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Full Length Research Paper

Production and characterization of clay – cow dung insulating fire - bricks

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The use of clay is of high economic potential in Abeokuta, South West Nigeria, to metallurgical, chemical and allied, ceramic and glass industries. This research work was carried out to investigate the suitability of using clay – cow dung to produce insulating firebrick and to determine the optimal ratio of the constituent. Two clay samples were collected from Ilese Awo clay deposit (Ilese Awo 1 and Ilese Awo 2). Preliminary test were carried out to determine the chemical constituents of clay samples and cow dung using Atomic Absorption Spectrophotometric Analysis (AAS). Six different compositions of brick samples were produced from the two clay samples, the brick samples were fired at a temperature of 1200^{o}C. Three of the sample (samples 4, 5 and 6) crumbled during firing while the remaining three samples (samples 1, 2 and 3) gave the following limits of results: - linear shrinkage: 6 – 8%, bulk density: 1.97 – 2.35g/cm3, porosity: 22.54 – 30.62%, permeability: 88 – 112%, cold crushing strength: 64 -152.5Kg/cm2, thermal shock resistance: 12 – 30 cycle, and thermal conductivity: 0.156 – 0.21W/mK. The results showed that all the brick samples had good insulating characteristics, suggesting that cow dung can be used as additive in production of insulating fire- bricks.

Keywords: Clay, Cow dung, Ilese Awo, Firing, Shrinkage, Refractoriness, thermal, conductivity

INTRODUCTION

The most commonly employed refractory brick is that made of fire clay (bureau of standard), The growing need of insulating fire bricks in steel industry, glass industry and some other chemical processing industry have promoted investigation into various alternative use of more economical materials. Even though it is specially designed for high heat environment, refractory brick will eventually start to fail and breakdown over time, this necessitate periodical removal and replacement of the refractory bricks with new ones to ensure that the device operate as intended and hence there is periodical demand for refractory bricks in all industry or outfit where it is used (Wikipedia, the free encyclopedia. 2011). Clay has the property of forming a coherent, sticky mass when mixed with water, being readily mouldable when wet but if dried retains its shape (Gerhard, 1986).

This property accounts for its utilization for the production of pots, plates, cups, ovens as well as refractory brick. Composite refractory brick has been identified as a solution to obtain both chemical and physical properties needed to be possessed by a good refractory brick (Borode et al., 2009) this is achieved by engineering clay with either synthetic or organic

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additives. The aim of this study is to examine the effect of cow dung on engineering properties of Ilese Awo clays in production of insulating fire bricks for industrial applications such as furnace lining, incinerator lining and reactors lining.

Chemical nature of clay

Clay minerals chemically consists of ions in their structure arranged in parallel plane forming layers, a unit crystalline clay fundamentally contain two parallel sheet of tetrahedral sheet (the tetrahedral cation is usually Si+4) and Octahedral sheet (the octahedral cation is usually Al+4) which combine themselves to form more complex units. The combined ratio of tetrahedral to octahedral sheet gives rise to sub- classification of clay-mineral as 1:1 and 2:1 types. In ratio 1:1 type, one tetrahedral sheet linked to one octahedral sheet to form a systematic stack, whereas two tetrahedral sheets linked with one octahedral sheet to form a systematic stack of 2:1 type of clay minerals (Grim, 1968). The chemical nature of the clay mineral as well as the type of minerals between two different sheets gives each clay what group it belong and determine physical and chemical characteristic as well as firing behaviour of the clay group.

Cow dung

Cow dung is the faeces of the bovinc species. The species include the Cow, Buffalo, Ox, and Bullock. It is mainly the rejects herbivorous matter which is acted upon by symbiotic bacterial residing within the animal's rumen. The resultant faeces matter is rich in minerals like potassium, magnesium, sodium and manganese. Cow dung is comprised of organic matter including fibrous material that passed through the cow digestive system. The chemical composition of cow dung contains carbon, nitrogen, hydrogen, oxygen, phosphorus, salt, urea, mucus, as well as cellulose, lining and hemicelluloses (Awodun, 2008).

MATERIAL AND METHODS

The refractory materials used for the various mixes are clay from two deposits in Ilese Awo, Abeokuta, Ogun State, South West Nigeria and cow dung obtained from Federal University of Agriculture, Abeokuta (FUNAAB) farm. The clay samples were chemically analysed at International Institute of tropical Agriculture (IITA) Ibadan. Specimens were prepared and tested at ceramic section of Federal Institute of Industrial Research Oshodi (FIIRO), Lagos state Nigeria. 60Kg of clay samples were collected from each deposit. The samples were collected by hand from existing open pits of the deposit sites, namely: Ilese Awo1 and Ilese Awo 2, located at Abeokuta south local government in Ogun State, South West of Nigeria. 40Kg of cow dung was collected from FUNAAB farm cattle ranch.

Materials processing

There are several methods of beneficiating Kaolin, The complexity of the treatment sequence primarily depends on the nature of the deposit and the desired product (Prasad,et al., 1991). The clay samples were processed manually. Each clay sample was crushed using mortar and pestle. They were soaked in two different clean baths of water for 72 hours, to enable dissolution of foreign particles in the clays, were washed with clean water and on the fourth day. Slurries were sun-dried respectively to dryness in the atmosphere, the two clay samples were granulated and sieved to the desire particle sizes (300µm). The collected cow dung sample were crushed with mortar and pestle and then sieved to desire particle size of 300 mesh (300µm).

Chemical Analysis (Ilese Awo 1 and Ilese Awo 2 Clay deposits)

Chemical analyses of the two clay samples were determined using Atomic Absorption Spectrophotometer (AAS).The organic element composition of the clay samples was determined in the Analytical laboratory section of International Institute of Tropical Agriculture (IITA) Ibadan using Mehlich -3 extraction procedure to extract Ca, Mg, K, P, Zn, Mn, and Fe . The lab wares were acid-rinsed in 0.01N Hydro Chloric Acid (HCl), followed by two rinses in distilled water, and extraction was carried out in a thermo electron cooperation GP8 centrifuge, and the extracts were neatly transferred from the centrifuge to tubes which was read on Buck scientific 205 Atomic Absorption Spectrophotometer (AAS). The samples concentration was determine from a standard curve using these equation:

$$Soil\ concentration\left(\frac{Cmol}{kg}\right) = \frac{ppm\times 30}{Eq.wt\times sample\ wt.} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

PPM = Part per million

Eq. wt. = Equivalent weight (g) Sample wt. = Sample weight (g)

The chemical composition of the cow dung sample was determined in the analytical laboratory of International Institute of Tropical Agriculture (IITA) Ibadan. Dry ash digestion procedure was used for chemical analysis of cow dung in which the sample was ashed for 2hr at temperature of 500oC using Ney VulcanTM 3-550 furnace, and allowed to dry cool for additional 2hr after which the ashed cow dung was carefully digested in aqua

Table1. Ratio of clay/cow dung mixture (%)

Sample	Clay (%)	Cow dung (%)	Clay (g)	Cow dung (g)	Total Clay/cow dung % mixture
1	100	0	100	0	100
2	90	10	90	10	100
3	80	20	80	20	100
4	70	30	70	30	100
5	60	40	60	40	100
6	50	50	50	50	100

Table 2. Chemical Composition of the Clay Samples

Samples(%)	P	Ca	Mg	K	Zn	Cu	Mn	Fe	SiO2	Al_2O_3	LOI
A	0.01	2.92	0.42	0.15	0.07	0.01	0.02	0.14	46.37	26.74	23.15
B	0.01	4.14	0.56	0.26	0.08	0.01	0.03	0.15	51.1	23.48	20.18

A- Ilese Awo 1 clay sample
B- Ilese Awo 2 clay sample

regia solution and centrifuged for 10min at 300rpm with the aid of thermo electron cooperation GP8 centrifuge. The nutrients (Ca, Mg, K, Na, Zn, Mn, and Fe) were determined from the digest using Buck Scientific 205 Atomic Absorption Spectrophotometer (AAS).

Production of test specimens

The production of insulating fire brick using clay and cow dung was carried out as shown in Table 1The processed clay and cow dung were stored in their respective labelled dry containers. Equivalent percentage cow dung compositions were measured with every 1kg of clay sample. These materials were wet-mixed until a satisfactory even distribution of aggregate was achieved in a container and each aggregate were used to mould test specimen in a specimen mould of internal dimension (Ø30 X 40) cm. The test specimen were left to dry atmospherically and then dried in an electric dryer at 110^{O}C.

Engineering properties test

Six test specimens were prepared for each of the engineering properties namely: linear shrinkage, bulk density, porosity, permeability, thermal shock resistance, refractoriness and compressive strength, these is done for six different clay/cow dung mix (0, 10, 20, 30, 40, and 50% cow dung composition) was carried out at the Ceramic Section of Federal Institute of Industrial Research Oshodi Lagos, and engineering property test were carried out for each specimen.

Linear shrinkage

The test specimens were dried in Naberthern (30 - 300℃) furnace for 24 hours at 110oC their dimensions (length, breath and height) were measured using vernier caliper, Lengths measured were recorded as dry length (LD) and then fired in GEMCO (SON – Holland – Telex 59388) furnace to temperature of 1200oC, cooled to room temperature and their measurement were taken as fired length and recorded as (LF). For each sample, 6 different specimens were tested and the averages of the above parameters were used to calculate the linear shrinkage using formula (2):

$$\%LS = \frac{L_D - L_F}{L_F} \times 100 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (2)$$

%LS is the percentage linear shrinkage of the specimens.
LD – Dry Length
LF – Fired length

Bulk Density

All test specimens were dried at 110oC for 24 hours to ensure total moisture loss, and then fired to a temperature of 1200oC in GEMCO (SON – Holland – Telex 59388) furnace, their corresponding weight after firing were measure and recorded as Wf using Navigator™ N3B110 Ohaus Electronic weighing machine, They were allowed to cool and then immersed in a beaker of water, the pores in the specimen were filled with water and bubbles were observed ensuring well soaked specimen, their soaked weight were measured suspended in air and recorded as Wa. They were then suspended in water in a beaker, one after the other using a sling and their respective suspended weight were measured and recorded as WW. The bulk density was

Table 3. chemical composition of Cow dung samples

Samples(%)	P	Ca	Mg	K	Zn	Cu	Mn	Fe	Na
Cow dung	0.38	1.57	0.51	0.82	0.0052	0.0003	0.011	0.015	0.004

Table 4. Ilese Awo1 Linear shrinkage

Cow dung (%)	**0**	**10**	**20**	**30**	**40**	**50**
Ilese Awo 1 clay (%)	6	6	6	ND	ND	ND
Ilese Awo2 clay (%)	8	7.5	6	ND	ND	ND

ND – Not detectable

Table 5. Ilese Awo 1 Bulk density

Cow dung (%)	**0**	**10**	**20**	**30**	**40**	**50**
Ilese Awo 1 clay (g/cm^3)	2.16	2.02	1.97	1.68	1.31	1.23
Ilese Awo2 clay (g/cm^3)	2.35	2.21	2.13	1.67	1.43	1.31

calculated as (2):

$$BD = \frac{W_f}{W_a - W_w} \quad \left(\frac{g}{cm3}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(3)$$

BD - the Bulk density (g/cm^3).

Apparent Porosity

The apparent porosity of the specimen was calculated using the parameters obtain in the experimental procedure of bulk density, using the formula:

$$\mathrm{AP} = \frac{\mathrm{W_a - W_f}}{\mathrm{W_a - W_w}} \ \mathrm{X}\,100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Permeability

The dry weight of the green state specimen was obtained for each one of the specimen by direct weighing and recorded as Wd and then, immersed in a beaker of water for 2 minutes and their wet weight taken as Ww. The difference in weight was computed and corresponding permeability was calculated through equation below (2):

$$P = \frac{W_w - W_d}{W_w} \ X\,100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (5)$$

Thermal Shock Resistance (TSR)

This test was carried out to determine the number of operating cycle the refractory bricks can withstand before total failure. Each sample dimensioning Ø30mm and 40mm height was placed in furnace and heated to attain the test temperature of 1200℃; each sample was then carefully withdrawn from the furnace and held for 10minutes. The procedure was repeated until an appearance of a crack was visible. The number of repeated cycles necessary to cause a crack was noted and recorded for each of the sample as the measure of its thermal shock resistance. The average of ten samples in each brick specimen composition was taken as thermal shock resistance (Borode et al., 2009).

Refractoriness

This is the measure of maximum temperature at which a refractory brick will fuse. The test was carried out to determine the temperature at which each test sample with a certain percentage composition of cow dung will fuse. Each test sample was placed in the furnace and the temperature was raised to 1000℃. The sample was then observed for fusion under the increment of the temperature at interval of 50℃ until fusion was observed (Gerhard, 1987).

The results obtained for the different experiments carried out in this investigation are presented in table 2 - 9 below:

DISCUSSIONS

Compositions 4 – 6 crumbled during firing and hence their linear shrinkage and thermal shock resistance could not be detected. This indicates that cow dung content was too high for clay to bind. 1 – 3 show a good level of refractoriness.

Linear shrinkage

From the results (Table 4) the percentage shrinkage value of the sample at 1200ᴼC ranges from 6% for composition 1 of Ilese Awo 1 clay to 6% for composition

Table 5. Ilese Awo 1 Bulk density

Cow dung (%)	0	10	20	30	40	50
Ilese Awo 1 clay (g/cm^3)	2.16	2.02	1.97	1.68	1.31	1.23
Ilese Awo2 clay (g/cm^3)	2.35	2.21	2.13	1.67	1.43	1.31

Table 6. Ilese Awo 1 Porosity

Cow dung (%)	0	10	20	30	40	50
Ilese Awo 1 clay (%)	26.52	28.07	30.62	32.15	33.84	36.88
Ilese Awo2 clay (%)	22.54	25.27	27.45	32.58	34.27	37.48

Table 7. Ilese Awo 1 Permeability

Cow dung (%)	0	10	20	30	40	50
Ilese Awo 1 clay (%)	88	96	108	116	126	130
Ilese Awo2 clay (%)	94	102	112	124	130	138

Table 8. Ilese Awo 1 Thermal shock resistance

Cow dung (%)	0	10	20	30	40	50
Ilese Awo 1 clay (Cycle)	30+	20	16	8	ND	ND
Ilese Awo2 clay (Cycle)	30+	18	12	8	ND	ND

ND - Not detectable

Table 9. Ilese Awo 1 Cold crushing strength

Cow dung (%)	0	10	20	30	40	50
Ilese Awo 1 clay (Kg/cm^2)	150.6	109	64	51.6	28.6	<25
Ilese Awo2 clay (Kg/cm^2)	152.5	132.5	104.0	61.0	38.0	<25

Note : firing temperature for all samples is 1200^{O}C

3 and 8% for composition 1 of Ilese Awo2 clay to 7%, it is clear that for the same weight percent of cow dung in different clay sample, the higher the clay content , the lower the linear shrinkage.

Bulk density

From Table 5, sample 1 showed the highest bulk density, 2.16g/Cm3 while sample 3 showed 1.97 g/Cm3 for Ilese Awo 1 clay, sample 1 of Ilese Awo 2 clay showed the highest bulk density of 2.35 g/Cm3 while its sample 3 gave bulk density of 2.13 g/Cm3. The higher the percentage of cow dungs in a sample, the lower the bulk density (Gerhard, 1987).

Porosity

Table 6 showed the result of the sample porosity test, Ilese Awo 1 clay showed porosity ranges from 26.52% for sample 1 to 30.62% porosity for sample 3. Ilese Awo 2 clay showed porosity ranges from 22.54% for sample 1 to 27.45% for sample 3; these indicate that the higher the percentages of cow dung in a sample, the higher its porosity. This is as a result of cow dung burning out during firing and leaving plenty of pores in the brick, the brick become more porous and hence the better heat insulator the brick would be as a result of trapped air in the pores (Hassan,et al., 1993).

Permeability

In table 7 Ilese Awo clay showed permeability ranges from 88% for sample 1 to 108% for sample 3, while T able7 showed permeability ranges from 86% for sample 1 to 112% for sample 3. It may be said that the higher the percentage of cow dung in a sample, the higher the permeability, this is as a result of more pores in the brick during firing; these pores allow the passage of fluid.

Thermal shock resistance (TSR)

Table 8 showed a decrease in TSR as percentage of cow dung in the sample increases. Ilese Awo 1 clay gave highest TSR of 30cycle for sample 1 and 16cycle for sample 3, while Ilese Awo2 showed highest TSR of 30cycle for sample 1 and 12cycle for sample 3.

CONCLUSIONS

According to the properties of the brick samples examined and analysed in this study, it can be concluded that:

Clays from Ilese Awo in Abeokuta, Ogun state, South West Nigeria are suitable for the production of Insulating fire bricks.

Sample 1, 2 and 3 are all insulating fire bricks that can withstand temperature up to 1200^{O}C.

Sample 1, 2 and 3 composition contain clay more than 2/3 of total weight of the insulating brick and hence suitable for minimal effective moisture content.

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