Original Research Article

EFFECT OF RICE HUSK REINFORCEMENT ON STRENGTH OF EARTH BLOCKS

ABSTRACT

The high deficit of housing in Africa occasioned by poverty, high inflation rates, high population growth rate and soaring costs of construction materials, makes quality housing out of the reach of low-income earners who make up the bulk of Africa's population. This study evaluated the performance of rice husk-reinforced compressed earth blocks. Compressed earth blocks measuring 200 mm x 100 mm x 100 mm reinforced with rice husk (0-1.5%) by weight of laterite were produced and tested for their densities and compressive strengths after 28 days of curing. The results obtained revealed that the addition of rice husk to the matrix led to an increase in the compressive strength of the blocks. The addition of 0.5%, 1.0% and 1.5% of rice husk resulted in a 1.34%, 3.49% and 6.28% decrease in density and a 15.46%, 10.31% and 5.15% increase in the compressive strength respectively when compared with the control. The blocks may be used for non-load bearing applications as their compressive strengths fall below the minimum requirements specified for load-bearing walls by the Nigeria Building and Road Research Institute. An optimum reinforcement of the blocks with 0.5% rice husk is recommended.

Keywords: rice husk, earthen construction, compressive strength, compressed earth blocks, sustainable construction materials

1. INTRODUCTION

The surge in global population has led to an increased demand for infrastructure resulting in an increased demand for building and construction materials like cement and natural aggregates. Natural aggregate reserves are continuously been depleted due to their continuous exploitation, leading to the scarcity of natural aggregates in some climes. Environmental pollution and climate change which are majorly influenced by the wastes generated from agricultural and industrial processes are issues of global discuss. The emission of carbon (iv) oxide (CO_2) in the manufacturing process of cement, for example, is a major greenhouse gas that contributes to the depletion of the ozone layer [1-2].

Quality infrastructure such as housing is integral to human sustenance as it is the second basic need of man after food. Quality housing is not limited to the physical structure alone but includes all necessary facilities for the good health and well-being of man [2]. Nigeria, like most developing countries, is currently plagued with a high deficit of housing. This is occasioned by poverty, high inflation rates, high population growth rates and soaring costs of construction materials, making quality housing out of the reach of low-income earners who make up the bulk of Nigeria's population [3].

Earth blocks which constitute green building materials are experiencing a new popularity in Africa and developing countries across the globe due to their cost-effectiveness, availability of earth, ease of use, good fire resistance, low energy consumption, quicker and easier construction requiring low-skilled labour, adequate strength development, good acoustic and thermal properties, little or no environmental pollution in its life cycle, low waste generation, and its environmentally friendly [4-9]. They are usually stabilized to improve their engineering properties. Typical cement-stabilized earth blocks require less than 5% of the energy required for the manufacture of similar fired clay bricks and concrete masonry units [10, 2]. Agricultural waste fibres have over time proven to improve the mechanical and durability properties of earth blocks and offer the possibility of building more robust and comfortable homes in developing countries [11].

Rice husk (RH), the outer shell of rice grain is a waste generated by rice-processing mills. RH makes up about 20-22% of the weight of rice [12-13]. About 1.1 million metric tonnes of RH is annually generated as wastes in Nigeria are indiscriminately disposed of the environment, resulting in environmental pollution [13]. RH is averagely composed of about 40-50% cellulose, 25-30% lignin, 15-20% silica, and 10-20% moisture content [13-14]. Rice husk ash (RHA), obtained from the burning of RH has extensively been used by various researchers in cement and soil composites. There is however little information about the use of RH for earth block production. Labintan *et al.* [11] carried out a study to investigate the influence of rice straw on the physical and mechanical properties of adobes. The adobes comprised a mixture of sandy clay and different proportions (0-40%) of rice straw. From their findings, the shrinkage, density and workability of the blocks reduced as the proportion of rice straw in the matrix increased. They also observed that the mechanical properties (compressive, tensile and flexural strengths) of the blocks increased as the proportion of rice straw in the matrix increased. They recommended an optimum of 25% rice straw (40mm) by volume for the adobes produced. Verma and Sharma [15] studied the effect of marble powder, paddy straw fibres and sugarcane bagasse ash on the compressive strength and water absorption of CEBs. Marble powder was used to replace soil by 25%, 35% and 45%, paddy Straw fibre replaced soil by 0.6%, 0.8% and 1% while sugarcane bagasse ash replaced soil by 8%,10% and 12%. Their findings reveal that as the proportion of marble powder increased, the dry density and compressive strength of the blocks increased while the water absorption reduced. However, as the proportion of paddy straw fibre and sugarcane bagasse ash increased, the dry density and compressive strength of the blocks reduced while the water absorption increased. Bazuhair [16] evaluated the effects of rice husk fibre on the properties and behaviour of compressed earth blocks. Different percentages of rice husk fibre (0.5, 1, 1.5, 2, 2.5, and 3%) were blended into a mixture of clay and pit sand. The results obtained reveal that as the amount of rice husk fibre in the matrix increased, the compressive strength, shrinkage, drying time, and cube crushing strength of the CEBs produced reduced up to about 50% while the modulus of rupture increase up to about 45%.

The current study evaluated the effect of rice husk on the density and compressive strength of compressed earth blocks made from lateritic soil.

2. MATERIALS AND METHODS

2.1 Materials

The following materials were sourced and used in the study:

2.1.1 Soil

Reddish-brown lateritic soil was used for this research. The soil was obtained from an existing borrow pit at Akpataega, Idah, Kogi State, Nigeria, at a depth of ~1.5m. The soil was free from organic matter and deleterious materials. The soil (passing through sieve 4.75mm) was analysed to establish its geotechnical properties by BS 1377 [17] at the Soil Mechanics Laboratory, Department of Civil Engineering, The Federal Polytechnic, Idah, Kogi State. The geotechnical properties are presented in Table 1.

Table 1. Geotechnical Properties of the Soil

TEST	RESULT
Specific gravity (%)	2.61
% passing BS 200 sieve (0.075mm)	3.3
Natural moisture content (%)	10.8
Maximum dry density (kg/m^3)	2066.38
Optimum moisture content (%)	10.6
Condition of sample	Air dried
Liquid limit (%)	29
Plastic limit (%)	23
Plasticity index (%)	6
Coefficient of curvature	1.98
Coefficient of uniformity	8.82

2.1.2 Rice Husk

The rice husk (RH) used for this research was obtained from rice mills at Egah Market in Idah, Kogi state. The rice husk was washed with warm water to remove oil and dirt, and sun-dried before it was used. A photograph of the rice husk sample used is shown in Figure 1.

Fig. 1: sample of rice husk used

2.1.3 Water

Fresh, colourless, odourless and tasteless potable water that is free from injurious amounts of oils, alkalis, salts, sugar organic matter or any other substances, was used for this research.

2.2 Experimental Investigation

2.2.1 Mixture Proportioning, Moulding and Testing of Blocks

The soil was reinforced with rice husk proportions of 0%, 0.5%, 1% and 1.5% by weight of laterite for each mix. The mix proportion of the specimens is presented in Table 2. Block specimens of size 200 mm x 100 mm x 100 mm were moulded from the fibre-reinforced lateritic soil samples. The lateritic soil and RH were thoroughly mixed under dry conditions after which an appropriate amount of water (the optimum moisture content) was added to the mixture. A total of 20 blocks were moulded with five blocks for each set of mix and compaction was done in accordance with BS 1377 [17]. Mixing of the materials, moulding and compaction of the blocks was carried out manually. The freshly moulded blocks were carefully extruded in good shape on a clean, hard and flat surface after which they were left to cure under a shade for 28 days. Water was sprayed on the blocks once every morning and evening for the 28-day curing period. The density and compressive strength of the blocks were tested in accordance with BS 771-1 [18] and BS 12390-4 [19] after 28 days of curing. Figures 2a and 2b show the freshly moulded blocks and compressive strength test setup respectively.

Table 2. Mix proportion of the specimen

Mix ID	RH (Kg/m^3)	Laterite (Kg/m^3)
C (control)	0.00	20.63
R1	0.10	20.52
R2	0.21	20.42
R3	0.31	20.32

Fig. 2. (a.) freshly moulded block specimen (b.) compressive strength test setup

3. RESULTS AND DISCUSSIONS

The results obtained are presented as follows

3.1 Density

The average density of the blocks produced is presented in Table 3 and Figure 3. The density of the blocks decreased with the addition of RH to the matrix. The addition of 0.5%, 1% and 1.5% of rice husk resulted in a 1.34%, 3.49% and 6.28% decrease in the density respectively. The decrease in density may be due to a reduction in the compact and dense nature of the earth blocks because the rice husk is less dense when compared with lateritic soil.

Table 3: Average density of blocks

MIX ID	RH (%)	Average Density (Kg/m^3)	Change in Density (%)
R1	0%	2176.67	0.00
R2	0.5%	2147.56	-1.34
R3	1%	2100.80	-3.49
R4	1.5%	2040.08	-6.28

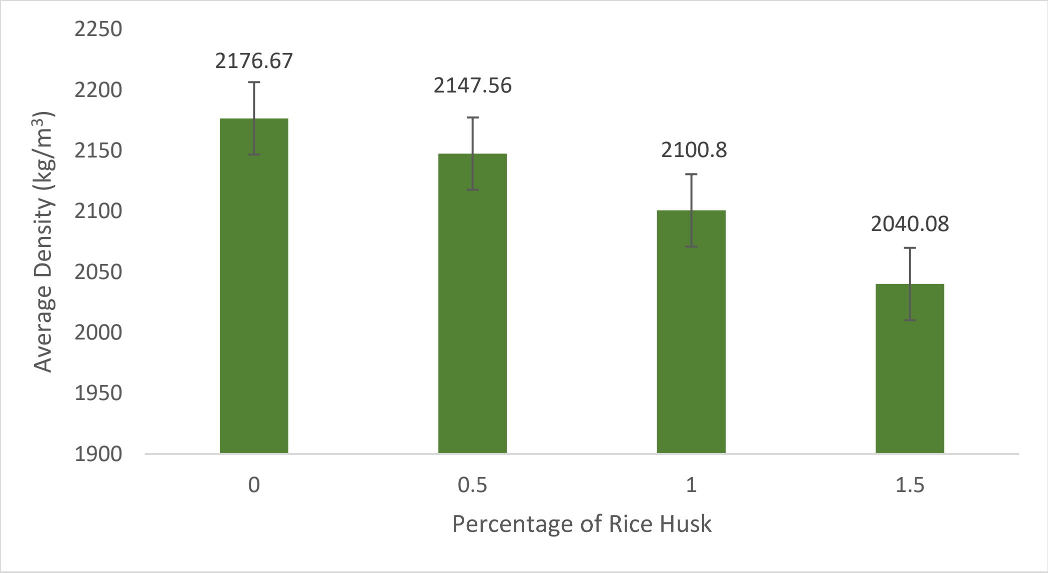

Fig. 3: Average density of blocks

3.2 Compressive Strength

The average compressive strength of the blocks produced is presented in Table 4 and Figure 4. When compared to the control mix, it was shown that adding RH to each matrix resulted in a significant increase in the compressive strength of the blocks. However, the addition of RH in the matrix beyond 0.5% resulted in a decrease in the compressive strength. The addition of 0.5%, 1% and 1.5% of rice husk resulted in a 15.46%, 10.31% and 5.15% increase in the compressive strength respectively.

The increase in strength of the blocks upon addition of RH to the soil matrix may be attributed to the presence of lignin and silica in RH [13-14] which has been reported by Klapiszewski et al [20] and Abhilash et al [21] to have positive effects on the strength of cement composites.

The increase in the compressive strength of the blocks may also be attributed to the strength and toughness of the fibres, while the decrease in the compressive strength beyond 0.5% RH proportion in the matrix results from the increase in the volume of pores in the matrix as the fibre content increases. Similar trends were reported by [22-24] when natural plant fibres were used in earth block production. Danso et al. [22] and Mostafa and Uddin [23] opine that strength development of soil-fibre mixes mostly depends on the formation of fibre-matrix, matrix-matrix and fibre-fibre bonds. The creation of an isotropic matrix between the soil mix and the fibre network results in a strength increase as such a matrix opposes the movement of particles thereby creating stability in the matrix. They further stated that these bonds can be affected by the quantity of fibre present. An increase in fibre content results in a decrease in fibre-matrix and matrix-matrix bonds, and a reduction in the cohesion of the fibre with the soil due to knotting and overlapping of the fibres, resulting in a reduction of the compressive strength of the blocks.

The blocks produced may be used for non-load bearing applications as their compressive strengths do not meet the minimum compressive strength requirements of 1.65 N/mm^2 for load-bearing lateritic blocks as specified by the Nigeria Building and Road Research Institute [25].

Table 4. Average Compressive Strength of Blocks

MIX ID	RH (%)	Average Compressive Strength (N/mm^2)	Change in Compressive Strength (%)
C (control)	0.0	0.97	0.00
R1	0.5	1.12	15.46
R2	1.0	1.07	10.31
R3	1.5	1.02	5.15

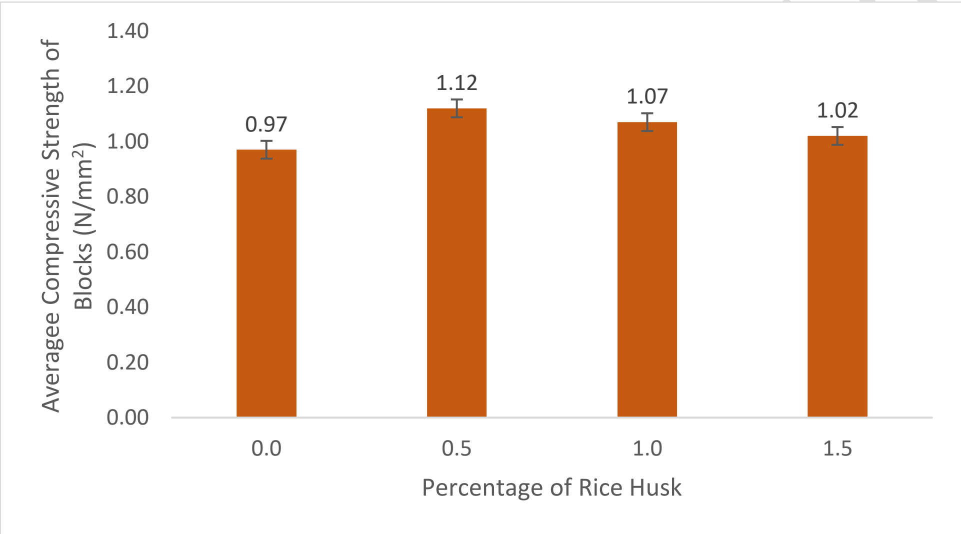

Fig. 4. Average Compressive Strength of Blocks

4. CONCLUSION

Compressed earth blocks reinforced with rice husk (0-1.5%) by weight of laterite were produced and tested for their compressive strengths after 28 days of curing. The compressive strength of the blocks increased with the addition of rice husk to the matrix. From the observations of this investigation, the following conclusions were made

1. The blocks reinforced with rice husk had better performance in their compressive strengths as compared to the unreinforced blocks.
2. When compared with the control mix, the addition of 0.5%, 1% and 1.5% of rice husk resulted in a 15.46%, 10.31% and 5.15% decrease in the average density respectively.

3. When compared with the control mix, the addition of 0.5%, 1% and 1.5% of rice husk resulted in a 15.46%, 10.31% and 5.15% increase in the average compressive strength respectively.
4. An optimum reinforcement of the blocks with 0.5% rice husk is recommended.
5. Rice husk can be used to improve the properties of CEBs for affordable eco-friendly housing in developing and low-income countries.
6. The blocks produced may be used for non-load bearing applications as their compressive strengths fall below the minimum compressive strength requirements of 1.65 N/mm^2 for load-bearing lateritic blocks as specified by the Nigeria Building and Road Research Institute
7. Further research can be carried out to evaluate the effect of rice husk on the water absorption, erosion and efflorescence of CEBs.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

1. Yunusa, A., Onugba, M. A., Austyns, A. O., Ojih, C. U., and Oni, A. E., (2022). The use of waste marble dust as partial replacement for cement in concrete. *Current Journal of Applied Science and Technology*. *41*(8): 39-46. https://doi.org/10.9734/CJAST/2022/v41i831684

2. Onugba, M. A., Ogbaje, D. J., Atonu, Y. A., Uche, B. C., and Adeniyi, D. A. (2023). Effect of palm fibre on compressed cement-stabilized earth blocks. *Journal of Management and Technology*, *19*(1):356-365.
3. UN-HABITAT. (2016). World cities report – urbanization and development: emerging futures. United Nations Human Settlements Programme (UN-Habitat), Nairobi, Kenya https://unhabitat.org/sites/default/files/download-manager-files/WCR-2016-WEB.pdf
4. Adam, E. A., & Agib, A. R. A. (2001). Compressed stabilized block manufacture in Sudan. United Nations Educational, Scientific and Cultural Organization, Paris, France. https://unesdoc.unesco.org/ark:/48223/pf0000128236.locale=en
5. Harper, D. (2011). Alternative Materials of Stabilisation for Unfired Mud Bricks. https://vdocuments.mx/alternative-methods-of-stabilisation-for-unfired-mudbricks.html?page=1
6. Okere, C. E. (2020). Strength Property of Laterite Blocks made with Different Pozzolanic Materials. *NIPES Journal of Science & Technology Research*. 2(2), pp. 152-157. https://doi.org/10.37933/nipes/2.2.2020.15
7. Pacheco-Torgal, F. & Jalali, S. (2012). Earth Construction: Lessons from the Past for Future Eco Efficient Construction, *Construction & Building Materials*. 29, pp. 512-519. https://doi.org/10.1016/j.conbuildmat.2011.10.054
8. Riza, F. V., Rahman, I. A. & Zaidi, A. M. A. (2010). A brief review of compressed stabilized earth brick (CSEB). *Int. Conf. Sci. & Soc. Res.* (CSSR 2010), Kuala Lumpur, Malaysia, December 5-7, 2010 pp. 999-1004. https://dx.doi.org/10.1109/CSSR.2010.5773936
9. Subramanian, G. K. M., Balasubramanian, M. & Kumar, A. A. J. (2022). A Review on the Mechanical Properties of Natural Fiber Reinforced Compressed Earth Blocks. *Journal of Natural Fibers*. 19(14), pp. 7687-7701, https://doi.org/10.1080/15440478.2021.1958405
10. Asha, P., Johnson, K., Sachin, C. M., Vetrivel, V., and Prasanna, E. (2020). Performance of compressed stabilised earth blocks with rice husk ash. *Current Journal of Applied Science and Technology*. *39*(25): 143-153, https://doi.org/10.9734/CJAST/2020/v39i2530894
11. Labintan, C. A., Adadja, C. E., Gibigaye, M., Zahrouni, H., and Hattab, M. (2019). The influence of rice straw on the physical and mechanical properties of banco, an adobe reinforced with rice straw. *International Journal of Engineering and Advanced Technology*, *9*(2): 2363-2367
12. Nabil, M., Essa, A., Mahmood, M. and Rabah, M. (2021). Effect of rice husk ash (RHA) and slag as partial replacement of cement on reinforced concrete slabs. *Journal of Engineering Research and Reports*. 20(11): 34-40, https://doi.org/10.9734/JERR/2021/v20i1117403
13. Okpoechi, C. U., Emma-Ochu, C. A., Ibemere, L. C., Ibe, P., Onwuka, E. O. and Suagwu, A. O. (2021). Production of light weight blocks using rice husk. *International Journal of*

Environment and Climate Change. 11(9): 24-30, https://doi.org/10.9734/IJECC/2021/v11i830473

14. Singh, B (2018). Rice husk ash. In R. Siddique & Cachim, P. (Eds.) *Waste and supplementary cementitious materials in concrete* (pp. 417-460). Woodhead Publishing Series in Civil and Structural Engineering, https://doi.org/10.1016/B978-0-08-102156-9.00013-4
15. Verma, A., and Sharma, T. (2021). Experimental study of the strength aspects of compressed stabilized earth blocks using marble dust, sugarcane bagasse ash and paddy straw fiber. *IOP Conf. Ser.: Earth Environ. Sci.*, *889*(012025), https://doi.org/10.1088/1755-1315/889/1/012025
16. Bazuhair, R. W. (2023). Laboratory evaluation of the effect of rice husk fiber on soil properties and behaviors. *J. Umm Al-Qura Univ. Eng. Archit.*, https://doi.org/10.1007/s43995-023-00027-z
17. BSI (1990). BS 1377: Methods of testing soils for civil engineering purposes. British Standards Institution, London
18. BSI (2003). BS EN 771-1: Specification for clay masonry units. British Standards Institution, London
19. BSI (2019). BS EN 12390-4: Testing hardened concrete. compressive strength – specification for compression testing machines. British Standards Institution, London
20. Klapiszewski, L., Klapiszewska, I., Slosarczyk, A. and Jesionowski, T. (2019). Lignin-based hybrid admixtures and their role in cement composite fabrication. *Molecules.* 24, 3544, https://doi.org/10.3390/molecules24193544
21. Abhilash, P. P., Nayak, D. K., Sangaju, B., Kumar, R., Kumar, V. (2021). Effect of nano-silica in concrete; a review. *Materials.* 278, 122347, https://doi.org/10.1016/j.conbuildmat.2021.122347
22. Danso, H, Martinson, D. B., Ali, M., Williams, J. (2015). Physical, mechanical and durability properties of soil building blocks reinforced with natural fibres. *Construction and Building Materials*. 101: 797-809. https://dx.doi.org/10.1016/j.conbuildmat.2015.10.069
23. Mostafa, M., and Uddin, N. (2016). Experimental analysis of compressed earth block (CEB) with banana fibers resisting flexural and compression forces. *Case Studies in Construction Materials*, *5*:53–63, http://dx.doi.org/10.1016/j.cscm.2016.07.001
24. Onugba, M. A., Omisande, L. A., Alhassan, Y. A., and Abdullahi, A. O. (2023). Enhancing earth-based building materials: effect of palm fibre reinforcement on compressive strength. *Journal of Engineering Research and Reports*, *25*(11): 55-63, https://doi.org/10.9734/JERR/2023/v25i11020
25. Nigeria building and road research institute (NBRRI). NBRRI Interlocking block making machine. NBRRI Newsletter. 2006;1(1):15-17