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The Effect of Temperature Difference on the Thermal Shock Behavior of Onibode Fire-Clay Material with the Addition of Alumina

F. I. Apeh[1],D.E. Esezobor[2] , G. I. Lawal[3], S.O. Adeosun[4,] and J. M.Agunsoye[5]
[1]*Nigerian Building and Road Research Institute, Engineering Materials Research Department, Km10, Idiroko Rd., P.M.B. 1055, Ota, Ogun State.*
[2, 3,4 &,5,] *Department of Metallurgical and Materials Engineering University of Lagos, Nigeria.*

---ABSTRACT---
This work is directed at studying the effect of temperature differenceon the Thermal Shock Resistance (TSR) of Onibode fireclay materialdeposit from Ogun State South West Nigeria. TSR is one the very important properties of refractory materials which determines the durability or life spanof the material in service. As a result, thermal shock resistance of the materials was studied under different temperatures to determine the behavior of the materials upon addition of alumina in different proportions. Thermal shock resistances of the materials at 900^{0}C, 1.000^{0}C, 1,100^{0}C, 1,200^{0}C, 1,300^{0}C and 1,400^{0}C, respectivelyof different batches of experimental samples were recorded.The result of the experiment revealed that, with the increase in temperatures, the thermal shock resistance of the material decreases. This has been attributed to the state of the material leaving a very high temperature to very low temperature zones which affects the material structures; as expansion and contraction of the materials at elevated and low temperatures were very high due to the porosity of the materials. Consequently, the shock on the material will be very high leading to the decrease in the cycles recorded.

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I. INTRODUCTION

Development of new refractory materials for improves properties for its application in the various industries has been the focus of many researchers in the last decade. Refractory materials are materials of construction at high temperatureenvironments and as such, should be able to withstand any sudden physical and chemical changes without any significant effect on the material. The physical and chemical interaction between materials takes place in the furnace at very high temperature.The applications of these materials are not limited to the following; kilns, vessels, reactors, furnaces, incinerators, boilers, pre-heating equipment lining and the rest. The need for this material is enormous in the application industries (Apeh et al., 2011).

Selection of refractory materials for a particular purpose is always guided by the nature and the environment(s) at which the operation is taken place (Gupta, 2008).The method of heating and cooling of a furnace plays a very significant role in the life span of the refractory materials used for the lining of the furnace, which is related to the thermal shock resistance of the material. Sudden failure of these materials has significant impact on capital, equipment, time, energy and life. Thermal shock resistance is one of the very important properties of refractory materials that determine the number of cycles the lining material can be used before replacement. Therefore, the need to study the behaviors of these materials to determine their maximum life span when in operation was very important. In this study, the effect of temperatures difference on the fireclay collected from Onibode, Ogun State, South West Nigeria was investigated with the addition of alumina for the purpose of increasing the refractoriness value of the material. The alumina used was collected from ALSCON, Ikot Abasi, Akwa Ibom State, South-South, Nigeria.As a result, thermal shock resistance of the materials was studied under different temperatures to determine the behavioral trend of the materials.

II. EXPERIMENTAL METHOD

2.1 Materials

The fireclay sample collected from Onibode South-West and alumina from ALSCON, Ikot Abasi, South-South of Nigeria were analyzed for various properties before subjecting it to the thermal shock resistance under different temperatures. The fireclay sample was crushed, soaked, air–dried and sieved through 63 microns aperture.

Test sample pieces (control) were prepared in conformity with ASTM standards for each test, ASTM (2007). They were rammed into standard sizes using (Standard Laboratory Rammer. Ridsdale & Co., Ser. No. 891), dried and fired in accordance to Standard,ASTM (2007). The samples were then tested for permeability to air, cold crushing strength, fired and linear shrinkage, bulk density, apparent porosity, thermal shock resistance, refractoriness, loss on ignition. Similarly, the blended clay with alumina in various proportions (90%, 10%; 80%, 20%; 70%, 30% and 60%, 40%) was carried out and the thermal shock resistance under difference temperatures conducted. The chemical analysis of the clay materials was carried out using Atomic Absorption Spectrophotometer (AAS, PG990AFG). The percentage compositions of the various constituents are recorded in Table 1, while Table 2 shows their physical analysis.

2.1.1 Thermal Shock Resistance Under Different Temperatures

Test samples with diameter 50mm x 75 mm were placed in a muffle furnace model (Nabertherm), in batchesat temperatures of 900^oC,1,000^oC,1,100^oC,1,200^oC,1,300^oC and 1,400$^oC$for 10 minutesfor each batches for the experiments at different temperatures as indicated above were prepared. The samples were further cooled for 10 minutes in the air, and then were returned to the furnace for the duration of 10 minutes. The process was repeated until the test samplecracked. The number of heating and cooling cycles for each sample prepared was recorded (Table 4).

III. RESULTS AND DISCUSSION

The chemical composition of the clay deposits is shown in Table 1. From Table 1 below the alumina contents of the materials are 37.40% and 98.60% respectively. The result shows that alumina content of Onibode of 37.40% is within the standard value of 34% stipulated for fireclay materials. This explains why the Onibode clay has a good refractoriness of 1550^oC, Kachiev (1993), (Table 2). Conversely, the alumina material collected has refractoriness value of >1600^oC and the addition of this material to the clay(Onibode clay) has contributed to the high refractoriness recorded in the blended states. The presence of high value of impurities in aluminosilicate refractory, such as Fe_2O_3, lowers the refractoriness and service limits of the bricks. The fireclay sample belongs to the family of aluminosilicate and is acidic refractory, based on Chesti (1986).

Table 1.Chemical Analysis of the Materials

Samples	Chemical Analysis,%											
	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	CuO	MnO	K_2O	Cr_2O_3	V_2O_5	ZrO_2	LOI
Onibode Clay (ON)	37.40	50.80	5.83	3.60	0.24	0.06	0.02	0.98	0.06	0.14	0.18	0.67
Alumina (AL)	98.60	-	0.09	-	0.25	0.07	0.02	-	0.04	-	-	0.09

The moisture content of the fireclay collected from Onibode and Alumina were 1.90 and 4.70%, respectively. This implies that Onibode clay will requires more water for proper mixing of the material. The apparent porosity of Onibode clay which is 28.18% falls within the standard values of 20-30%, according to Chester (1973).Low percentage of apparent porosity enhances the entrapping of gases in the material. This will adversely affects the life span of the refractory material when in operation,(Gupta 2008). From the analysis on the clay materials, the thermal shock resistances (TSR) of theclay fall within the accepted value of 25-30 cycles as reported by De Bussy (1972). However, with the increase in temperatures that is, 1,000^oC,1,100^oC,1,200^oC,1,300^oC,and 1,400^oC the thermal shock resistance of the material decreases (Table 4). The decrease in the TSR of the materials under different temperatures was as a result of the material leaving a very high temperature to a very low temperature zones; as expansion and contraction of the materials at elevated and low temperatures were very high due to the porosity of the materials. Consequently, the shock on the material will be very high leading to the decrease in the cycles. This means that the material will records more cycles under low temperatures than in high temperatures which is evidence in the results obtained. Figure 1 shows the trend of TSR with the increase of temperatures on the material. It was observed from the analysis that the refractoriness of Onibode clay (1,550^oC)falls within the standard value(1500-1750^oC) for fireclays.(Grimshaw, 1971); but with the addition of alumina, the refractoriness value of this material increases,(Table 2& 3). The linear shrinkage of the clay was within the accepted value (Chester 1973), which was 2%. With this, the materials will have a better interlock of grains and enhanced strength of refractory when in operation. The value of the cold crushing strength obtained for Onibode and the alumina are 16.3 MPa and 5.6 MPa, respectively. Thus, the Onibode clay has more resistance to load, tension and shear stresses than the Alumina material. This value for the clay fallswithin the standard value as reported by De Bussy (1972). The average bulk density of the clay samples is as shown in Table 2and is within the acceptable values.Similarly, the permeability of the analyzed clay and alumina as recorded in Table 2 is within the stipulated standard values. Table 3 shows the results of the blended materials with alumina.

Table 2. Physical and Thermal Properties of the Control Materials

Properties	Sample	
	Onibode Clay	Alumina
Fired Linear Shrinkage,%	2.0	1.5
Permeability to Air	78	82
Apparent Porosity %	28.18	28.34
Bulk Density, g/cm^3	2.23	2.3
Cold Crushing Strength,MPa	16.3	5.6
Thermal Shock Resistance, Cycles	+30	28
Refractoriness,°C	1550	>1600
Moisture Content, %	1.90	4.70

Table 3. Physical and Thermal Properties of the Blended Materials

Properties	Sample Composition				
	ON 100%	ON 90%+AL10%	ON 80%+AL20%	ON 70%+AL30%	ON 80%+AL20%
Fired Linear Shrinkage,%	2.0	**2.10**	**1.5**	1.0	**2**
Permeability to Air	49	69	**70**	76	**78**
Apparent Porosity %	28.18	29.87	**32.7**	38.71	**43.44**
Bulk Density, g/cm^3	2.23	2.24	**2.30**	2.12	**1.99**
Cold Crushing Strength, MPa	20.3	21.3	**16.3**	18.4	**16.8**
Thermal Shock Resistance, Cycles	+30	+30	**+30**	+30	**+30**
Refractoriness, °C	1550	>1600	**>1600**	>1600	**>1600**
Moisture Content, %	1.90	2.20	3.00	3.40	12.4

Table4.Analysis of the Thermal Shock Resistance Under Different Temperatures

SAMPLE NO.	%, COMPOSITION	THERMAL SHOCK RESISTANCE, CYCLES					
		900°C	1,000°C	1,100°C	1,200°C	1,300°C	1,400°C
1	**ON 100%**	**+30**	**30**	**28**	**28**	**24**	**23**
2	**ON 90%, AL10%**	**+30**	**30**	**28**	**28**	**25**	**25**
3	**ON 80%, AL 20%**	**+30**	**30**	**27**	**27**	**24**	**23**
4	**ON 70%, AL 30%**	**+30**	**30**	**27**	**27**	**24**	**23**
5	**ON 60%, AL40%**	**+30**	**30**	**27**	**26**	**23**	**23**

NB: ON - Onibode Clay and AL - Alumina

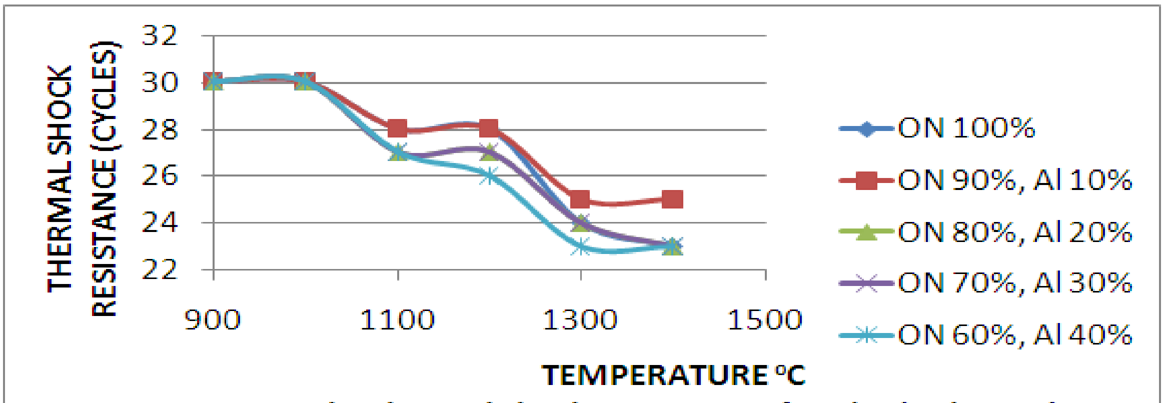

Fig.1. The thermal shock resistance of Onibode clay and its…

IV. CONCLUSION

The investigation carried out on the clay deposit, Onibode with the addition of aluminarevealed that the service properties of Onibode clay improved with the increase in the alumina additions. The chemical analysis of the clay materials carried out using Atomic Absorption Spectrophotometer (AAS, PG990AFG) shows the percentage compositions of the various constituents, which indicate that clay is of the family of aluminosilicate. The study on the thermal shock resistance revealed that, with the increase in temperatures the thermal shock resistance of the materials decreases. This was attributed to the fact that the specimens were leaving a very high temperature to a very low temperature zones; as expansion and contraction of the materials at elevated and low temperatures were very high due to the porosity of the materials. Consequently, the shock on the material will be very high leading to the decrease in the cycles. This means that the materials will records more cycles under low temperatures than in high temperatures. The higher the percentage of alumina in the clay, the higher the refractoriness result obtained.Permeability,which is the property of refractory material that allows the escape of gasses during operation,is also appropriate for the clay materials. The results of the analysis of the thermal shock resistance under different temperatures on the clay sample with the addition of alumina indicated that,thermal shock resistance of the materials decreases with the increase in temperatures; but the addition of alumina increases the refractoriness value of the materials for it to be used at high temperate environments under normal on and quenching conditions of the furnace.

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