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Development of High-Strength Insulating Refractory Bricks Using Locally Sourced Materials

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The country depends largely on foreign insulating and refractory bricks even though researches have shown that the necessary raw materials which are Ball clay, kaolin, saw dust, charcoal, and rice husk were used for the production of refractory bricks are prevalent and available in the country. The uses of locally sourced materials are to be encouraged in the production of refractory bricks rather than importing refractory bricks from other countries. The aim of the study is to produce insulating refractory bricks from locally available materials that exhibit good thermal and mechanical properties. The experimental method of research was adopted to formulate the refractory bricks using the sourced clay and other locally available materials. The samples of the bricks produced were passed through series of tests; compressive load tests, thermal shock test, porosity test, shrinkage test, physical observation, and water absorption for certainty about the bricks to be referred to as refractory bricks. With the varying compositions of the materials, it was observed that the more the percentage composition of clay and kaolin than the combustible such as rice husk in a refractory brick, the higher the compressive load strength; with the increased level of combustible in a refractory brick, the higher the water absorption which is not appropriate for a good

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refractory brick. All these factors were incorporated into making several insulating refractory bricks and were eventually used in the repair of kiln. The properties of the locally produced bricks were compared to those with imported materials and could be observed that the properties were alike. Based on the finding of this study, the conclusions can be summarized as: the locally sourced materials can equally perform the same functions with the foreign materials.

Keywords: Brick; chimney; clay body; conduction; degradation kiln; kiln chamber; retention; refractory.

1. INTRODUCTION

Refractories are mineral and chemical-based materials with very high heat resisting properties which make them ideal for the use in construction of kilns, furnace walls and ceilings in various industries such as metallurgical, chemical, cement, glass and petrochemicals. Refractories are materials which are used has the ability to tolerate of high temperatures [1]. The ability to withstand exposure to heat above 1300ºC is the critical distinction separating refractories from other ceramics, fibres and coating applications, [2].

At the moment, the country depends largely on foreign insulating and refractory bricks and because of this Nigeria needs to discontinues importation of these refractory bricks and develops its own technology or become import dependent with retrogressive economic implication [3-6]. Reviewed literatures have shown that the necessary raw materials are available in the country [7]. With the revamping of the iron and steel industry through the rehabilitation of various inland rolling mills and the potential completion and commissioning of the multi-billion dollar Ajaokuta Steel complex to produce 1.3 million tonnes of liquid steel, there will be a great increase in consumption of refractory materials. Ajaokuta steel was estimated to require 36,000 tonnes of refractory bricks worth over Sixty million naira just for furnace lining purposes only and more than 80% of the refractory bricks to be required are fired clay [8]. The four refineries in Nigeria were recorded to have gulped about $850 million for their turn around maintenance between 1997 and 2002. Other demands for refractory products come from chemical, hardware, cement and glass industries. The refractory needs of these industries were well over 300,000 tonnes as at the year 2000 [9]. These refractory materials are at present sourced by importation. The enormous cost of importing refractories annually according to Hassan, Yami, Raji, & Ngala, (2001) and Yakubu & Abdulrahim [10] was to the tune of USD $2.9 billion.

In view of these, this research is being carried out to explore the local availability of clay and other materials which are being neglected for imported refractory products for the production of refractory bricks with the same standard and properties as the imported refractory products.

2. METHODS AND MATERIALS

The experimental research method was used for the formulation of the refractory bricks using clay sourced from Auchi, Edo State, saw dust, charcoal, kaolin and rice husk sourced from Akure, Ondo State, Nigeria respectively.

2.1 Method

The research method that was used is experimental, in which the ball clay has been sourced for from Auchi in Edo State, Nigeria. Different particles such as stone, sticks and leafs where carefully pick from the clay and then sun dried for two weeks. The rice husk was sourced for here in Akure along Ondo road at a rice mill; the rice husk was also sun dried for one week and was grinded and sieved. Both the saw dust and charcoal they were also sourced for within Akure Ondo State, Nigeria. Both of the materials were also sun dried for about two weeks before they were grinded in the department with the grinding machine at the department; thereafter they were sieved and packed inside sack and kept in an open and dry condition. The following Raw materials clay, Calcine clay, Kaolin, Calcine kaolin, Sawdust, Rice husk and Charcoal were taken to Engineering Materials Development Institute (EMDI) at Akure for XRF test.

The Table 1 shows the composition of tri-axial blend method that was used to produce samples of bricks from each of the materials that were sourced for.

2.2 Materials Blends

A working recipe was formulated for the production of refractory bricks by adjusting the recipes and raw materials from secondary sources to suit the purpose of this research and then, the recipes were to be tested by producing varying samples of insulating refractory bricks from the adjusted recipes. Moulded samples and metallic moulds are shown in Fig. 1. The prepared samples were sun dry to ensure evaporation of moisture. They were further fired in a furnace at temperature of 20^{0}C till the temperature of 1150^{0}C was reached. The samples were then soaked at 1150^{0}C for 24 hours and allowed to cool in the furnace for 24 hours.

Equipment: The equipment used in this development include: Shovel, Pestle, Mortar, Cubicle Mould (10.0 x 10.0 x 10.0 cm), Rectangular Mould, Electric Balance, Cold Crushing Strength Machine, Grinding machine and Electric test kiln.

2.3 Some of the Test Conducted

2.3.1 Compressive strength

The strength of the bricks was determined by testing in compression testing machine. Specimens of brick units are tested under uniaxial compressive loading. The bricks were loaded between two plywood sheets and the machine pressed. The wooden cube mould at the studio was used to mould all the samples after mixing with water. After the completion of the moulding, wet weight measurements were taken, thereafter all those moulded cubes was not expose to sun but were exposed to air to dry. After they are all dried, dry weight measurements was also recorded down thereafter all the samples were fired with the gas test kiln to 1130°C and also inside the electric kiln to 1150°C more than Four times under the supervision of the technologist. After the firing, the weight of the fired samples were taken and thereafter immersed inside water for 24 hours; after the 24 hours had elapsed, the samples were removed from water and the measurements were taken and recorded. After all these, those samples were taken to the Civil Engineering Laboratory of the University for Compressive Strength test which was done with the supervision of the technologist. Compressive strength load results of the samples highlighting the main materials such as sawdust, rice husk and charcoal are shown in the Table 2.

Table 1. Composition of the materials for production

Composition	1	2	3	4	5	6	7	8
Kaolin	50	45	40	35	30	25	20	35
Combustible	40	40	40	40	40	50	60	30
Clay	10	15	20	25	30	25	20	35

Fig. 1. Moulded samples

Table 2. Compressive strength of the samples

S/No	Sawdust	Rice Husk	Charcoal
1.	2.5	2.4	2.9
2	3.3	2.5	2.5
3	4.0	3.4	2.0
4	3.1	3.9	2.6
5	2.0	3.8	3.9
6.	1.8	1.7	2.6
7.	1.1	1.1	1.0
8.	5.2 Kn2.0 (N/mm^2)	2.8	3.7

2.3.2 Thermal shock test

Samples were taken to the department of Metallurgical and Material Laboratory of the University for Thermal Shock Test. This thermal shock was done with the use of Detachable Muffle Furnace. The samples were thereafter fired inside an electric kiln at the Industrial Design department studio to a temperature of 1150^{0}C. The samples were removed the second day for visual observation and for further tests.

3. RESULTS AND DISCUSSION

3.1 Properties of the Insulating Bricks

Properties test were conducted on the insulating bricks products made. The properties examined include compressive load test, thermal shock test, porosity test, water absorption test. The results obtained for the different experiments carried out in this investigation are presented in tables and the properties are discussed below.

3.2 Discussion

Silica content that is present in the rice husk is 45.40 while the one in saw dust is 2.93 and for the charcoal are 5.90. Since the silica content that was found in the rice husk is more than the two combustible materials, therefore rice husk was chosen to be the combustible material that was mixed with ball clay and kaolin for the production of insulating bricks that was used for this research work.

Table 3. Calculation for wet weight, dry weight, water absorption on rice husk sample

Batch code	Wet weight (g)	Dry weight (g)	% Water Absorption
1	234	108.5	29.64
2	236.5	175.3	34.91
3	226.5	172.9	31.00
4	228.6	174.4	31.08
5	235	177.6	32.32
6	225.7	158.5	42.39
7	205.5	143.4	43.31
8	230.5	180.7	27.56

Source: Laboratory and Studio Analysis, 2022

Table 4. Calculation for wet weight, dry weight, water absorption on saw dust samples

Batch code	Wet weight (g)	Dry weight (g)	% Water Absorption
1	222.5	174.9	27.22
2	225.2	181	24.42
3	220	177.5	23.94
4	223	179.1	24.51
5	220.5	169	30.47
6	210.5	165.5	27.20
7	180.7	132.5	36.38
8	233	189	23.28

Source: Laboratory and Studio Analysis, 2022

Table 5. Calculation for wet weight, dry weight, water absorption on charcoal samples

Batch code	Wet weight (g)	Dry weight (g)	% Water Absorption
1	223.6	178.4	25.34
2	220.3	177.2	24.32
3	222	178.7	24.29
4	227.8	183	24.28
5	219.1	177.3	23.58
6	206.6	164.8	25.36
7	198.1	156.3	26.74
8	238.3	193.8	18.67

Source: Laboratory and Studio Analysis, 2022

Table 6. Chemical content that is present in the rice husk, saw dust and charcoal

Chemical	Rice Husk	Charcoal	Saw Dust
Alumina	4.86	0.6148	-
Silica	45.40	5.90	2.93
Potassium	10.28	10.40	11.37
Calcium	1.20	39.30	58.99
Iron	17.98	33.60	19.05
Sulphur	4.07	2.65	3.67

Source: Laboratory and Studio Analysis, 2022

Table 7. Summary of the tests carried out on those materials particularly on the rice husk

Samples No	Compressive Load (N)	Strength (N/mm^2)	Water Absorption (%)	Total Shrinkage (%)
1	2400	0.96	29.64	3.33
2	2500	1.00	34.91	6.67
3	3400	1.36	31.00	5.00
4	3900	1.56	31.08	3.33
5	3800	1.52	32.32	3.33
6	1700	0.62	42.39	5.00
7	1100	0.44	43.31	3.33
8	2800	2.12	27.56	3.33

Source: Laboratory and Studio Analysis, 2022

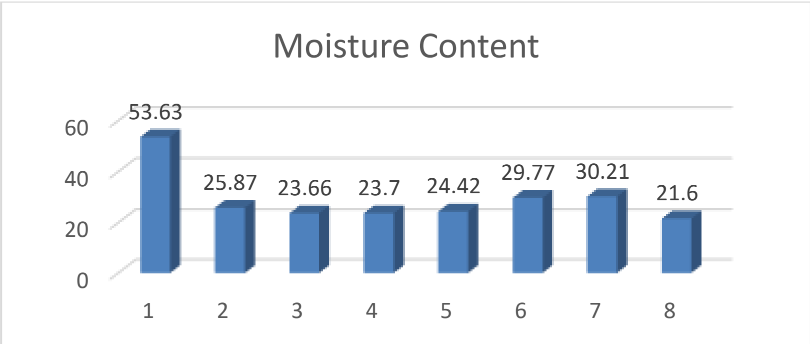

Fig. 2. The relationship between moisture content % and the sample composition
Source: laboratory test and studio analysis 2022

Observation: In the table above, sample 1 showed the highest percentage moisture content of 53.63 percentage while sample 8 showed the lowest moisture of 21.60 percentage. This is dependent on the cumulative weight percent of clay and kaolin treated as a whole within the brick structure.

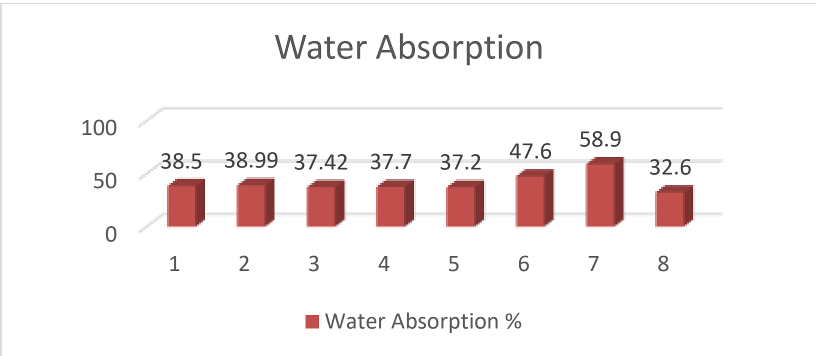

Fig. 3. The relationship between water absorption % and sample No
Source: Laboratory and studio analysis (2022)

Observation: From the table above, sample 7 shows the highest of 58.9% followed by the sample 6 which is 49.6% while sample 8 showed the lowest of 21.48%. The reason why sample 7 has the highest water absorption is because the percentage of rice husk that is present in the composition is more than the rest of the other composition.

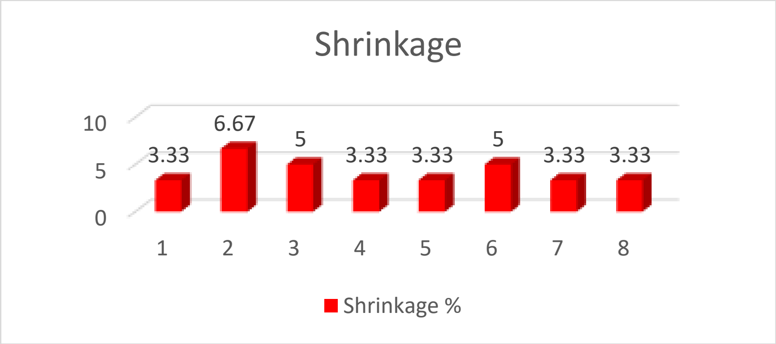

Fig. 4. The relationship between total shrinkage % and sample no
Source: Laboratory test and studio analysis (2022)

Observation: From the shrinkage summary, sample 2 has the highest shrinkage of 6.67% while sample 3 and 6 has the same percentage of 5% and sample 1, 4, 5, 7 and 8 has the same percentage of shrinkage of 3.33%.

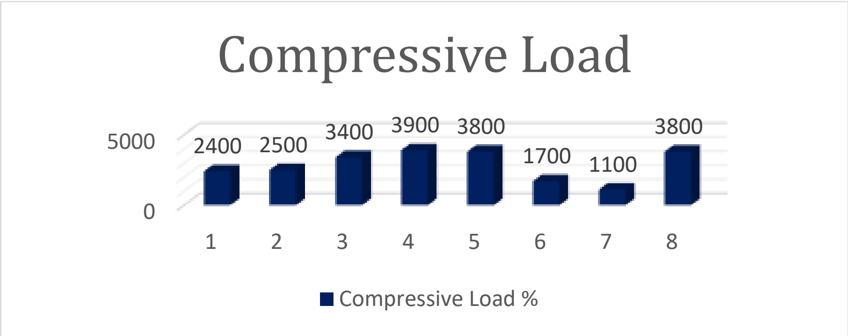

Fig. 5. The relationship between compressive load (N) and sample number
Source: Laboratory test and studio analysis (2022)

Observation: From the figure above, the highest percentage sample is 4 with 3,900 while sample 5 followed with the total number of 3,800 and sample 7 is the lowest because the percentage of the rice husk present in the composition is more than the clay and kaolin.

3.3 Findings

Based on the properties of the bricks samples tested and analyzed in this study, it can be finally said that; the local raw materials-ball clay, kaolin and rice husk are suitable for the production of insulating fire bricks. Out of sample 1-8, it was observed that it is only sample 3, 4 and 5 that are the best samples that can withstand high temperature. So, therefore sample 5 composition was used to produce the final bricks.

4. CONCLUSION

The performance evaluation of refractory bricks produced from locally sourced clay materials from Auchi, Edo State, saw dust, charcoal, kaolin and rice husk sourced from Akure, Ondo State. Nigeria respectively have been studied .The results showed that these local clays develop are suitable to produce locally available refractory bricks which was found to compare favourably with the imported refractory bricks. Refractory material produced from Auchi, Edo State, saw dust, charcoal, and kaolin and rice husk sourced from Akure, Ondo State. Nigeria clay was found to be the one with the best properties. It had a bulk density, porosity, cold compressive strength, Characteristics of elemental were determined using X-Ray Fluorescence (XRF). This enable us to know the amount of percentage of element that is present in each of the materials that the researcher sourced for the purpose and withstand high temperature and to also find out how long the kiln would be able to last up to.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Omotoyinbo JA, Oluwole OO. Working properties of some selected refractory clay deposits in South Western Nigeria. Journal of Minerals & Materials Characterization & Engineering. 2008;7(3): 233-245.
2. Musa U, Aliyu MA, Mohammed IA, Mohammed AD, Sadiq MM, Isah AG. A Comparative Study of the Refractory Properties of Selected Clays in Niger State, Nigeria. Journal of Advances in Biotechnology & Chemical Processes. 2012;1(2):1-5.
3. Aigbodion VS, Abdul Rasheed A, Olajide SO, Agunsoye JO, Sulaiman IY. Potential of Tin Tailings an Industrial Waste for Refractory Materials, Journal of Minerals & Materials Characterization & Engineering. 2010;9(2):123-131.
4. Mohammad KU, Rahaman PF. A study on the potential applications of rice husk derivatives as useful adsorptive material; 2018.
5. Onyemaobi OO, Omotoyinbo JA, Borode JO. Suitability of some local clays as refractory materials. Annual conference of the Science Association of Nigeria., University of Agriculture, Abeokuta, Nigeria; 1995.
6. RMRDC. Investment profile on manufacturing of building materials from sawdust. Prepared for investment forum on 145 CARD International Journal of Engineering and Emerging Scientific Discovery Volume 2, Number 2, June 2017 Economic Grass Cutter husbandry and manufacturing of building materials from saw dust organized by RMRDC and FRIN, (Ibadan); 2002.
7. Obadinma EO. Development of Refractory Bricks for Heat Treatment Facilities. Journal of Science and Technology Research. 2003;2(2):13-17.
8. Adondua S. Indigenous Refractory Raw Materials Base for Nigeria Steel Industries. Journal of the Nigerian Society of Chemical Engineers (NSCHE). 1988;7(2):322.
9. Ndaliman, MB. Refractory properties of termite hills under varied proportions of additives. AU J T. 2007;159-162.
10. Yakubu SO, Abdulrahim MY. Suitability of Birinin Gwari and Maraban Rido Clays as Refractory Materials. American Journal of Engineering Research. 2014;3(3):8-15.

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