THE EFFECT OF ADDITIVES ON THE PROPERTIES OF IPETUMODU CLAY USED AS A REFRACTORY MATERIAL

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ABSTRACT

The effects of some additives on the refractory properties of a clay has been investigated. The clay sample was first analyzed to determine its chemical composition. Different additives (graphite, bentonite and coal dust) were added alone to the clay in varying proportions of 20%, 25%, 30%, 35% and 40% and then subjected to various tests designed to determine the effect of each additive on the refractory properties of the clay. The tests carried out on the samples were refractoriness, thermal shock resistance, permeability, apparent porosity, bulk density, cold crushing strength, linear shrinkage and moisture content. Also compounded and tested is another mixture of 70% clay and 10% each of all the additives for the purpose determining the composite effect of all the additives on the refractory properties of the clay. The results of this work revealed that the sample with composition of 70% kaolinite clay, 10% graphite, 10% bentonite and 10% coal dust gave the best combination of refractory properties and would be most suitable as a refractory material.

INTRODUCTION

Refractory materials are important components of equipment used in the production, refining and handling of metals, ceramics and glasses. They are also used for constructing heat treatment furnaces and other high temperature processes [1]. There are several types of refractories and they are classified based on their properties and characteristics. Fired-clay is an alumino-silicates refractory that occurs in nature as rocks which may be consolidated or unconsolidated. The wide application of clay in homes and industries is based on its intrinsic properties, namely, high chemical stability, high aesthetic value; wear resistance, high strength at elevated temperatures and thermal shock resistance

(TSR). Other clays are distinctive in two major properties which make them technologically useful; plasticity and composition of extremely fine crystals or particles [11]. The properties of clays that are of interest are: strength, shrinkage and vitrification range. These properties have relationship with physical properties and service properties of refractory [17]. Hence, for clay to considered as a refractory material a variety of properties must be examined. These properties are obtainable from tests such as Pyrometric Cone Equivalent [PCE], *reheat load hot,* modulus of rupture, thermal spalling, slag and carbon monoxide resistance tests [3]

Additives are blended with clay with the aim of modifying the properties of its refractories for improved performance.

Sixteen (16) clay sources have been determined and their suitability as refractories are investigated and also the effect of additives are tested [2,4,14]. It is observed that the properties of locally available clay compare favourably with each other [15], however, it is suggested that the properties of local clays can be improved by use of suitable additives, through blending or improved production processes [4].

This study has determined the effects of additives such as graphite, charcoal dust and bentonite in varying proportions individually and collectively on the properties of Ipetumodu clay as a refractory material

EXPERIMENTAL TECHNIQUES

Clay samples were collected from Ipetumodu, a town in Osun state of Nigeria and the chemical composition is :SiO_2- 62.15% ; Al_2O_3- 28.32%; Fe_2O_3– 5.26%; K_2O- 0.44%; Na_2O-0.08% ; CaO- 0.1%; MgO- 0.1%; P_2O_5- 0.22% and TiO_2 – 2.4%

The samples were prepared into slurry mix with the aim of removing the unwanted particles in them. The mix was then dried and blended with various additives in varying percentages to produce Clay sample + graphite, clay sample + charcoal dust, Clay sample + bentonite and clay samples + graphite + charcoal dust + bentonite. The pure sample without any additive was used as the control experiment.

The samples' additives were mixed with clay in any of the combinations above in proportions of 20%, 25%, 30%, 35%and 40%. The last sample combined 10% of each of the additives together with clay.

The samples were compacted by hydraulic press, dried at 110°C for about 24 hrs and then fired at 1400°C to produce various types of fired clay refractory materials. All these were then subjected to various types of tests described below to determine their suitability as refractory materials.

Permeability to air: The samples for this test were prepared to the standard specifications 5.08 cm diameter by 5.08 cm height using standard rammers. The pieces thereafter were air dried for 24hrs and then oven dried at 110°C for 12 hrs. The sizes for the samples were completely selected on all sides while the lower side is exposed to an orifice. A cylinder was filled with 200 cm^3 of water and the bell jar was put in place.

The orifice was opened and the time taken for 200 cm^3 of water to displace equal volume of air through the specimen was taken. The pressure difference between the surfaces was measured by a manometer. Permeability was calculated from the equation

$$PA = \frac{Vh}{Apt} \quad (1)$$

where PA= permeability number; V= volume of air (cm^3); h= Height of specimen (cm)

A. = Cross section of area of specimen (cm^2); p= Pressure of air in cm of water and t= Time (minutes).

Thermal Shock Resistance: Samples were prepared to 50mm by 75mm dimensions.

The pieces were inserted into a furnace that has been maintained at 900°C for 10 minutes. The specimen were removed and cooled for 10minutes. This procedure is repeated until the test pieces were readily pulled apart in the hands. The number of heating and cooling cycles for each specimen is recorded.

Refractoriness: This test was carried out by mounting the samples on a refractory plague along with some standard cones whose melting point is slightly above or below that expected of the test cone. The plague was then put inside the furnace and the temperature raised at a rate of 100°C per hour. The test continued until the tip for the test piece was removed and the temperature was recorded as the refractoriness of the sample.

Cold Crushing Strength: The test pieces were prepared to a standard size of 76.2 mm cube on a flat surface. The samples were fired in a furnace at 1400°C and the temperature was maintained for 6 hours. The samples were then cooled to room temperature. The specimen was placed on a compressive tester and load was applied axially by turning the hand wheel at a uniform rate till failure occurred. The manometer readings were recorded and the cold crushing strength determined according to:

$$CC = \frac{\max imumload(kN)}{cross\sec tionalarea(m^2)} \quad (2)$$

Linear shrinkage: Test pieces were made into standard slabs and marked along a line in order to maintain the sample position after heat – treatment. The distances between the two ends of the slabs were measured. The samples were air – dried for 24 hrs and oven dried at 110°C for another 24hrs. They were then fired at 1400°C for 6 hrs. The test pieces were cooled to room temperature and measurements were taken.

The fired linear shrinkage was calculated using:

$$\text{Fired shrinkage} = \frac{D1 - F1}{D1} \times 100\% \quad (3)$$

where, D1 = dried length and F1 = fired length.

Bulk Density: Representative samples were prepared by measuring 60 mm x 60 mm x 15 mm and the bulk density was calculated from eqn. (4).

$$\text{Bulk Density} = \frac{P_w \times W_d}{W_d - W_P} \times 100\% \quad (4)$$

Where, P_w = Density of water (g/cm^3); W_d = the weight of test pieces which are air dried for 24 hrs and then oven dried at 110°C and W_p = after soaking, the specimen were suspended in a beaker of water.

Apparent Porosity: Representative pieces were prepared and the apparent porosity were calculated from eqn. (5)

$$\text{Apparent porosity} = \frac{W_s \times W_d}{W_s - W_P} \times 100\% \quad (5)$$

Where, W_d and W_p are as defined in equation 4; W_s = the weight of the samples that were fired at 1400°C

Moisture content: Three samples were used and their initial weights were recorded as wet weights. The samples were then dried at 110°C for 24 hrs and their weights are noted until there was no more loss in weight.

The moisture content was calculated using the expression

$$\%Moisture\,Content = \frac{loss\,in\,weight}{original\,weight} x100 \quad (6)$$

RESULTS AND DISCUSSION

Chemical Analysis

The chemical composition of the sample showed that it is found to qualify as fireclay suitable for refractory material [9 and 13].

The alkaline earth minerals are low and below the normal values with the exception of TiO_2.

Refractoriness

The lowest temperature obtained was 1440°C for clay sample with 40% bentonite, while the highest was above 1800°C for both clay sample with 40% graphite and clay sample with equal mixture of additives. The pure samples gave a value of 1610°C which falls within the range of 1580 - 1750°C for fireclays [8 and 10]. The clay samples with graphite have good values which range between 1620 and 1800°C and this implied that they can be applied for high temperature applications as refractory materials.

The clay sample with coal dust gave values lower than normal values that is 1470-1550°C and this shows that their usage is restricted most especially to non- ferrous materials. On the other hand clay samples with bentonite produced values that first increased from 1560 – 1690°C and then dropped to 1440°C (Table 1).

Thermal Shock Resistance (TSR)

All the samples investigated had TSR that fall within the acceptable values of 25- 30 cycles with the exception of pure clay sample with 22 cycles, clay samples with graphite (10-18 cycles) and clay samples with coal dust of 20% and 25% (22 cycles) (Table 2). The clay samples with bentonite and equal mixture for additives had values higher than the recommended minimum.

The implication of this is that the operation life as refractory material is longer. On the other hand, those with lower values are likely to be subject to mending or replacement at short intervals and therefore may be restricted to lining of ladles used as slag pots [4].

Permeability

The permeability number of all the samples fell within the internationally accepted range of 25- 90 with the exception of clay samples with coal dust which has a range of 102 – 130. Also that of clay samples with graphite is 96-116[Table 3]. These permeability values may make the clay with coal dust and that with graphite susceptible to gas leakages and liquid penetration.

Apparent Porosity

The values for clay samples with 53% and 40% of graphite and dust are significantly higher than the normal values of 20- 30 %.

This appears to be a limiting factor in their use as insulating bricks [4]. The clay samples with 20%, 25% and 30% of bentonite have lower values on the other hand. This makes them better insulator materials [15]. The values are as presented in Table 4

Bulk Density

The average bulk density of the samples was within the range of 1.7 – 2.1 g//cm^3 specified for dense firebricks and 2.2 – 2.80 g/cm^3 for high alumina refractoriness [7].

Bulk density is an important property in forming operation. Table 5 presents the values obtained for bulk density.

Cold Crushing Strength

The values were found to be adequate as they were higher than the recommended minimum of 5MN/m^2 [6]. The sample was 15.8MN/m^2 while the sample with equal mixture of additive is 16.11 MN/m^2. The values obtained for clay samples with graphite, coal dust and bentonite were 14.2 – 12.2 MN/m^2; 16.4 -13.2 MN/m^2 and 16.9-14.3 MN/m^2 respectively that is they decrease with increasing composition (Table6).

Linear Shrinkage

The average linear shrinkage for all the samples are 4% with exception of pure sample that has a value of 6% and the bentonite samples which decreased from 4% to 2% as the bentonite composition increased. These values are below the recommended values of 7-10% [5] which are considered reasonable, because lower values are better. It is noted that higher shrinkage values may result in warping and cracking which cause loss of heat.

Moisture Content

The moisture content for both pure clay sample and sample with equal mixture of additives is 4%. The sample with graphite has values ranging between 2 and 3% while that of bentonite samples increased from 2-4%. On the other hand the coal dust samples have average of 3%. The moisture content affects the strength [12 and 16].

CONCLUSION

It may be concluded that the pure clay sample is very good as a refractory material. The clay sample with equal mixture of graphite, coal dusts and bentonite as additives gave the best composition with the best properties. The bentonite samples gave a good result with the exception of low apparent porosity at low composition. The coal dust samples have high permeability number which needs to be reduced while graphite samples have high permeability number and a low operational life due to its lower thermal shock resistance.

Table 1: Refractoriness (°C)

Pure : 1600°C **70 + 10+10+10: > 1800°C**

Composition (%)	**20**	**25**	**30**	**35**	**40**
Graphite	1620	1670	1740	1800	>1800
Coal dust	1550	1520	1510	1490	1470
Bentonite	1560	1600	1650	1690	1440

Table 2: TSR (Cycles)

Pure : 22 **70+ 10+10+10: 30+**

Composition (%)	20	25	30	35	40
Graphite	18	18	14	10	10
Coal dust	22	22	26	26	28
Bentonite	30+	30+	30+	30+	30+

Table 3: Permeability

Pure : 82 **70+ 10+10+10: 86**

Composition (%)	20	25	30	35	40

Graphite	96	100	104	107	116
Coal dust	102	112	118	126	130
Bentonite	62	68	70	72	76

Table 4: Apparent Porosity (%)

Pure : 2.25 **70+10+10+10: 2.68**

Composition (%)	20	25	30	35	40
Graphite	2.62	2.60	2.77	2.82	2.88
Coal dust	2.14	2.10	1.84	1.74	1.68
Bentonite	1.96	2.22	2.27	2.45	2.58

Table 5: Bulk Density(g/cm^3)

Pure : 2.6 **70+10+10+10: 2.4**

Composition (%0	20	25	30	35	40
Graphite	2.3	2.5	2.6	2.6	2.6
Coal dust	2.2	1.9	1.7	1.6	1.6
Bentonite	1.9	2.1	2.2	2.3	2.4

Table 6: Cold crushing strength (MN/m^2)

Pure : 15.8 **70+10+10+10: 16.1**

Composition (%)	20	25	30	35	40
Graphite	14.2	14.0	13.3	12.3	12.2
Coal dust	16.4	15.9	15.0	14.4	13.2
Bentonite	16.9	16.6	15.2	15.9	14.3.

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