

INVESTIGATING THE EFFECT OF RICE HUSK WASTE ASH AS POZZOLANIC MATERIAL IN CONCRETE MIXTURES FOR NIGERIAN CEMENT INDUSTRIES

Felix, A.M.¹ and Wilberforce, K.I.²

¹Department of Agricultural and Bioenvironmental Engineering Technology, Adamawa State Polytechnic, Yola

²Department of Civil Engineering Technology, Adamawa State Polytechnic, Yola

*Corresponding email: fmodiahmed@gmail.com

ABSTRACT

The high price of construction materials, especially cement, is considered to be one of the major challenges that hinders the successful delivery of infrastructures across the Nigeria. One way of addressing this high cost of cement is by utilizing locally available waste such as rice husk. This paper sought to investigate the possible use of yola rice waste husk ash in concrete characteristics at various replacement amounts.. Experimental work was done on the collected ingredients of concrete, coarse aggregate, fine aggregate, and rice husk, chemical analysis test of the RHA, mix proportioning of the materials, and concrete mixing with different RHA proportions. The physico-mechanical qualities of standard grade concrete specimens with the addition of finely ground rice husk ash obtained from yola rice mill outlet were evaluated. As a response, 96 concrete cube specimens were molded in varied quantities of ground risk husk ash, including 5%, 10%, 15%, and 20% replacement levels, and 12 cube specimens with the addition of super plasticizing admixture. All of the specimens were cured in a laboratory setting, and compressive strength values were taken after 3, 7, 28, and 56 days of curing. According to the findings, Nigerian rice husk ash is adequate for 5% to 15% replacement levels. However, slump flow and density of specimen tests suggest that the results have deteriorated as the rice husk ash amount of replacement has increased. The laboratory test results were also confirmed using analysis of variance (ANOVA) and further post-hoc testing. Further studies should focus on examining the RHA for high strength and high-performance concretes and evaluate the pozzolanic activities of the RHA in nigeria using X-ray diffraction analysis.

Keywords: Rice husk, cement, Materials, Physico-mechanical, Workability, Compressive Strength.

1 INTRODUCTION

Pozzolanas are materials containing silica and/or alumina which on their own have little or on binding property but, when mixed with lime in the presence of water, will set and harden like a cement. They are important ingredient in the production of alternative cementing material to Portland cement (OPC). Recently, numerous agricultural wastes are added to cement as a pozzolanic material to enhance the overall properties of concrete and reduce the increasing consumption and cost of Portland cement [1]. The most commonly used pozzolanic materials in different concrete mixes are fly ash, ground granulated blast-furnace slag, silica fume, and natural pozzolanic materials coming from agricultural wastes [2]. Supplementary cementitious materials, when partially incorporated with Portland cement, contribute to the fresh and hardened properties of concrete mixes through pozzolanic

activity Earlier studies suggest that these supplementary cementitious materials, also known as SCMs, can enhance the quality of concrete mixes by improving slump flow and consistency, increase compressive strength at later curing ages, reducing bleeding, segregation, and heat of hydration, retarding the setting time for hot weather concreting, improving finishing and pumping capability, and reducing plastic shrinkage cracking [3]. In the past, the construction industry was booming in different developing countries including Nigeria, the main reason was that the Nigerian government, together with various key stakeholders, has been working towards improving the overall growth of the construction sector as part of the growth and transformation plan through various policies and initiatives, such as the various housing schemes both at federal and states levels. However, the high price of construction materials, especially cement, is considered to be one of the major challenges that hinders the successful delivery of infrastructures across the nation. Hence, it is vital to find different alternative cement replacements to tackle this problem. One way of addressing this high cost of cement is by utilizing locally available agricultural wastes such as rice husk [4]. Prior studies have shown that rice husk ash (RHA) has a potential to replace cement between 10 and 30% by weight, enhancing compressive strength, chloride ion resistance, and alkali silica reactivity [5]. Nevertheless, the production and quality of RHA depend on various factors such as fineness, burning condition, temperature, heating rate, and duration. RHA can typically have two types of states, amorphous or crystalline state [6]. These states differ in the extent of burning temperature where amorphous form is found at a temperature between 300°C and 900°C, while burning RHA beyond 1000°C produces crystalline silica [7, 8]. A study by [9] identified that RHA in amorphous state is highly reactive and good for use in concrete. In addition to its high cost, the production of cement has serious environmental and economic impacts compared to other concrete ingredients [7]. The most significant environmental factors are the consumption of limited natural resources and CO₂ emissions [10]. Previously, different researchers have highlighted the application of these natural pozzolans to reduce the environmental impact of cement production [11]. These findings stressed the introduction of cement replacing materials which have an overall lower cost of production, lower CO₂ emission, and reduced energy consumption to produce a more environmentally, friendly, and green concrete [11]. RHA is one of those cement replacing materials [12] As it is an agricultural residue, the portion of Portland cement replaced with RHA can greatly reduce the environmental hazards to the ecosystem [13]. Thus, this study for the investigates the properties of RHA to address the increasing cement cost through the introduction of an alternative pozzolanic material in concrete production of the Nigerian construction sector. Prior studies reveal that the properties of RHA are greatly affected by the type of species, burning temperature, and duration [14]. When dealing with a single experimental data/information, if there are multiple independent variables/cases and a single dependent variable, the method implemented to test the effect of those independent variables on the dependent variable is called two-way factorial ANOVA [15], When multiple variables are used, each variable will have different levels. Therefore, it is customary to analyse the combination of different levels on each variable. In this context, this study explored and examined the RHA through a laboratory led experiment to compare the impact of the addition of the admixture in the concrete mixture. Furthermore, this paper explored the validation of laboratory test results through a statistical analysis.

2 MATERIALS AND METHODS

The aim of the current study is to evaluate the suitability of using RHA as a pozzolanic material in normal grade concrete mixtures. The study mainly focuses on exploring the fresh concrete property such as workability and hardened concrete properties including compressive strength of concrete cube specimens made with various RHA replacement levels. Further, statistical analysis was conducted to validate the laboratory test results and draw a reliable conclusion. The first stage summarizes prior studies made using RHA as a partial cement replacement, cement hydration in relation to pozzolans and pozzolanic reaction, the importance of RHA in concrete and other sectors, and the different properties and forms of RHA through an extensive literature review and selection of different materials used for the study, which helps to identify the burning temperature of RHA and in the selection of concrete ingredients. The second stage focuses on the experimental work done on the collected ingredients of concrete, coarse aggregate, fine aggregate, and rice husk, chemical analysis test of the RHA, mix proportioning of the materials, and concrete mixing with different RHA proportions; from this, the materials used for concrete casting are identified and oxide composition

test of RHA is performed. The third stage incorporates the recording and analysis of test results obtained from the experiment, statistical analysis of the results, cost comparison, and conclusions given based on the above mentioned analysis and the recommendations outlined for future work.

2.1 RHA Manufacturing Process

There are two ways of manufacturing RHA: the first one is on a controlled burning environment (which is more preferable) and the uncontrolled one. For this study, the raw rice husk was carefully selected and purchased from one of the rice milling company in Yola. The overall stages of the production process, physical and chemical tests of the RHAs, are given as follows.

Production Process. The first stage of the production of RHA is a routine physical examination to check the overall quality of husks. Then, the rice husk was allowed to burn in a laboratory muffle furnace at a temperature of 550°C for a total of 6 hours in a controlled burning process inside the furnace before and then cooling for about 24 hours. Finally, the husk is grinded to the required size using ultra centrifugal mill; then the RHA is sieved by 75 μm ASTM sieve in order to remove larger size particles before it is used in the concrete mix.

Physical Examination (Test). After the burning process of the husk is completed, it appeared whitish-grey colour. This whitish-grey colour means that the husk is completely burned with a lower carbon content. the fact that the rice husk has turned into Grey when grinded proves that the rice husk meets the physical (colour) requirement as reported by various researchers. Laboratory. The test result shows that the RHA used in this study also complies with ASTM C618.

2.2 Cement

A total of 108 concrete cube specimens were casted for the study. Consequently, the most commonly used cement types in Nigeria, Ordinary Portland cement (OPC) having grades of 42.5 R and 42.5N.

2.2.1 Fine Aggregate

According to ASTM C33, aggregates which are less than 4.75mm are designated as fine aggregates ASTM C 33, 2010). For this study, locally available well graded crushed basaltic stones are used as a fine aggregate. Table 1 shows different tests were performed on the fine aggregates and compared with the ASTM standards.

Table 1. Properties of fine aggregate used in this study

Characteristics	Test method	Test result	ASTM requirement	Remark
Unit weight	ASTM C29	1566 kg/m ³	1200 - 1750 kg/m ³	√
Fineness modulus	ASTM C125	2.78	2.3 -3.1	√
Specific gravity	ASTM C128	2.77	2.4 - 2.9	√
Absorption	ASTM C128	3.15%	0.2% - 2%	√
Moisture content	ASTM C566	1.60%	Nil	√

2.2.2 Coarse Aggregates

Table 2 shows properties of coarse aggregate obtained from well graded crushed basaltic stones. According to ASTM C33, aggregates which are larger than 4.75mm are designated as coarse aggregates.

Table 2. Properties of coarse aggregate used in this study

Characteristics	Test method	Test result	ASTM requirement	Remark
Nominal	max aggregate size	25mm	Nil	√
Unit weight	ASTM C29	1653 kg/m ³	1200 - 1750 kg/m ³	√
Specific gravity	ASTM C127	2.6	2.4 -2.9	√
Absorption	ASTM C127	1.95%	0.2% - 4%	√
Moisture content	ASTM C556	0.22%	Nil	√

2.3 Samples' Preparation

After the required materials were collected, various tests were performed on each ingredient and compared with the respective ASTM standards to determine their suitability for use in mix proportioning. The samples were designated as control (OPC), RHA5%, RHA10%, RHA15%, RHA20%.

2.3.1 Mix Design and Mixing Procedure

The mix design was performed for C-25 grade nonair entrained concrete as per ACI 211.1. For half of the mixtures, water cement ratio is held constant at 0.49 and, for the rest of the cubes, a water cement ratio of 0.43 and a superplasticizer were used to investigate the workability and compressive strength values of each concrete mix. For all mixes, a constant amount of 179 kg/m³ of water, 1120 kg/m³ of coarse aggregates, and 820 kg/m³ of sand were used for all mixes. Similarly, 360 kg/m³ of cement was used for the control mixes (OPC); then, 342, 324, 306, and 288 kg/m³ of Portland cement were used for 5, 10, 15, and 20% RHA replaced concrete mixtures, respectively [17, 18,19]. the general procedures of concrete mixing start from materials collection. the collected materials were tested, standardized, and prepared for mixing. the next step was performing mix proportioning for the given grade of normal weight structural concrete and the mixing will follow by controlling all of the factors that affect the overall quality of concrete. At the time of casting, a constant ambient temperature was tried to be maintained. The control mix using both Ordinary Portland cement with crushed rock fine and coarse aggregate are proportioned by weight. After that, the OPC was replaced by RHA at 5, 10, 15, and 20%. The samples were compacted in three layers and demoulded after 24 hours of casting. Finally, the cubes were immersed in water until their test reading was taken. For the test, 15 ×15 ×15 cm of 120 concrete cubes was casted.

2.4 Conducting of Tests

Compressive strength of concrete cube specimens is determined after 3, 7, 28, and 56 days of testing using a compressive strength testing machine in the Civil Engineering laboratory of Adamawa state Polytechnic Yola. All samples were moist cured until the test dates. the reported results are the average of three samples.

2.5 Statistical Analysis

Statistical analysis was performed using a two-way factorial analysis of variance (ANOVA) for compressive strength, age of cubes, and RHA replacement levels using a 95% confidence interval. Post hoc test is also conducted for various RHA replacement levels.

3 RESULTS AND DISCUSSION

3.1 Workability

The first test conducted to the freshly mixed concrete made with the addition of RHA in various percentages was workability test. Workability can be defined as the property of freshly mixed concrete or mortar which determines the ease and the homogeneity with which it can be properly mixed, placed, compacted and finished. The results reveal that the control concrete cube specimen produced mainly with OPC demonstrated a higher workability value when compared with the remaining mixtures. It is also important to note that, as the RHA replacement level increases, the value of slump reduced due to the fact that RHA particles had a better fineness and absorption capacity than cement. This is also supported by previous studies carried out by [16]. However, for RHA replacement of 15% and lower values, the findings of slump reveal that the workability is in the required range of 25 to 50 mm, as depicted in the mix proportioning. Accordingly, this decrease in workability of freshly mixed concrete mixes negatively affects the ease of placing concrete in different structural elements, which in turn affects the quality and performance of concrete at any level. Further, additional 4% Mega Flow SP1 (super plasticizing admixture). was used for some of the batches during mixing, in order to improve the workability of the concrete cube specimens and enhance the consistency and ease of placement of the mixes (Table 3). The results reveal that the addition of the superplasticizer increases the workability and made the concrete flow.

Table 3. Workability test results of freshly mixed concrete mixtures

Designation	RHA percentage	replacement	W/C ratio
Control (OPC)	0%	30mm	0.49
RHA 5 %	5%	28mm	0.49
RHA 10%	10%	25mm	0.49
RHA 15%	15%	25mm	0.49
RHA 20%	20%	20mm	0.49

3.2 Compressive Strength

3.2.1 Early Strength Development

At the 3rd day of curing, control (OPC) and RHA5% showed a better compressive strength development compared with other mixtures. Similarly, the compressive strength development trend decreased as the RHA replacement percentage increased (Table 4). Moreover, at the 7th day of curing in the laboratory, the compressive strength test result shows that concrete cube specimens produced with the addition of RHA performed well, as with control (OPC). However, the control (PPC) mixture had a lower compressive strength test result in comparison with all the remaining mix proportions. In both 3rd and 7th day curing ages, the early compressive strength development of cube specimens decreased as the percentage replacement of RHA increases from 5% to 20%. The reason is that natural pozzolanic materials hydrate slowly in comparison with the hydration of ordinary Portland cement, provided that curing temperature is maintained in both cases].

3.2.2 Compressive Strength Trend

The overall compressive strength development trend at the 3rd, 7th, 28th, and 56th curing days is illustrated in Table 4.

Table 4. Average compressive strength result

Designation	3rd day	7th day	28th day	56th day
Control (OPC)	17.22	29.99	33.31	34.6
RHA 5%	17.3	31.76	35.76	38.16
RHA 10%	17.66	29.54	34.88	40.21
RHA 15%	14.99	28.12	33.88	36.87
RHA 20%	14.26	26.38	31.36	33.55

Concrete without super plasticizer: Concretes made with the addition of RHA show a good compressive strength development and achieved the target mean strength of 33.5 MPa at 28 days except control (PPC) and 20% replacement level. Although the RHA 20% showed the lowest 28th day result with 31.36 MPa, concrete mixes pass the 25 MPa specified compressive strength at the age of 28th day. Compressive strength at 56th day is found to be higher at 5%, 10%, and 15% replacements than the control OPC mix. However, as the RHA replacement percentage increased, the compressive strength decreases. It is also shown in Table 4 that age is an important factor in the compressive strength development of pozzolanic materials. Concretes made within incorporation of pozzolanic materials show a good strength development as the curing age increases up to 56th days, where at the 56th day RHA 10% showed an average compressive strength of 40.2 MPa (the highest compressive strength of concrete mixes) which agrees with [19, 20]

Table 5. Statistical analysis results of the main effects and interaction effect

Sources	Sum of squares	f	df	Mean square	Pvalue
Curing duration	2735.7	330.5	3	911.9	2.98×10^{-12}
Rice husk ash	363.9	32.9	4	90.98	3.54×10^{-7}
Curing duration × rice husk ash	93.2	2.8	12	7.8	6.94×10^{-3}

Table 6. Post hoc analysis for RHA replacements.

(I) RHA	(J) RHA	Mean difference (I-J)	Std. error	P value	95% confidence interval		
					Lower bound	Upper bound	
Tukey's HSD	RHA 10%	-1.7917*	-0.59411	0.034	-3.4885	-.0948	
	RHA 15%	0.3175	-0.59411	0.0948	-1.3793	2.0143	
	0% (OPC)	2.3908*	-0.59411	0.002	0.694	4.0877	
	RHA 5%	-1.9642*	-0.59411	0.016	3.661	0.2673	
	0% (OPC)	1.7917*	-0.59411	0.034	0.0948	3.4885	
	RHA 15%	2.1092*	-0.59411	0.008	0.4123	3.806	
	RHA 10%	RHA 20%	4.1825	-0.59411	<0.001	2.4857	5.8793
	RHA 5%	-0.1725	-0.59411	0.998	-1.8693	1.5243	
	0% (OPC)	-0.3175*	-0.59411	0.983	-2.0143	1.3793	
	RHA 10%	-2.1092	-0.59411	0.008	-3.8060	-.4123	
	RHA 15%	RHA 20%	2.0733*	-0.59411	0.01	0.3765	3.7702
	RHA 5%	-2.2817*	-0.59411	0.004	3.9785	0.5848	
0% (OPC)	-2.3908*	-0.59411	0.002	4.0877	0.694		
RHA 10%	-4.1825*	-0.59411	<0.001	5.8793	2.4857		
RHA 20%	RHA 15%	-2.0733*	-0.59411	0.01	3.7702	0.3765	
RHA 5%	-4.3550*	-0.59411	<0.001	6.0518	2.6582		
0% (OPC)	1.9642*	-0.59411	0.016	2673	3.661		
RHA 10%	0.1725	-0.59411	0.998	-1.5243	1.8693		
RHA 5%	RHA 15%	2.2817*	-0.59411	0.004	5848	3.9785	
RHA 20%	4.3550*	-0.59411	<0.001	2.6582	6.0518		

3.2.3 Hypothesis Testing in Factorial ANOVA

Testing hypothesis helps in finding closure in an experiment based on the formulated hypothesis. Normally, there are two types of hypotheses, null hypothesis and alternative hypothesis. Null hypothesis denoted by “ H_0 ” is a hypothesis that is used to disprove or reject a statement, while an alternative hypothesis (H_a) is used to explain the cause of a phenomenon or anticipated relationship of the variables or treatments. The alternative and null hypotheses for two variables can be expressed using the following two statistical notations:

Alternative hypothesis H_a : $\mu_1 \neq \mu_2$: μ_1 and μ_2 represent alternative hypothesis.

Null hypothesis H_0 : $\mu_1 = \mu_2$, where μ_1 and μ_2 represent the null hypothesis.

During the computation of a factorial ANOVA, since there are multiple independent variables, normally various null and alternative hypothesis will be formulated depending on the number of cases considered in study. The impacts of those multiple independent variables can be categorized as main effects and interaction effects. Main effect in this case is considered as the individual effects of RHA replacement and curing age on compressive strength, whereas interaction effect is the simultaneous effects of both RHA replacement and curing age on compressive strength. For the current investigation, the following hypotheses are formulated:

Null hypothesis (H_0): μ_01 : rice husk ash addition does not have an impact on the concrete compressive strength property.

μ_02 : curing duration does not have an impact on the concrete compressive strength property.

μ_03 : the integration of rice husk ash addition and curing duration does not have an impact on the concrete compressive strength property. Significant factors affecting the compressive strength of concrete are as follows.

In this study, two-way factorial ANOVA with a confidence interval of 95% and a significant level of $\alpha = 0.05$ is used to analyse the factors affecting compressive strength of concrete. The decision rule for the conducted F-test on SPSS® for the main effect is the following: if P value < 0.05 , then the variable is considered as a significant factor which affects the compressive strength of concrete, so the null hypothesis is rejected. If P value ≥ 0.05 , the factor is reflected as no significant and the null hypothesis will not be rejected. After conducting the F-test for main effects, post-hoc test is done to analyse the interaction effect of the variables. The interaction effects consist of four labels for the ages, 3, 7, 28, and 56 days and six labels of RHA replacement, with two control mixes for 0% and 5%, 10%, 15%, and 20% replacement levels for concretes made with and without admixture. The profile plot of different RHA replacements for estimated marginal means of strength at different testing days is illustrated as follows. Based on Figure 8, the estimated marginal means at the 7th day show a larger difference compared with the other days. RHA 5% replacement has a better marginal mean up to 56th day and is more significant than the others, while, at the 56th day, RHA 10% shows an increase in marginal mean. Based on the profile plot, the strength development of control (OPC) mix is very significant in early days (3rd and 7th day) of concrete mixing; after 7th day, the strength development becomes lower. However, concretes made with RHA replacement continue their strength development up to 56th days which aliens with the previous studies mentioned in the literature review. Consequently, as the RHA replacement levels between 5% and 15% show a better marginal means for more than 7th strength (Table 5), this reveals that pozzolanic materials continue their strength development at a later day as long as there is favourable amount of temperature and moisture.

3.2.3 Post Hoc Test

Post hoc tests were further conducted for additional exploration of whether the differences among those means are significantly different within each level or not. Tukey's HSD test is used, as it is one of the popular post hoc test methods. The post hoc test result of RHA replacement is illustrated in Table 6. Based on the Tukey's HSD test, we can conclude that there is a statistically significant difference between 0% (OPC) and RHA 5%, 10%, and 20% which has α value of 0.016, 0.034, and 0.002, respectively, which all are less than 0.05. However, RHA 15% has α value of 0.983 and this number is greater than 0.05. Thus, there is no statistically significant difference between 0% (OPC) and RHA 15%.

4 CONCLUSIONS

From the study, it is concluded that the rice husk burnt at 550°C for 6 hours yields a good pozzolanic property for use as a supplementary cementitious material in concrete. The RHA used in the study also conforms to the chemical analysis requirements of class N pozzolan specified in ASTM C618. The laboratory test results reveal that the compressive strength of concretes made with RHA replacement of 5% to 20% significantly increases with an increase in age. However, as [21-22] argued, the workability of the trial mixes slightly decreases as the percentage of RHA increases. In this regard, the decrease in workability can be improved by adding a proper dosage of super plasticizing admixture. The statistical analysis results show that RHA replacements and age of concrete cubes significantly affect concrete compressive strength at 95% confidence interval and the cost analysis also shows that using RHA can save up to 10% of the total cost of concrete with 5% to 20% cement replacement levels. Previously, multiple researchers in different regions tried to show the effect of using RHA as a supplementary cementitious material in concrete by replacing it in 5% to 30% of ordinary Portland cement. However, there are still a dearth of studies that investigate the effect of using RHA with different cement types like Portland pozzolanic cement with admixture and without admixture. Although previous studies tried to compare the test results using two-dimensional graphs, there are limited studies that justified RHA use in concrete through a statistical approach. Thus, in addition to the analysis of various test results, this study also conducted a statistical analysis to investigate the validity of laboratory test results. Consequently, as the production process of RHA does not require a huge technology and finance, environmental and economic benefits can be exploited easily by using it especially in developing countries like Nigeria, where the expansion of rice production capacity is one of the government's changing policies as an alternative food self-

sufficiency. Future studies could focus on examining the RHA for high strength and high-performance concretes and evaluates the pozzolanic activities of the RHA using XRD analysis.

REFERENCES

1. Chao-Lung, H., Anh-Tuan, B.L., Chun-Tsun, C. and Chun-Tsun, C. (2011). Effect of rice husk ash on the strength and durability characteristics of concrete. *Journal of Construction and Building Materials*, vol. 25, no. 9, pp. 3768-3772.
2. Mann, S. (2018). Achieving Sustainability by Partial Replacement of Cement with Rice Husk Ash. *International Journal of Engineering Research and Applications*, vol. 8, no. 10, pp. 9-13.
3. Khan, R. (2012). Reduction in environmental problems using rice husk ash in concrete. *Construction and Building Materials*, vol. 30, pp. 360-365.
4. Belay, S. and Woldeesenbet, A. (2016). Study of the potential of Ethiopian rice husk as a partial replacement of cement. *PROCEEDINGS Construction Research Congress*, pp. 310-320.
5. Okumu, M.A., Eric, M. and Karnja, T.O. (2020). Probing Optimal Blends of pozzalans to Develop Supplementary cementing material within Busia County Kenya. *Journal of Applied Physics*, vol. 12, no. 1, pp. 112-125.
6. Ramesh, S., Kavitha, S. and Ash, R.H. (2014). Experimental study on the behaviour of cement concrete with rice husk ash (rha). *International Journal of Engineering Science and Innovative Technology*, vol. 3, no. 6, pp. 101-107.
7. Abood-Habeeb, G. and Bin-Mahmud, H. (2010). Study on properties of rice husk ash and its use as cement replacement material. *Materials Research*, vol. 13, no. 2, pp. 185-190.
8. Bie, R.S., Song, X.F., Liu, Q.Q., Ji, X.Y. and Chen, P. (2015). Studies on effects of burning conditions and rice husk ash (RHA) blending amount on the mechanical behavior of cement. *Cement and Concrete Composites*, vol. 55, no. 11, pp. 162-168.
9. Kulkarni, M.S., Mirgal, P.G., Bodhale, P.P. and Tande, M.S. (2014). Effect of rice husk ash on properties of concrete. *Journal of Civil Engineering and Environmental Technology*, vol. 1, no. 1, pp. 26-29.
10. Gursel, A.P., Maryman, H. and Ostertag, C. (2016). A life-cycle approach to environmental, mechanical, and durability properties of green concrete mixes with rice husk ash. *Journal of Cleaner Production*, vol. 112, pp. 823-836.
11. Hu, L., He, Z. and Zhang, S. (2020). Sustainable use of rice husk ash in cement-based materials: environmental evaluation and performance improvement. *Journal of Cleaner Production*, vol. 10, no. 5, pp. 264-272.
12. Raikwar, P. and Tare, V. (2014). Study of concrete properties using rice husk ash and marble powder. *International Journal of Emerging Technology and Advanced Engineering*, vol. 4, no. 8, pp. 680-688.
13. Prasara, A.J. and Gheewala, S.H. (2017). Sustainable utilization of rice husk ash from power plants: a review. *Journal of Cleaner Production*, vol. 167, pp. 1020-1028.
14. Amin, M. and Abdelsalam, B.A. (2019). Efficiency of rice husk ash and fly ash as reactivity materials in sustainable concrete. *Sustainable Environment Research*, vol. 1, no. 1, pp. 1-10.
15. Yeh, A.B. (2005). Fundamental of Probability and Statistics for Engineers. *Technometrics*, vol. 47, no. 2, pp. 271-272.
16. Pode, R. (2016). Potential applications of rice husk ash waste from rice husk biomass power plant. *Renewable and Sustainable Energy Reviews*, vol. 53, pp. 1468-1485.

17. Dixon, D.E., Jack, R.P., George, R.U.B., Subcommittee, A.C., Edward, A.A., Stanley, G.B. and Leonard, W.B. (1991). Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91). *Farmington Hills, MI, USA: American Concrete Institute*, vol. 2, no. 9, pp. 261-265.
18. Ganiron, T.U. (2013). Sustainable Management of Waste Coconut Shells as Aggregates in Concrete Mixture. *Journal of Engineering Science and Technology Review*, vol. 16, 5, pp. 311-322.
19. Oyebisi, S. and Alomayri, T. (2022). Cement-based concrete modified with Vitellaria Paradoxa ash: A lifecycle assessment. *Construction and Building Materials*, vol. 342, pp. 127-906.
20. Joudi-Bahri, I., André, L., Mongi, B.O. and Taoufik, A. (2012). Use of limestone sands and fillers in concrete without superplasticizer. *Cement and Concrete Composites*, vol. 34, no. 6, pp. 771-780.
21. Mahmud, H.B., Malik, M.F., Kahar, R.A., Zain, M.F. and Raman, S.N. (2009). Mechanical properties and durability of normal and water reduced high strength grade 60 concrete containing rice husk ash. *Journal of Advanced Concrete Technology*, vol. 7, no. 1, pp. 21-30.
22. Amin, M.N., Hissan, S., Shahzada, K., Khan, K. and Bibi, T. (2019). Pozzolanic reactivity and the influence of rice husk ash on early-age autogenous shrinkage of concrete. *Frontiers in Materials*, vol.1, no.1, pp. 1-10.