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# Influence of Rice Straw Ash on Workability and Strength of Concrete

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**Abstract**. Cement manufacturing is a major contributor to the waste of energy as about 3.4GJ of thermal energy is needed to produce 1 tonne of Portland cement, not to mention the emissions of greenhouse gases like carbon di oxide due to the calcination of limestone during Portland cement production. These emissions have caused a dramatic rise in global warming. There is a pressing need for innovative recycling technology that can reduce the negative effects of waste on ecosystems and people. Rice straws are the waste produced after the threshing of rice. The goal of this study is to investigate the influence of rice straw ash on workability and strength of concrete. The rice straw used was the straw of a specific rice variety locally called mass I gotten from Akpugo, Enugu, Nigeria. The rice straw was calcined by open burning to produce the rice straw ash (RSA). The materials used were preliminary tested to determine their physical properties and chemical composition. The rice straw ash was used to replace Ordinary Portland Cement (OPC) at 0, 5, 10, 15, 20 and 30% respectively. The workability and compressive strength test were done for all replacement levels. Using slump test, the concrete workability was evaluated. For this study, 72 cubes were cast, cured in water for 7, 14, 21, and 28days before been tested under compression. From the investigation, percentage increase in RSA replacement decreased the concrete workability. The sample containing 0%, 5%, and 10% RSA attained 9%, 6.1% and 2.2% more strength compared to the design strength at 28th day of curing. While the 15%, 20% and 30% attained 17.3%, 28.9% and 67.6% lower strength compared to the design strength at 28th day of curing. The experimental result was analysed using statistical product and service solution (SPSS) and excel spreadsheet regression (ESR). This study suggests that the optimum replacement level of rice straw ash from structural reinforced grade 25 concrete point of view is 10%. The predictive models were tested and found to be adequate.

**Keywords:** Rice straw; Rice straw ash (RSA), Workability, Compressive strength, Statistical analysis.

## 1. Introduction

In modern times, concrete is used more than any other material in the construction industry [1–3]. Study by [4] projected that by 2050, yearly consumption of concrete would exceed 18 billion tons, largely due to rising demand for infrastructure and building. [5] defined concrete as a composite material. The dry mix consists of cement, coarse and fine aggregates. Cement is a major component in concrete production. According to [6], the production of cement requires a huge quantity of raw materials as about 1.5 tons of raw materials are required to produce 1 ton of cement. [7, 8] revealed that the type of cement widely used for concrete production is ordinary Portland cement. Studies by [9] reported that concrete production cost largely depends on its constituents' materials. Previous studies by [10 - 12] reported that most developing countries of the world especially sub-Saharan Africa (SSA) have seen acute shortages in affordable housing infrastructure due to the high cost of building materials and fall in housing infrastructure development. The high cost at which Ordinary Portland Cement (OPC) is purchased has led engineers and researchers back to the drawing board to look for alternative cementitious material for OPC in concrete production [13], such that many countries of the world now use blended cements for construction [14].

Amin et al. [15], and [16] reported that globally, agricultural waste is produced from crop farms annually. These wastes include but are not limited to corn cob, anacardium occidentale nutshell, groundnut shell, rice husk and straw which are used as pozzolanas in concrete production. Study by [17–23] has confirmed the suitability of corn cob ash, anacardium occidentale nutshell ash, and groundnut shell ash as pozzolanas in Concrete production. Also, studies by [24–27] have shown the effectiveness of rice husk ash (RHA) as Ordinary Portland cement substitute for making durable concrete.

Rice straws are the waste produced after the threshing of rice. After removing mature paddy, it is threshed [28]. Grains are separated from panicles without removing the husks by threshing harvested paddy on hard surfaces [29] or by using combined harvester [30]. Singh et al. [31] reported that enormous amount of rice straw is generated from rice crops and are unsustainably used as crop residue in the fields by farmers. Annual global rice straw generation stands at 731 million tons out of which 20.9 million tons is generated by Africa, 667.6 million tons by Asia and Europe 38.6 million tons [32]. According to [33] rice straw generated by China and India annually stands at 74.70 and 60.08 million tons.

In Nigerian, African rice and the Asian rice are the varieties cultivated in the past by farmers. [34] reported that in modern times, New Rice for Africa (NERICA), faro 14, mass I, II, III, Canada, Chinyereugo, Awilo, E4314, E4077 have been introduced as new rice varieties. Oko et al. [34] also observed that mass I variety of rice cultivated in Nigeria has an average plant height of 144.01cm, average leaf area of 63.8cm$^2$ and average panicle length of 24.7cm. Study by Okoro et al. [35] revealed that the mass variety of rice is cultivated on a large scale by farmers in Enugu state because of the availability of the seedlings. In Nigeria, rice straw is easily available for rice straw ash production. Several studies by [15], [36–42] have shown the effectiveness of rice straw ash as substitute for OPC as pozzolanic material in concrete production.

This study used the straw of a specific rice variety widely cultivated in Enugu state Southeastern Nigeria popularly known as mass I to produce rice straw ash (RSA) to replace Ordinary Portland cement in the making of concrete to potentially make houses affordable in rural areas where mass I rice straw can be found easily and places where Ordinary Portland Cement are very expensive and are not readily available. This will in turn help authorities/governments at all levels to produce sustainable low-cost housing units for their citizens. Also, according to [43] Ordinary Portland cement production impacts negatively on our environment more than the other components of Concrete. Hence, using Rice straw ash, which is a safer and more sustainable building material as an alternative to cement application, will help reduce environmental pollution.

## 2. Material and Methods

### *2.1. Materials*

The rice straw used for the research was sourced from a rice farm in Akpugo, Nkanu west, Enugu, Southeastern Nigeria. The rice straw which was already dry prior to when it was obtained, was cleaned, free from dirt and other unwanted materials. The rice straw was calcined

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by open burning at 535$^0$C for one hour thirty minutes to produce the rice straw ash (RSA). No improved burning technology was used in producing the RSA. The RSA obtained was not further grinded, but sieving was done to remove unburned particles. The RSA was stored in sealed plastic bag until they were used. Maximum size of 20mm crushed granite obtained from a local granite supplier in Agbani was used as the coarse aggregate. The use of 20mm maximum size for the coarse aggregates agrees with [44]. The river sand used was obtained from a local sand supplier in Enugu. To ensure that water to cement ratio of the concrete was not affected, all the aggregates were air dried, and their saturated surface dry condition obtained. Preliminary tests were carried out on the materials. The OPC and RSA were Chemically analyzed using X-RAY FLUORESCENT Analyzer (Model QX 1279) to determine the different oxide compositions. The tests were conducted at Fugro Nigeria limited laboratory. The rice straw ash was used to replace ordinary Portland cement at various percentages. The concrete samples were made using readily available ordinary Portland cement (OPC). The mixing and curing of the concrete were done with clean water devoid of impurities (pH = 6.9). A mix ratio of 1(cement:2.2(fine aggregate):4.5(coarse aggregate) was used to produce the concrete samples at a design strength of 25N/mm$^2$.

### *2.2. Methods*

#### *2.2.1. Batching and Mixing of Concrete*

The experimental design included six mixtures. The first concrete samples contained 0% Rice Straw ash and 100% Ordinary Portland cement. This mixture was labelled as CS0,100. The OPC was partially replaced with 5%, 10% 15% 20% and 30%, by weight of RSA, in the remaining five mixtures. These mixtures were labelled as CS5,95, CS10,90, CS15,85, CS20,80, and CS30,70, respectively. The materials were batched by weight with respect to the mix ratio and mixing occurred manually. The OPC and RSA were measured and thoroughly mixed to achieve a uniform colour. The mix was then spread on already measured fine aggregate on the hard clean floor of the laboratory and mixed thoroughly before the coarse aggregate and water were added. The mixing operation has then been repeated as for the dry state until the mixture appeared uniform in colour and consistency.

#### *2.2.2 Workability test*

Abram's slump cone apparatus was used to carry out workability test in accordance with [45]. This test gives a measure of the ease with which the concrete can be cast. Workability test was conducted on the CS0,100 which is the control and as well as on the CS5,95, CS10,90, CS15,85, CS20,80, and CS30,70 concrete. The test was carried out just after mixing was completed. The cone height was measured, recorded, and in triplicate layers was filled with concrete. Each layer was tamped with 25 strokes each. The vertical cone was removed. The height difference of slump cone and slump was measured and recorded.

#### *2.2.3. Sample Preparation for Strength test*

Various procedures, including oiling the inside of the cubical moulds with the help of a brush to lubricate the moulds and allow for easy de-moulding. The moulds meet the requirements of [46]. Moulding, de-moulding, and curing were done during the process of preparing the

IOP Conf. Series: Earth and Environmental Science **1342** (2024) 012018 doi:10.1088/1755-1315/1342/1/012018

concrete cubes for strength test. The sample was cast into the oiled moulds in triplicate layers with a mason's trowel. The first, second and third layers were tamped with 25 blows each and were uniformly spread over the cross section of the mould in accordance with [47]. A total of 72 cubes were made during this study. The following day, samples were de-moulded and cured in a tank until tested. The laboratory process also considered the precautions noted in [48], [49].

*2.2.4 Concrete compressive strength test*

The concrete samples were tested under compression after curing the concrete samples for 7, 14, 21 and 28days. The testing machine meets the requirements of [50]. Triplicate samples of concrete cubes were used for the test. This was done for each of the days of curing in accordance with [51]. The test was carried out in the civil engineering concrete laboratory in Madonna university Nigeria. Seventy-two samples were crushed.

*2.2.5. Statistical Analysis*

Statistical product and service solution (SPSS) and Excel Spreadsheet Regression Analysis (ESRA) are among the powerful tools that have proven their efficiency in experimental data statistical analysis like data normality check and modelling of concrete properties respectively. Statistical Product and Service Solution (SPSS) is used to test for normality of experimental data and to check for the presence of univariate outlier within the data. Test for normality is vital since the data generated from research works are continuous data (that is real numbers). For the normality check, for sample sizes less than or equal to fifty ($n \leq 50$) Shapiro-Wilk test is used while for sample sizes greater than fifty ($n > 50$) Kolmogorov-Smirnov test is used while box plot is used to check for the presence of univariate outlier. The experimental data is said to be normally distributed if p-value is greater than or equal to the level of significance, that is ($p \geq \alpha$). If the data is not normally distributed or there is presence of univariate outlier, the experimental data is transformed using natural log before the models are developed using the transformed data set.

Regression analysis is one of the methods of generating empirical models to predict the values of a dependent response variable in terms of other independent variables. It investigates functional relationships among variables [52]. According to [24] it is expressed in mathematical form displayed in 1.

$$Y = Q(X_1, X_2 \ldots\ldots\ldots\ldots X_K) \quad 1$$

For equation 1, Y stands for the dependent variable and $X_K$ are independent variables. Researchers usually carry out a model adequacy test to ensure experimental data and model generated data have no significant difference.

Working with ESRA, the model for this study was statistically carried out. The model for concrete strength was done with respect to the standard linear-iterative manner as stated by [53]. The variables relationships were established. Statistical t-test at 95% accuracy level was used to test the empirical models. If t Stat is less than t Critical two tail, accept the null hypothesis. Accepting the null hypotheses implies that there is no significant difference between model generated date and experiment generated data at 95% accuracy level. Rejecting the null hypothesis which means accepting the alternative hypothesis implies that there is a significant difference.

IOP Conf. Series: Earth and Environmental Science **1342** (2024) 012018 doi:10.1088/1755-1315/1342/1/012018

## 3. Results and Discussion

### *3.1 Preliminary Test*

Table 1 details the physical characteristics of the materials used for this study.

**Table 1:** Materials physical characteristics

| **Property type** | **Fine aggregate.** | **Coarse aggregate** | **RSA** | **OPC** |
|---|---|---|---|---|
| Colour | Light brown | Shades of grey | Dark grey | Grey |
| Relative density | 2.65 | 2.70 | 2.21 | 3.09 |
| Water absorption (%) | 0.84 | 0.63 | - | - |
| Bulk density (Kg/m$^3$) | 1645 | 1700 | - | - |
| Coefficient of Gradation, $C_c$ | 1.12 | 1.28 | - | - |
| Coefficient of Uniformity, $C_u$ | 3.13 | 1.54 | - | - |
| Fineness modulus | 3.22 | 2.02 | - | - |

### *3.2 Chemical Composition of OPC and RSA*

The Chemical composition of the Ordinary Portland Cement and Rice Straw ash used for the research are shown in table 2. According to [54], the combined percentages of ($SiO_2$ + $Al_2O_3$ + $Fe_2O_3$) for any pozzolana suitable for use in making concrete should be more than 70%. The RSA had 70.49% indicating that it is a good pozzolanic material but its loss on ignition of 8.60 is less than 12. The percentage calcium oxide in the RSA is 3.10% while it is 65.15% in OPC. Similarly, the percentage iron III oxide in RSA is 0.65% which is very low compared to 2.91% of OPC. $Fe_2O_3$ is responsible for imparting colour on cement products, and this could be the reason for the dark grey colour of RSA. The 68.23% of silica composition of RSA falls within the range reported by [55].

**Table 2:** Chemical composition of OPC and RSA

| **S/No** | **Oxide** | **OPC % composition** | **RSA % composition** |
|---|---|---|---|
| 1 | Silica dioxide ($SiO_2$) | 20.31 | 68.23 |
| 2 | Aluminium oxide ($Al_2O_3$) | 8.04 | 1.51 |
| 3 | Calcium oxide (CaO) | 65.15 | 3.10 |
| 4 | Magnesium oxide (MgO) | 3.30 | 1.72 |
| 5 | Ferric oxide ($Fe_2O_3$) | 2.91 | 0.65 |
| 6 | Manganese oxide (MnO) | 0.18 | 0.13 |
| 7 | Potassium oxide ($K_2O$) | 0.22 | 10.40 |
| 8 | Sodium oxide ($Na_2O$) | 0.72 | 0.66 |
| 9 | Sulphur trioxide ($SO_3$) | 2.60 | 0.79 |
| 10 | Loss on ignition (LOI) | 1.27 | 8.60 |

*3.3 Workability*

In this unit, the result of the slumps indicating the workability of RSA concrete has been discussed. The results for all compositions are depicted in table 3. The workability varied between 22 to 30mm. All the slumps formed were true slumps. The CS0,100 had a better slump compared to the rest of the concrete types. Slump values decreased with increase in RSA percentage. The presence of the RSA within the concrete affected its rheological behaviour. Hence, making it more unworkable. The low workability values of the concrete containing high percentages of RSA can make its casting process in the field to be a little difficult. As stated by [56] The concrete can be made more workable by the addition of sulfonated naphthalene formaldehyde condensate which is a chemical admixture to enhance the casting process in the field.

**Table 3:** Slump test of concrete

| Sample | Slump (mm) | Degree of workability |
|---|---|---|
| CS0,100 | 30 | Low |
| CS5,95 | 30 | Low |
| CS10,90 | 27 | Low |
| CS15,85 | 25 | Low |
| CS20,80 | 25 | Low |
| CS30,70 | 22 | Very low |

*3.4 Concrete Compressive Strength*

The 7, 14, 21, and 28 -day compressive strength test results for all compositions are depicted in figure 1. These compressive strength values are obtained as the average of three specimens, meticulously cast from the same proportion and tested under identical conditions. From the results obtained, the compressive strength at 7days for SC0,100, SC5,95, SC10,90, SC15,85, SC20,80 and SC30,70 was 22.74MPa, 22.07MPa, 21.18MPa, 16.15MPa, and 13.18MPa, and 5.45MPa respectively. This high early strength development by the SC0,100, SC5,95, SC10,90 could be attributed to the brand of OPC used. It also indicates that concrete containing lower percentage of RSA has high early strength development capacity. For the 15-30%, which were low, shows that concrete containing higher percentage replacement level of RSA does not develop strength rapidly at earlier days of curing. At 28days, the strength obtained for the different levels of replacement was 27.26MPa, 26.52MPa, 25.56MPa, 20.67MPa, 17.78MPa, and 8.1MPa. The control sample that is SC0,100 has the highest compressive strength values over time while the values for the CS5,95, CS10,90, CS15,85, CS20,80 and CS30,70 samples increased with curing age but was not more than the control at the different ages of testing. The increase in the strength of all the samples over time implies that as the hydration continues, more calcium silicate hydrate is formed that increases the strength. The control strength for 14, 21 and 28days of curing was 23.85MPa, 25.36MPa and 27.26MPa bringing about 5%, 12% and 20% increase respectively with respect to the 7$^{th}$ day strength.

Further analysis of the result showed that the CS0,100 concrete gained 9% strength compared to the design concrete strength at 28$^{th}$ day of curing. The CS5,95 and CS10,90 attained 6.1% and 2.2% strength higher than the design strength at 28$^{th}$ day of curing. While the CS15,85; CS20,80 and CS30,70 attained 17.3%, 28.9% and 67.6% lower strength compared to the design strength at 28$^{th}$ day of curing. This is a drop in strength of the concrete and could be linked to the percentage increase of RSA. This might also be because of the RSA weighing less than OPC. The lower strength attained by CS15,85 CS20,80 and CS30,70 at 28th day of curing could also be attributed to the RSA not been grounded to increase its pozzolanic reactivity.

However, The CS5,95 and CS10,90 that is concrete containing 5% and 10% OPC replacement with RSA, gained compressive strength greater than the design strength at 28th day of curing, making it an excellent choice for developing structural reinforced grade 25 concrete for building construction.

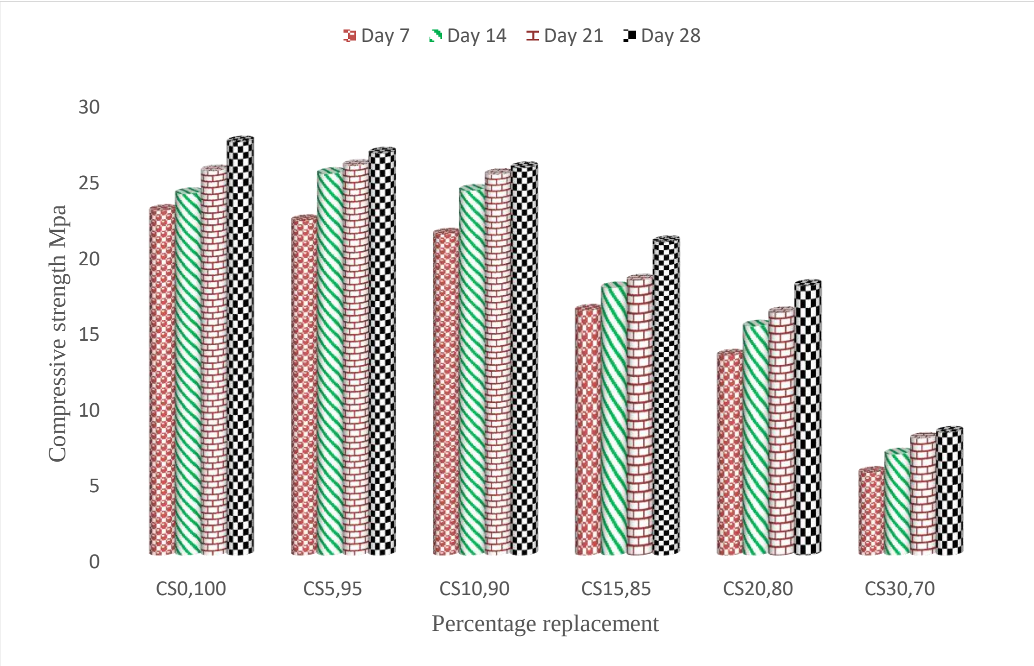


**Figure 1:** Average cube strength of concrete

*3.5 Statistical Analysis*

With reference to appendices A and B, computed mean and standard deviation of the experimental data generated for the rice straw ash (RSA) concrete with respect to workability and compressive strength are 26.50, 3.15 and 19.05, 6.79 respectively. There skewness and kurtosis values of -0.14, -0.63 and -1.58, -0.64 are all less than 1.96 indicating that the data are not skewed, and the distribution curves are all mesokurtic which show that the data are normally distributed. A further look at appendices A and B, show that the Shapiro-Wilk p-values for workability and compressive strength of 0.46 and 0.07 are all greater than or equal to the level of significance (i.e $p \geq 0.05$) confirming also that the data are normally distributed. For the presence of outlier, the box plots confirms that there are no univariate outliers, meaning that the data does not need transformation before generating the predictive models.

The models developed for the concrete are shown in 2 and 3. For model 2, W stand for workability and RL stand for calcined RSA % replacement level while for model 3, C stand for

Compressive strength, CA stand for curing age (days) and RL stand for calcined RSA % replacement level.

$$W = 30.27 - 0.28RL \quad (2)$$

$$C = 24.09 + 0.19CA - 0.63RL \quad (3)$$

The regression analysis of the data for model 2 and 3, displayed R-square values of 0.94 and 0.85, which shows a high level of correlation, which means that about 94% and 85% of the variation in the outcome variables (workability and compressive strength) was explained by the model. The remaining 6% and 15% is due to bias and error. The t-test analysis carried out on the data validated the models and hence, null hypothesis is therefore accepted for the models. Therefore, the model is adequate. This shows that the experiment generated slump value and compressive strength results and model generated slump value and compressive strength results has no significant difference. Thus, models 2 and 3 could be reliably used to predict RSA outcome variables.

## 4. Conclusion

This experimental study comprehensively assessed the workability and strength behaviour of concrete made with rice straw ash which was used to replace ordinary Portland cement up to the tune of 30%. The conclusions reached at the end of the study are as follows:

i. The chemical composition shows that the rice straw ash has combined percentages of ($SiO_2 + Al_2O_3 + Fe_2O_3$) of 70.49% indicating that it is a good pozzolana.
ii. The workability and compressive strength of concrete was negatively influenced by the increase in the percentage replacement of OPC with RSA.
iii. The compressive strength of RSA concrete increased as the curing age increases indicating the proportional relationship between compressive strength and the curing ages of concrete.
iv. The optimum replacement level of rice straw ash in concrete mixes from structural reinforced grade 25 concrete point of view is 10%.
v. Beyond 10% replacement level of OPC with RSA in concrete mixes, compressive strength reduces and is lower than the design strength.
vi. The Shapiro-Wilk p-values of 0.46 and 0.07for the experimental data generated are all greater than the level of significance ($p \geq 0.05$) demonstrating that the data are normally distributed, and the models developed predicted the workability and compressive strength of the RSA concrete up to a precision level of 94% and 85%.

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## REFERENCES

[1]. Oyebisi S., Ede A.N., Olutoge F. and Olukanni D. (2020). Assessment of activity Moduli and acidic Resistance of Slag-based Geopolymer Concrete Incorporating Pozzolan. Case Studies in Construction Materials, 13: 1–16, http://dx.doi.org/ 10.1016/j.cscm.2020.e00394.

[2]. Bajad M.N. (2020). High Quality Concrete Comprising of Several Mix of ACM's. Civil and Environmental Engineering. 16(1): 138–147, http://dx.doi.org/ 10.2478/cee-2020-0014.
[3]. Zongjin L. (2011). Advanced Concrete Technology. New Jersey: John Wiley and Sons.
[4]. Taylor M., Tam C. and Gielen D. (2006) Energy Efficiency and CO2 Emission Reduction Potentials and Policies in the Cement Industry. in *IEA-WBCSD*, Paris, 1–13
[5]. Prab B., Thomas J.M. and Ban S.C. (2006). Reinforced concrete. Design theory and examples, 3rd ed. London: Taylor and Francis Group.
[6]. Tayeh B.A, Akeed M.H., Qaidi S. and Bakar B.H.A. (2022). Influence of micro silica and polypropylene fibres on the fresh and mechanical properties of ultra-high performance geopolymer concrete, Case Studies in Construction Materials. 17: 1–16, http://dx.doi.org/ 10.1016/j.cscm.2022.e01367.
[7]. Joshua O., Olusola K.O., Ogunde A.O., Amusan L.M. Ede A.N., Tunji-Olayeni, P.F. (2016). Assessment of the utilization of different strength classes of cement in building constructions in Lagos, Nigeria. International Journal of Civil Engineering and Technolog*y*. 8(9): 1221 – 1233.
[8]. Ede A.N., Bamigboye G.O., Olofinnade O.M., Shittu K.K. (2016). Influence of Portland cement brands and aggregates sizes on the compressive strength of normal concrete, Materials Science Forum, 866: 78 – 82.
[9]. Oyejobi D.O., Jameel M., Sulong N.H.R., Raji S.A. and Ibrahim H.A., (2020). Prediction of optimum compressive strength of light-weight concrete containing Nigerian palm kernel shells. Journal of King Saud University of Engineering Science, 32(5), 303–309, http://dx.doi.org/10.1016/j.jksues.2019.04.001.
[10]. Ezeigwe P.C. (2015). Evaluation of the Causes of Housing Problems in Nigeria: A Case Study of Awka the Capital City of Anambra State. Journal of Economic Sustainability Development. 6(20): 87–93.
[11]. Igwe P.U., Okeke C.A., Onwurah K.O., Nwafor D.C. and Umeh C.N. (2017). A Review of Housing Problems. International Journal of Environmental. Agricultural. Biotechnology. 2(6): 3092–3099, http://dx.doi.org/ 10.22161/ijeab/2.6.40.
[12]. Danso H. (2015). Use of Agricultural Waste Fibers as Enhancement of soil blocks for Low- cost Housing in Ghana. PhD thesis University of Portsmouth, Portsmouth.
[13]. Ettu L.O., Ezenkwa C.S., Amatobi D.A., Onyezewe E. and Ogbonnaya P. (2016). Tensile Strength of Concrete Containing Rice Husk ash from Different Calcination Methods. Int. Res. J. Eng. Technol., 3(7): 50-55.
[14]. Bakar B.H.A., Putrajaya R.C. and Abdulaziz H. (2020). Malaysian Saw dust -Improving the Durability and Corrosion Resistance of Concrete: 'Pre-Review,' Concrete. Research. Letter, 11: 6–13.
[15]. Amin M., Tayeh B.A, Kandil M.A, Agwa I.S. and Abdelmagied M.F. (2022). Effect of rice straw ash and palm leaf ash on the properties of ultrahigh-performance concrete. Case Studies in Construction Material, 17: 1-15, http://dx.doi.org/ 10.1016/j.cscm.2022.e01266.
[16]. Akinfemi A. (2012). Upgrading of Sugarcane Bagasse by Solid state Fermentation with Pleurotus Sajor-caju and Pleurotus florida and the Impact on the chemical Composition and in vitro digestibility. Biotechnology and Animal Husbandry, 28(3): 603–611.
[17]. Oyebisi S., Owamah H. and Ede A. (2021). Flexural optimization of slag-based geopolymer concrete beams modified with corn cob ash. Science Iran. 28(5): 2582–2595, http://dx.doi.org/10.24200/sci.2021.57211.5120.

[18]. Oyebisi S., Ede A., Owamah H., Igba T., Mark O. and Odetoyan A. (2021). Optimising the Workability and Strength of Concrete Modified with Anacardium Occidentale Nutshell Ash, Fibers, 9(7): 41-48, http://dx.doi.org/10.3390/fib9070041.
[19]. Adesanya D.A. and Raheem A.A. (2009). Development of corn cob ash blended cement. Construction and Building Materials, 23(1): 347–352, http://dx.doi.org/ 10.1016/j.conbuildmat.2007.11.013.
[20]. Olafusi O. and Olutoge F. (2012). Strength Properties of Corn Cob Ash Concrete. Journal of Emerging Trends in Engineering and Applied. Sciences, 3: 297–301.
[21]. Mahmoud H., Belel Z.A. and Nwakaire C. (2012). Groundnut shell ash as a partial replacement of cement in sandcrete blocks production. 1(3): 1026-1032.
[22]. Ikumapayi C.M. (2018). Properties of groundnut shell (Arachis hypogaea) ash blended Portland cement. Journal of Applied Sciences and Environmental Management. 22(10): 1553-1556, http://dx.doi.org/10.4314/jasem.v22i10.3.
[23]. Oyebisi S., Olutoge F., Kathirvel P., Oyaotuderekumor I., Lawanson D., Nwani Joy., Ede A., Kaze R. (2022). Sustainability assessment of geopolymer concrete synthesized by slag and corncob ash. Case Studies in Construction Materials, 17
[24]. Ettu L.O., Ibearugbulam O.M., Ezenkwa C.S., Amatobi D.A. and Onyezewe E. (2016). Split Tensile Strength of Concrete Incorporating Rice Husk ash and Sawdust. ash. Journal of Multidisciplinary Engineering, Science and Technology, 3(7): 5194-5198.
[25]. Zareei A., Ameri F., Dorostkar F. and Ahmadi M. (2017). Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties. Case Studies in Construction Materials, 7: 73–81, http://dx.doi.org /10.1016/j.cscm.2017.05.001.
[26]. Zaid O., Ahmad J., Siddique M.S. and Aslam F. (2021). Effect of Incorporation of Rice Husk Ash Instead of Cement on the Performance of Steel Fibers Reinforced Concrete. Frontiers Material, 8: http://dx.doi.org /10.3389/fmats.2021.665625
[27]. Gautam A., Batra R. and Singh N. (2019). A study on use of rice husk ash in concrete. Engineering Heritage Jouurnal, 3: 01–04, http://dx.doi.org / 10.26480/gwk.01.2019.01.04.
[28]. Danbaba N., Idakwo P.I., Kasum A.I., Bristone C. and Bakare S.O. (2019). Rice Postharvest Technology in Nigeria: An Overview of Current Status, Constraints and Potentials for Sustainable Development. *OALib*, 6(8): 1–23, http://dx.doi.org/10.4236/oalib.1105509.
[29]. Kamai N., Omoigui L.O., Kamara A.Y. and Ekeleme, F. (2020). Guide to rice production in Northern Nigeria. Nigeria: International Institute of Tropical Agriculture.
[30]. Alizadeh M.R. and Bagheri I. (2009). Field Performance Evaluation of Different Rice Threshing Methods. International Journal of National Engineering Science, 3(3): 155-159.
[31]. Singh R., Srivastava M. and Shukla A. (2016). Environmental sustainability of bioethanol production from rice straw in India: A review, Renewable Sustainable Energy Review 54: 202–216, http://dx.doi.org /10.1016/j.rser.2015.10.005.
[32]. Tsunatu D.Y., Atiku K.J., Samuel T.T., Hamidu B.I. and Dahutu D.I. (2017). Production of Bioethanol from rice straw using yeast extracts peptone dextrose. Nigeria. Journal of Technology, 36(1): 296-301, http://dx.doi.org/10.4314/njt.v36i1.36.
[33]. Sarnklong C., Cone J.W., Pellikaan W. and Hendriks W.H. (2010). Utilization of Rice Straw and Different Treatments to Improve Its Feed Value for Ruminants: A Review, Asian-Australia Journal of Animal Science, 23(5): 680–692, http://dx.doi.org/ 10.5713/ajas.2010.80619.

[34]. Okoh A.O., Ubi B.E. and Effisue A.A. (2012). A Comparative Study on Local and Newly Introduced Rice Varieties in Ebonyi State of Nigeria based on Selected Agronomic Characteristics. International Journal of Agriculture and Forestry., 2(1): 11–17, http://dx.doi.org/10.5923/j.ijaf.20120201.03.

[35]. Okoro J.C., Ugah D.E., Aroh J.A., Obioha O.G., Charles E.U. and Agwu E.A. (2023). Perceived Factors Influencing Farmers' Preference for Rice Varieties in Enugu State, Nigeria. Journal of Agricultural Extension, 27(1): http://dx.doi.org/10.4314/jae.v27i1.8.

[36]. Abitha A., Jesty C.A., Siyad S., Vijay P.C., Sreerekha R.S. and Dhanya B.S. (2023). Feasibility assessment of rice straw ash as a supplementary cementitious material Materials Today Proceeding, 1-5: http://dx.doi.org/10.1016/j.matpr.2023.01.165.

[37]. El-Sayed M.A. and El-Samni T.M. (2006). Physical and Chemical Properties of Rice Straw Ash and Its Effect on the Cement Paste Produced from Different Cement Types. Journal of King Saudi University of Engineering Science, 19(1): 21–29, Jan. 2006, http://dx.doi.org/10.1016/S1018-3639(18)30845-6.

[38]. Hakeem I.Y., Amin M., Zeyad A.M., Tayeh B.A., Maglad A.M. and Agwa I.S. (2022). Effects of nano sized sesame stalk and rice straw ashes on high-strength concrete properties. Journal of Cleaner Production., 370: 133-142, http://dx.doi.org/ 10.1016/j.jclepro.2022.133542.

[39]. Hidalgo S., Soriano L., Monzó J., Payá J., Font A. and Borrachero M. V. (2021). Evaluation of Rice Straw Ash as a Pozzolanic Addition in Cementitious Mixtures. Applied Sciences, 11(2): http://dx.doi.org/ doi:10.3390/app11020773.

[40]. Nguyen C.V. and Mangat P.S. (2020). Properties of rice straw reinforced alkali activated cementitious composites. Construction and Building Materials, (61): 120-136, http://dx.doi.org/10.1016/j.conbuildmat.2020.120536.

[41]. Roselló L., Soriano L., Santamarina M.P., Akasaki J. L., Monzó J. and Payá J. (2017). Rice straw ash: A potential pozzolanic supplementary material for cementing systems. Industrial Crops Production, 103: 39–50, http://dx.doi.org/ 10.1016/j.indcrop.2017.03.030

[42]. Shang X., Yang J., Song Q. and Wang L. (2020). Efficacy of modified rice straw fibre on properties of cementitious composites. Journal of Cleaner Production, 276: 124-134, http://dx.doi.org/10.1016/j.jclepro.2020.124184.

[43]. L. Reig *et al.*, (2023). Reutilization of Ceramic Waste as Supplementary Cementitious Material, in Building Engineering Facing the Challenges of the 21st Century: Holistic Study from the Perspectives of Materials, Construction, Energy and Sustainability, D. Bienvenido-Huertas and J. Durán-Álvarez, Eds., in Lecture Notes in Civil Engineering, Singapore: Springer Nature, 553–576, http://dx.doi.org/10.1007/978-981-99-2714-2_30.

[44]. Shetty M.S. (2012). Concrete Technology: Theory and Practice. New Delhi: S. Chand.

[45]. ASTM C143, (2015). "Test Method for Slump of Hydraulic-Cement Concrete," ASTM International, West Conshohocken, PA, USA., http://dx.doi.org/10.1520/C0143_C0143M-12.

[46]. BS EN 12390-1, Testing hardened concrete. Part 1, Shape, dimensions and other requirements for specimens and moulds. London: BSI, 2012.

[47]. ASTM C192, "Practice for Making and Curing Concrete Test Specimens in the Laboratory," ASTM International, West Conshohocken, PA, USA., 2015. http://dx.doi.org/10.1520/C0192_C0192M-14.

[48]. Ogundipe K.E., Ogunde A., Olaniran H.F., Ajao A.M., Ogunbayo B.F, and Ogundipe J.A. (2018). Missing gaps in safety education and practices: academia perspectives," Int. J. Civ. Eng. Technol. IJCIET, 9(1): 273-289.

[49]. Elizah O., Olaniran H., Adekunle A. and Fatai O. (2018). Assessing the Impact of Quality Supervision on Construction Operatives' Project Delivery in Nigeria, International Journal of Civil Engineering Technology, 9: 426–439,

[50]. BS EN 12390-4, "Testing hardened concrete: Compressive strength. Specification for testing machines," BSI British Standards, London, 2019. http://dx.doi.org/10.3403/30371544.

[51]. BS EN 12390-3., "Testing hardened concrete: Compressive strength of test specimens," BSI British Standards, London, 2019. http://dx.doi.org/10.3403/30360097.

[52]. Samprit C. and Ali S. H. (2006). Regression Analysis by Example. New Jersey: John Wiley and Sons.

[53]. Cindy D.K. and Robert J.F.J. (2007). Modelling, and Interpreting Interactive Hypotheses in Regression Analysis. Michigan: University of Michigan Press.

[54]. ASTM C618, "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete," ASTM International, West Conshohocken, PA, USA., 2019. doi: 10.1520/C0618-19.

[55]. Nguyen V.N., Detras M.C., Migo M., Quilloy R., Balingbing C., Chivenge P. and Gummert M. (2020). Rice Straw Overview: Availability, Properties, and Management Practices. 1–13. http://dx.doi.org/10.1007/978-3-030-32373-8_1.

[56]. Ezenkwa C. and Elogu T. (2023). Uncracked Palm Kernel Shell Effect on Compressive Strength of Concrete. Engineering and Technology Journal, 1–8, http://dx.doi.org/10.30684/etj.2023.140014.1460.

# APENDICES

## Appendix A

**Tests of Normality for Workability**

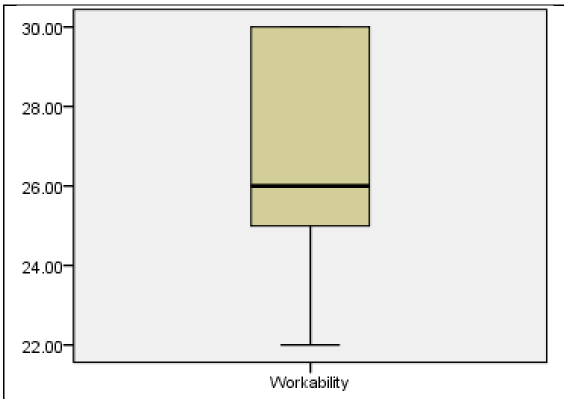
| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Workability | .200 | 6 | .200* | .913 | 6 | .459 |

*. This is a lower bound of the true significance.

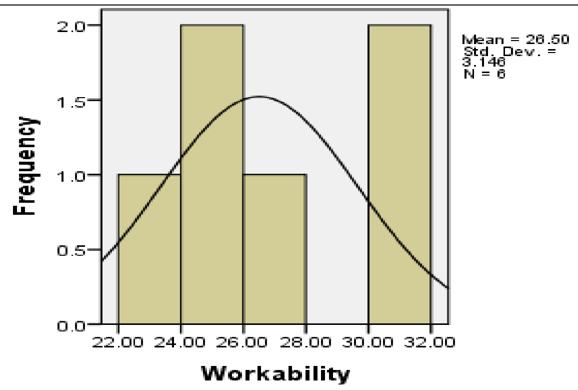
a. Lilliefors Significance Correction

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| Workability | Mean | | 26.5000 | 1.28452 |
| | 95% Confidence Interval for Mean | Lower Bound | 23.1980 | |
| | | Upper Bound | 29.8020 | |
| | 5% Trimmed Mean | | 26.5556 | |
| | Median | | 26.0000 | |
| | Variance | | 9.900 | |
| | Std. Deviation | | 3.14643 | |
| | Minimum | | 22.00 | |
| | Maximum | | 30.00 | |
| | Range | | 8.00 | |
| | Interquartile Range | | 5.75 | |
| | Skewness | | -.116 | .845 |
| | Kurtosis | | -1.105 | 1.741 |




Box plot




Normal distribution curve

# Appendix B

**Tests of Normality for compressive strength**

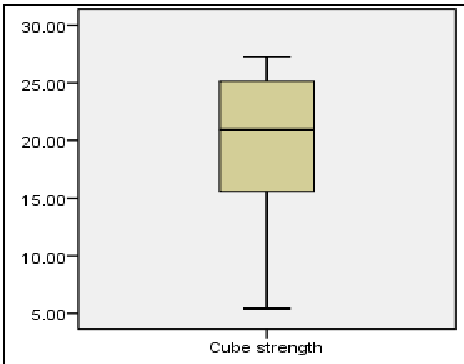
| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Compressive strength | .136 | 24 | .200* | .895 | 24 | .067 |

*. This is a lower bound of the true significance.

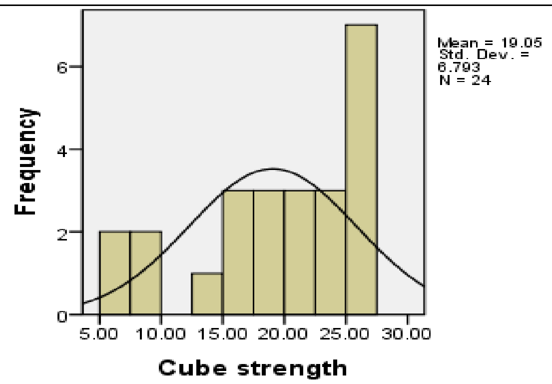
a. Lilliefors Significance Correction

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| Cube strength | Mean | | 19.0504 | 1.38666 |
| | 95% Confidence Interval for Mean | Lower Bound | 16.1819 | |
| | | Upper Bound | 21.9189 | |
| | 5% Trimmed Mean | | 19.3455 | |
| | Median | | 20.9250 | |
| | Variance | | 46.148 | |
| | Std. Deviation | | 6.79321 | |
| | Minimum | | 5.45 | |
| | Maximum | | 27.26 | |
| | Range | | 21.81 | |
| | Interquartile Range | | 9.83 | |
| | Skewness | | -.747 | .472 |
| | Kurtosis | | -.584 | .918 |




Box plot




Normal distribution curve