Advances
2021; 2(2): 23-29
http://www.sciencepublishinggroup.com/j/advances
doi: 10.11648/j.advances.20210202.12

Evaluation of the Foundry Properties of Stabilized Ile-Ife and Akure Anthill Clay

Afolabi Tola Toyin*, Adara Peace Pamilerin*, Omotoyinbo Joseph Ajibade, Alabi Oladunni Oyelola, Omokafe Michael Seun*

Metallurgical and Materials Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Nigeria

Email address:

afolabitolatoyin@gmail.com (A. T. Toyin), adex.peace@gmail.com (A. P. Pamilerin), ajibadeomotoyinbo@yahoo.com (O. J. Ajibade)
*Corresponding author

To cite this article:

Afolabi Tola Toyin, Adara Peace Pamilerin, Omotoyinbo Joseph Ajibade, Alabi Oladunni Oyelola, Omokafe Michael Seun. Evaluation of the Foundry Properties of Stabilized Ile-Ife and Akure Anthill Clay. *Advances*. Vol. 2, No. 2, 2021, pp. 23-29. doi: 10.11648/j.advances.20210202.12

Received: December 10, 2020; **Accepted**: June 28, 2021; **Published**: July 8, 2021

Abstract: The samples were sourced from the teak plantation in the Federal University of Akure, Ondo, State and Moremi street in Ile-Ife, Osun state, Nigeria. The clay samples were pulverized and grounded using the Denver Laboratory Jaw Crusher, Model BDA 15561 and ground/milled using Bico Ball Milling Machine, Model 69012 (USA), and sieved using the combination of BS Sieve no 10 (2.00mm), BS sieve no 16 (1.18mm), BS sieve no 20 (850µm to be free of stones and gravels. Akure Anthill clay in its crude was characterized using Energy Dispersive X-ray Fluorescent Spectrometer (ED-XRFS) and assayed 21.97% Fe_2O_3, 44.50% SiO_2, 27% Al_2O_3, 3.03% TiO_2, 1.43% K_2O, 0.32% CaO, 0.37% RuO_2, 1.38% BDL. Ile-Ife anthill clay in its crude was also characterized and found to contain 17.27% Fe_2O_3, 50.8% SiO_2, 26% Al_2O_3, 2.20% TiO_2, 1.37% K_2O, 1.16% CaO, 0.31% RuO_2, 0.46% BDL. The refractoriness of this anthill was also investigated and found to be 1400°C. This implies that both Akure and Ile-Ife anthill clay is not suitable for application in furnaces carrying out operations and melting operations at elevated temperatures beyond 1400°C. But it possesses good thermal stability at 10% bentonite, 10% kaolin and 25% bentonite respectively which is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications.

Keywords: Ile-Ife Anthill Clay, Akure Anthill Clay, Refractoriness, Foundary Properties

1. Introduction

Recently, the use of natural clays for the production of refractories has been one of the major focus of researchers in materials science. These areas of research focus could lead to the improvement and advancement of the industrialization of a nation and also the foreign exchange of the expensive refractory materials. There has been much of this research area advancement in Nigeria because some research work on refractory fireclays have been worked upon by researchers. However, upgrades in the refractory properties of the natural clays is cogently needed for suitable sue in metallurgical furnaces. To this effect, materials like asbestos and graphite have been previously added to deposits of natural clay like ant and termite hills for refractoriness enhancement [1].

Refractory can be defined as a materials' potential to maintain its chemical identity and physical shape when under the condition of high temperatures. The various shapes which are used in lining furnaces are referred to as refractories. Refractories are in heterogenous, inorganic, porous and non-metallic materials composed of mineral aggregates with thermal stability, additives and a binder phase. For the construction of furnaces in metallurgical industry, refractories are the major components used. They find their usefulness in the lining of holding, smelting, melting and re-heating furnaces. And it is also important to note that a refractory is such a material that has the capacity sustain and withstand abrasive or corrosive solids actions, liquids or gases at extremely elevated temperatures as stated by Energy Efficiency Guide in the year 2006 [5]. The doggedness and ableness to withstand sudden temperatures changes, low thermal expansion coefficient and ability to conserve heat are the other generalized requirements of refractory materials. But on a general not, refractory conditions vary from one application to another.

According to Wikipedia, an ant-hill, in its simplest form, is a pile of earth, sand, pine needles, or clay or a composite of these and other materials that build up at the entrances of the subterranean dwellings of ant colonies as they are excavated. A colony is built and maintained by legions of worker ants, which carries tiny bits of dirt and pebbles in their mandibles and deposit them near the exit of the colony. They normally deposit the dirt or vegetation at the top of the hill to prevent it from sliding back into the colony, but in some species, they actively sculpt the materials into specific shapes, and may create nest chambers within the mound.

Reference to the use of silicon carbide by [8] and silica, mica and bentonite by [13] on the refractory properties of some other local deposits have also been reported. But some clay type such as kaolinite clay [2] are plastic in nature, and therefore might not need any binder type. Alumina and Silicate binders [10] have both been used to enhance clay refractories working temperatures and as binders for refractory materials. Recently, some research works have been done on Nigerian refractories include that of Borode *et al.* [3] on some Nigerian clay sustainability as refractory raw materials. The effects of silicon carbide on some Kankara Clay refractory properties has also been worked upon by Hassan *et, al.* [9].

This research was prompted by the need to utilize our available local raw materials for foundry applications, thereby saving costs in the metal casting industry.

2. Experimental Part

2.1. Material Sourcing

The materials used for this research work including 50kg of naturally occurring anthill clay was obtained at the Federal University of Technology, Akure (FUTA) from one of the many abounding mounds in the teak plantation, and Moremi street in Ile-Ife, Osun state, Nigeria in which 15kg was collected for the experiment.

2.2. Communition of Akure and Ile- Ife anthill Clay

Ant-hill lump preparation was carried out in the mineral processing laboratory by crushing using the Denver Laboratory Jaw Crusher, Model BDA 15561 and ground/milled using Bico Ball Milling Machine, Model 69012 (USA) at the Metallurgical and Materials Engineering (MME) Mineral Processing laboratory, FUTA, respectively.

2.3. Particle Size Analysis of Akure and Ile- Ife Anthill Clay

The combination of a sieve shaker and set of its sieves was used to classify the particle sizes of BS Sieve no 10 (2.00mm), BS sieve no 16 (1.18mm), BS sieve no 20 (850µm. The ratio 45:25:30 was used to mix the sized clay respectively, resulting to coarse and fine particles which is combinable to aid pore closing during calcination and sintering processes.

2.4. Moulding/Compaction

After a homogenous mixture of the anthill clay of both Ile-Ife and Akure with the additives, kaolin, bentonite and water, then the production of the disc samples is obtained by ramming the plastic paste into the steel casing which is cylindrical in shape through the use of FUTA Cold compression moulding machine at the Foundry laboratory for the test samples selected. Two set of test samples were developed for each of the refractory tests selected. Average records obtained from each of the test performed on the samples was recorded.

Figure 1. *Pyrometric Cone Equivalent of Akure and Ile-Ife Anthill Clay.*

2.5. Chemical Analysis of the Anthill Clays

The clay samples obtained from the pure sieved clay particles was chemically analyzed. Chemical analysis of the anthill clay was carried out using Energy Dispersive X-ray Fluorescent Spectrometer (ED-XRFS) at National Metallurgical Development Council (NMDC) Jos, Nigeria. Ile-Ife anthill clay in its crude was characterized and found to contain 17.27% Fe_2O_3, 50.8% SiO_2, 26% Al_2O_3 and other trace compounds while Akure anthill clay contained 21.97% Fe_2O_3, 44.5% SiO_2, 27% Al_2O_3 and other trace compounds.

2.6. Test for Refractoriness Using Pyrometric Cone Equivalent

The determination of temperature of fusion of the test samples is the major aim of this test. Normally, due to chemical complexity, refractories usually melt over a temperature range. Therefore, it is ideal to use cone fusion method for the fusion point or refractoriness assessment. The pyrometric cone equivalent (PCE) is the standard cone equivalent use to melt to same extent as that of the test cone. In accordance to ASTM C24-01, the measurement of PCE is always taken through the making of the material cone-like shape, and then fire it till it bends to 3 O'clock. Pyrometric cones are cones also known as self-supporting cones made with ceramics in the form of small triangular prisms, such that when set at small angle and heated at a particular temperature rate, it bends over in an arc and the tip reaches the base level. The viscous flow of the viscous liquid within the cone is the pivoting cause behind the bending of the during this process. It must be noted that for each of the cone composition, when heated at standard rate, the final (endpoint) temperature when the cone tip touches the base/supporting plate is calibrated.

3. Results

The results obtained along the course of this research are presented in Tables 1–4 and Figures 2 to Figure 9 respectively.

Table 1. *Chemical Analysis of Crude Ile-Ife anthill Clay.*

Sample / Assay (%)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	CaO	RuO_2	BDL
Crude	50.8	26	17.7	2.20	1.37	1.16	0.31	0.46

Table 2. *Chemical Analysis of Crude Akure anthill Clay.*

Sample / Assay (%)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	CaO	RuO_2	BDL
Crude	44.5	27	21.97	3.03	1.43	0.32	0.37	1.38

Table 3. *Result of Refractoriness of the Anthill Clay Samples.*

Sample Name	Refractoriness (°C)
Ile-Ife Anthill Clay	1400
Akure Anthill Clay	1400

Table 4. *Summary of the test carried out with Akure and Ile-Ife Anthill Clay with varied percentage of Bentonite.*

Percentage of Binder	Loss On Ignition (g)		Apparent Porosity (%)		Linear Shrinkage (%)		Dry Compressive Strength (N/mm^2)	
BENTONITE	AKURE	ILE IFE	AKURE	ILE IFE	AKURE	ILE IFE	AKURE	ILE IFE
0	5.1733	2.8123	21.72	15.19	2.82	2.4	2544	2813
5	4.8262	3.3979	21.82	18.73	2.37	3.3	5162	3133
10	4.8632	3.4708	21.34	18.46	1.89	2.36	2488	7237
15	4.2813	3.6049	19.08	15.14	2.85	2.83	3927	10,051
20	4.4555	4.3543	17.60	17.06	2.81	4.18	7620	14,097
25	5.0698	2.7374	18.16	16.47	2.85	1.89	6717	13,067

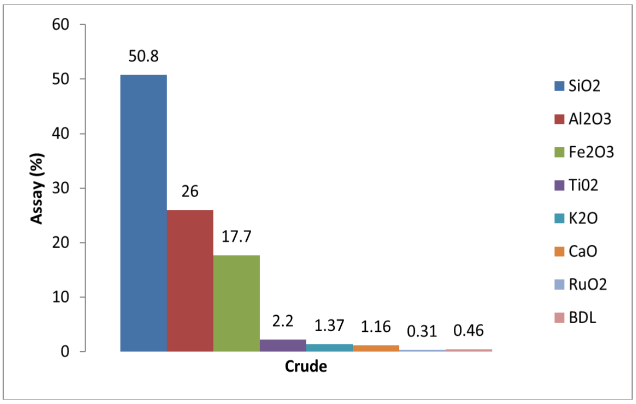

Figure 2. *Chemical Analysis of Crude Ile-Ife anthill Clay.*

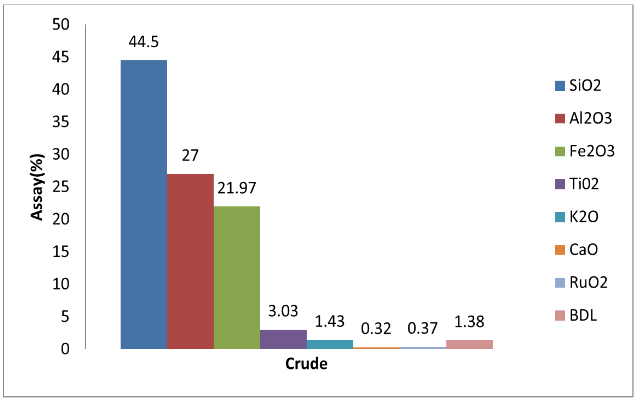

Figure 3. *Chemical Analysis of Crude Akure anthill Clay.*

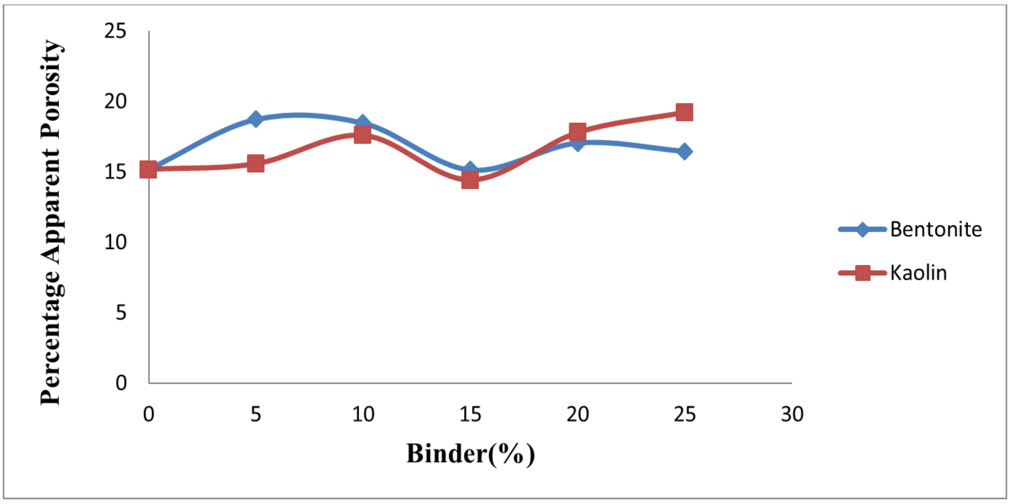

Figure 4. *Percentage apparent Porosity of Ile-Ife Anthill Clay.*

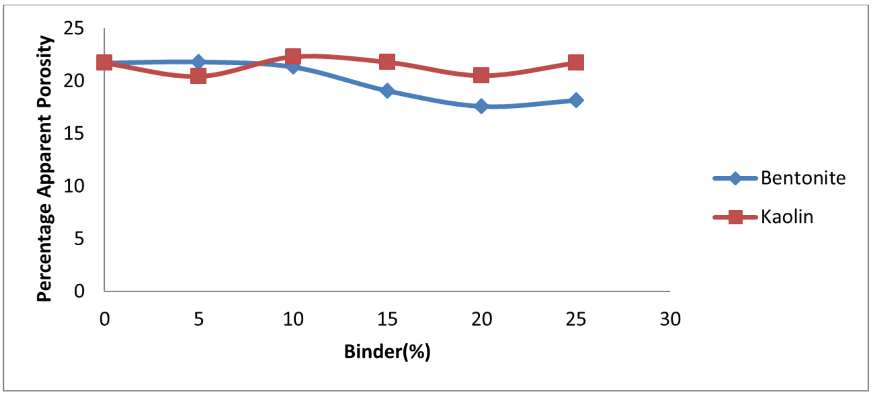

Figure 5. *Percentage apparent Porosity of Akure Anthill Clay.*

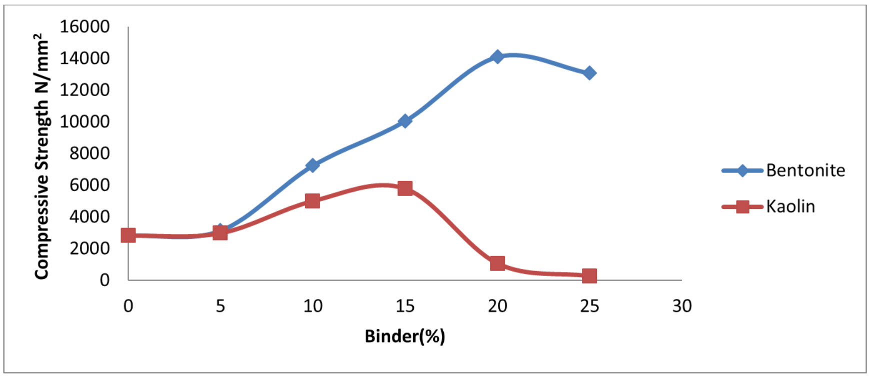

Figure 6. *Compressive Strength of Ile-Ife Anthill Clay.*

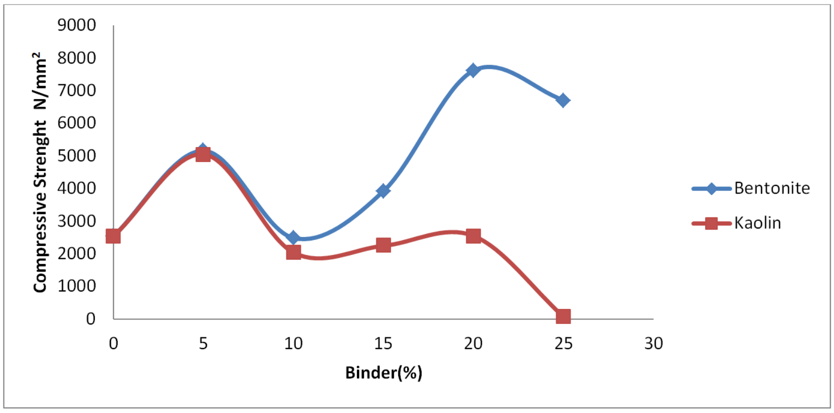

Figure 7. *Compressive Strength of Akure Anthill Clay.*

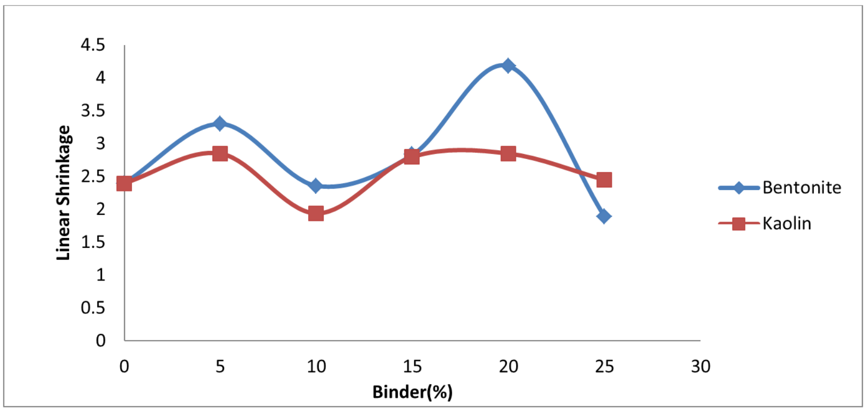

Figure 8. *Linear Shrinkage of Ile-Ife Anthill Clay.*

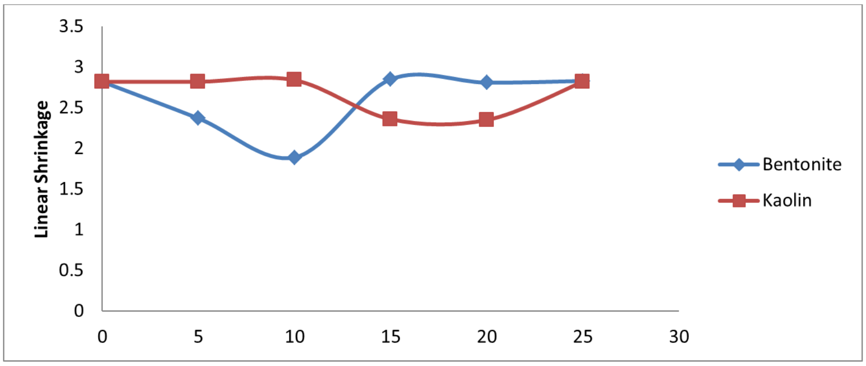

Figure 9. *Linear Shrinkage of Akure Anthill Clay.*

4. Discussions

Table 1 and Table 2 show the Chemical Analysis of Crude Ile-Ife anthill Clay and Akure anthill Clay respectively. Figure 2 and Figure 3 also shows the graphical representation of the Chemical Analysis of Crude Ile-Ife and Akure anthill Clay respectively. It is seen that Ile-ife anthill higher assay value of SiO_2 (50.8) and CaO (1.16) than that of Akure anthill clay which is 44.5 and 0.32 respectively. On the other hand, Ile-ife anthill higher assay value of Al_2O_3 (27), Fe_2O_3 (21.97), TiO (3.03), K_2O (1.43), RuO_2 (0.37) and BDL (1.38) than that of Akure anthill clay which is 26, 17.7, 2.20, 1.37, 0.31 and 0.46 respectively. A high percentage of silica in the samples was noticed from the samples. The mound/hill can, therefore, be classified under siliceous fireclay [13]. It was further discovered from the result that the clay type belongs to the fire clay which is a standard accepted by Hassan and Adewara [7] and falls within the range of semi-plastic fireclays [6]. It can also be classified under Acid refractories based on their chemical reactivity. Table 2 reflects the Ant-hill Clay Samples Refractoriness test result. This implies that both Akure and Ile-Ife anthill clay is not suitable for application in furnaces [14] carrying out operations and melting operations at elevated temperatures beyond 1400°C.

Figure 4 reflects that there is optimum porosity of 18.73% demonstrated in the Ile-Ife anthill at 5%, which compulsorily affects the yield of the clay as a refractory material. It also reveals that minimum porosity of 15.14% was observed at 15% of bentonite. This therefore implicates, as a result of the high inherent strength of the clay at lowest porosity, that the clay has more potential for refractory application. This figure reveals that at 25% kaolin, highest porosity of 19.24% was observe which will definitely affect the yield of the clay as a refractory material and lowest porosity of 14.44% was obtained at 15% kaolin which implies that the clay will serve better as a refractory material because it possess high strength at low porosity.

The refractories porosity has been affected by a number of factors which includes ramming force per unit area, particle sizes and shapes, composition of the clay, and the occurring reactions during firing [4]. The porosity of the refractory material is a measure of how easy gas and liquid can penetrate through refractory material.

The study result obtained as shown in (Figure 4) depicts in percentage form, that most of the test samples are highly porous. And this is because in the composition of the sample's combustible materials are part of its material constituents which burns off during firing. The Manual ramming method employed in this research work reduces densification. It also contributes to the recorded high porosity. The strength of the clay material was also affected by the presence of pores through the reduction of the cross-sectional area exposed to the applied force. In brittle clays, the presence of the pores also as concentrator or stress raiser. It can be seen that the sample 1 has the lowest porosity due to its relatively low loss during ignition coupled with its high fineness grain number (smaller number), which means that it's made of the lowest amount of materials that are combustible.

Figure 5 reveals that at 5% bentonite highest porosity of 21.82% was observed in the Akure anthill clay which will definitely affect the yield of the clay as a refractory material and lowest porosity of 18.16% was obtained at 20% bentonite which implies that the clay will serve better as a refractory material because it possess high strength at low porosity. The Loss on Ignition value signifies that during firing, a quantified organic material has been burnt off. And thus, resulting to its high porosity value, even though its grains are very fine and closely rammed together during the ramming process. This figure reveals that at 10% kaolin, highest porosity of 22.31% was observed which will definitely affect the yield of the clay as a refractory material and lowest porosity of 20.45 was obtained at 5% kaolin which implies that the clay will serve better as a refractory material because it possess high strength at low porosity. There are a number of factors that are known to affect the porosity of refractory raw materials, especially fireclays. Some of the factors include the clay composition, size and shapes of particles, ramming pressure, and the reaction occurring on firing. The porosity measures the ease with which liquid and gas slip through the refractory material. The graphical representation of the result of the percentage apparent porosity test is depicted in Figure 5. This parameter is a micro structural variable that must be controlled to produce a suitable refractory [13]. Porosity, grain size and grain orientation are the microstructural parameters of significant importance to the strength of inorganic materials [11].

Figure 6 reveals that at 20% bentonite the highest compressive strength of the Ile-Ife Anthill Clay was noticed (14.097 x 10^3N/mm^2), while at 0% bentonite possess the most minimum compressive strength (2.81 x 10^3N/mm^2). At 15% kaolin the highest compressive strength is noticed (5.79 ×10^3N/mm^2), at 25% kaolin the lowest value is observed (272N/mm^2). The compressive strength differences, aside these aforementioned two extremes of the Ile-Ife Anthill samples is increases which occurred as a result of the closeness in the batch samples mean grain fineness number and water content amount, and This figure reveals that at 5% bentonite highest porosity of 21.82% was observed which will definitely affect the yield of the clay as a refractory material and lowest porosity of 18.16% was obtained at 20% bentonite which implies that the clay will serve better as a refractory material because it possess high strength at low porosity. The Loss on Ignition value signifies that during firing, a quantified organic material has been burnt off. And thus, resulting to its high porosity value, even though its grains are very fine and closely rammed together during the ramming process. This figure reveals that at 10% kaolin, highest porosity of 22.31% was observed which will definitely affect the yield of the clay as a refractory material and lowest porosity of 20.45 was obtained at 5% kaolin which implies that the clay will serve better as a refractory material because it possess high strength at low porosity. Figure 6 gives a graphical representation showing the apparent porosity percentage of the tested sample. A suitable refractory can there be developed/manufactured by controlling this micro structural variable parameter [13].

The strength of the inorganic materials is of great significant and are greatly influenced by its microstructural parameters which includes grain orientation, grain size and porosity [11].

Figure 7 reveals that at 20% bentonite the highest compressive strength of the Akure antihill clay sample was noticed (7.62 x 10^3N/mm^2), while at 0% bentonite has the lowest compressive strength (2.54 x 10^3 N/mm^2). At 5% kaolin the highest compressive strength is noticed (5.05 ×10^3 N/mm^2), at 25% kaolin the lowest value is observed (71N/mm^2). The compressive strength differences, aside these aforementioned two extremes of the Akure anthill clay samples improves which occurred as a result of the closeness in the batch samples mean grain fineness number, ramming force per unit area and water content amount.

Figure 8 reveals that at 20% bentonite highest linear shrinkage (for Ile-Ife anthill clay) of 4.18 was observed and lowest linear shrinkage of 1.89 was obtained at 25% bentonite which implies that good thermal stability is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications. This figure reveals that at 5% and 20% kaolin highest linear shrinkage of 2.85 was observed and lowest linear shrinkage of 1.94 was obtained at 10% kaolin which implies that good thermal stability is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications.

Figure 9 reveals that at 15% bentonite highest linear shrinkage (for Akure anthill clay) of 2.85 was observed and lowest linear shrinkage of 1.89 was obtained at 10% bentonite which means that good thermal stability is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications. This figure reveals that at 10% kaolin highest linear shrinkage of 2.84 was observed and lowest linear shrinkage was obtained of 2.35 at 20% kaolin which also implies that good thermal stability is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications. Figure 9 also reveals linear sample shrinkage variation fall within a confined range after firing and drying which is generally low. This orchestrates from the chemical composition, porosity and particle size variations, which are not substantially large to engineer very wide shrinkage values variation.

5. Conclusion

The refractory product may be recommended for use in sintering furnaces, re-heating furnaces operating below 1400°C, and for non-ferrous casting furnaces. But it possesses good thermal stability at 10% bentonite, 10% kaolin and 25% bentonite respectively which is one of the characteristics or properties of the clay sample which makes it suitable for low refractory furnace lining applications.

Acknowledgements

Authors appreciate the Federal University of Technology Akure for their support.

References

[1] Akeem D. A., Omotoyinbo J. A., and Davies F., Effect of High Alumina Cement on Selected Foundry Properties of Ant-Hill Clay, Leonardo Electronic Journal of Practices and Technologies, 2012, 9, p. 37-46.

[2] Al-Amaireh. Improving the Physical and Thermal Properties of the Fire Clay Refra ctory Bricks Produced from Bauxite. Journal of Applied Sciences. 2006, 6 (12), 2605 – 2610.

[3] Borode, J. O., Onyemaobi, O. O., and Omotoyinbo, J. A. (2000): Suitability of some Nigerian Clays as Refractory Raw Materials, Nigerian Journal of Engineering Management, Vol. 3, pp 14 18.

[4] Callister, W. D. Fundamentals of Materials Science and Engineering an Introduction. Anti-Corrosion Methods and Materials. 2000, 47, 69-185.

[5] Energy Efficiency Guide for Industry in Asia (online), Thermal Energy Equipment: Furnaces and Refractories, Available at: http: www.energyefficiencyasia.org (Accessed 26/07/2010).

[6] Gupta O. P. Elements of Fuels, Furnaces and Refractories, 5th ed., India, Romesh Chander Khanna, 2008, p. 665-791.

[7] Hassan S. B., Adewara J. O. T., Refractory Properties of Some Nigerian Clays, Nigerian Society of Engineers Technical Transactions, NSE, Nigeria, 1994, 29 (3), p. 13-19.

[8] Hassan S. B., Effect of Silicon Carbide on some Refractory Properties of Kankara Clay, Journal of Applied Science, Engineering and Technology, 2005, 5, p. 21-26. 59.

[9] Hassan, S. B. (2001): Effect of Silicon Carbide on Some Refractory Properties of Kankara Clay, proceeding on Nigerian Metallurgical society.

[10] Hosseini P., Eslami E., Poorjafari M., Vahidi S., Madari A., The Comparison of Silicate Binder RefractoryConcreteswith Alumina Binder Concretes, First International and 14thb National Studentship Conference on Civil Engineering, Semnan University, I. R. IRAN, 2008, p. 1- 6.

[11] Imasogie and Aramide. Refractry Properties of Locally Sourced materials for Lining Salt-bath Austempering Furnaces. Ife Journak of Technology. 2006, 15 (2), 19-26.

[12] Ndaliman M. B., Refractory Properties of Termite Hills under Varied Proportions of additives, Leonardo Electronic Journal of Practices and Technologies, 2006, 9, p. 161-166.

[13] Olasupo O. A., Borode J. O., Development of Insulating Refractory Ramming Mass from Some Nigerian Refractory Raw Materials, Journal of Minerals & Materials Characterization & Engineering, 2009, 8, p. 667-678.

[14] Osarenmwinda, J, and C P Abel. "Performance Evaluation of Refractory Bricks produced from locally sourced Clay Materials", Journal of Applied Sciences and Environmental Management, 2014.