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# Performance Evaluation of Irefin (Isan Ekiti) Clay in the Production of Refractory Bricks

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**ABSTRACT:** The performance evaluation of refractory brick produced using Isan Ekiti clay (Ball clay and Kaolin) with saw dust as the combustible materials was investigated with a view of determining the most suitable percentage compositions. The clay samples were sourced from Isan Ekiti was crushed, pulverized, and sieved to produce very fine grains of less than 120 µm particle size distribution for all samples. Four compositions were developed from admixture of the clay and combustible materials. Samples produced from the compositions were then tested for shrinkage, porosity, bulk density, average crushing strength, and water absorption after firing to 1000 $^{o}$c. Samples A-D had percentage total shrinkage ranging from 8% - 20% with corresponding bulk density ranging from 0.66g/cm$^3$ – 1.07g/cm$^3$. All the samples had crushing strength ranging from 1.1- 4.2 N/mm$^2$ with corresponding percentage porosity ranging from 47.7% - 65.2%, while the percentage water absorption range from 41.3% - 98.4%. It was discovered that the higher the combustible materials the higher the shrinkage, porosity and water absorption, while the lower the bulk density and crushing strength of the bricks. However, sample D of the bricks produced with the lowest percentage combustible gave the average result when considering the percentage shrinkage, porosity, bulk density, crushing strength, and water absorption. Therefore, sample D with (70% of kaolin, 15% of ball clay, and 15% of saw dust) was used in the production of refractory bricks, and thereafter used to build a testing kiln.

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Refractory Bricks is defined as a block of ceramic material used in lining furnaces, kilns, fireboxes and fireplaces. A refractory brick is built primarily to withstand high temperature but will also usually have a low thermal conductivity for greater energy efficiency. In order word, it is a non-metallic brick that can withstand extreme temperatures in which it has high resistance to fusion. Irefin-Isan Ekiti is small village situated in Oye Ekiti (Ekiti north local government), Ekiti State. Its geographical coordinates are 7$^o$ 55” 0” North, 5$^o$ 19” 0” East and its original name (with diacritic) is Isan Ekiti. People in this village are known for pottery making, the usefulness of the clay in this area, and the town being known for pottery, necessitate the quest to inquire more on its physiochemical properties and its suitability their clay for refractory brick production. The people of Irefin-Isan Ekiti are known for production of traditional pottery; Most of the pots they produced are terracotta which cannot withstand high temperature. This study envisage on how to make the local potter associate with modern firing technique by making use of their raw materials to production a better kiln for firing a their wares to a higher temperature. Clay is chemically known as hydrated alumina silicate ($Al_2O_3.6SiO_2.2H_2O$) which is derived from the chemical and mechanical disintegration of rocks, this could be igneous, metamorphic and sedimentary. Clay is a natural raw materials for many industrial finished products such as refractories, ceramics wares, clay varies in different colours from white to dull grey or brown to deep orange-red. Refractories are also materials which remain unmelted at high temperature.

They are chemically inert, strong enough to withstand the weight, wear of the melted material, slag resist to cracking and splitting under various temperatures to be easily molded into bricks or other forms of construction materials. A refractory brick is built primarily to withstand high temperature, but will also usually have a low thermal conductivity for greater energy efficiency. Refractories are used in boiler

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furnaces; blast furnaces, gas retort setting, lime kilns, metallurgical furnaces for melting, reheating and heating treatment of iron, steel or nonferrous metals. Thus, this study was carried out to investigate the performance of the kaolin and ball clay found in Irefin-Isan Ekiti, Ekiti State, Nigeria in the production of refractory bricks

## MATERIALS AND METHODS

*Material:* The materials involve in this investigation are majorly two different clay sourced from Irefin-Isan Ekiti. One is identified to be Kaolin, while the other is the ball clay. The admixture of the two clay and saw dust as combustibles were done at four different compositions by varying the materials.

*Methods:* The raw materials dug from the research area were packed, bagged and transported to laboratory for experimental analysis. The materials were first sun dried for a week to remove moisture content in order to ease pounding and grinding of the materials. The dried samples were then crushed to break the lumps using mortar and pestle, and further pulverized using a grinding machine to achieve a very fine particles size. Macro size sieve mesh of 120mm was used to sieve the materials. 600g of each of the sample was dried in the oven to further remove the moisture content in the materials, then used for the chemical composition test of the sample. Homogeneous mixing of the materials compositions was done by adding 600g of water to the composition.

**Table 1**: Brick production Sample Compositions

| **Composition** | **A (%)** | **B (%)** | **C (%)** | **D (%)** |
|---|---|---|---|---|
| **Kaolin** | 55 | 60 | 65 | 70 |
| **Ball Clay (binder)** | 15 | 15 | 15 | 15 |
| **Combustible (Saw dust)** | 30 | 25 | 20 | 15 |

**Fig. 1** Produced Samples before Firing

The materials were thoroughly mixed together and was molded into a wooden cubic mould of 50 × 50 × 50mm in accordance to standard precision of an Automatic Digital Readable machine (ADR). Five replicates of each sample compositions were also made in order to have enough samples for the tests that were carried out. The samples produced were sundried for 2 weeks, and later oven dried at 100ºC to remove moisture content in the samples. The green weights of the samples were taken before they were finally fired in the kiln at 1000ºC for 8 hours and allowed to cool in the kiln.

**Fig. 2** Produced Samples after Firing

*Tests Procedure:* The following tests were carried out on the samples produced to ascertain the suitability of the materials and compositions for refractory brick production; the procedures are as well explained:

*Water Absorption:* The percentage of the relationship of weight of the water absorb to the weight of the dry samples were determined using the below formula:

$$\text{Water Absorption} = \frac{W_2 - W_1}{W_1} \times \frac{100}{1} \ldots\ldots\ldots\ldots 1$$

Where $W_1$ is dried weight; $W_2$ is soaked weight

This test was carried out after the firing of the test samples; in which the test samples were boiled for two hours and soaked in the water for 14hours immediately after offloading it from the kiln just to make absorb enough water. The weight of the dry test samples were subtracted from the weight of soaked test tiles, divided by the weight of dried test samples and the result obtained was multiplied by 100.

*Apparent Porosity:* This express the percentage relationship of the volume of the pores in the specimen to its exterior volume. The water absorbed was determined using the below formula:

$$\text{Apparent Porosity} = \frac{S-D}{S-I} \times \frac{100}{1} \ldots\ldots\ldots\ldots\ldots 2$$

Where S = soaked weight, D= Dried weight, and I = immersed weight

The test was carried out by measuring the dried fired test samples weight (D). Records of samples boiled for two hour and later soaked for fourteen hours were also measured by weighing the samples (S). The immersed weight i.e. the suspended weight of the fired test samples in water were taken also.

*Bulk density:* A sample in gram per cubic ($g/cm^3$) is the quotient of its dry weight divided by the exterior volume, including pores B [$g/cm^3$].

$$\text{Bulk Density} = \frac{D}{S-I} \ldots\ldots\ldots\ldots\ldots\ldots 3$$

*Cold Crushing Test:* This test indicate the compressive stress that a brittle solid (as stones or concrete) can attain without fracture. This is calculated from the maximum load indicated at the failure and the means cross-sectional area over which the load is applied. The formula involve is:

$$\text{Compressive Strength} = \frac{\text{Force Appied (N)}}{\text{Cross Sectional Area (mm)}} \ldots\ldots 4$$

## RESULTS AND DISCUSSION

The results of the physical analyses tests that were carried out on the samples are as presented in Table 2.

**Table 2:** Results of Physical Analysis tests Carried out on the Samples

| Samples | Water Absorption (%) | Apparent Porosity (%) | Bulk Density ($g/cm^3$) | Cold Crushing ($N/mm^2$) |
|---|---|---|---|---|
| **A** | 98.4 | 65.2 | 0.66 | 1.1 |
| **B** | 75.6 | 64.3 | 0.85 | 1.8 |
| **C** | 66.3 | 63.8 | 0.96 | 3.6 |
| **D** | 44.3 | 47.7 | 1.07 | 4.2 |

*Water Absorption:* the result form the water absorption show that as the saw dust admixture in the composition from A-D reduces, the water absorption reduces as well. This is expected because during firing of the samples, the sawdust which is a combustible materials burn off from the composition and leaves behind pores in the composition. It is this pores in the material that absorbs water. The space (pore) in the composition is traps heat during firing and insulate the thermal flow since air insulate better than any solid materials (Aramide 2012). This implies that for a refractory materials to have a good thermal insulation, it must be porous to a reasonable extent. The result of the percentage water absorption of the refractory brick samples as produced in Table 2 indicates that sample A-D of brick had a range of 41.3% - 98.4%. However, all samples fell out of the required recommended water absorption range of 15% - 30% of a refractory brick (Schacht 2019).

*Apparent Porosity:* The result of the percentage porosity of the bricks indicated that sample A-D of brick had a range of 47.7% - 65.2% as revealed in Table 2. The porosity of the materials produced decreases as the combustible material is decreasing. According to (Osarenmwinda and Abel 2014), the porosity of a materials is directly proportional to the void/ air pocket contained in the material. Hence, the higher the porosity, the higher the refractoriness of the material. However, all the samples fell within the required recommended porosity range of 40% - 85% of a refractory brick ("Charles Schacht Refractories Handbook 2004" n.d.). Sample D was considered most suitable because of its low range of porosity among others with 47.7%, as it is observed that a good refractory must not be too porous.

*Bulk Density:* The result of the bulk density conducted revealed that sample A has the lowest bulk density value of 0.66%. Samples A-D had the range value of 0.66 $g/cm^3$ – 1.07 $g/cm^3$. It was observed that the higher the percentage of combustible materials, the lower the bulk density. This is corroborated in (Aramide 2012) that the bulk density of a material decreases as the percentage composition of admixture combustible material (sawdust) increases. This is due to the fact that the matter content of the whole composition will be reduced as the combustible material burns off during firing.

**Fig 3:** Cold Crushing Test

*Cold Crushing Strength:* The cold crushing strength of the samples were determined as shown in Table 2 above. An Automatic digital readout (ADR) machine was used to conduct this experiment (see figure 3).A force was applied on each sample to determine the compressive stress at which the samples can attain without fracture.

**Fig.4**: Brick Making Process

**Fig 5**: Test Kiln at Completion

Sample A had the least cold crushing strength of $1.1 N/mm^2$, while sample D had the highest cold crushing strength of $4.2\ N/mm^2$. It was observed from the result that the cold crushing strength of the sample increases as the combustible materials in the sample decreases. This as well reduces the content of the sample, alongside with the void created in the sample which make it fragile to shock (Aramide 2012). Moreso, the reduction in matter content of the sample, reduces the load bearing capacity of the sample since there is less materials in the sample to carry load (Abdul Kadir et al. 2010).

Of all the compositions tested, sample D was found to be more suitable for ceramic bricks production for construction of kiln, and was used in the production of refractory bricks ceramic test kiln (figures 4 & 5).

*Conclusion:* The performance evaluation of Irefin (Isan Ekiti) in the production of refractory brick was investigated. It was discovered that the clay has the potential to perform as raw materials for refractory production.

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