0,09% weight – ASTM

D4239-02, 2002) contents. Palm kernel shells (PKS) are hard, carbonaceous, organic by- products of the processing of the palm oil fruit. It consists of small size particles, medium size particles and large size particles in the range 0-5mm, 5-10mm and 10-15mm (Alengaram, Mahmud, Jumaat & Shiraz, 2010). The shells have no commercial value, but create disposal and waste management problems.

Usage of Palm Kernel Shell in Construction

Palm kernel shells are generally not used in construction. They are used as fuel by local blacksmiths and as fill material or as palliatives (Osei and Jackson, 2012). Osei and Jackson (2012) reported that palm kernel shells could be used as coarse aggregates in concrete. Palm kernel shells can be used as partial replacement for coarse aggregates up to 10% for heavily trafficked roads and 50% for light trafficked road.

Ndoke (2006) investigated the suitability of palm kernel shells as partial replacement for coarse aggregates in asphaltic concrete. Olutoge (2010) investigated the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in the production of reinforced concrete slabs. He concluded that 25% sawdust and palm kernel substitution reduced the cost of concrete production by 7.45%. He also indicated the possibility of partially replacing sand and granite with sawdust and palm kernel shell in the production of lightweight concrete slabs.

According to Olutoge, Quadri and Olafusi (2012), Palm kernel shells ash can be used in concrete .This ash has pozzolanic properties that enables it as a partial replacement for cement but also plays an important role in the strength and durability of concrete. Olanipekun (2006) compared concrete made with coconut shells and palm kernel shells as replacement for coarse aggregates and concluded that coconut shells performed better than palm kernel shells as replacement for conventional aggregates in the of concrete.

Chemical Composition of PKS

The chemical composition of PKSA depends on number of factors including; species of the tree, growing conditions and the combustion methods that include combustion temperature, efficiency of the boiler, and supplementary fuels used. The ash produced sometimes varies in tone of color from whitish grey to darker shade based on the carbon content in it. In other words, the physical characteristic of PKSA is very much influenced by the operating system in the palm oil factory (Olutoge et al., 2012). Like the coal fly ash, PKSA can be classified as either class F (pozzolana) that contains less than 10% lime (CaO) or class C with more than 10% lime (CaO) content.

Generally, after combustion, the main constituents of the PKSA as determined by Olutoge et al in their research: Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete and other researchers are Silicon (SiO_2), Aluminum (Al_2O_3), and Iron Oxide (Fe_2O_3). The total amount of SiO_2, Al_2O_2 and Fe_2O_3 present in PKSA is 66.572% which is more than the minimum required (50% Min.) specified by ASTM, for Type C Ash; while its Calcium oxide (CaO) content is about 8.786%. The specific gravity of the PKSA was gotten to be 2.30; which was less than that of the OPC of 3.15. This means a considerable greater volume of cementitious materials will result from mass replacement for cement (Olutoge et al., 2010).

MATERIALS AND METHODS

The following materials were used in the preparation of the concrete cubes that were used for the studies: Palm kernel shell ash, Cement (ordinary Portland cement), Fine Aggregate, Coarse Aggregate and Water.

Processing of Palm Kernel Shells Ash

The palm kernel shell was obtained from Asamang in the Skyere South District of the Ashanti region of Ghana. It was thoroughly washed with clean water to remove the sand particles which were mixed up with it as a result of how the palm kernels are extracted by the local folks. The washed shells were then sun dried for three days to keep it dried for easy combustion. It was burnt in an uncontrolled combustion for 36hours and grinded into fine ash particles. The PKSA was sieved through a 45um sieve in order to remove any foreign material and bigger size ash particles. Only the fine ashes which passed through 45um sieve were collected. The chemical analysis of the PKSA samples was further carried out at the Kwame Nkrumah University of Science and Technology (KNUST) chemistry laboratory to determine its chemical composition. PKSA being sieved is shown in Figure 1.

Figure 1. Ash of the Palm Kernel Shell

Test for Particle Distribution of Crush Granite

This test was in accordance with BS 812: Part 103.1: 1985. These apparatus were used for the test: Quartering Machine, Automatic sieve shaker, Trays, Set of BS Sieves and Beam balance. The samples were air dried and quartered to get a statistically convenient sample for the test. The quartered sample was weighed and recorded. The weighed crush granite was poured into the arranged BS sieves and covered. The sieves containing the material were subjected to five minutes shaking using the automatic shaker. The remained sample on each sieve were weighed and recorded. Figure 1 and 2 shows the crushed granite and Automatic sieve shaker respectively.

Figure 2. Crush Granite

Figure 3.Shaker for Sieving of Aggregate

Test for Clay and Silt

This test was in accordance with BS 882:1992. Sample of sand was taken to the laboratory for silt and clay test. The following materials and tools were used for the test: sand, salt, water, measuring cylinder-250ml and 500ml, and stirring rod. To start, a saline solution was prepared by taking 2.5g of fine salt and dissolving it into 250ml of water in the 500ml measuring cylinder. The purpose of the saline solution was to accelerate the rate of settling of the various particles of the sand. 50ml of saline solution was poured into the 250ml cylinder (glass). The sand was then added into the same cylinder with the 50ml saline solution till the water level in the same cylinder reached the 100ml reading level. An additional saline solution was added till the water reads 150ml. The additional water was to facilitate the ease of stirring. The stirring rod was used to stir the mixture thoroughly. The cylinder was then placed on a flat surface for three hours for sedimentation. The height of sand and silt were measured and expressed in percentage:

$$Silt\ and\ Clay\ Content(\%) = \frac{\text{Height of Silt and Clay X 100}}{\text{Height of Sand}}$$

Test for Particles Distribution of PKSA

To test for particle distribution of PKSA, the sieve analysis method was used for the study which was in accordance with ISO 4406. 150 grams of PKSA was sampled which was made to pass through BS sieve of sizes ranging from 0.045mm to 0.6mm to obtain the various particle sizes. The percentage of PKSA passing through the sieves were recorded and shown in Figure 9.

Batching and Mixing

The materials were batched using weight proportioning method. The mix ratio used was 1: 2: 4 (cement: fine aggregates: coarse aggregates). The palm kernel shell ash was added by weight of the cement in variation from 0% to a maximum of 20% in steps of 5%. A 0.5 water cement ratio was used to determine the amount of water required for mixing each batched of mix. Due to the smaller volume of concrete mixed for each batched of mix, a hand mixing method was adopted. The amount of fine aggregates (sand) required was first measured and placed on the mixing platform. The cement was then measured with its corresponding PKSA percentage and spread on the measured sand. These materials were mixed thoroughly until no distinction could be made between them using shovel. The coarse aggregate was later measured and added to the unified mix of cement, PKSA and sand. Afterwards, the four materials were mixed together to obtain a uniform mix. Per the calculation made, half of the batched water was then poured into the mix and turned several times to obtain a uniform paste before adding the remaining water.

Workability Test

A truncated cone, 300 mm height and 100 mm diameter at the top and 200 mm diameter at the bottom slump cone was filled in three layers. Each layer was given 25 number of blows with tamping rod of length 600mm long and 16mm diameter with a hemispherical tip. The top of the concrete was levelled with a trowel by a screeding motion. Immediately, after screeding off, the cone was slowly lifted up straight.

The slump cone was then set next to the concrete and the difference in height between the slump cone and the specimen was measured using steel tape measure. The test was performed for all samples. The slump test was performed in accordance with BS 1881: Part 102:1983. Find set up for slump test in Figure 4.

Figure 4. Set up for Slump Test

Casting

A total of fifteen concrete cubes of sizes 150mm x150mm x 150mm were cast using varying OPC-PKSA ratio as indicated above. For each percentage replacement, three cubes A metallic moulds having an internal measurement of 150 × 150 × 150mm was in accordance with BS 1881: Part 108: 1983 were used. Before casting, the metallic moulds were oiled to restrain blow holes and other surface defects. The moulds were filled in three layers, with each layer being tamped 35 times with a tamping rod. The casted specimens were left in the moulds for 24 hours before being de-moulded and then cured in water basin until it was time to be tested. Samples of specimen are shown in Figure 5.

Figure 5. PKSA Concrete Cubes

Curing of Specimen

For this research, after twenty four hours of casting the specimen were de-moulded and cured by immersing them in a water basin containing water sample that was used for the mixing. The specimen was tested at 28days of curing for compression. All the cubes were cured in the material laboratory of Sunyani Polytechnic. Figure 6 depicts the curing procedure for cubes.

Figure 6. Curing of Concrete Cubes

Test for Density

To be able to calculate the density of the spacemen, the spacemen were weighed prior to crushing using digital electronic weighing machine and the weight obtained were recorded according to the various replacement levels. The densities of the various blocks were calculated using:

$$Density = \frac{\text{Mass}}{\text{Volume}}$$

Test for Compressive Strength

This test was carried out at the 28 days of curing. Prior to crushing, the weights of the concrete cubes were recorded to determine their densities. The test was conducted at the Sunyani Polytechnic Building Construction laboratory. A digital compressive strength testing machine produced by Controls Milano, Italy was used. The compressive strength was determined by crushing the concrete cube specimens in the compression machine. The crushing was done with an increasing compressive load which was applied to the specimen until failure occurred. The maximum compressive load was recorded at the point where the cube starts to deform. Figure 7 shows compressive strength testing machine.

Figure 7. Compressive Strength Testing Machine

Test for Correlation between Strength and PKSA Percentage in the Mix

The study used Microsoft Excel 2013 version to test for correlation between the two variables; strength and PKSA percentage in a mix. Here, a scatter diagram was generated as well as correlation coefficient which tell how strong the relationship was. The result of the test is shown in Figure 12.

Test for Water Absorption

Water absorption is one of the durability properties of concrete which determines the water tightness of concrete. The test was conducted according to BS 1881-122:2011 where the concrete cubes were air dry and its weight measured after concrete has been de-moulded. The specimen was then submersed in water for 28 day, it was surface dry and its weight measured again. The differences in weight gives the water absorption rate of the specimen. Here, The lower the absorption, the better the result.

RESULTS AND DISCUSSIONS

Silt and Clay Test Analysis

This test was conducted to ascertain the fitness of the fine aggregate for concrete production. The allowable percentage of silt and clay for concrete should not exceed 16% by standard. The study recorded 7.93% of silt and clay which is within the limits, therefore, the sand is fit for concrete (IS 2386-Part II).

Sieve Analysis of Crushed Granite

Coarse aggregates used in concrete contain aggregates of various sizes. Proper gradation of coarse aggregates is one of the most import factors in producing workable concrete (Neville et al., 2010). Proper gradation ensures that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids so as to influence concrete strength and density. A well-graded aggregate has a gradation of particles size that fairly evenly spans the size from the finest to the coarsest and it is characterized by the S-shaped in gradation curve. From Figure 8, the gradation curve is S-shaped indicating the crushed granite for the study was well graded (Building Research Institute, 2016).

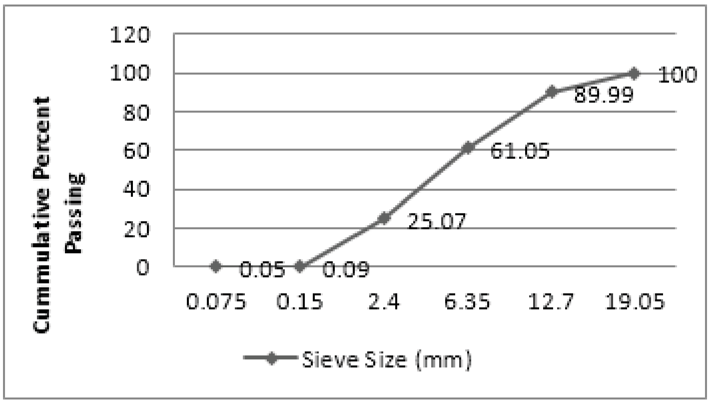

Figure 8. Particles distribution of crushed granite.

Particles Distribution of PKSA

Figure 9 below shows the particle distribution of PKSA. 100% of PKSA passed through the 0.6mm while 99% passed through 0.4mm sieve. The PKSA which passed through the 0.045mm was 31.3% being the least.

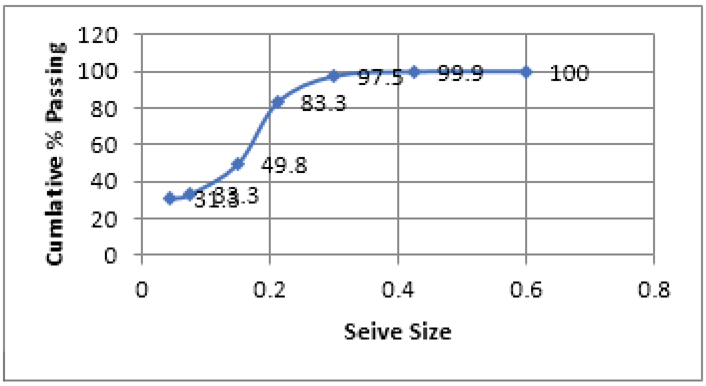

Figure 9. Particle Sieve Analysis of PKSA

Chemical composition of Palm Kernel Shell Ash (PKSA)

The result of the chemical analysis carried out on the palm kernel shell ash is presented on Table 1. According to Neville (2002), the raw materials used in the manufacture of Portland cement, consists mainly of lime, silica, alumina and iron oxide. The chemical analysis of the palm kernel shell ash reveals that it contains some quantities of these elements. The chemical constituents of the PKSA are Silicon (SiO2), Aluminium (Al2O3), and Iron Oxide (Fe2O3). The total amount of SiO2, Al2O3 and Fe2O3 present in the PKSA used for this research is 80.49% which is more than the minimum required 50% specified by the American Society for Testing and Materials (ASTM D5370-14) for type C ashes. Furthermore, this is also in line with ASTM C 618-78 which specifies a minimum requirement of (SiO2+ Al2O3 +Fe2O3 = 70%) for pozzolanas materials. It was seen that PKSA contains all the essential oxides present in OPC and these oxides are important for the properties of concrete. Igarashi et al., (2005) are of the view that when pozzolanic materials are incorporated to concrete, the silica present in these materials reacts with the Ca (OH)2 released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H), which improves durability and the mechanical properties of concrete. Hence, PKSA can be used effectively as a supplementary cementitious material.

The ash produced sometimes varies in tone of colour from whitish grey to darker shade based on the combustion method and the carbon content in it. In other words, the physical characteristic of PKSA is very much influenced by the operating system in the palm oil factory (Utsev and Taku, 2012). The colour of the PKSA was dark grey and this was due to environment the combustion took place. Figure 10 shows the ash of PKSA.

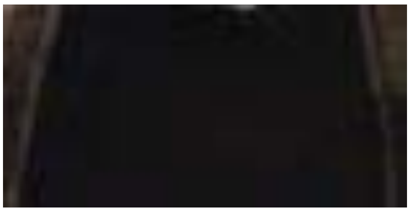

Figure 10. Ash of PKSA

Table 1: Chemical Composition of PKSA

Chemical Composition	OPC	PKSA
SiO2 (silicon)	22.13	63.05
Al2O3 (aluminium)	3.74	13.65
Fe2O3 (iron oxide)	2.97	3.99
CaO (calcium oxide)	63.36	4.27
MgO (magnesium oxide)	2.58	2.79
K2O (potassium oxide)	0.52	6.04

Workability

The result of the workability test is shown in Figure 11. Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labour and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding or segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs and or pockets may also be visible in finished concrete (Neville et al., 2010). According to Neville et al., (2010), workability is influenced by a number of factors which include: Water content in the concrete mix, Amount of cement & its Properties, Aggregate Grading (Size Distribution), Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.), Temperature of the concrete mix, Humidity of the environment, Mode of compaction, Method of placement of concrete and Method of transmission of concrete.

The degree of workability ranges from very low to high: 0-25 very low, 25-50 low, 25-100 medium, and 100-172 high (Neville et al., 2010). The slump results from the study were within the range of 50 to 64 which fall within the low range of 25 to 100. The slumps of the samples were seen to be increasing with increase in PKSA percentage. The slump of the concrete increased as the percentage of PKSA increases and decrease in comparison with the conventional concrete, Amu et al., (2011). Neville et al, (2010) reported that grading affects workability of concrete. The differences in the slump of samples was ± one, the differences may be due to operational error such as measuring of the water etc. There were no significant effects of PKSA replacement level on workability (slump).

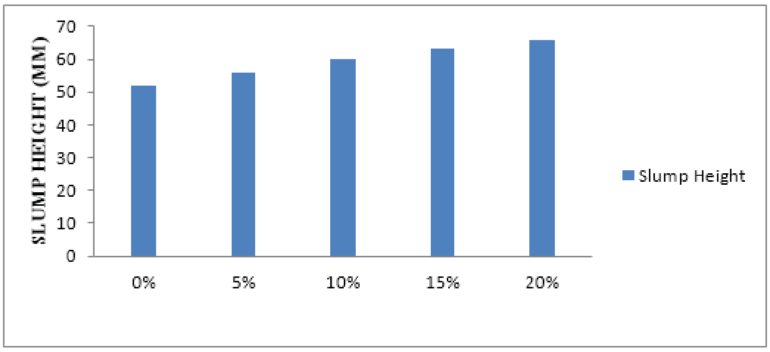

Figure 11: Summary of Workability Test on the Various Mix Ratios

Compressive Strength

Compressive strength test result is shown in Table 2. From the Table 2, the control (0%) yielded the highest compressive strength of 30.08N/mm2 (± 0.42). At 5% replacement of PKSA the strength was 17.29N/mm2 (± 0.34) which was reduced to 15.72 (±0.58) at 10% replacement. With 15% replacement of PKSA, the strength was 14.63N/mm2 (±0.49) which reduced to 12.26N/mm2 (±0.05) at 20% replacement of PKSA.

The targeted strength for the concrete mix design for the study was 30MPa. With the exception of the control, none of the four treated samples exactly hit the targeted strength. It was observed that there was reduction in strength as the percentage of PKSA increases. The reduction in strength was expected because the quantity of the chief compounds in the OPC was not the same with the PKSA. The strength pattern of PKSA concrete in this study was in line with other researchers such as Vignesh et al., (2013) who obtained decrease in compressive strength with increase in the percentage replacement of OPC with CSA Malhotra and Mehta, (2004). They investigated agricultural by-product pozzolans have been used in the manufacture and application of blended cements. Nimityongskul and Daladar (1995) highlighted the potentialities of coconut husk ash, corn cob ash, and peanut shell ash as good pozzolans. Elinwa and Awari (2001) successfully investigated the potentials of groundnut husk ash concrete by partially replacing Ordinary Portland Cement with groundnut husk ash.

Adesanya (1996) investigated the properties of blended cement mortar, concrete, and stabilized earth made from OPC and corn cob ash and recommended that corn cob ash can serve as replacement for OPC in the production of cement composites. Dwivedia et al. (2006) successfully investigated the pozzolanicity of bamboo leaf ash. Martirena et al., (1998) found that sugar industry solid wastes such as sugar cane straw ash has pozzolanic activity derived from its high content of amorphous silica. Many other researchers have confirmed rice husk ash as pozzolanic material that can be used to partially replace OPC in making cement composites (Cordeiro et al., 2009; Habeeb and Fayyadh, 2009; Rukzo et al., 2009).

Table 2 Compressive Strength of PKSA

Sample	N	Mean (N/mm^2)	Std. Dev.
0%	3	30.08	0.42
5%	3	17.29	0.34
10%	3	15.72	0.58
15%	3	14.63	0.49
20%	3	12.26	0.05

One common characteristic about these studies stated above which is in line with this current study is about the strength development in these agro by-product for partial replacement of OPC, all these studies recorded a reduction in strength with the increasing in the percentage of agro ash. Even though there was a reduction in strength of PKSA concrete, it was evident that 5% PKSA Concrete at 28 days curing age was 17.29N/mm2 meets the minimum required strength of concrete (10 to 40 MPa) at 28 days; it is therefore recommended for normal concrete works.

Strength versus PKSA Proportion in a Mix

Figure 12 shows the relationship between compressive strength and PKSA percentage replacement in concrete mix. It can be observed that there is a negative correlation between the two variables. The R2 = 0.7487 indicates that 74.87% of the variation in compressive strength can be explained by the percentage of PKSA in the concrete. It can also be noticed that the compressive strength of the PKSA $y = -76.6\chi + 25.656$, the value 25.656 is the constant for determining the compressive strength of PKSA concrete. The value -76.6 is the co-efficient of PKSA percentage in a mix which means that if the PKSA (χ) is increased by one unit, the strength will on average decrease by 76.6.

Furthermore, correlation coefficient was computed from the sample data using the Pearson Correlation Coefficient, it was found out to be -0.87 which indicate a strong negative correlation between the variable that is the association between strength and PKSA replacement is inversely proportion – as PKSA replacement percentage increases strength reduces (Bluman, 2004). The result was in line with Vignesh et al., (2014). They utilize coconut ash for partial replacement of OPC. Their study concluded a reduction in strength as the coconut ash in is increased in the mix proportion.

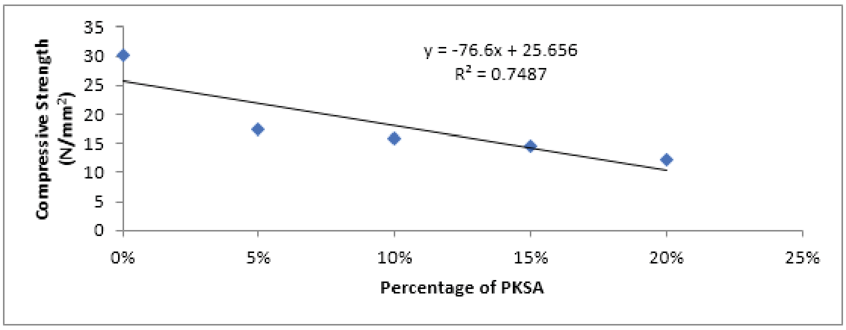

Figure 12: Strength versus PKSA Proportion in a Mix

Water Absorption of PKSA Concrete

From Table 4, it was observed that as the replacement levels of PKSA increases, there was a corresponding increase in water absorption rate. This is because; PKSA concretes retain water for a longer period before it starts to dry up slowly. PKSA concretes do absorb water faster than OPC concretes; thereby retarding hydration processes in the PKSA concrete. Considering the water absorption property of PKSA concrete, it is not recommended for substructure construction which is more likely to be susceptible to moisture.

According to ASTM C1585, water absorption is influenced by a number of factors which include concrete mixture proportions, the presence of chemical admixtures and supplementary cementatious materials, the composition and physical characteristics of the cementatious component and of the aggregate, the entrained air content, the type and duration of curing, the degree of hydration or age, the presence of micro-cracks, the presence of surface treatment such as sealers or form oil and placement method such as consolidation and finishing. This study was in line with Nagalakshmi (2013) who obtained higher water absorption as the percentage of fly ash increases.

Table 4: Water absorption of PKSA

Sample	N	Mean (%)	Std. Dev.
0% (Control)	3	0.047	0.005
5%	3	0.049	0.004
10%	3	0.056	0.001
15%	3	0.058	0.001
20%	3	0.090	0.001

Density of PKSA concrete

The density of concrete is determined largely by the type of aggregate and the cement used in the mixture. Enrique, (1966) reported that since aggregates, cement, water and air have different specific weights, the overall density of any concrete mix depends largely on the relative amount of these materials present. The average density of PKSA concrete cubes ranged between 2167Kg/m3 and 2088Kg/m3as shown in Figure 13. It was observed from the research that, the control obtained the highest of 2167Kg/m3. The density kept reducing as the percentage of PKSA increases. This was expected, since the density of cement is higher than that of the PKSA. This is in line with Vignesh et al., (2014), who had average density decrease with percentage replacement from 2525.5Kg /m3 for OPC to 2314Kg / m3, at 30% replacement.

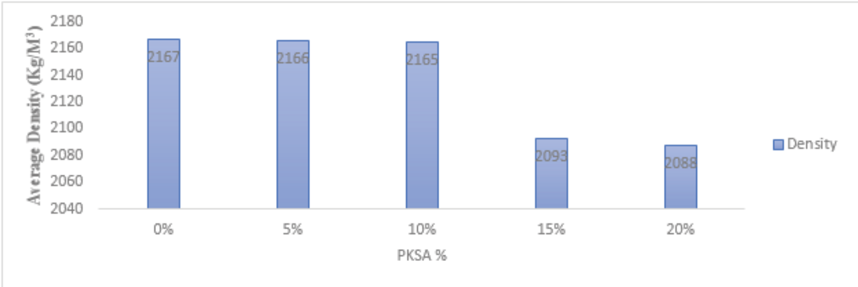

Figure 13. Density of PKSA Concrete

Relationship between density and compressive strength of PKSA Concrete
The mechanical properties of concrete are highly influenced by its density. A denser concrete generally provides higher strength and fewer amount of voids and porosity (Iffat et al., 2015).

The densities of the various replacement levels of PKSA with their corresponding compressive strength were compared to test if there is a correlation between them using the Pearson correlation coefficient. From Table 4 in the previous chapter, Pearson correlation coefficient was computed to be 0.63 using Excel indicating a correlation between the variables.

From Table 5, it was observed that as the PKSA percentages are increased in the mix, it showed a reduction in strength as well as density. The result was in line Iffat et al., (2015) that there is a relation between concrete strength and density.

Table 5: Relationship between Density and Compressive Strength of PKSA Concrete

Sample	Compressive Strength (N/mm^2)	Density (Kg/m^3)
0%	30.08	2167
5%	17.29	2166
10%	15.72	2165
15%	14.63	2093
20%	12.26	2088

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

Summary of Findings
From the research, the following findings were revealed.

The PKSA has most of the chemical constituent present in OPC cement but in varying quantity. The constituent includes silicon, aluminium, iron oxide, calcium oxide, magnesium oxide and potassium oxide. The colour of the PKSA was dark grey.

The replacement of PKSA in the mix design made concrete workable relatively to the control concrete. The introduction of PKSA in the concrete mix saw a decline in the 28 days compressive strength. The reduction in strength was expected because the quantity of chief components in OPC was not the same with the PKSA.

The relationship between strength and PKSA proportioning in the mix was inversely proportional, that is as PKSA percentage in the mix increases; there was an average reduction of strength by 47.08%. The PKSA concrete absorbed more water than the control (plain concrete). There was also a reduction in density with the addition of PKSA relative to the control.

Conclusion
The focus of study was to find a replacement for cement in concrete production. From the findings obtained, it is evident that PKSA has some basic parameters that could improve some properties of concrete when used in partial replacement of cement.

Recommendations
These recommendation have been made following the result from the study:

- Since PKSA concrete has high water absorption rate, it is not recommended for moisture prone areas.
- With the addition of the PKSA made concrete relatively workable, it can serve as plasticizer.
- The replacement of PKSA in concrete saw a decline in strength, however, it is recommended that replacement rate of 5% is good for normal concrete works.
- There are various varieties of palm oil fruits such as dura, tunera and pisifera, it is recommended that a further study should be conducted to see the chemical composition of these fruit and in relation to OPC.

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