1st International Civil Engineering Conference (ICEC 2018)
Department of Civil Engineering
Federal University of Technology, Minna, Nigeria

Statistical Modeling of Compressive Strength of Ordinary Portland Cement concrete with Rice Husk Ash

*Mustapha, G. A.[1]; Aguwa, J. I.[2]; Bala, A.[3]
[1] Department of Civil Engineering, Federal University of Technology, Minna
[2] Department of Civil Engineering, Federal University of Technology, Minna
[3] Department of Civil Engineering, Federal University of Technology, Minna
*Corresponding author email: mgabdul1@yahoo.com

ABSTRACT

The study aimed at developing a model function to analyse the statistical data of the compressive strength of an ordinary Portland cement concrete with 15% replacement of cement with RHA. A total of twenty (20) concrete cubes were produced and cured for 28 days and the compressive strengths were plotted against cube weights. Regression analysis was then used to analyse the experimental values. R^2 values between 31-44% were recorded from the different models. It was observed that the polynomial function has the highest coefficient of determination to the experimental values. The linear function shows the least statistical values of 1.39 for standard deviation and 0.15 for coefficient of correlation. The mathematical models developed are in conformity with experimental values with minimal variability.

Keywords: *Aggregate, Cement, Compressive strength, Mean Strength, Rice husk.*

1 INTRODUCTION

Concrete is a mixture of water, cement, aggregate and admixtures, which are used to improve certain properties of concrete in its fresh or hardened state. In every concrete or composite construction, the strength of concrete is unavoidably an integral design factor. Though, durability due to environmental conditions, flexural and tensile strength ability are also important factors. BS 8110: Part 1specified strength requirement in terms of characteristic strength with a certain level of probability of the strength falling less than it. Typically, 5 per cent or 1 in every 20 chance of cube strength is expected to fall below the characteristic strength at 28 days of curing in water (Jackson and Dhir, 1996).

Concrete is an essential civil engineering material, its strength is dependent on various properties of its constituent materials, construction methods adopted, loading and environmental conditions to which it will be subjected to during its life time (Deepa et al, 2010). The production of concrete to meet certain requirements is not void of certain level of variability in the construction method as well as materials involved, which consequently affect the desired outcome in terms of strength variations for a concrete mix. Therefore, the need for quality control measures aim at limiting as much as possible the variability inherent in it. Statistical quality control methods provide a scientific approach to understand the variability of materials and processes with regards to specifications with proper tolerance to cater for unavoidable variations.

The use of artificial pozzolans as Supplementary Cementitious Materials (SCMs) in concrete production has necessitated the need to study the strength of pozzolanic concrete using statistical modeling to determine the effects of its constituent materials. The coefficient of determination R^2 is defined as the **proportion of the total variation in Y "explained" by the** regression of Y on X. it ranges from 0 when estimated regression model explains none of the variation in Y to 1 (when all points lie on the regression line) (Mahmoud, 2012).

Abdullahi et al. (2017) adopted a linear polynomial model in their study of modified water-cement ratio law for compressive strength of rice husk ash concrete to examine the age long water-cement ratio law of Ordinary Portland Cement (OPC) concrete to cater for concrete with rice husk ash. They conducted test on one hundred and fifty (150) concrete cubes focusing on the water-binder ratio at six (6) different replacement levels (5%, 10%, 15%, 20%, 25%, and 30%) of OPC with RHA. It was concluded from their studies that the model fitted adequately into the experimental data with an adjusted coefficient of determination of 73.0%.

Ettu et al (2016) conducted a research on the tensile strengths of concrete containing rice husk ash using different incineration methods. Three different percentage replacement level (5%, 10% and 15%) of OPC with RHA at curing ages of 28, 90 and 150 days were adopted for the model analysis. Regression analysis of OPC-RHA concrete confirms the 95%

adequacy of the model prediction of the split tensile strength.

Mahmoud (2012) in his study presented statistical modeling and prediction of compressive strength of concrete containing different matrix mixtures at fixed age or at different age of 1, 3, 7, 28, 56, 90 and 180 days. The parameters of the mixture examined were; time, water, cement, metakaolin, silica fume, aggregates and super plasticizer on the compressive strength of concrete. It was concluded that the predicted model has high correlation to the experimental results for the concrete compressive results.

Tanwani and Memon (2016) study the relationship between weight and concrete strength at 28 days of curing using trend line analysis. It was observed that the trend line fit by power function gives lowest deviation from mean strength with minimum error of 0.01% and maximum error of 10.33% with regards to other functions. Which best represent the relationship between weight and compressive strength observed.

Rachna et al. (2015) conducted a research work to propose the statistical model for predicting concrete strength using linear regression analysis. The regression model was developed for fly ash replacements at 0 and 15% and curing ages of 28, 56 and 91 days. Four variables were considered in predicting the strength, namely; water-binder ratio, fine aggregate-binder ratio, coarse aggregate-binder ratio and binder content.

Pozzolans such as rice husk ash (RHA) when blended with ordinary Portland cement behave as a cementitious material and give rise to hydrated calcium silicate (CSH) as a results of pozzolanic reaction of the silicate oxide (SiO_2) with the Calcium Oxide (CaO) liberated during hydration (Neville, 2011). Literature has shown that Rice husk ash contains more than 80% silicon oxide (Siddique, 2008) and other compounds which influence the desired output of a normal or light concrete. Pozzolanic blended cement has low heat of hydration compared to ordinary Portland cement (Mostafa and Brown, 2005). Rodrigues et al., (2006) observed that the incorporation of RHA in the composites could cause an extensive pore refinement in the matrix and in the interface layer, thereby decreasing water permeability. Furthermore, low heat development and resistance to sulfate attack are attributed to pozzolans as the hydration of cement results in great heat liberation, and the differential temperature between the initial setting time and hardening of cement causes shrinkage cracks.

This study is aimed at achieving a correlation between experimental data and mathematical models by analyzing the statistical values of the compressive strength relative to the weight of the cubes to determine some confidence level and degree of variability from targeted mean strength.

2 METHODOLOGY

The preliminary analysis of constituent materials; fine aggregate, coarse aggregate and Rice husk ash to determine some physical and chemical properties were conducted. Physical properties such as; specific gravity, bulk density, water absorption, particle size distribution of aggregates and rice husk ash were determined at the civil engineering laboratory of the Federal University of Technology Minna. Ten trials were conducted each for the specific gravity, bulk density, moisture content and water absorption tests and the mean values were recorded as shown in Table 1.Thus, the chemical analysis for the oxide composition for the Rice husk ash was conducted at the chemistry department laboratory of Ahmadu Bello University, Zaria.

A concrete mix design using the British “DOE” method was adopted and a mix ratio of 1:1.6:2.7 (Cement: Fine Aggregate: Coarse Aggregate) at a constant water-cement ratio of 0.5 with a target-mean strength of 25 N/mm^2 was designed as shown in Table 1. The cement content batched was replaced with 15% Rice husk ash as a supplementary cementious material. ASTM C618 (2008) specified a maximum replacement of cement at 20% for a normal quality and economy concrete at 28 days of curing. A total number of 20 concrete cubes of 150 mm x 150 mm x150 mm dimension were prepared and the compressive strength values at 28 days of curing in water in accordance with BS 1881:part 116(1983). The concrete cubes were weighed after 28 days of curing and the corresponding compressive strength were computed. The experimental compressive strength and its corresponding mass were used to plot a scattered graph in Microsoft excel and analysed using trend line functions and the corresponding coefficient of determination values derived. The statistical data of the experimental compressive strength were then compared with the predicted mathematical models to check the level of conformity which are presented in Table 8 and Figure 4.

2.1 MATERIALS

Cement: Commercially available Ordinary Portland cement was used for this purpose.

Rice husk ash: Rice husk was locally sourced from available milling plant and incinerated under controlled temperature of 500-600oC.

Aggregate: Crushed granite and river bed sand were used as coarse aggregate and fine aggregate respectively.

Water: Potable water was used for the experiment.

TABLE 1: MATERIALS PER CUBIC METER OF CONCRETE

Material	Proportion	Weight (Kg)
Cement	1	420.00
Fine Aggregate	1.6	654.90
Coarse Aggregate	2.7	1115.10
W/C ratio	0.50	210.00

3 RESULTS AND DISCUSSION

3.1 Physical Properties of the Constituent Materials

Table 2 shows the physical properties of the constituent materials. The mean-specific gravity of the fine and coarse aggregate was 2.63 and 2.70, the mean value for the crushed granite aggregate used falls within the range of 2.6 and 3.0 reported by Neville (2011). The mean specific gravity for RHA obtained was 1.94, a value less than what was obtained by Oyetola and Abdullahi (2004), but within the range of 1.9 and 2.4 specified for pulverized fuel ash (PFA) as reported by Neville (2011). Bui et al., (2005) and De Sensale (2006) reported that the low specific gravity of RHA relative to cement specific gravity of 3.15 will results in concrete of a less density as percentage replacement increases with respect to the cement.

The mean compacted and loose bulk densities derived for the coarse aggregate are 1814.05 kg/m^3 and 1589.13 kg/m^3 respectively, while that of fine aggregate were 1769.83 kg/m^3 and 1892.86 kg/m^3 as shown in Table 2. The ratio of the loose bulk density to the compacted bulk density for the coarse and fine aggregate are 0.88 and 0.93 respectively, which lies within the range of 0.87 and 0.96 stated in Neville, (2011). The bulk density is directly related to how densely the aggregate is packed, it measures the volume the aggregate will occupy in concrete which is a factor of particle size and shapes. For a coarse aggregate of given specific gravity, a higher bulk density means that there are fewer voids to be filled by fine aggregate and cement paste (Neville, 2011).

3.2 PARTICLE SIZE DISTRIBUTION

The particle size gradation of the fine and coarse aggregates are as shown in Table 3 and 4 and Figure 1 and 2 respectively. From the test result, the cumulative percentage of fine aggregate passing 600 μm sieves is not less than 84%. This according to BS 882 (1992) satisfies the requirement for fine grading, and will influence the workability of concrete mix.

TABLE 2: PHYSICAL PROPERTIES OF THE CONSTITUENT MATERIALS

	Properties	Cement	Fine Aggregate	Coarse Aggregate	Rice Husk Ash
1	Specific Gravity	3.15	2.63	2.7	1.94
2	Bulk density: Compacted Loose	- -	1892.86 kg/m^3 1769.83 kg/m^3	1814.05 kg/m^3 1589.13 kg/m^3	476.19 kg/m^3 397.0 kg/m^3
3	Moisture content	-	0.14%	0.16%	-
4	Water absorption	-	23.67%	1.6%	-

The coarse aggregate has particles completely passing sieve 50 mm and 37.5 mm meeting the requirement of BS 882 (1992), and mostly retained on sieve sizes 20 mm to 10 mm with less fine particles. Neville (2011) stated that when crushed rock coarse aggregate is used in concrete production, a slightly higher proportion of fine aggregate is required than with gravel aggregate in order to compensate for the lowering of workability by the sharp angular shape of the crushed particles.

TABLE 3: SIEVE ANALYSIS OF FINE AGGREGATE

Sieve Size (mm)	Weight Retained (g)	Percentage Retained	Percentage Passing	cumulative % passing
5.00	22.40	4.5	95.5	95.5
3.35	10.20	2.0	98.0	93.5
2.36	22.70	4.5	95.5	88.9
2.00	15.20	3.0	97.0	85.9
1.18	79.70	15.9	84.1	70.0
0.85	57.90	11.6	88.4	58.4
0.60	76.70	15.3	84.7	43.0
0.43	83.30	16.7	83.3	26.4
0.30	32.40	6.5	93.5	19.9
0.15	87.60	17.5	82.5	2.4
0.08	9.90	2.0	98.0	0.4
Pan	1.90	0.4	99.6	0.0

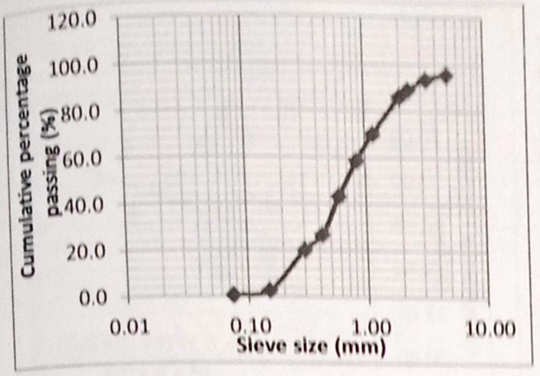


Figure 1: Particle size distribution of fine aggregates

TABLE 4: SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve Size (mm)	Weight Retained (g)	Percentage Retained	Percentage Passing	Cumulative % Passing
50	0.00	0.00	100.00	100.00
37.5	0.00	0.00	100.00	100.00
20	1194.20	59.74	40.26	40.26
14	643.40	32.18	67.82	8.08
10	144.00	7.20	92.80	0.88
6.3	15.40	0.77	99.23	0.11
5	0.80	0.04	99.96	0.07
Pan	1.30	0.07	99.93	0.00

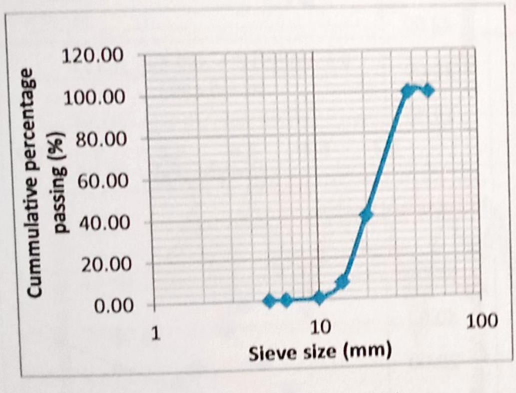


Figure 2: Particle size distribution of coarse aggregate

3.3 CHEMICAL COMPOSITION OF RHA

The oxide composition of the rice husk ash used is shown in Table 5. It can be observed that the rice husk ash has high silica content above 88% which is a measure of its reactivity. Silica is the compound responsible for strength development in concrete (Nair *et al.*, 2008). Also, the total percentage composition of Aluminum Oxide (Al_2O_3), Silicon Oxide (SiO_2) and Iron Oxide (Fe_2O_3) was found to be 91.92%, it exceed 70% minimum value for Class F fly ash (ASTM C618, 2005). This is an indication of a high pozzolanic reactivity of the rice husk ash sample and a suitable pozzolans for cement partial replacement in concrete.

TABLE 5: CHEMICAL COMPOSITION OF RHA

Elemental Oxide	Percentage Composition
Na_2O	0.0%
MgO	0.67%
Al_2O_3	2.47%
SiO_2	88.77%
P_2O_5	3.65%
SO_3	1.28%
K_2O	0.88%
CaO	1.05%
TiO_2	0.33%
Cr_2O_3	0.00%
Mn_2O_3	0.13%
Fe_2O_3	0.68%
ZnO	0.04%
SrO	0.01%

3.4 DENSITY OF HARDENED CONCRETE

The density range of the concrete samples as shown in Table 6 was 2491.85 kg/m^3 and 2702.22 kg/m^3; this is above the ranges of RHA concrete from the findings of Adenuga et al. (2010) and Yuzer et al. (2013) for normal weight concrete, that is, 2200 and 2550 kg/m3 as per ACI Committee 213 (2003). The experimental values of the densities indicate that concrete produced with 15% RHA cement replacement can be regarded as a normal weight concrete.

3.5 COMPRESSIVE STRENGTH

The experimental compressive strength values of the cubes specimens at 28 days of curing are shown in Table 6. The minimum compressive strength was 23.11 N/mm^2 and the maximum of 30.89 N/mm^2. The mean value of the compressive strength was 26.76 N/mm^2, the standard deviation derived was 2.48 and the coefficient of variation was 9.27%. The inbuilt function of trend line analysis in Microsoft excel package has options with linear, polynomial, logarithm, exponential and power functions. The experimental values of the compressive strength and the corresponding weight were plotted on scattered graph in Figure 3(a-e) and fitted with trend line to develop mathematical models of the various trend line functions and R^2 as shown in Table 7. The R^2 value is an important parameter in regression analysis as it gives the percentage variation of fitted data. From the predicted models, the polynomial function was found to have the highest value of R^2 of 43.93%. The equations in Table 7 represent the relationship between the compressive strength (y) and the mass (x) of the concrete cubes with regards to the model functions. The model functions were used to re-evaluate the compressive strength as a function of weight of concrete cube and the statistical data of the experimental compressive strength compared with the predicted models is given in Table 8.

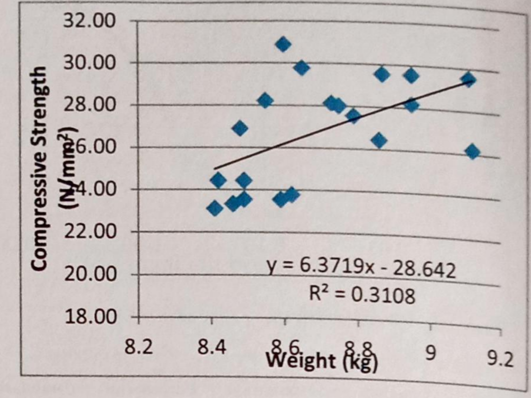
From Table 8, the linear function has the minimum standard deviation of 1.39 compared to other functions; it gives lowest deviation from the mean strength and a least coefficient of correlation of 0.15. Therefore, the linear function can best represent the relationship between weight and compressive strength of concrete cubes.

TABLE 6: CONCRETE COMPRESSIVE STRENGTH AT 28 DAYS CURING AGE

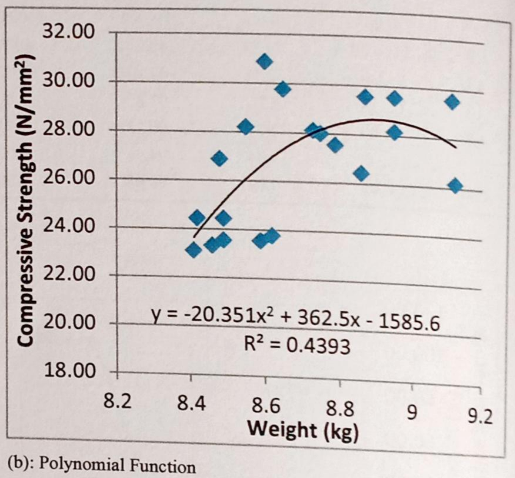
Sample	Mass of Cube (Kg)	Crushing Load (KN)	Density of Cube (Kg/m^2)	Compressive Strength (N/mm^2)
1	8.6	695	2548.15	30.89
2	8.87	465	2628.15	20.67
3	8.62	535	2554.07	23.78
4	9.11	465	2699.26	20.67
5	9.12	589	2702.22	26.18
6	8.49	550	2515.56	24.44
7	8.95	434	2651.85	19.29
8	8.73	433	2586.67	19.24
9	8.75	430	2592.59	19.11
10	8.46	525	2506.67	23.33
11	8.55	635	2533.33	28.22
12	8.48	605	2512.59	26.89
13	8.79	620	2604.44	27.56
14	8.49	530	2515.56	23.56
15	8.59	530	2545.19	23.56
16	8.41	520	2491.85	23.11
17	8.42	550	2494.81	24.44
18	8.95	465	2651.85	20.67
19	8.86	495	2625.19	22.00
20	8.65	670	2562.96	29.78

TABLE 7: TREND LINE MATHEMATICAL MODELS FOR COMPRESSIVE STRENGTH

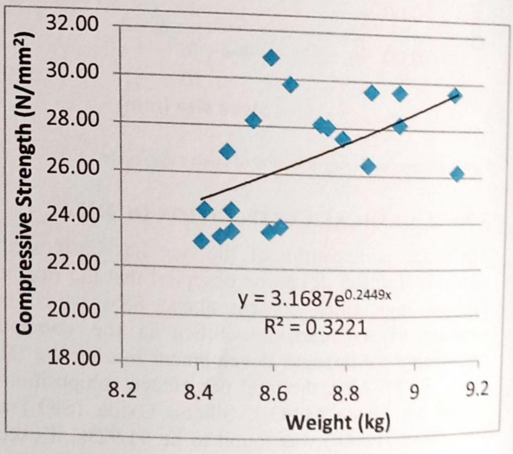
Function Type	Mathematical Model	R^2
Linear	$y=6.3719x-28.642$	0.3108
Polynomial D-2	$y=-20.351x^2+362.5x-1585.6$	0.4393
Exponential	$y=3.1687e^{0.2449x}$	0.3221
Logarithm	$y=56.134\ln(x)-94.625$	0.3153
Power	$y=0.251x^{2.1571}$	0.3268



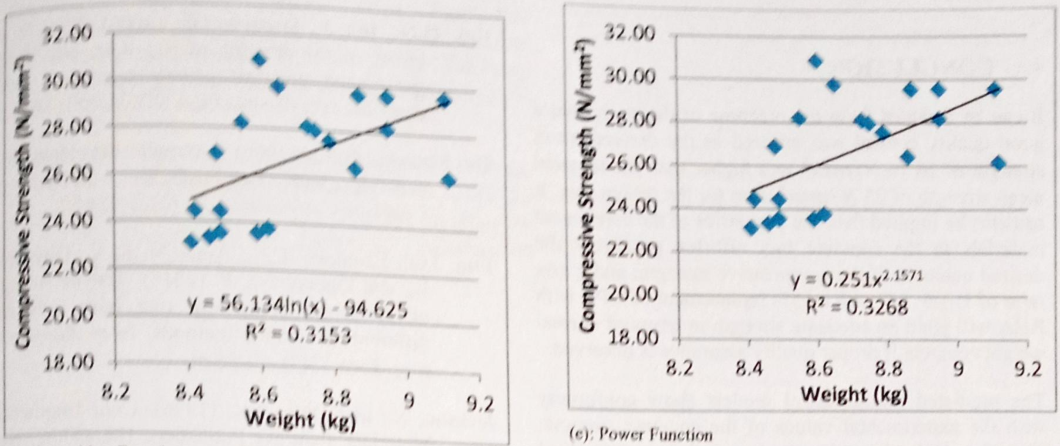
(a): Linear Function



(b): Polynomial Function



(c): Exponential Function



(d): Logarithm Function

(e): Power Function

Figure 3(a-e): Experimental Trend line Functions

TABLE 8: STATISTICAL PARAMETERS OF EXPERIMENTAL AND PREDICTED MODELS OF COMPRESSIVE STRENGTH

Parameter	Experiment	Linear	Polynomial	Exponential	Logarithm	Power
Minimum	23.11	24.95	23.64	24.85	24.91	24.81
Maximum	30.89	29.47	28.62	29.56	29.46	29.54
Mean	26.76	26.76	27.77	26.68	26.76	26.67
Standard Deviation	2.48	1.39	1.65	1.44	1.40	1.45
Correlation Coefficient		0.15	0.18	0.15	0.15	0.16

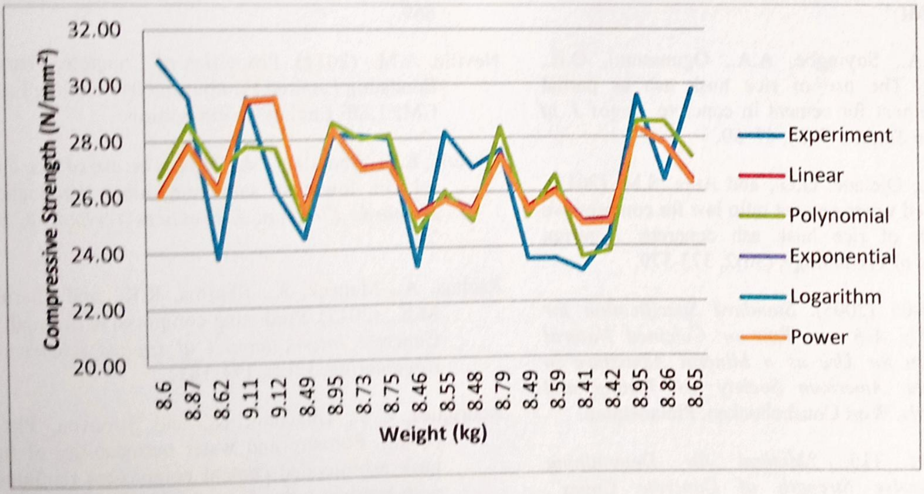


Figure 4: Compressive strength/weight experimental and model functions

4 CONCLUSION

It can be deduced from the outcome of the study that a good quality control was ensured as the derived mean strength of 26.76 N/mm^2 was higher than the targeted mean strength of 25 N/mm^2 used for the design mix. It can also be implied that, the properties of the constituent materials in the concrete mix affected positively the desired outcome of the compressive strength, and a mix ratio of 1: 1.6: 2.7 with a 15% replacement of OPC with RHA will yield an adequate strength in terms of normal weight concrete if proper quality assurance is observed.

The predicted mathematical models show conformity with the experimental values of the concrete strength. Therefore, it leads to the conclusion that mathematical functions can adequately represent compressive strengths given the weight as variables.

More so, sustainable environment can be guarantee if industrial and agricultural waste can be transformed into economic benefit and by so doing reducing environmental challenges associated with the built environment.

REFERENCES

ACI Committee 213 (2003). Guide for Structural Lightweight Aggregate Concrete - ACI 213R-03, *American Concrete Institute*, Farmington Hills, MI.

Adenuga, O.A., Soyingbe, A.A., Ogunsanmi, O.E., (2010). The use of rice husk ash as partial replacement for cement in concrete. *Lagos J. of Environ Studies*. 7 (2), 47–50.

Abdullahi, M., Ojelade, G.O., and Auta, S.M. (2017). Modified water-cement ratio law for compressive strength of rice husk ash concrete. *Nigerian Journal of Technology*, (36)2, 373-379.

ASTM, C618-05 (2005). *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete. American Society for Testing and Materials*, West Conshohocken, Philadelphia.

BS 1881:Part 116. "*Method for Determining Compressive Strength of Concrete Cubes*", British Standard Institution, Her Majesty Stationary office London, 1983.

BS8110. (1997). *Structural Use of Concrete*: Parts 1-3, BSI, London, United Kingdom.

Bui, D.D., Hu, J., Stroeven, P., (2005). Particle size effect on the strength of rice husk ash blended gap-graded portland cement concrete. *Cement and Concrete Composition*. 27 (3), 357–366.

De Sensale, G.R., (2006). Strength development of concrete with rice-husk ash. *Cement and Concrete Composition*. 28 (2), 158–160.

Ettu, I.O., Ezenkwa, C.S., Amatobi, D.A., Onyezewe, E., and Ogbonnaya, P. (2016). Tensile strengths of cooncrete containing rice husk ash from different calcination methods. *Inter. Research J. Eng. Tech*., 3(7), 50-55.m /

Jackson, N., and Dhir, R.K. (1996). Civil Engineering Materials. Palgrave Publishers, Hampshire, New-York. Fifth edition.

Mahmoud, S.A., (2012). Statistical modelling and prediction of compressive strength of concrete, *Conc. Research* Letters, Vol.3(2).

Mustafa, N. Y., and Brown, P. W. (2005).Heat of hydration of high reactive pozzolans in blended cements: Isothermal conduction calorimeter. *Thermochimica Acta*, 435(2), 162-167. Doi:10.1016/j.tca.2005.05.014

Nair, D., Fraaij, A., Klaassen, A., and Kentgens, A. A. (2008). Structural investigation relating to the pozzolanic activity of rice husk ashes. *Cement and Concrete Research (Elmsford)*. 38(6):861-869.

Neville, A.M., (2011). Properties of Concrete, Pearson Education Limited Edinburgh Gate Harlow Essex CM20 2JE England. Fifth edition.

Oyetola, E.B., Abdullahi, M., 2004. The use of rice husk ash in low-cost sandcrete block production. *Leonardo Electron. J. Practices Technol*. 8, 58–70.

Rachna, A., Maneek, K., Sharma, R.K., and Sharma, M.K., (2015). Predicting compressive Strength of Concrete. *International J. of Applied Science and Engineering*, 13(2), 171-185.

Rodrigues, C.S., Ghavami, K., and Stroeven, Piet . (2006). Porosity and water permeability of rice husk ash-blended cement composites reinforced with bamboo pulp. Journal of Materials Science. 41(21): 6925-6937.

Siddique, F. (2008). *Waste materials and by-products in concrete*. Springer Press.

Tawani, S. and Memon, B.A. (2016). Trend line analysis of weight versus compressive strength of concrete. *International Journal of Emerging Technology and Innovative Engineering*, (2) 7, 345-360

Yuzer, N., Cinar, Z., Akoz, F., Biricik, H., Gurkan, Y.Y., Kabay, N., Kizilkanat, A.B., (2013). Influence of raw rice husk addition on structure and properties of Concrete. *Construction Building Materials*. 44, 54–62.