Characteristics of Palm Kernel Shell-Concrete

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Abstract:

An experimental investigation on the use of palm oil shell (PKS) as partial replacement by wt. % of crushed aggregate has been evaluated. A mix ratio of 1: 1.5: 3 with a cement content of 382 kg/m^3, and water-cement (w/c) ratio of 0.55, was used for concrete specimen. Four concrete mixes labeled M-00 to M-30, at replacement intervals of 10 %, were used to fabricate concrete specimens that were cured above the conventional age of 28 days (i.e. up to 90 days), before testing. The microstructure results showed that PKS used had acceptable qualities within the specified limits of lightweight aggregate, and both the workability and compressive strength of the PKS-concrete decreased as the percentage replacement was increased. It was observed that curing above the conventional age of 28 days, additional improved the strength of the concrete specimens. The optimum replacement level was at 10 %., and a linear regression model that was significant with good correlations of the statistical data was developed.

Keywords:

Palm Kernel Shells, Aggregates, Compressive Strength, Microstructure, Statistical Interpretations

1. Introduction

The development and construction pressures on our conventional materials, and the growing needs for sustainability, have opened up new areas for research, thus motivating researchers to focus their investigations on the use of waste or recycled materials for potential use as construction materials. For some years, palm kernel shells (PKS) as replacement material for normal weight aggregate (NWA) have attracted the interest of researchers in the palm oil producing nations for use in the concrete industry. Tables 1 and 2 are reproduced from the review works on PKS [1] where details on their characteristics are given. However, some of the highlighted setbacks in the optimal utilization of PKS are: developing adequate and reliable technology for its production [1] and also, the need for proper documentations of every process and data generated.

Nigeria is a leading producer of palm oil ranking 4th largest in the world, and accounting for 3% of the world's production. PKS is a waste product at the time of extracting oil from oil palm tree [2,3]. This needs to be economically and environmentallydisposed to avoid environmental nuisance and therefore, to preserve the environment, researchers have taken initiative to utilize PKS as a replacement aggregate for the normal weight aggregate (NWA). Alengaram et al [1] has given a compressive review of the utilization of oil palm kernel shell as lightweight aggregate in concrete. The review showed that OPKSC has compatible mechanical properties and structural behaviour to normal weight. They opined that OPKSC can be produced to medium and high strength concrete, and equally of note, mentioned in the review, was that sustainability issues combined with higher ductility and aggregate interlock characteristics of OPKSC compared to NCW have been the recent thrust in many researches that have been mounted to further investigate the use of OPKSC as LWA.

Daneshman and Saadatian [4] studied the influence of oil palm shell (OPS) on workability and compressive strength of high strength concrete. They used OPS at replacement levels of 10 % to 50 % by wt. % of the coarse aggregate, and cured the specimens for 28 days, and concluded that the rate of workability for OPS samples showed a relatively medium to high workability, ranging from 28 mm to50 mm, with compressive strength reaching up to 52 N/mm^2 for 28 days. The optimum replacement at this strength was 30 % wt. % of NWA.

Zarina Itam et al [5] investigated the feasibility of using palm kernel shell as LWA for concrete production in proportions of 1: 1.41: 3.81, w/c of 0.45, and a replacement level of 0 % to 100 % by wt. % of coarse aggregate, to produce concrete specimens that were cured in water for 7, 14 and 28 days. Some of their conclusions were that using PKS increased the water absorption and decreased both the workability and compressive strength. Their results fell into the range acceptable for LWA, and thus they concluded that there is potential to use PKS as aggregate replacement for lightweight concrete.

The experimental investigations on the effects of replacing crushed granite in concrete with PKS on the strength, density and workability was reported by [6]. They used two mixes batched by volume and weight in the ratios of 1:2:4 and cured for 7, 14, 21 and 28 days. The results obtained showed that the compressive strength, density and workability of PKS concrete decreased as the percentage replacement was increased.

Teo et al [7] worked on the structural concrete using oil palm shell (OPS) as lightweight aggregate. A mix of 1: 1.66: 0.60, comprising of cement: fine aggregate: oil palm shell was used. The cement content was 510 kg/m^3 and water-cement ratio was 0.38. They used superplasticizer of dosage 1.41/100 kg cement, and the OPS aggregate was mixed at saturated surface dry (SSD) condition based on 24 h submersion in potable water. They reported on the compressive strength, bond strength, modulus of elasticity, and flexural behaviour of OPS concrete. The results showed that OPS have good potentials as coarse aggregate for the production of structural lightweight concrete. The full-scale beam tests showed that the deflection ranged between 252 and 263.

Chai et al [8] substituted normal weight coarse aggregate with dry oil-palm-boiler clinker (OPBC) aggregates up to 75 % (by volume) in a high strength normal weight concrete. They used a mix of 1: 1.52: 1.82, a water-cement ratio of 0.34, and

SP dosage of 5 kg/m^3, and cured from 1 to 56 days. The effectiveness of this substitution on the properties of the concrete such as workability, density,, compressive and splitting tensile strengths, and modulus of elasticity was studied. They therefore concluded that concrete containing 50 % OPBC can be considered as semi-lightweight concrete with high strengths and that splitting tensile strength with modulus of elasticity were reduced.

Traore et al [9] contributed to the knowledge of oil palm shells (OPS) concrete by studying the physical, mechanical and thermal behaviour of the concrete specimens. They used concrete mix of 1: 1.66: 1.19 and water-cement ratio of 0.4, and SP dosage of 4 % to 7.15 %, was applied to the different mix to maintain a slump range of 0-20 mm. A cement content of 550 kg/m^3 and OPS of 0 %, 50 % and 100 % were used, and the specimens cured for 28 days. The results showed that replacing crushed granite aggregate by OPS increased the apparent porosity of the concrete, and they concluded that this behaviour made the concrete lighter, and thus, the concrete mechanical strength was lower.

As stated earlier, there is need for process understanding, and a unified technological documentation on the use of PKS. These are primarily for the benefits of the construction and concrete industries, and in the application of our design codes.Therefore, the thrust and interest of this research is to further study and analyse the effects of this material in concrete when curing is extended beyond the conventional age of 28 days (see review woks by [1, 10]. The work therefore studied the density, water absorption, compressive strength and microstructure of PKS-concrete for the periods of 90 days.

Table 1. *Physical properties of OPKS aggregate [1].*

Name of author (year)	Specific gravity	Loose bulk density (kg/m^3)	Compacted bulk density (kg/m^3)	Moisture content (%)	Water absorption 24h (1h) %	Porosity (%)
Abdullah (1984)	-	-	620	-	-	-
Okafor (1988)	1.37	512	589	-	27.3	
Okpala (1990)	1.14	545	595	-	21.3	37
Basri et al (1999)	1.17	-	592	-	23.32	-
Mannan and Ganapathy (2002)	1.17	-	592	-	23.32	-
Teo et al (2006)	1.17	500-600	-	-	33	-
Ndoke (2006)	1.62	-	740	-	34	28
Jamaat et al (2008)	1.37	566	620	9	23.8	-
Mahmud et al (2009)	1.27	-	620	8-15	24.5 (10-12)	-
Alengaram et al (2010a)	1.27	-	620	-	25	-
Gunasekaran et al (2011)	1.17	-	590	-	23-32	-
Shafigh et al	1.22	-	683	-	7.65 & 9.70	-

(2012) [10]					[10 & 30 min]	
Shafigh et al (2012) [10]	1.22	-	683	-	10.20 & 18.73 [1 & 24h]	-
Poh-yap et al (2017) [11]	1.37	-	635	-	24	-
Traore et al (2017)[9]	1,340 (kg/m^3)	560	-	-	23.3	-
Chai et al (2017) [8]	1.9	-	1409	-	2.31 [30 min], 4.11	-

Table 2. *Mechanical properties of oil palm kernel shell [1].*

Name of author (year)	Abraison Value (LOS Angeles) %	Aggregate Impact Value (AIV) %	Aggregate Crushing Value (ACV) %
Okafor (1988)	-	6	10
Okpala (1990)	3.05	-	4.67
Basri et al (1999)	4.8	-	-
Mannan and Ganapathy (2001, 2002)	4.8	7.86	-
Olanipekun (2005)	3.6	-	-
Teo et al (2006)	4.9	7.51	8
Ndoke (2006)	-	4	-
Jamaat et al (2008)	8.02	3.91	-
Mahmud et al (2009)	3.91	3.91	-
Mannan et al (2006)	-	1.04 – 7.86	-
Poh-Yap et al [11]	5	2.11	-
Traore et al [9]	13	-	-

2. Materials

The cement used is Ashaka Portland cement. The physical and chemical properties of the cement are shown in Table 3 and Table 4. It conformed to BS EN 196-3 [12]. The fine aggregate used was river sand, free from deleterious matters and has a specific gravity of 2.64, bulk density of 1528 kg/m^3, and moisture content of 0.42. The fine aggregate is uniformly graded and falls into zone 2 of the grading curve. Table 5 is the sieve analysis of the fine aggregate. The coarse aggregate was sourced from a quarry site in Bauchi town and has a maximum size of 20 mm. The characteristics of the coarse aggregate and PKS are shown in Table 6, while Table 7 is the particle size distribution. Both the fine and coarse aggregates conform to BS EN 1097 [13]. The palm kernel shell used was sourced from Ekpoma, Edo State, Nigeria. Ekpoma is a town in the savannah region, in the southern part of the country.

Table 3. *Physical Properties of Ashaka PC.*

Parameter	**Value**
Specific gravity	2.98
Bulk density (kg/m3)	1475
Specific surface area (Blaine) m2/kg	355
Loss on ignition (%)	1.51

Moisture content	0.39
pH	12.4

Table 4. *Chemical Properties of Ashaka PC.*

Oxide Composition	Percentage by Weight (%)
CaO	62.12
SiO_2	20.69
Al_2O_3	6.14
Fe_2O_3	2.32
SO_3	1.63
MgO	1.22
Na_2O	0.9
K_2O	1.01

Table 5. *Sieve Analysis of Fine Aggregate.*

Sieve size	Cumulative % Passing
5.00mm	_
2.00mm	93.00
1.18mm	78.00
600µm	43.80
300 µm	20.40
150 µm	8.20
63 µm	8.16
Pan	0.00

Table 6. *Characteristics of the Coarse Aggregate and Palm Kernel Shells.*

Physical Properties	Gravel	PKS
Specific gravity	2.75	1.33
Bulk density (kg/m^3)	1,714	694
Water absorption (%)	0.04	17.48
Void ratio	0.38	0.48
Porosity	0.27	0.32
ACV (%)	3.69	0.36
AIV (%)	7.28	1.91

Table 7. *Particle Size distribution of the Coarse Aggregate and Palm Kernel Shell.*

Sieve size(mm)	Cumulative Passing (%)	
	Coarse Aggregate	Palm kernel shell
75	-	-
63	-	-
50	-	-
37	-	-
28	-	-
20	94.4	-
14	65.9	98.5
10	24.9	64.8
6.3	3.7	10.7
5	1.5	3.1
3.35	0.6	1
Pan	0	0

3. Experiments

The properties examined were the workability, compressive strength and microstructure of the PKS-concrete Experiments were mounted using a concrete mix ratio of 1: 1.5: 3, with a cement content of 382 kg/m3 and water-cement ratio of 0.55 (Table 8). For the slump and compressive strength tests, four mix parameters were used and labeled M-00, M-10, M-20, and M-30, respectively. The mix labeled M-00 was the control, while the rest were having the various replacement levels of PKS by wt % of the crushed aggregate.

Table 8. *Concrete Mix Proportions.*

Mix type	Cement (kg/m^3)	PKS (kg/m^3)	Sand (kg/m^3)	Cement (kg/m^3)	Water (kg/m^3)	W/C
M-0	1265	----	543	382	210	0.55
M-10	1138.5	126.5	543	382	210	0.55
M-20	1012	253	543	382	210	0.55
M-30	885.5	379.5	543	382	210	0.55

3.1. Slump of PKS-Concrete

Workability is the ability of fresh concrete to flow and properly fill the formworks. It was measured using the slump cone. The cone was placed on a horizontal, non-absorbent and rigid base and filled up with fresh concrete with 25 strokes of a tamping steel rod. Immediately after, the vertical difference between the top of the mould and the displaced slumped specimen is measured. The difference is the slump and indicates the flowing ability of the concrete. The results are shown in Table 9.

Table 9. *Slump Test Values.*

Mix type	Slump (mm)
M-00	15
M-10	10
M-20	5
M-30	5

3.2. Compressive Strength of PKS-Concrete

The compressive strength test was carried out using mould cube sizes of 100 mm, and tested in accordance with ASTM C192/C192M [14]. They were cured for 3 days to 90 days before testing to failure using a motorized ELE-machine. At the end of each curing regime, three samples were tested to failure and the average recorded. The results of cube compressive strengths are shown in Table 10.

Table 10. *Compressive Strength of PKS-Concrete.*

Mix No	3 d	7 d	28 d	60 d	90 d
M-00	17.9	21.3	24	28.3	33.8
M-10	22.2	23.3	24	24.8	26.5
M-20	12.9	14.5	16.9	19	21.2
M-30	8.5	10.4	11.8	13.3	15.6

3.3. Microstructure of PKS-Concrete

For the microstructure test, crushed samples from the compressive strength tests were used for each of the cured specimen. The tests were performed on the control specimen and the sample with the optimum replacement level (M-10). The results are shown in Table 11.

Table 11. *Microstructure of PKS-Concrete.*

Mix No	Parameter	3 d	7 d	28 d	60 d	90 d
M-00	Porosity	30	27	20	8	4
	Unhydrated cement	16	15	9	5	2
	Calcium hydroxide (Ca(OH)2)	25	19	13	11	5
	Calcium silicate hydrate (CSH)	43	46	74	90	91
M-10	Porosity	27	25	15	7	4
	Unhydrated cement	15	14	9	5	3
	Calcium hydroxide (Ca(OH)2)	14	10	8	3	2
	Calcium silicate hydrate (CSH)	46	54	57	64	71

4. Discussions

4.1. Physical and Mechanical Properties of PKS as Aggregate

The physical properties of the PKS used in this work are shown in Table 6 and has a specific gravity of 1.33. This value is approximately 48.4 % of the crushed aggregate used. The published range for PKS in the literature is around 1.17–1.62 [1] and thus, the value from this research falls within the specified range for all PKS. The particle size distribution (Table 7) is in the range of 3.35 mm to 14 mm. The same value of range has been reported in [1]. The PKS has a bulk density of 694 kg/m^3 as compared with 1714 kg/m^3 of the crushed aggregate. This is approximately 41 %. The reported values of loose and compacted bulk densities in the literature are in the range of 600 – 740 kg/m^3, respectively [1], and the water absorption is 17.48 % as against 0.04 % for crushed aggregate. The mechanical properties of PKS change depending on their physical properties. The water absorption of crushed aggregate in the literature is in the range 0.5-1 %, and well above the 0.04 % for this research. The void ratio and porosity are given as 0.48 and 0.32, as against the values of 0.38 and 0.27, respectively for the crushed aggregate. This shows that the crushed aggregate is more compact than the PKS. This may be attributed to the irregular shapes of the PKS.

The mechanical properties of PKS such as aggregate crushing value (ACV) and aggregate impact value (AIV) are 0.36 % and 1 91 %, respectively. These are 9.8 % and 26.2 % approximately of the crushed aggregate. Table 2 shows the results obtained by previous researchers on PKS. It has been reported that the abrasion resistance of light weight aggregate (LWA) are inferior to natural weight aggregate (NWA), and this is due to lower stiffness of LWA [1]. The range of abrasion values for PKS aggregate is 3-8 % as compared to the crushed aggregate of 20-25 % (Table 2).

4.2. Slump of PKS-Concrete

Figure 1 shows the slump of PKS-concrete. The slump decreased as the percentage replacement of PKS by wt. % of crushed aggregate increased. The workability of the PKS-concrete therefore is decreased. Daneshmand and Saadatin [4] also reported the same observation of reduction in slump as PKS increased. The slump test is the standard test for workability of concrete. It measures the consistency according to ACI 116R [15]. The attributed reason for the decrease was due to the specific surface of the PKS, and thus would require more cement paste for proper lubrication of the aggregate, therefore reducing the fluidity of the mix [6].

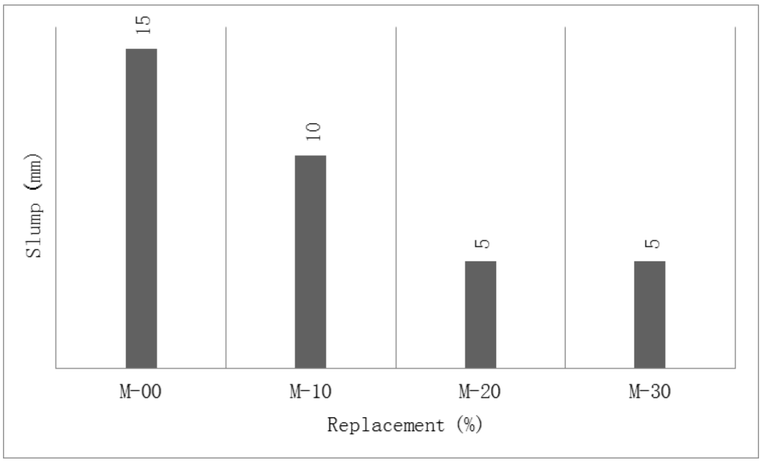


Figure 1. *Slump of PKS-Concrete.*

4.3. Compressive strength of PKS-Concrete

The compressive strength of PKS-concrete is shown in Figure 2. It showed that as the replacement levels increased, the compressive strength decreased. The differences in strength development as curing proceeded, with the control mix are further shown in Figure 3. These are given as: + 24 %, - 28 % – 53 %, (3 days); + 9 %, - 32 % – 51 % (7days); 0 %, - 30 %, – 51 % (28 days); - 12 %, -33 %, – 53 % (60 days), and – 22 %, -37 % -54 % (90 days), respectively. This is to say, there was a positive increase in strength above the control from 3days to 28 days, and a decrease of 12 % at 60 days and 22 % at 90 days, at 10 % wt. % of NWA. The reductions in strength have been attributed to many factors and these could be due to PKS having lower strengths compared to the crushed aggregate, the irregular shapes of the PKS which could prevent adequate compaction, and the bonding between PKS and cement paste because of the smooth surfaces of the PKS [16]. It was equally important to note that 10 % t gave the best strength, and that curing at this replacement above 28 days, was approximately 3 % for 60 days and 10 % for 90 days, respectively. This showed that extending the period curing can also contribute to strength development.

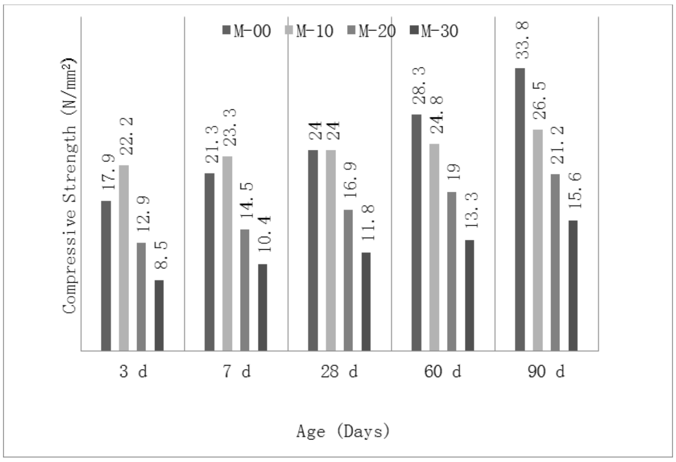


Figure 2. *Compressive Strength of PKS-Concrete.*

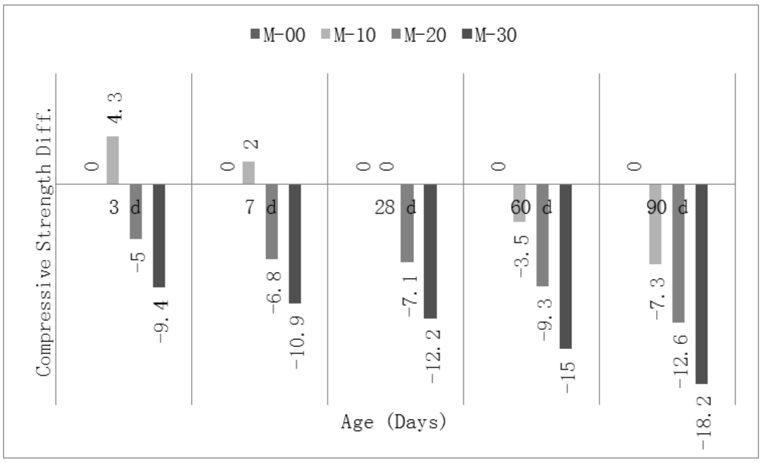
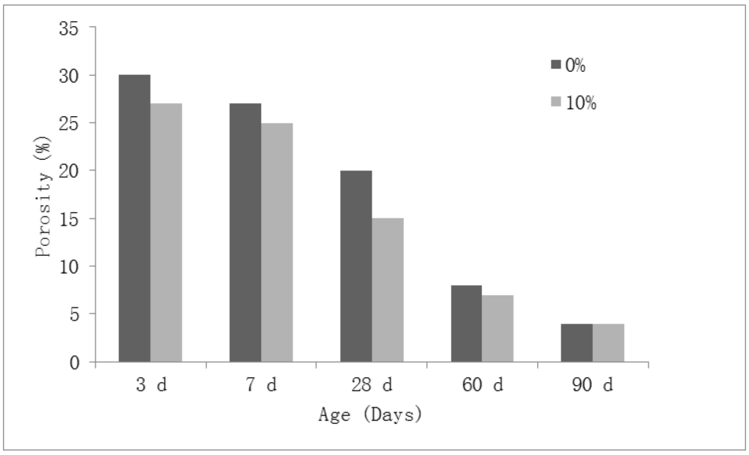


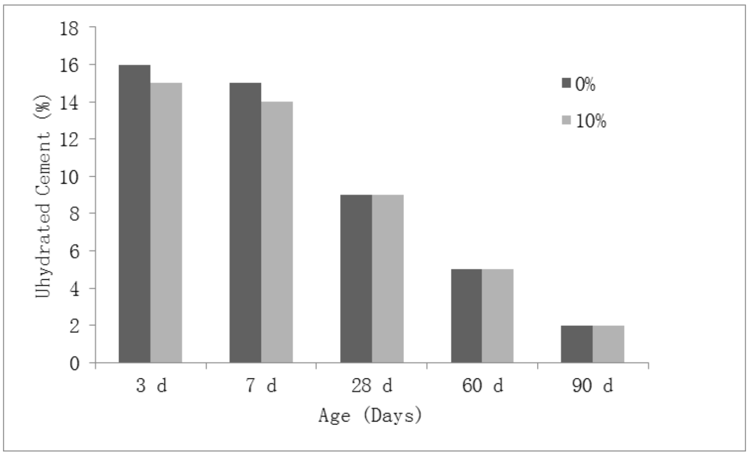
Figure 3. *Strength Development Difference.*

4.4. Microstructure of PKS-Concrete

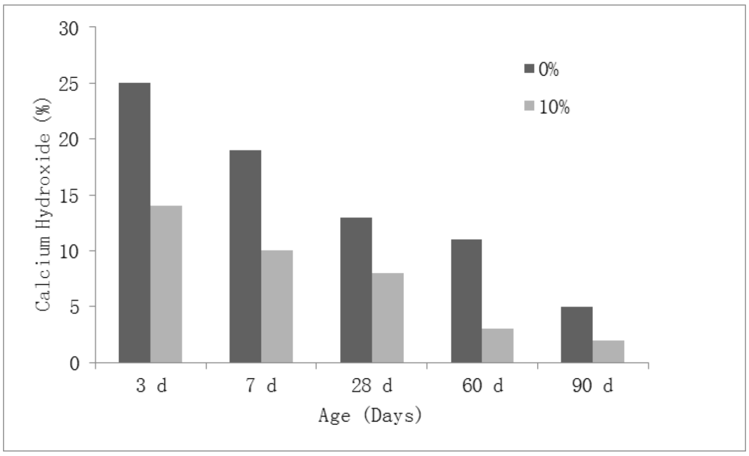
Figure 4 (a-d) showed the effects of PKS addition on the concrete specimens. It was observed that porosity, unhydrated cement, and calcium hydroxide decreased in quantity as curing proceeded (a-c). We know that decrease in these parameters will improve the compactness of the concrete and the water absorption of PKS-concrete. Equally, the decrease in $Ca(OH)_2$ showed that the risk in corrosion is minimized. The C-S-H increased with curing and this is a property that is responsible to impact strength. This was well established at the optimum replacement, where strength continued to increase above the strength achieved at 28 days.



(a)



(b)



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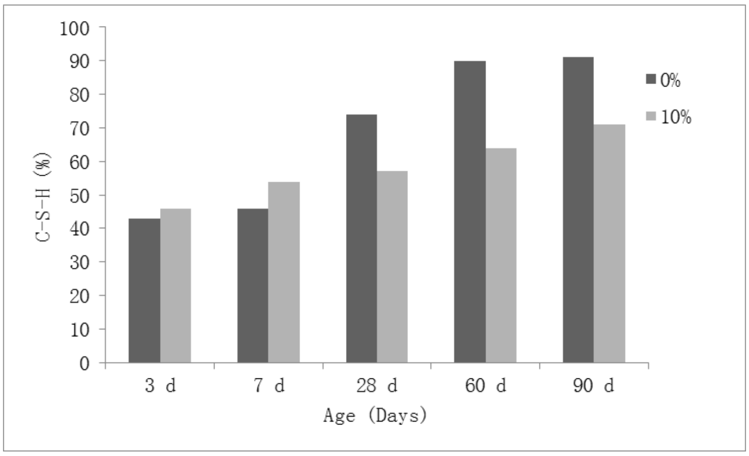


(d)

Figure 4. *Microstructure of PKS-Concrete.*

5. Descriptive Statistics

Tables 12, 13, and 14, showed in details the various degrees of performances and interactions of the PKS-concrete, carried out using the Minitab 17 Software. Tables 12a and 12b are the statistical parameters for the within-test, and the between-test results. The within-test is the variation that occurred in the cement matrix as curing proceeded within the same mix. Thus, this was for a particular mix, measured along the row. The between-test is test down the column, involving different mixes, and measured at the same age of curing. This is termed the batch to batch measurement. Measurements were made on the mean, standard error of the mean (SE.Mean), standard deviation (St.Dev) and coefficient of variation (Coef.Var).

The mean value characterizes the central tendency or location of the data. These ranged from 11.92 to 25.06 for the within-test, and 14.00 to 22.54, for the between-test. The within-test value for the coefficient of variation ranged from 6.70 to 24.71, while the between-test is from 34.21 to 42.88. The coefficient of variation provides a general feeling about the performance of a method and its distribution around the mean, and expresses the variation as a percentage of the mean. Thus, the larger the coefficient of variation is, the greater the spread in the data. The standard error, standard deviation and variance for the within- and between-tests are 0.72-2.77/2.68-3.47, 1.62-6.19/6.0-7.76, and 2.62-38.35/36.04-60.15, respectively. The standard error of the mean (SE Mean) estimates the variability between sample means, and the standard deviation and thus, establishes a benchmark for estimating the overall variation of a process. Whereas, the standard error of the mean estimates the variability between samples, the standard deviation measures the variability within a single sample. The variance (standard deviation squared) measures how spread-out the data are about their mean. A higher standard deviation value indicates greater spread in the data. The greater the variance is the greater the spread in the data.

Table 12a. *Descriptive Statistics for Within-Test Data.*

Mix No	Mean	SE Mean	StDev	Variance	CoefVar
M-00	25.06	2.77	6.19	38.35	24.71
M-10	24.16	0.72	1.62	2.62	6.7
M-20	16.9	1.49	3.34	11.17	19.77
M-30	11.92	1.21	2.71	7.37	22.77

Table 12b. *Descriptive Statistics of PKS-Concrete for Batch to Batch.*

Age (Days)	Mean	SE. Mean	St.Dev	Variance	CoefVar
3	14	2.68	6	36.04	42.88
7	15.98	2.71	6.05	36.59	37.85
28	17.7	2.74	6.12	37.41	34.56
60	19.74	3.02	6.75	45.59	34.21
90	22.54	3.47	7.76	60.15	34.41

Tables 13a and 13b are the Pearson correlation and p-value structure used to model the fact that repeated measurements on individuals are potentially correlated (and therefore is dependent). It is a [3 x 3] and [4 x 4] matrix, respectively, and it can be said that the variables were strongly correlated and very significant, with *p*-values in brackets, for both the within- and in between-tests.

Table 13a. *Pearson Correlation and P-Value of PKS-Concrete for Within Test Data.*

Mix No	M-00	M-10	M-20
M-10	0.996 (0.000)	-	-
M-20	0.991 (0.001)	0.984 (0.002)	-
M-30	0.996 (0.000)	0.997 (0.000)	0.994 (0.001)

Table 13b. *Pearson Correlation and P-Value of PKS-Concrete for Batch to Batch.*

Age (Days)	3	7	28	60
7	0.990 (0.001)	-	-	-
28	0.967 (0.007)	0.991 (0.001)	-	-
60	0.904 (0.035)	0.952 (0.012)	0.983 (0.003)	-
90	0.828 (0.083)	0.897 (0.039)	0.943 (0.016)	0.987 (0.02)

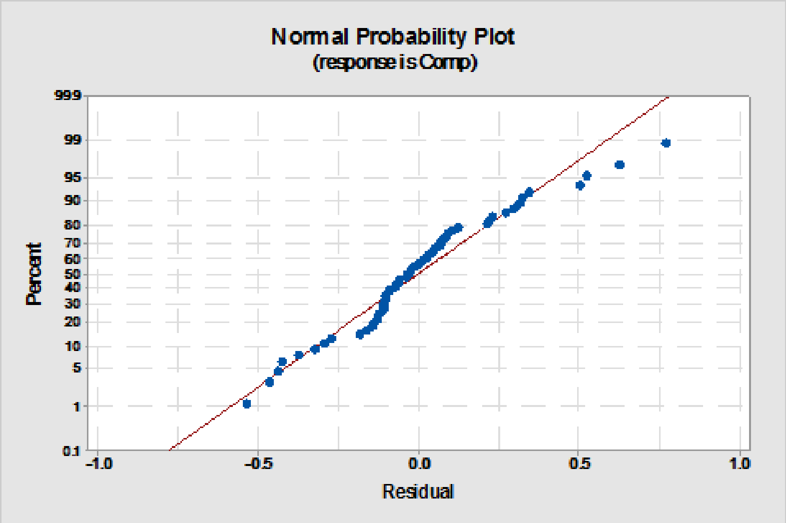
Tables 14a and 14b are the covariance for the within- and between-test data. It is a [4 x 4] and [5 x 5] matrix, respectively. Covariance is a measure of how changes in one variable are associated with changes in a second variable. Specifically, covariance measures the degree to which two variables are linearly associated. In this case, the mix and the age of the concrete are the variables. Table 14a showed levels of interactions between each mix with other mixes. The interactions of the various mix with the control (M-00) showed that as the replacement increased, interaction slowed down. The between test (batch to batch) interactions showed that as the curing increased the interactions of the mix continued to increase (Table 14b). This showed a good reflection of the hydration process and tied to the strength development of PKS cement concrete.

Table 14a. *Covariance of PKS-Concrete for Within Test Data.*

Mix No	M-00	M-10	M-20	M-30
M-00	38.35	-	-	-
M-10	9.99	2.62	-	-
M-20	20.51	5.33	11.16	-
M-30	16.74	4.38	9.01	7.37

Table 14b. *Covariance of PKS-Concrete for Batch to Batch Data.*

Age (Days)	3	7	28	60	90
3	36.04	-	-	-	-
7	35.95	36.59	-	-	-
28	35.5	36.67	37.41	-	-
60	36.63	38.89	40.6	45.59	-
90	38.55	42.08	44.71	51.7	60.15



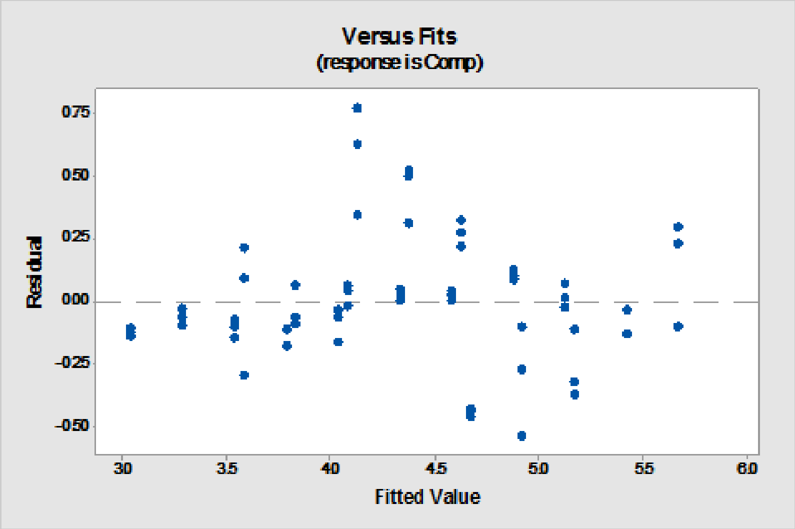


Figure 5. *Linear Regression Model of PKS-Concrete.*

A linear regression model for the compressive strength was also developed using the Minitab 17 Software. The Box-Cox transformation (λ) = 0.5, was applied to the compressive strength data, and the derived model is given as: $(comp)^{1/2} = 4.96 - 0.54\,mix + 0.25\,age$, with a standard deviation (s) of 0.257, and a correlation factor (r^2) of 88.74 %, r^2 (*adj*) = 88.35 % and r^2 (*pred*) = 87.45 %. This showed an interaction between the mix and age of approximately, 88 %. The analysis of variance (ANOVA) showed that the regression model, mix and age are significant with a *p-value < 0.00*. The coefficients of the transformed response for the constant, mix and age, are very significant with *p-values of 0.00*. Figure 5 shows the residual plots for the linear regression model chosen.

6. Conclusions

The effects of using PKS as partial replacement by wt. % of crused aggregate in various proportions for the production of concrete have been evaluated. The following are the conclusions:

The physical and mechanical properties of the PKS used for this work fall within the specified limits for lightweight aggregate.

The workability of PKS-concrete decreased as replacement level was increased. This effect was attributed to the specific surface of the PKS.

The compressive strength of PKS-concrete decreased as the percentage replacement increased, and the optimum replacement level was at 10 %.

The reduction in strength have been attributed to factors like PKS lower strength, irregular shapes and poor bonding of the cement paste.

Curing PKS-concrete above the conventional age of 28 days increased strength minimally from 3 % at 60 days to 10 % at 90 days.

The use of PKS modified the microstructure of the PKS-concrete

The statistical evaluations of the data derived on the PKS-concrete, showed concrete of adequate quality, and the derived model is significant.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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