COMPARATIVE STRENGTH OF PARTIALLY REPLACED RICE HUSK ASH WITH CEMENT MORTAR A CASE STUDY OF OBUBRA L.G.A OF CROSS RIVER STATE

www.akwapolyjournal.org
P-ISSN: 2536-6733 | E-ISSN: 2616-0773

Supported by: tetfund TERTIARY EDUCATION TRUST FUND
TETFund/DESS / POLY / IKOT-OSURUA/ ARJ /1-2)

**Engr. Okon*[1], K. P., Engr. Mkpa, E. O., Engr. Saturday, S. A,
Engr. Inyang, E, &**
Department of Civil Engineering, School of Engineering
Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene
Akwa Ibom State

Akpan, B.E (Arc.)
Federal Polytechnic, Nyak Shendam, Plateau State
Corresponding author: sunday.saturday@akwaibompoly.edu.ng

Abstract
The paper assesses and compares the strength of cement mortar that is partially replaced with rice husk ash (RHA). The *primary* objective of this study is to evaluate the feasibility of using RHA in construction projects as a cost-effective and sustainable alternative to traditional cement-based mortar. The study also seeks to address the pressing environmental issues associated with the disposal of agricultural waste. The study results expect to provide valuable insights into the potential benefits and drawbacks of using RHA in construction projects, particularly in terms of its impact on the durability, strength, and overall quality of the mortar. The idea is to generate wealth by selling RHA to potential buyers instead of disposing of it. Samples of RHA are being mixed into the cement mortar at replacement levels ranging from 5% to 25%. A range of laboratory tests is being conducted to evaluate properties such as particle size distribution, compressive strength, flexural strength, bulk density, and water absorption. The results from the laboratory tests show that as the percentage of RHA increases, the density of the RHA with cement mortar decreases from 2.316 kg/m3 to 1.853 kg/m3. Water absorption of RHA with cement mortar increases from 0.45% to 8.1% as the percentage of RHA increases from 0% to 25%. Compressive strength decreases from 23.4 KN/m2 to 7.31 KN/m2, and flexural strength decreases from 3.93 KN/m2 to 0.54 KN/m2. An optimal percentage of RHA with cement mortar is recommended to be between 10% and 15%.

Key words: *Rice Husk Ash* ***(RHA),*** *Ordinary Portland Cement* ***(OPC),*** *Compressive Strength, Flexural Strength, Water Absorption.*

Introduction

Rice husk is a residue from rice production that accounts for 20% of the 649.7 million tons of rice produced annually worldwide. When incompletely burnt, the husk produced from milling plants contributes to air pollution. An effective approach to tackle the environmental challenge is to explore alternative cementing materials, which can serve as a viable solution. Significant efforts worldwide focus on using indigenous and waste materials such as rice husk as concrete ingredients. If sufficiently ground, the ash produced from controlled burning can be used as a cement replacement material in mortar. Studies have shown that adding rice husk ash (RHA) to Portland cement improves the early strength of mortar and forms a calcium silicate hydrate (CSH) gel around the cement particles. This gel is highly dense and less porous, which may increase the strength of mortar against cracking. The chemical composition of rice husk varies depending on the type of paddy, crop year, and climatic and geographical conditions.(cf:Mehta et al, (1992);Saraswathy and Ha-Won,(2007)Roy et al (2014)

Rice was introduced into Nigeria in 1920 by Agboola and is believed to have originated from southern India. In Nigeria, rice is cultivated in appreciable quantities in several states, including Ogun, Osun, Niger, Sokoto, Ebonyi, Borno, Benue, and Cross River State. Rice can be cultivated in upland cultivated on normal loamy soil or swamps. Local milling, which involves peeling off freshly covered rice, is mainly done by young men and women using firewood as the heat source. After milling, the husk is obtained, and about 100% of the husk is wasted and could be used as fuel. RHA can enhance the compressive strength of concrete when used as a partial replacement for cement. The optimum replacement level of OPC by RHA to give maximum long-term strength enhancement has been reported between 10% and 30%, with 15% cement replacement by RHA being optimal for achieving maximum strength.(Cf:Mahmud et al. (1996)

However, the use of RHA in the construction industry has yet to be adopted, possibly due to a lack of understanding of its effect on concrete characteristics. Several studies have been conducted on the characteristics of RHA cement mortar in terms of strength and durability. However, only a few researchers have examined the effects of RHA grinding time and its characteristics. (Cf:Akande et al, (2010); Tashima et al, (2004); Zhang et al, (1996). Global rice production is approximately 580 million tonnes annually, increasing as the world's population and rice consumption grow.Pande et al, (2001) Consequently, the paper aims to determine the effect of partially replacing cement with RHA on the strength of mortar, develop and improve an alternative use of RHA in the construction industries, and provide baseline data for further research on using RHA in cement mortar. By applying supplementary cementitious material, cement can be minimized or reduced while the strength and durability of concrete can be improved compared to conventional concrete. This will help reduce concrete production costs as well as the negative impact on the environment.

Findings

This explains the processes and methods adopted in collecting data for the research. A descriptive and quantitative research approach was used, and a series of laboratory works experimented to determine the "comparative strength of partially replaced RHA with cement mortar". Cement mortar specimens were collected from the materials laboratory of the Civil Engineering Department, Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene. The cement used was ordinary Portland cement produced by Lafarge Cement Plc in Calabar, Cross River State. The fine aggregate was mined from a river at Ikot Osurua Community in Ikot Ekpene L.G.A, Akwa Ibom State. RHA was collected from a rice mill site at Obubra L.G.A of Cross River State and oven-dried in the laboratory, while the water supply was from a clean water source in the civil engineering laboratory of Akwa Ibom State Polytechnic. The tests conducted in the laboratory were: (a) particle size distribution, (b) compressive strength, (c) flexural strength, (d) bulk density, and (e) water absorption.

Particle Size Distribution Test Result

The result obtained from the sieve analysis conducted on fine aggregate and RHA is shown in Tables 2.1 and Figures 2.1. The fine aggregate has a uniformity coefficient of 2, implying well-graded sand. The sand fell within zone 3 and is acceptable for making mortar, according to B.S 4551.

Table 2.1: Sieve Analysis of Fine Aggregate.

Sieve Size	Weight Retained	Percentage Retained	Cumulative Percentage Retained	Percentage Passing
10.0mm	-	-	-	100
6.30mm	10.05	1.01	1.01	98.99
5.0mm	5.50	0.55	1.56	98.44
3.35mm	4.05	0.41	1.97	98.03
2.36mm	16.80	1.68	3.65	96.35
1.18mm	90.05	9.01	12.66	87.34

0.6mm	255.95	25.6	38.26	61.74
425 µ	260.6	26.1	64.36	35.64
300 µ	247.10	24.71	89.07	10.93
150 µ	95.55	9.56	98.63	1.37
75 µ	9.55	0.96	99.59	0.41
Pan	2.55	0.26	99.85	0.15
Summation of Mass =1000g				

Weight of pan = 116.65g

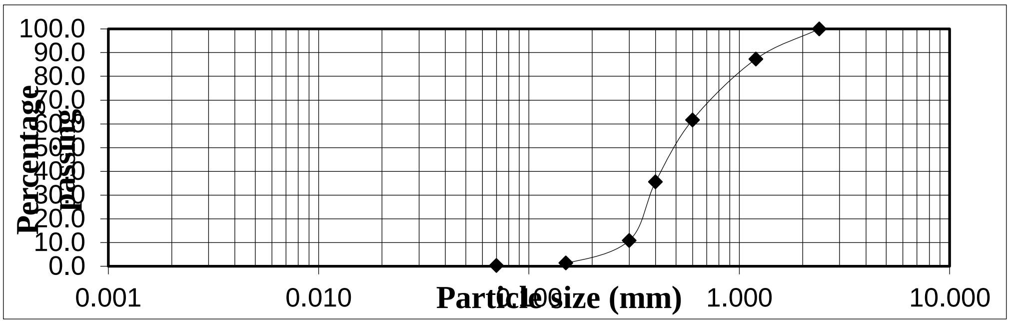


Figure 2.1 Particle size distribution curve for fine aggregate.

Compressive Strength Result

As shown in the result obtained in Figure 2.2, it is seen that the compressive strength of the mortar cubes was below that of the control sample, but between 10-15% replacements, the strength increases above the control strength; this shows that at 10% - 15% RHA replacement, a better compressive strength is achieved. Table 2.2 shows the compressive strength of partially replaced RHA with cement for ages seven days and 14 days for 0% (control), 5%, 10%, 15%, 20% and 25%.

This implies that for a project that requires a higher volume of mortar and 15% of the total volume of the cement required is saved as a result of its partial replacement with RHA, a huge sum of money must have been saved, which can take care of other items in the project, and by so doing reduces the effect of environmental pollution and wastages of the RHA.

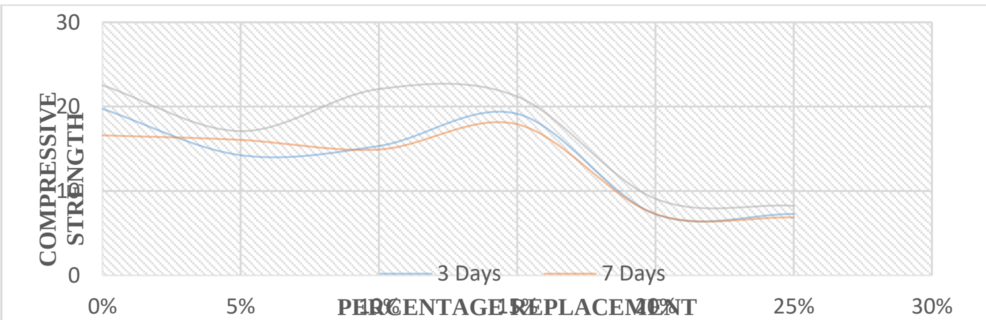


Figure 2.2: Variations of Strength of Mortar and the Percentage Replacement of RHA

Table 2.2 Test Results for Compressive Strength of Mortar at 7 Days

Table 2.2.1: **0% RHA REPLACEMENT. (CONTROL)**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
C 2	**100 x 100**	**7**	**2284**	**2.284**	**154.45**	**15.45**
C 9	**100 x 100**	**7**	**2200**	**2.200**	**163.05**	**16.31**
C3	**100 x 100**	**7**	**2180**	**2.180**	**180.32**	**18.03**

Table 2.2.2: **5% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 1	**100 x 100**	**7**	**2198**	**2.198**	**167.18**	**16.72**
No. 2	**100 x 100**	**7**	**2190**	**2.190**	**149.13**	**14.91**
No. 5	**100 x 100**	**7**	**2170**	**2.170**	**165.66**	**16.56**

Table 2.2.3: **10% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 11	**100 x 100**	**7**	**2246**	**2.25**	**192.22**	**19.22**
No. 8	**100 x 100**	**7**	**2236**	**2.24**	**176.10**	**17.61**
No. 3	**100 x 100**	**7**	**2178**	**2.18**	**79.35**	**7.94**

Table 2.2.4: **15% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 7	**100 x 100**	**7**	**2154**	**2.154**	**131.91**	**12.43**
No. 1	**100 x 100**	**7**	**2126**	**2.126**	**183.57**	**18.35**
No. 2	**100 x 100**	**7**	**2152**	**2.152**	**229.39**	**22.94**

Table 2.2.5: **20% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 1	**100 x 100**	**7**	**2076**	**2.076**	**99.24**	**9.92**
No. 11	**100 x 100**	**7**	**2064**	**2.064**	**57.93**	**5.79**
No. 4	**100 x 100**	**7**	**2054**	**2.054**	**61.74**	**6.17**

Table 2.2.6: **25% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 10	**100 x 100**	**7**	**2022**	**2.022**	**72.75**	**7.28**
No. 2	**100 x 100**	**7**	**2128**	**2.128**	**69.26**	**6.93**
No. 8	**100 x 100**	**7**	**2020**	**2.020**	**64.10**	**6.41**

Test Results for Compressive Strength of Mortar at 14 Days

Table 2.2.7: **0% RHA REPLACEMENT. (CONTROL)**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
C1	**100 x 100**	**14**	**2358**	**2.358**	**216.67**	**21.67**
C4	**100 x 100**	**14**	**2284**	**2.284**	**223.24**	**22.32**
C6	**100 x 100**	**14**	**2296**	**2.296**	**236.08**	**23.61**

Table 2.2.8: **5% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 12	**100 x 100**	**14**	**2208**	**2.21**	**180.12**	**18.01**
No. 8	**100 x 100**	**14**	**2200**	**2.200**	**150.58**	**15.06**
No. 6	**100 x 100**	**14**	**2192**	**2.192**	**182.17**	**18.22**

Table 2.2.9: **10% RHA REPLACEMENT.**

Mark on Cubes	SIZE of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 2	**100 x 100**	**14**	**2276**	**2.28**	**228.13**	**22.81**
No. 9	**100 x 100**	**14**	**2130**	**2.13**	**230.40**	**23.04**
No. 11	**100 x 100**	**14**	**2176**	**2.18**	**204.18**	**20.42**

Table 2.2.10: **15% RHA REPLACEMENT. (CONTROL)**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 5	**100 x 100**	**14**	**2126**	**2.126**	**230.61**	**23.06**
No. 9	**100 x 100**	**14**	**2168**	**2.168**	**212.14**	**21.21**
No. 11	**100 x 100**	**14**	**2168**	**2.168**	**193.33**	**19.33**

Table 2.2.11: **20% RHA REPLACEMENT.**

Mark on Cubes	Size of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 5	**100 x 100**	**14**	**2072**	**2.070**	**83.64**	**8.36**
No. 4	**100 x 100**	**14**	**2074**	**2.074**	**78.85**	**7.89**
No. 8	**100 x 100**	**14**	**2070**	**2.070**	**110.32**	**11.03**

Table 2.2.12: **25% RHA REPLACEMENT.**

Mark on Cubes	SIZE of Cubes (mm)	Age (Days)	Weight of cubes (g)	Density Kg/m^3	Crushed Load (KN)	Strength N/mm^2
No. 9	**100 x 100**	**14**	**2180**	**2.180**	**104.20**	**10.42**
No. 12	**100 x 100**	**14**	**2098**	**2.098**	**74.49**	**7.45**
No. 15	**100 x 100**	**14**	**2188**	**2.188**	**68.80**	**6.88**

2.3 Density Test Results

The results of RHA's effect on cement mortar density are shown in Table 4.3 and Figure 4.3. The density of RHA-mortar decreases as the percentage of the pozzolan increases. This is due to the replacement of Portland cement with a lightweight pozzolan. The specific gravity of cement is greater than that of rice husk ash. The reduction in the bulk density results in lightweight mortar without increasing the pore spaces in the sample.

Weight of casted cubes of Cement & RHA mix proportion before curing. (Kilogram)						
S/No.	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**
1	2.316	2.108	2.160	2.064	1.948	2.058
2	2.264	2.148	2.206	2.046	1.914	1.984
3	2.152	2.144	2.130	2.094	1.928	2.046
4	2.234	2.154	2.132	2.080	1.940	2.068
5	2.330	2.160	2.190	2.048	1.914	2.014
6	2.258	2.136	2.140	2.096	1.922	1.876
7	2.278	2.130	2.194	2.108	1.914	1.938
8	2.272	2.156	2.176	2.098	1.934	1.853
9	2.180	2.174	2.058	2.100	1.922	2.048
10	2.282	2.158	2.198	2.138	1.936	1.882
11	2.250	2.152	2.110	2.084	1.912	2.034
12	2.276	2.162	2.182	2.106	1.910	1.916

Table 2.3: Density of Hardened Mortar (Kg/m^3)

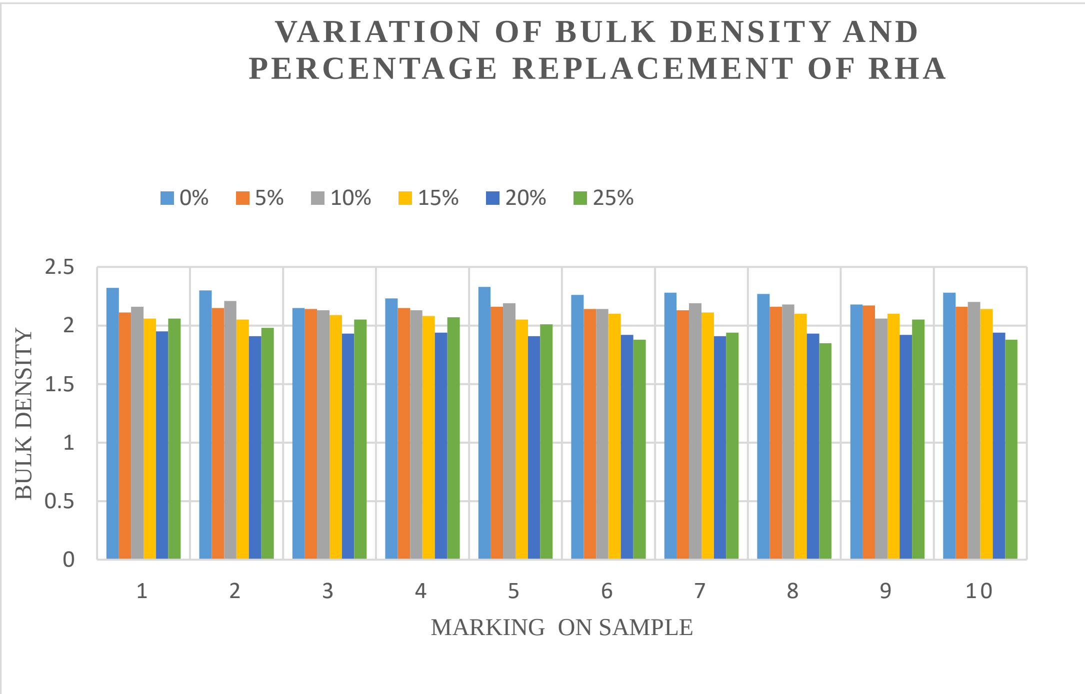


Figure 2.3: Variation of Bulk Density.

2.4 Results for Water Absorption Test

Table 4.4 and Figure 4.4 show that the highest water absorption was at 25%, followed by 20% RHA replacement. This implies that higher RHA particles possess the highest surface area and fineness and lower reaction ability than cement (Shetty, 2004).

Both of these features result in high water demand to wet the surface area of RHA, as investigated by (Zhang et al., 1996; Ganesan et al., 2008).

According to Habeeb et al., due to the increment of the specific surface area of RHA, more water is required to wet the surface area of RHA. Since then, the water/fine aggregate ratio has been maintained.

Table 2.4 Water Absorption Table

Percentage RHA	0	5	10	15	20	25
Average calculated water absorption (expressed in percentage)	0.45	1.345	1.77	1.19	3.6	8.1

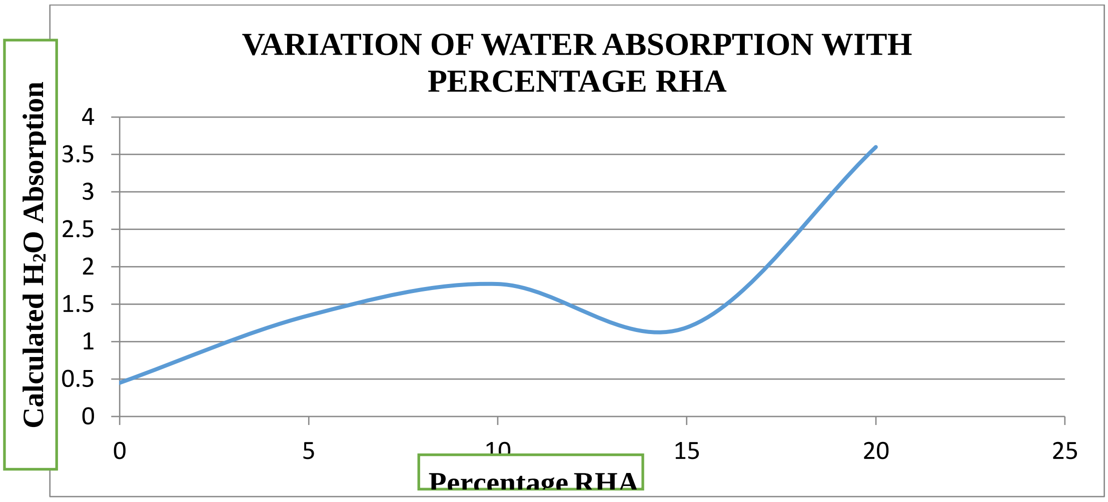


Figure 2.4: Variation of Percentage RHA with Water Absorbed.

2.5 Results for Flexural Strength Tests.

From the result obtained in Table 4.5 and its graphical representation in Figure 4.5, it can be seen that there was a relative increase in flexural strength between (5 -10) per cent RHA replacement.

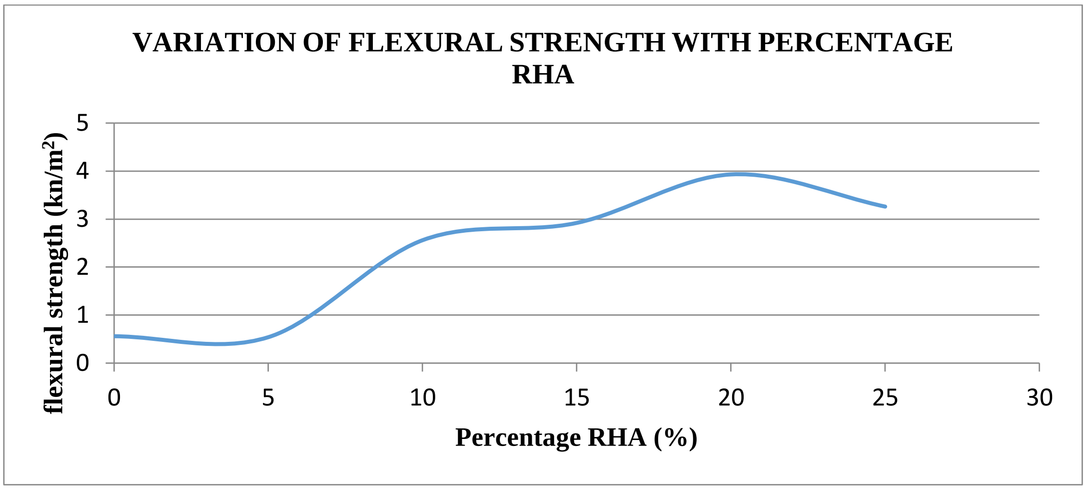
This is regarded as the safe region from the strength test result because, beyond or below this region, the strength recorded is relatively low compared to the control specimen, which is the (0%) replacement.

Table 2.5 (7 days strength)

S/No.	Percentage Replacement	Weight of Cylinder (Kg) + Sample	Load (KN)
1.	**25%**	**10.504**	**25.7**
2.	**20%**	**10.584**	**24.4**
3.	**15%**	**11.102**	**115.0**
4.	**10%**	**11.390**	**131.4**
5.	**5%**	**11.656**	**176.8**
6.	**0% (Control)**	**11.616**	**146.8**

Table 2.5.1

Percentage RHA (%)	0	5	10	15	20	25
Flexural strength (KN/m^2)	0.56	0.54	2.56	2.92	3.93	3.26



Conclusions and Recommendations

Conclusion

The test results indicate that Rice Husk Ash has a high silica content and can be used partially instead of cement. One potential benefit of this approach could be reducing the exorbitant expenses associated with cement, especially in cases where lightweight concrete and non-load-bearing walls are involved. In addition, agricultural waste such as Rice Husk Ash can benefit construction applications, reducing its negative environmental impact. Rice Husk Ash's compressive strength is high, making it a great option for load-bearing members when used as a 10% to 15% replacement. Finally, it is worth noting that the high surface area of Rice Husk Ash results in a greater water absorption ratio, especially at 20% to 25% cement replacement..

Recommendations

The findings from the experiment involving the partial substitution of cement with Rice Husk Ash (RHA) to produce construction materials revealed that RHA can be a valuable resource in the construction industry. The study recommends that RHA be primarily used to produce lightweight mortars and non-load-bearing elements such as walls and internal partitions. However, using RHA may also be extended to modify the geotechnical properties of problematic soil during road construction. This modification can be achieved by adding RHA to the soil and mixing it thoroughly to improve its strength, stability, and overall performance. While using RHA in construction has great potential, it must be applied appropriately to ensure its effectiveness and safety.

References

Agbede, I. O, and Joel, M, (2011), Effect of rice husk ash (RHA) on the properties of Ibaji burnt clay bricks, *American Journal of Scientific and Industrial Research*, Vol. 2, Page (2-4), U.S.A.

Ajay, K. (2012), *Properties and industrial applications of rice husk*, Vol. 2, page (2-6), India.

Ajijola, S. (2012), Appraisal of rice production in Nigeria: A case study of North central states of Nigeria, *Journal of Stored Products and Postharvest Research,* Vol. 3(9), page (133 – 136), Nigeria.

Amitkumar, I. (2015), Use of Rice Husk Ash in Concrete, *Journal of Mechanical and Civil Engineering* .Vol. 12, page (29-31), India.

Basha, E. A. (2003), "Effect of the Cement-Rice Husk Ash on the Plasticity and Compaction of Soil." *Electronic Journal of Geotechnical Engineering,* Vol. 8, page (2-6). Saudi Arabia.

British Standard (BS) (1881), Part III (1983). Method of Normal Curing of Test Specimen British Standards Institution, Her Majesty Stationery Office, London

Dabai, M.U. (2009), Studies on the Effect of Rice Husk Ash as Cement Admixture, *Nigerian Journal of Basic and Applied Science*. Vol. 17, page (252-256). India.

El-Sayed, Sedek A. S. (2013), Performance of Cement Mortar Made with Fine Aggregates of Dune Sand, *Jordan Journal of Civil Engineering,* Volume 7, No. 3, page (270), Kharga Oasis, Western Desert, Egypt.

Farah N. A. (2010), Contribution of Rice Husk Ash to the Properties of Mortar and Concrete, *A Review of Journal of American Science*. Vol. 6, page (4-9).

Giddel, M. R. and A.P. Jivani (2007), Waste to Wealth - Potential of Rice Husk in India, *A literature review, Proceedings of the International Conference on Cleaner Technologies and Environmental Management PEC, Pondicherry,* Page (586 – 590), India.

Jinan, J & Hassan, A. 2007, *Use of Rice Husk Ash in Cement Mortar,* page (1-6), Bangladish

Kartini. K, (2011), Rice Husk Ash – Pozzolanic Material for Sustainability, *International Journal of Applied Science and Technology,* Vol. 1, Page (2-5), Malaysia.

Kersten M.S, (1949), *Thermal properties of soils*. Bull. 28. University of Minnesota. Institute of Technology, Engineering Experiment Station, Page (52 – 53), India.

Khana, M. N. N. , M. Jamil, M. R. Karimc and M.F.M. Zain, (2014), Strength and Durability of Mortar and Concrete Containing Rice Husk Ash: *A Review, World Applied Sciences Journal*, Page (752-765), Malaysia.

Kumar, S., (2013), Utilization of Rice Husk and Their Ash, A Journal of Chemical and Environmental Sciences, Vol. 1(5), Page (3-8) India.

Makarand, S. K & Paresh G.M, (2014), Effect of Rice Husk Ash on Properties of Concrete, Journal of Civil Engineering and Environmental Technology, Vol. 1, Page (26-29), India.

Manoj, A & Narsee, M (2014), Soil Stabilization Using Waste Rice Husk Ash, Cement, Lime & Gypsum, Vol. 4, page (1-9). Florida.

Md. Harunur R, Md. Keramat A. M & Tarif U. A, (2011), Long Term Effect of Rice Husk Ash on Strength of Mortar, International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering. Vol. 4, No. 7, India.

Michael T, (2005). The Most Important Property of Cement-Lime in Masonry Construction, International Building Lime Symposium Vol. 1, page (2-7), Orlando, Florida.

Narayanan. S. P, (2013), Properties of Rice Husk Ash (RHA and MIRHA) Mortars, Research Journal of Applied Sciences, Engineering and Technology. Vol. 7, page (3-8). Malaysia.

Obilade, I.O, (2014), Use of Rice Husk Ash as Partial Replacement for Cement in Concrete, International Journal of Engineering and Applied Sciences. Vol. 5, (2-6). Nigeria.

Omar T. F, (1981), Thermal Properties of Soil, United State Army Corps of Engineers, Cold Region Research & Engineering Laboratory, Page (16-17), New Hampshir, USA.

Oyekan, G. L. (2011), Study on the engineering properties of sandcrete blocks produced with rice husk ash blended cement, Journal of Engineering and Technology Research Vol. 3(3), Page. (88-98). India.