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12

REFRACTORY PROPERTIES OF GETSO AND DANBAKOSHI KAOLIN DEPOSITS FOR INSULATION FIREBRICKS IN NIGERIA

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Abstract
Over 4 million tons of kaolin deposit exists in Getso and Danbakoshi, an area in Kano State. Kaolin is the raw material needed for the production of insulation fire bricks and users are all heat using industries. Getso deposit raw nature identified slight pink while Danbakoshi is identified as little yellowish in colour. The two materials were beneficiated and then X- Rayed. Fluorescence Spectrometer (XRFS) was used to determine the elemental composition of each sample. Grog were prepared by calcining the kaolin samples to 1200ºc and mechanically sieved through 14BS, 25BS, 36BS, 100BS sieve sizes. 1-2 mesh – screened charcoal was employed as fugitive to create pores within the bricks structure through burn-out process. Experimental method was used; 15 units tri-axial matrix blend technique was employed to composed the recipe of the three materials: Kaolin, Grog and Charcoal. Slip casting was used to produce the bricks which were fired to 1250ºc. The bricks properties such as: Apparent porosity, Bulk density and Compressive strength were investigated using ASTM C20-00 (2015). The results showed that the insulating bricks produced have properties comparable with international accepted standard for firebrick insulating material. The Getso firebricks can therefore be used as class 23 bricks of 1250ºc temperature in the lining of kiln, ovens, heat treatment furnace and soaking pit. While Danbakoshi bricks were found to be suitable for 20 class bricks of 1093ºc temperature range in lining of incinerators, boilers reheating and holding Raku kiln and back-up bricks.

Key Words: Refractory, Kaolin, Deposits, Insulation, Properties

Operational Definition of Terms

Body: Any clay, or admixture with other ceramic materials.
Comminute: Reduced, broken or ground up material to form smaller particles.
Difloculant: The dispersion of a clay slip leading to increase fluidity.
Grog: Fired clay grounded and incorporated into clay bodies to give texture, to assist drying and to increase firing strength and reduce clay shrinkage.
Green strength: Unfired ceramics article, is an important virtue in a body.
Levigate: To separate finer grain from coarser ones by suspension in a liquid.

Introduction

Heat treatment is so important to the development of clay and glazes including refractory production. Energy, integral to heat treatment is an expensive commodity, and ceramic processes tend to be energy demanding. No high temperature operation can go without heat management ironically; we are in era of endless energy cost. One of the solutions is a situation under which kiln temperature can be insulated and managed to reduce fuel cost (Shaaibu, 2016). Insulating refractories allow a kiln to reach temperature relatively faster thus, saving time while protecting the surrounding environment from noticeable heat.
Kaolin and fire clay are the raw materials needed for the production of fire insulation bricks; they form well over 70% of the refractory needed by the Nigerian industries. Kaolin the principal raw material is said to occur in commercial quantity in most Nigerian states with possible exception of some states that lie on the coast (Chigbo, 2009). Refractory-user industries are all heat using industries, such as iron and steel, glass, cement, galvanizing, ceramics, petroleum refining, etc. Studies have confirmed that the demand for kaolin is very substantial and that several of Nigeria's Kaolin deposits and allied raw materials are imminently suitable for ceramic (Chigbo, 2009).
Ahmed (1986) in Sullayman (2006) states that 28,000 tons of refractory bricks worth 30 million naira were needed in Nigeria in 1986 further more Sullayman (2006) indicates that the same quantity of bricks mentioned above would cost N3.915 Billion at the exchange rate of Naira to the American Dollar in 2013. Invariably the world refractory demand is expected to grow annually by 3.4 percent by 2016 (American Ceramics Society, 2013).
The exploration of mineral resources has without doubt, rapidly contributed towards achieving most of the technological advancement in every development facet, as well as played a major role in human

development. In Nigeria, after the oil boom of the 1970s, mining and processing of raw material resources ebbed, despite the significant role they played in nation building. For instance, Kano state was created on May 27th, 1967 from the Northern region by the regime of General Yakubu Gowon. Apart from being a commercial and industrial center in northern Nigeria, Kano is also among the states blessed with vast deposits of mineral resources that are in commercial quantities (Ado, 2006). The mineral deposits found in Kano includes: Granite, Laterite rocks, Niobium, Uranium, Tin, Silver, Lead, Zinc, Copper, Lithium, Glass sand, Tantalite, Columbite, Kaolin and Feldspar (Ado, 2006).

Getso and Danbakoshi, areas in Kano state are said have over 4 million tons of kaolin (Ado, 2006), however these minerals are largely unexploited. Chiagbo (2009) observed that raw materials buried in the ground are not wealth, they have to be mined, processed and put to industrial use to become wealth, and that the process not only creates wealth but also creates employment. According to Chigbo (2009) the ceramics industry covers up to 700 products and processes and Nigeria has enough raw materials in this field to support a vigorous ceramic industry and make a great impact on the production and productivity of those industries that need ceramic product as raw material or intermediates.

Getso (Gwarzo Local Government Area)

Gwarzo is a local government area in Kano State, about 72 kilometers from the state capital. It is headquartered in Gwarzo town: with an area of 393 km^2 with coordinates of 11^0 55N 7^0 56E. A Kaolin processing company is situated within Gwarzo town as a joint venture company of the Raw Materials Research and Development Council (RMRDC) and Kano State government since January, 1999. Getso is a village in Gwarzo Local Government Area about fourteen kilometers away from the kaolin processing company. The kaolin deposit in Getso is beneath the ground, the community virtually benefits from it. Professional mining activities were stopped at the same time the kaolin processing company closed production. Local mining activities continued until the community stopped their activities as a result of the death of a local miner, who was accidently buried under ground in the area. More so unregulated activities of the miners have burrowed the land and eroded some access roads. However, children are still seen in a few places in recent time extracting the material to use as paint (Shaaibu 2016)

Danbakoshi (Shanono Local Government)

Danbakoshi is a village in Shanono Local Government Area which share boundary with Gwarzo Local Government Area. The village is more than 35 Km from the Kaolin Processing Company in Gwarzo Local Government Area. The kaolin deposit in Danbakoshi is observed to be mixed with considerable amount of sand which seems to be left behind when granite parent rock change into clay, and form in pockets within the parent rock (Shaaibu, 2016).

Jonker (2006) opined that shrinkage behavior of an insulating material is used for evaluating its maximum possible temperature of application. Schulle and Schlegel (1991) reported shrinkage standard for refractory lightweight brick and concrete on linear shrinkage 1-7% and refractory fibers 2 to 5% the isothermal heating time required for the thermal treatment also fluctuates between 4 and 24 hours. Jonker (2006) stated that, Porosity is the main influence on the effective lowering of thermal conductivity. Odo, Nwoye, Ameh and Nnamchi, (2013) reported that porosity which is the most important property distinguishing insulating bricks from conventional dense bricks fall within the internationally recommended standard of 25 and 50% porosity according to BNZ (2012), Hegazy, Fouad and Haassanain, (2012). Bhatia (2011) in his work mentioned that uniformly small size sized pores distributed evenly in the whole body of the insulating brick are preferred. In addition to that Schulle and Schlegel both stated that high insulating refractory material is distinguished from lightweight materials of 45- 75. Extremely lightweight materials have a porosity of 75-85%. Sullayman (2003) mentioned that the bench mark for refractory materials should have minimum alumina content of 34% and less than 1.30% Fe_2O_3 and other fluxing agent content. Kruger (1996) initiates that the higher the fugitive additives in the kaolin body the better the insulation efficiency and lower the density. Careful selection of particles size distribution and additives enable the manufacture of low-shrinkage refractories. Nanthaphong and Sadipown (2011) used charcoal additives in the particles ranging from 2-3mm (size1), 1-2mm (size 2) to less than 0.5mm (size 3) and produced lightweight briquette clay fired at 950^{o}C. And increased in the content of charcoal lead to an increased in the shrinkage and water absorption and decreased in the bulk density and compressive strength. Andy, Magni, Steve & Chris (2012) all asserted that insulating firebrick can be manufactured by pressing, extrusion, casting and slinger etc. and can also be manufactured by cast process which offer the lowest thermal conductivity, and reduces energy usage by up to 30%, chamber temperatures and CO_2 emissions and allow faster heating and cooling rates compared to insulating firebricks manufacture by other processes.

Materials and Method

The materials used for the study are the kaolin deposit in Getso, Gwarzo local government area and Danbakoshi in Shanono local government area both in Kano state. Charcoal used as pore forming agents in the bricks. Other materials used include, sodium silicate as difloculant, corn starch as binder and Plaster of Paris (P.O.P.) was used for the mould. The experimental method was adopted for the sourcing of materials, processing and production technique. X-ray fluorescence spectrophotometer (XRF) was used for the qualitative determination of the elements in the kaolin samples. The kaolin samples were beneficiated through comminuting and molded to pancake and dried there after which grog was prepared by calcining the pancake to 1200 ^{0}C in oxidized kerosene fueled kiln. Retsch BB100-Mangan crusher was used to crush the calcined kaolin and milled in Jar mill machine Pascal 9VS model 1679-VX-A and particles screened using STSJ-3 screening machine. 1-2 mm Charcoal particles size was used as pores agents in the recipe due to its confirmed suitability as asserted by Nanthaphong and Sakdipown (2011).

Matrix blends systems were also used to formulate the recipe: a diagrammatic method of studying the effect of various mixtures possible with three materials (Robert, 1996). Tri-axial blend was adopted for the study and fifteen units of blends were selected from various blends system to test the zone of special interest and contrasting quality. Robert (1996) explained that exploring areas of interest to avoid fraction of materials is accomplished by scaling up the format, thereby expanding the chosen region of blend while retaining the convenient whole numbers. Part of the mixture volume percent was used to measure the materials: Kaolin, grog and charcoal for each unit was blended dry and then mixed with water; sodium silicate and liquid starch were hoomed in as difloculant and binder in the mixture. Casting method was employed as forming technique and three pieces' plaster of Paris (P.O.P) mold was used. After uniform slip mixture was assured and heavy cream slip obtained, the slip was discharged into the P.O.P. mould. When the seam line emerged between the moulds the solid the brick was separated from the mould. Casting was done for each composition blend of the two samples of Getso and Danbakoshi. The bricks were arranged in tri-axial form numbered A1-A15 for Getso sample and B1-B15 for Danbakoshi sample. The bricks were allowed to cure for 7 days inside studio. After the bricks were thoroughly dried, the dried density of each sample was measured which they were loaded in the kiln according to density, heavy ones under and lighter ones on top given two inches gap from each other to allow for adequate and efficient heat circulation.

The heat treatment started with long preheating and gradually to full firing in oxidized kerosene fueled kiln with atmosphere reaching up to temperatures of 1250 ^{0}C, Seger Pyrometric cone 8 was used to read the temperature. The fired insulation bricks properties of apparent porosity and bulk density were determined through Archimedean evacuation method using Mettler Toledo digital weighing balance machine PG 5002-5. The SM 100 Universal Material Testing Machine Cap. 100 KN (10 ton) was used to obtained compressive strength property. Apparent porosity, bulk density and compressive strength are primary properties of burned insulation fired brick (Berger, 2010). Those properties were measured as per standard of ASTM C20-97.

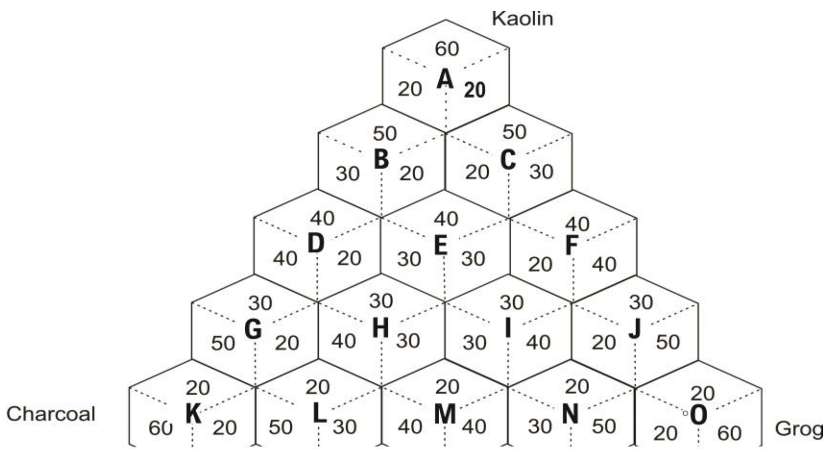

Figure 1 Tri-axial matrix blend (fifteen Units) Source: Shaaibu (2016)

Results and Discussion

Table 1. Chemical analysis of Getso

Oxide	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	S_2O_3	V_2O_3	NiO	CuO	BaO	Ga_2O_3	Ta_2O_5	WO_3	L.O.I
%	53.67	0.11	34.30	0.76	0.29	0.211	0.23	1.48	0.16	0.08	0.034	0.018	0.01	0.16	0.031	0.02	0.07	8.42

Table 2. Porosity Test Conducted on Getso Kaolin Bricks

Test	A	B	c	D	E	f	G	h	I	J	K	L	m	N	o
%	37	38	36	52	47	36	45	48	37	36	NA	47	44	39	38

Table 3. Density Test Conducted on Getso Kaolin Bricks

Test	A	b	c	D	E	F	g	h	I	J	K	L	m	n	O
G/cm^3	1.2	1.07	1.19	0.99	1.07	1.23	0.91	0.78	1.03	1.16	NA	0.80	1.01	1.04	1.14

Table 4. Compression Strength Test Conducted on Getso Kaolin Bricks

Test	A	b	c	D	E	F	g	h	I	J	K	L	m	N	O
N/mm^2	1.44	1.85	0.73	0.51	0.85	1.40	0.18	0.14	0.53	0.55	NA	0.20	0.20	0.69	0.79

Table 5. Chemical analysis of Danbakoshi

Oxide	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	S_2O_3	V_2O_3	NiO	CuO	BaO	Ga_2O_3	Ta_2O_5	WO_3	L.O.I
%	60.01	0.28	25.80	1.29	0.013	0.47	0.33	5.89	0.054	0.015	0.020	-	0.018	0.87	-	-	-	5.70

Table 6. Porosity Test Conducted on Danbakoshi Bricks

Test	A	b	C	D	E	f	j	H	i	J	K	L	m	N	o
%	31	31	31	43	29	30	36	34	34	31	46	44	33	34	34

Table 7. Density Test Conducted on Danbakoshi Bricks

Test	A	b	c	D	E	F	j	h	i	J	K	L	m	N	O
G/cm^3	1.29	1.17	1.25	1.04	1.19	1.24	0.92	1.19	1.16	1.21	0.78	0.88	1.05	1.13	1.18

Table 8. Compression Strength Test Conducted on Danbakoshi Bricks

Test	A	b	c	D	E	F	j	h	i	J	K	L	m	N	O
N/mm^2	2.61	1.16	1.77	0.98	1.63	2.02	0.59	0.43	1.00	0.96	0.31	0.22	0.78	0.61	1.40

Discussion of the results

The chemical analysis table 1 and table 5 show the elementals constituents and percentage of each kaolin sample which was determined by the X-ray fluorescence spectrophotometer (RXF): revealed that Getso kaolin has high alumina (Al_2O_3) of 34.30% and silica (SiO_2) 53.67%. Danbakoshi kaolin has high silica (SiO_2) of 60.01% and low alumina (Al_2O_3) of 25.80% as shown in table 5. More over fluxing agents in the samples which melt with increase in temperature and surrounds the refractory elements thereby decreasing porosity revealed that Danbakoshi kaolin is higher in iron (Fe_2O_3) 1.29% and Potassium (K_2O) 5.89% compared to that of Getso kaolin which has 1.48% of Potassium (K_2O) and 0.75% of iron (Fe_2O_3) (see table 1).

It was observed that 1200°C temperature used to calcine the kaolin samples to prepare the grog was adequate as the Jaw crusher in the ceramic studio crushed the calcined samples to different sizes that enabled the successful screening of particles and dust fraction was removed through sieve gradation processes. Grog was classified in to four particles grains sizes, with a maximum of 1.18 and minimum of 0.15. The four groups were adjusted and composed to form a group in the refractory body batches.

The charcoal crushed to powder and sieved to sizes, 1-2mm mesh used agrees with Nanthaphong and Sakdipown (2011) that the charcoal additives serving as pore agent creates pores within the brick structure after the charcoal is burned out. However, it was observed that the charcoal generates smoke during the firing. The charcoal was incorporated into the composition as a pore agents and was observed during the firing that the charcoal burned out at the temperature region of 650°C, as it was noticed at the beginning of the firing too much smoke emitted through the chimney as temperature raised and built up smoke reduced gradually and disappeared when temperature reached 650°C.

Apparent Porosity

The variation of Porosity of the samples indicated that Getso samples increased in porosity with an increase in charcoal, the increase was in the range of 37 to 53% as shown in table 2. Danbakoshi samples were observed to have low porosity in the range of 29 to 46% .as also shown in table 6. It was obvious that increase in charcoal content in the brick composition yielded a higher porosity. And this agrees with Nanthaphong and Sakdipown (2011) that porosity can be achieve in fired bricks with charcoal as pore agent.

Bulk Density

The variation of density of Getso samples indicated high density with increase in kaolin and grog as recorded in Table 3 with 1.23g/cm³ and decreased with an increase in charcoal. Danbakoshi samples density was higher as shown in Table 7 with 1.28g/cm³ and decreased with increase in and Porosity. It was observed that firing to 1250°C melted the low melting compounds in the body and the molten materials flows and penetrated the pores within the brick structure which reduced the much anticipated porosity and increased the brick density, strength and shrinkage.

Compressive Strength

The variation in the compression strength of insulation firebrick containing different ratio of kaolin, grog and charcoal indicate that the increase in compressive strength with density and decrease in compressive strength with increase in porosity. The highest compressive strength in Getso samples has 1.44 N/mm^2 (see table 4) and Danbakoshi 2. 61N/mm^2 (see table 8). These samples have the highest kaolin ratio in the composition which provide density with increase in temperature and agree with the chemical analysis which corroborates Jonker, Maree, Vender and Meriver (1998) that mineral composition of clay has bonding power, with an increase in temperature lower melting compounds melt and surround more refractory grain and provide mass interlocking particles and increase in strength.

Summary

X-ray fluorescence spectrometer (XRF) was used to determine the chemical constituents of the samples. Grog aggregates were composed and formed in to a group in refractory body batches. Charcoal was also sieved and screened using 1-2 meshes and used as pores agent in the body batches. Fifteen units of tri-axial blend were selected to formulate the body. Three materials of kaolin, grog and charcoal were added in part and by volume percent according to unit blend composition, dry mixing was made and followed by wet mixing with water. Difloculant (sodium silicate) and binder (cone starch) were also added in to the slip.

Bricks were produced through casting method. Slip was poured in to plaster mould: the mould absorbed the water and shaped the product, and then the product was removed from the mould and dried in the ceramics studio of Abubakar Tafawa Balewa University Bauchi (A.T.B.U.). The bricks were fired to 1250°C in kerosene fueled kiln under oxidized atmosphere. Cone 9 was used to read the temperature.

Conclusion

The outcome of the study produced two classes of insulation firebrick. The physical qualities of Getso kaolin with its slight pink coloring improved to white after firing indicating less iron content than that of Danbakoshi which remained yellowish after firing.

The chemical composition of Getso kaolin proved suitable for insulation properties at 1250°C as it possesses alumina content of 34.30% and minimal traces of fluxing agents 0.76% Fe_2O_3 and 1. 48% in K_2O. Low alumina content of 25.80% and high fluxing materials of 1.29% Fe_2O_3 and 5.89% K_2O possesses in Danbakoshi kaolin made unsuitable for insulation properties for class 23 (ASTM C155-70) as Robert by Classified. Sullayman (2003) reported that the benchmark for refractory materials should have minimum alumina content of 34% and less 1. 30% Fe_2O_3 and fluxing agent's content. Different mixtures of kaolin, grog and charcoal revealed high porosity in Getso samples 44-52% in Table 2, Danbakoshi samples displayed porosity of 44- 46%. Schull and Schlegal (1991) stated that high insulation refractory should have 45 – 75% porosity. The high porosity in Getso insulation firebrick indicated low density and low compressive strength in table 3. While less porosity in Danbakoshi kaolin brick indicated high density and high compressive strength in the table 4, Bhatia (2011) stated that degree of porosity provides low thermal conductivity which is the desirable feature of insulation bricks. Jonker et al (1998) stated that the numerous pores the thinner the enclosing walls of solid materials the lower the density and low strength. The casting method used to produce the bricks provides a good matrix of kaolin and grog with good pores network within the brick structure and pleasing surface texture. The refractory materials demonstrated good endurance under firing as the temperature raised gradually up to 1250°C.

Contribution to Knowledge

1. Production of insulating firebricks from local raw materials.
2. Production of insulation firebricks that withstand temperature of 1250°c
3. The suitability of charcoal as fugitive materials in the production of insulating fired brick.

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