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# Effects of Sawdust and Rice Husk Additives on Properties of Local Refractory Clay

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## ABSTRACT

*The effect of the addition of Sawdust and Rice husk to refractory clay on its properties was investigated. The clay sample was first analyzed to determine its chemical and physical properties. It was then thoroughly mixed with Sawdust and Rice husk separately and standard fireclay brick specimens prepared. They were then tested for properties such as refractoriness, fired shrinkage, apparent porosity and thermal shock resistance. Physical property test results showed that refractoriness reduced from 1300 $^0$C to 1200$^0$C on addition of both Sawdust and Rice husk as additives; shrinkage reduced from 3.89% to 3% on introduction of additives while thermal shock resistance of samples with additives are ten times better; porosity of the sample with Rice husk additive is 36.74%, that of the sample with Sawdust was 45.34% as compared with that of the sample without any additive which was 27.15%. bulk density reduced from 1.98g/cm$^3$ to 1.59g/cm$^3$ and 1.52g/cm$^3$ on addition of Sawdust and Rice husk respectively. Chemical composition tests showed a decrease in silica content from 62% to 54% on addition of additives; alumina content reduced 20% to 12% while iron oxide content increased from 7.58% to 8.38 and 7.99% on the respective addition of Sawdust and Rice husk to the clay material.*

***KEYWORDS*** **-** *additive, porosity, fired shrinkage, refractoriness, insulation, brick.*

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## I. INTRODUCTION

Most metallurgical processes are heat generating systems. Such systems require materials that can withstand not only the high temperature generated but equally must be able to withstand both physical and chemical action of molten metal, slag and gases without deteriorating. Engineering materials that possess these attributes are referred to as refractory materials. The base material for refractory production is clay. Clays are naturally occurring sediments produced by chemical actions resulting from weathering of rocks [1]. An earthly fine-grained material, which develops plasticity when mixed with water, clay has silica ($SiO_2$), alumina ($Al_2O_3$) and water as primary constituents. Other constituents are iron, alkaline, and alkaline earth metals [2].

Nigeria has appreciable distribution of metal and process industries where high temperatures are generated and as such have considerable needs for Refractories. Present economic realities dictate the need for internal sourcing of raw materials to be used in the production of engineering materials. Refractories, being a class of materials largely used in metallurgical plants and cement industries, are presently largely sourced by importation (about 38,000 to 120,000 tonnes annually) with enormous financial implications to the country [3].

## II. MATERIALS AND METHODS

### 2.1. MATERIALS

Clay used for the experiments was obtained from Mangada clay deposits in Biu local Government area of Borno state, Nigeria. The sawdust was obtained from a local Sawmill in Jimeta, Yola-North local Government area; while the rice husk was obtained from a local Rice mill in Girei, Girei local Government area of Adamawa state, Nigeria.

### 2.1.1. Material Preparation

The clay sample was dug from the deposit site using a hand-held hoe. The sample was sun-dried to reduce moisture content and enhance grinding. 500g of the sun-dried sample was grinded to powder using a jaw crusher. 400g of the sample was taken for physical property tests while the remainder was further ground to finer particles and then used for the chemical composition tests. The sample was weighed and further dried in an oven at 110℃ for one hour to ensure moisture evaporation.

## 2.2. METHODS

All the experiments for this work were carried out at the National Metallurgical Development Centre, Jos, Plateau State, Nigeria.

### 2.2.1. Determination of Properties

### 2.2.1.1. Chemical Composition

A 01g mass of the sample was weighed into a Teflon crucible. It was moistened with aquilegia (mixture of hydrochloric and nitric acid in a ratio of 3:1 by volume). About 15ml of hydrofluoric acid was added and the mixture was covered, heated and digested in an oven set at 100°C until the solution became clear. The ratio of the clay sample to that of the additives is 9:1. The additives were burnt to ashes before mixing with the clay. After undergoing the heating process, the sample was allowed to cool and then transferred to a 250ml plastic volumetric flask and mixed with distilled water. This is the stock solution which was used in determining the Silicon, Aluminium and Iron oxides [4]

### 2.2.1.2. Physical properties

### 2.2.1.2.1. Bulk Density

Bulk density is the weight per unit volume of the refractory material including the volume of open pore space. It could be determined using the direct volume measurement method [5]

A test specimen was cut from the core of the material sample using a cut-off wheel. The dry and saturated weights of the sample were determined. The bulk density was then calculated using the relation 1:

$$\text{Bulk Density, } y = \frac{W_A}{W_C - W_B}\rho_W \qquad (1)$$

Where $W_A$– weight of dry sample; $W_B$-weight of dry sample suspended in cold water; $W_C$- weight of soaked sample suspended in air; and $\rho_W$- density of water.

### 2.2.1.2.2. Thermal shock resistance

The sample was placed in a muffle furnace preset at 1200℃ minutes 10 minutes. It was then cooled outside the furnace for another 10 minutes and observed for cracks. The heating and cooling cycles are repeated until cracks are observed on the specimen. The number of these cycles undergone before cracking was recorded and this constitutes the thermal shock resistance of the material.

### 2.2.1.2.3. Porosity

Porosity is the percentage relationship between the volume of pore spaces and the total volume of the refractory. For determination of porosity, a prepared clay sample was air-dried for 24 hours. The sample was then oven-dried for another 24 hours at110℃ . It was then fired at 1100℃, cooled and transferred into a desiccator and weighed to the nearest 0.01g (dried weight). The specimen was then transferred into a 250ml beaker in an empty vacuum desiccator. Water was then introduced into the beaker until the test sample was completely immersed. The specimen was allowed to soak in the boiled water for 30 minutes the set up being agitated from time to time to assist the release of trapped bubbles after which the specimen was transferred into an empty vacuum desiccator to cool. The soaked weight was then taken and recorded.

The specimen was then weighed suspended in water using a beaker on a balance to obtain the suspended weight. The apparent porosity was calculated using:

$$\text{Apparent Porosity } = \frac{W-D}{W-S}\text{ x}100\% \qquad (2)$$

Where W- soaked weight; D- dried weight and S- suspended weight.

### 2.2.1.2.4. Fired Shrinkage

The test piece was made into a standard slab and a line marked along the length of the slab. The distance between the two ends of the slab was measured using a vernier caliper. The sample was air-dried for 24 hours and oven-dried at 110℃ for another 24 hours. It was then fired at 1100℃ for 6 hours. The test piece was cooled to room temperature and another set of measurement taken. The fired shrinkage was calculated using the relation:

$$\text{FiredShrinkage} = \frac{D_L - F_L}{D_L} \qquad (3)$$

Where $D_L$ − initial fired lenght $F_L$ − final fired lenght

### 2.2.1.2.5. Specific gravity

The specific gravity test is useful for determination of particle size distribution of any powdered material. It is defined as the ratio of the mass of the material to the mass of a quantity of water at 4℃ which has a volume equal to the solid volume at the temperature of measurement.

To determine the specific gravity, a flask was filled to a given level with water; a weighed amount of suitably ground and dried sample material was poured into it and the increase in volume which occurred was noted. The specific gravity of the sample was then calculated using the relation below [5]:

$$Specific\ gravity = \frac{b-a}{(d-a)-(c-b)}g \qquad (4)$$

where: a − weight of bottle; b − weight of bottle plus sample; c − weight of bottle plus sample plus distilled water; d − weight of bottle plus distilled water and g − density of water

### 2.2.1.2.6. Refractoriness

Refractoriness is the measure of the fusibility of a material and indicates the temperature at which the material softens. The parametric cone equivalence (PCE) method was used to determine the refractoriness of Mangada clay. The clay sample was dried and ground to pass through a 30 mesh British standard (B.S 1610R1942) test sieve and 50g was further ground to pass a 72 mesh sieve. Sieving was frequent to avoid excess of very fine powder. The sample was then thoroughly mixed, made into a plastic mass with water and an organic binder of 0.5% maximum ash content was added. The test piece was then formed in a suitable mould and calcinated at 1000℃. The mould was shaped into a pyramid with a triangular base (of sides 1.27cm with a tolerance of not more than 0.16cm on each side) and having one edge of the pyramid perpendicular to its base and 3.81cm long.

The test piece was mounted at the centre of a refractory plaque with its edge vertical to the base and fixed with cement containing calcined alumina. British standard pyrometric cones were cemented to the plaque but oriented so that they would bend away from the test piece with the numbers facing inwards and the edges opposite the numbers vertical. The refractory plaque with test piece and the surrounding pyrometric cone was placed in the furnace and the temperature raised at the rate of 10 − 15℃ per minute to an estimated temperature of 200℃ below the equating temperature observing the temperature rise rate with an optical pyrometer. The test was continued until the tip of test cone had bent over level with the base. The plaque carrying the specimen was then removed and allowed to cool and test piece and pyrometric cones examined when cold. The refractoriness is taken as the number of pyrometric cone that has bent over to a large extent similar to the test cone. The temperature is then read off from the equivalent of the cone number.

## III. RESULTS AND DISCUSSION

### 3.1. Physical Properties

The results of physical properties tests are presented in Table 1.

The apparent porosity of the sample with rice husk additive was found to be 45.70%; that of the sample with sawdust additive was 36.74% while that of the control sample was 27.15% meaning that the use of additives caused an increment in the apparent porosity of the samples. All the three samples have apparent porosity values above the indicated minimum limit of 20% for suitability of samples for use as refractory material [6].

Bulk density calculation results gave the bulk density as 1.52g/cm$^3$, 1.59g/cm$^3$ and 1.98g/cm$^3$ respectively for the sample with rice husk additive, sample with sawdust additive and the control sample. It is observed that use of additives led to a decrease in the bulk density of the material with addition of rice husk giving a higher effect. The obtained bulk densities for samples with additives are slightly lower than the recommended threshold values of 1.70g/cm$^3$ - 2.10g/cm$^3$ for dense fire bricks [5].

Table 1: Physical Properties of Mangada Clay with and without Additives.

| Sample | Physical properties | | | | |
|---|---|---|---|---|---|
| | Shrinkage, % | Apparent Porosity, % | Bulk density, g/cm$^3$ | Thermal shock resistance, cycles | Refractoriness, ℃ |
| Mangada clay without additives | 3.89 | 27.15 | 1.98 | 1 | 1300 |
| Mangada clay with Sawdust additive | 3.00 | 45.33 | 1.59 | 10 | 1200 |
| Mangada clay with Rice husk additive | 3.00 | 36.74 | 1.52 | 10 | 1200 |

Thermal shock resistance test carried out on all the samples gave a general picture of thermal instability as all samples have thermal shock resistance value of not greater than 10 cycles. The control sample showed the poorest thermal shock resistance of 1 cycle, whereas the sample with sawdust additive had the best thermal resistance of 10 cycles at 1200℃. Notwithstanding the fact that acceptable thermal shock resistance in practice is of values greater than 10 cycles, addition of sawdust caused an appreciable increase in the thermal shock resistance of the clay sample. Practical implication of this is that such materials could have their used restricted to lining of ladles and slag pots and other applications which are mended early at shock intervals [7].

Refractoriness of both the clay sample with sawdust additive and that with rice husk additive was found to be 1200℃. Such a value is indicative of low sintering temperature which in turn is an indication of poor refractoriness [8]. The refractoriness of mangada clay sample (control sample) was found to be 1300℃. It is worthy of note that introduction of additives tended to lower the refractoriness of the clay sample. The low refractoriness value is likely due to high silica content of the mangada clay.

Linear shrinkage of the control sample was slightly higher than those of the samples with additives (3.89% as against 3.00% for both samples with sawdust and rice husk additives). Based on earlier work carried out by Nwokolo, the optimum shrinkage for atypical kaolin at 1200℃ is 9% [4]. By comparison, all the investigated samples are not suitable for use as refractories.

### 3.2. Chemical composition

Result of the chemical analysis is presented in Table 2. From the table, the alumina contents are 12%, 12% and 20% respectively for the sample with sawdust additive, sample with rice husk additive and the control sample. This shows that use of additive caused a decrease in alumina content indicative that use of additives could result in improvement of the material's refractoriness as alumina content in clays is a strong indicator of the material's refractoriness [1].

Silica content result of the investigated samples also show the same tendency to decrease on introduction of additives as the of alumina content. The observed values were 54.50%, 54.70% and 62.00% silica content respectively for samples with sawdust additive, sample with rice husk additive and control sample. The silica contents of all the investigated samples fall within the range of the one suitable for fire clay production (50% - 70% silica content). As a result, such materials could be used as lining of heat treatment furnaces, melting furnaces for low melting point metals, liquid metal ladles and portions of blast furnaces.

The iron oxide ($Fe_2O_3$) content analysis revealed an increase from 7.58% for the control sample to 7.99% and 8.38% respectively for the sample with rice husk additive and that with sawdust additive. Meaning that the used of additive tended to enhance the iron oxide content of the sample with sawdust addition producing a higher effect than rice husk addition. Enhanced iron oxide content could be indicative of the suitability of the material for the production of ceramics [3]. It is also indicative of the fact that the use of sawdust and rice husk additives to the Mangada clay enhances its ability to meet iron oxide requirements for high melting clays.

Table 2. Chemical Properties of Mangada Cay with and without Additives

| Sample | Average Chemical content | | | |
|---|---|---|---|---|
| | $SiO_2$, % | $Al_2O_3$, % | $Fe_2O_3$, % | LOI, % |
| Mangada clay without additives | 62.00 | 20.00 | 7.58 | 0.00 |
| Mangada clay with Sawdust additive | 54.50 | 12.00 | 8.38 | 10.60 |
| Mangada clay with Rice husk additive | 54.70 | 12.00 | 7.99 | 9.85 |

## IV. CONCLUSION AND RECOMMENDATIONS

Based on the percentage $Al_2O_3$ content of both the clay samples with sawdust and rice husk additives, they are not very good candidate materials for the production of refractory bricks. The refractoriness of the clay sample is slightly negatively affected by the presence of the two additives.

The silica content of all the investigated clay samples, however, fall in the range recommended for materials suitable for use in lining of heat treatment furnaces, melting furnaces, liquid metal ladles etc. the iron oxide of samples with additives also give indications of the possibility of their use as ceramic raw materials.

The apparent porosity of the investigated clay with additives improved by 68% and 35% on addition of sawdust and rice husk respectively. The apparent porosity values also lie in the range acceptable for materials suitable for use in fire clay bricks. The use of additives reduced the linear shrinkage of the material by about 23%. The presence of additives negatively impacted on the refractoriness of the mangada clay. Thermal shock resistance of the material was improved about ten folds by the inclusion of additives. The bulk density was also noted to reduce by about 23% and 20% on addition of rice husk and sawdust respectively.

The observed changes in properties indicate that the presence of sawdust or rice husk as additives in the investigated material enhance the applicability of the Mangada clay as raw material in some industrial applications like ceramic applications, use as linings of heat treatment furnaces and use as insulating bricks.

## V. ACKNOWLEDGEMENT

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