CHARACTERIZATION OF RIVER NIGER SAND AT ITOBE WITH IYOLOKO CLAY AS A BINDER FOR FOUNDRY APPLICATION

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ABSTRACT

This study investigates the characterization of River Niger Silica sand at Itobe with Iyoloko clay as additives for its possible uses in sand casting in the foundries. A measure of 5-25 %wt Iyoloko clay was added to the sand mixture in ratio 3:1. The chemical, physical and mechanical properties measured includes: chemical analysis of the Iyoloko clay, particle size, density, permeability, compatibility, mouldability, moisture content, green compression and shear strength, dry compression and shear strength. The results revealed that, addition of Iyoloko clay to River Niger Silica sand at Itobe, increased the mouldability, grain fineness number (G.F.N), both green and dry strength, slightly decreased the density, permeability and moisture content. These results shows that better properties of foundry sand are achievable by addition of Iyoloko clay to River Niger Silica sand and can be used to enhance the mould properties of foundry sand.

Keywords: *foundry sand, Iyoloko clay, Strength, Mouldability, Compatibility, Particle size.*

1.0 Introduction

The urgent need to develop the foundry industries in Nigeria in order to meet the technological development of the country has generated great interest in the characterization of the locally available materials. Silica sand is an extremely good material for casting moulds because it has the ability to withstand the temperature of the molten metal, can absorb and transmit heat, and has sufficient permeability to allow gasses generated during casting to pass between the particles without causing casting defects (Yaro *et al*., 2006, Aigbodion *et al*. 2008). Foundry sands are produced within strict particle size distributions to tailor the properties of the material to the intended casting process (Aigbodion *et al*. 2008, Burns.1989, Asuquo. 1991). There are many deposits of silica sand usable in foundry applications scattered all over the country (Yaro *et al*., 2006, Asuquo and Bobo. 1991). The local foundry men have been using this without the knowledge of its physical, chemical and foundry (moulding) properties. Except these characteristics of the sand are known, it will be very difficult to use the sand and achieve the desired results. In a survey of sands used by some Nigerian foundries (RMDC, 1990), it was established that most of these foundries are using these sands without knowing their characteristics. The suitability of any particular sand for foundry mould production is determined by the properties and composition it possesses. These properties and composition are of great importance to both foundry engineers and technologists. Therefore, adequate investigations on sand are necessary before embarking on mould production. Therefore a research of this nature is very important and timely and this work is aimed at determining the chemical composition and physical properties of River Niger (Itobe deposit) using Iyoloko clay as an additive for foundry application.

2.0 Materials and Method

2.1 Materials

The materials that were used in this research are: River Niger natural sand collected from Itobe, located at the Eastern bank of River Niger in Ofu local government area of Kogi state. Iyoloko natural clay was collected from Iyoloko located at Ede community (a southern part of Idah) in Idah local government area of Kogi state, moulding box, measurement cylinder, water, and aluminum scraps.

2.2 Equipment

The equipment that was used in this research are: moisture tester, permeability machine, strength universal testing machine, speedy mouldability machines, heat treatment furnace, and oven.

2.3 Practical size analysis

The particle size distributions of the Iyoloko clay and that of 75wt% silica sand 25% clay were determined using the American Foundry Society (AFS) specification (Yaro *et al*., 2006, Nwajagu 1994). 100g each of the dried samples was taken and introduced unto a set of sieves arranged in descending order of fineness (1.60-0.10mm) and shaken for 15minutes which is the recommended shaking time to achieve complete classification of the sand. The weight retained on each sieve was taken and expressed as percentages of the total sample weight. Grain fineness number (GFN) was computed from the percentage weight of the retained sand.

2.4 Bulk density

The bulk density of the samples (Db) was determined by measuring the dry weight (D), suspended weight (S) and saturated weight (W) of the test samples. The bulk density was then computed from the relationship shown in Equation 1 (Nwajagu. 1994, Atama. *et al*. 2007).

$$Db = \frac{D}{W-S} \text{ g/cm}^3 \text{ ------------ (1)}$$

2.5 Moisture content determination

The moisture contents were determined using a speedy moisture tester. A sample of each mixture was weighed on the weighing balance of the tester and then introduced into the flask of the moisture tester. A known weight of calcium carbide was added into the flask for 3 minutes which is the recommended shaking time and the percentage moisture content of the sample was read directly from the calibrated dial instrument at the top of the flask attached to the machine (Yaro *et al*., 2006, Begeman and Amstrad. 1996).

2.6 Production of standard samples for the determination of moulding characteristics of the sand

Standard test samples for the determination of moulding properties of the sand were prepared by mixing known weight (0-75%) of the silica sand and the percentage of the clay were varied from 5, 10, 15, 20 and 25% were used, the mixture was packed into cylinder metal box and then rammed to obtain a cylindrical shape of dimension (6cm diameter by 6cm length). The produced samples for green properties are shown in Plate 1. After production, some of the produced test samples were baked at a temperature of 350^{o}c for 5hours using electric heat treatment furnace, for the purpose of determining the dry strength of the mould.

Plate 1: Standard test sample for the Green sand properties (Source: Produced by author).

2.7 Permeability

The test piece after ramming was subjected to a pressure of 12KN/m^{2}and then air was passed for 30seconds into the sample through an orifice of diameter 15mm. the volume of the air that was passed through the rammed sample in 30seconds was taken as permeability of the sand mixture (Muhammad *et al*. 2003, Nwankwo and Seghal. 1983).

2.8 Compatibility

The standard test sample was left in the cylinder of the ramming machine after the third drop it weight was taken as (W_1), it was then dropped for the fourth time its final weight after the fourth drop was determined as (W_2). The compatibility was then calculated using Equation (2) (Nwankwo and Seghal. 1983, Okezue 2004).

$$\text{Compatibility} = \frac{W1-W2}{W1} \text{ X } 100(\%) \text{ ---- (2)}$$

2.9 Mouldability

After ramming, the sand mixture test pieces were placed inside the moulability machine, switched on and allowed to run with the test pieces inside until it stopped. The weight of the sample that fell out of the sieve on the machine was taken as (Wb) and the weight of the initial test pieces as (Wa). Then the mouldability of the test sample was calculated from Equation (3) (Ihom *et al*. 2006).

$$\text{Mouldablity} = \frac{Wa-Wb}{Wa} \text{ X } 100(\%) \text{ ---------- (3)}$$

2.10 Green/Dry Compressive and Shear Strength Determination

The green compressive strengths (GCS) and the green shear strengths (GSS) was determined immediately after ramming, while the dry compression strengths (DCS) and dry shear strength(DSS) were determined after baking the rammed pieces. For the compression strengths the samples were placed between two parallel plates of a compressible jig, while for the shear strengths the samples were placed between the parallel plates of the shear jig. The samples and the jigs were then placed on the universal sand testing machine in such a manner that the movable jaws clamped the sample to fracture in a slow but continuous movement without shock. The values of the strength were directly read from the calibrated scales attached to the machine (Okezue. 2004, Aponbiede. 2000).

3.0 Result and Discussion

The result of the chemical analysis of the clay is shown in Table1and the particle size analyses are shown in Tables 2 and 3. The results of the moisture content, bulk density, permeability, compatibility and strengths are shown in Figures 1-7.

3.1 Chemical analysis

The chemical analysis of the clay shows that it contains 79%SiO_2, 8.79%Al_2O_3, 0.01%MgO and 0.02%S as in Table 1. The values are within the range of acceptable values for typical foundry sand (Aji *et al*., 2015, Idenyi and Ani. 2006).

3.2 Sieve analysis

The sieve analysis of the River Niger silica sand result shows that the sand has 28.96 Green fineness number (G.F.N) which make the sand to be coarse in nature and lower the bounding strength of the sand (Yaro *et al*., 2006), while the result of the sieve analysis of the clay was 90.19G.F.N. Blending the River Niger silica sand and Iyoloko clay in ratio of 3:1 resulted to an increase in the G.F.N of River Niger silica sand from 28.96 to 36.14G.F.N, this indicates that addition of clay to this sand increased the fineness of the sand. This means that casting done with the mixture can result to good surface finish as shown in Plate 2.

Table 1: Chemical composition of Iyoloko clay.

$Si0_2$	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	S	TiO_2
79.18%	8.79%	8.58%	0.12%	0.01%	0.96%	0.12%	0.02%	2.56%

Table 2: The Particle size analysis of Iyoloko clay.

S/no	Sieve no (mm)	%Wt Retained	Multiplier	Product
1	1.60	0	5	0
2	1.00	0.01	10	1
3	0.71	0.14	20	2.8
4	0.63	1.00	30	30.0
5	0.40	2.24	40	89.6
6	0.31	16.15	50	807.5
7	0.20	32.59	70	2281.3
8	0.16	30.77	100	3077
9	0.12	11.05	140	1547
10	0.10	2.02	200	404
11	Pan	1.98	300	594
	Total	97.95		8834.2
	G.F.N			90.19

Table 3: The Particle size analysis of River Niger silica sand with Iyoloko clay

S/no	Sieve no (mm)	%Wt Retained	Multiplier	Product
1	1.60	0	5	0
2	1.00	13.5	10	135
3	0.71	24.0	20	480
4	0.63	8.5	30	255
5	0.40	29.5	40	1180
6	0.31	7.5	50	375
7	0.20	6.0	70	420
8	0.16	1.5	100	150
9	0.12	1.2	140	168
10	0.10	0.6	200	120
11	Pan	0.2	300	60
	Total	92.5		3343
	G.F.N			36.14

Plate 2: Surface appearance of Aluminum ingots casted from the blended sand.

3.3 Moisture content

From the result of the moisture content it was observed that the moisture content slightly decreased with the percentage of clay in the sand mixture. The moisture content decreased from 5.8 to 1.7% at 5 and 25% addition of Iyoloko clay respectively as shown in Figure 1. The values of the moisture content obtained is an indication that the sand developed plasticity faster with the additions of Iyoloko clay and these values obtained are within the acceptable limit (Asuquo and Bobo. 1991).

3.4 Bulk density

The bulk density slightly decreased as the percentage of clay increased in the sand e.g. the bulk density decreased from 1.68 to 1.54g/cm^3 at 5 and 25% addition of clay (Figure 2). The slightly decreased of the bulk density is as a result of the bulk density of the clay which was found out to be 1.15g/cm^3 and that of the silica sand 1.71g/cm^3.

3.5 Permeability

The permeability of the sand mixture decreased to a minimum values of 86 at 25% addition of rice husk ash as shown in Figure 3, but the permeability values obtained are within the recommended acceptable limit for both ferrous and non-ferrous casting (Asuquo and Bobo. 1991) which means that mould produced from these blend will allow escape of gasses freely from the casting hence reducing the chances of getting gas inclusions in the casting.

3.6 Mouldability and Compatibility

The mouldability and compatibility values increased as the percentage of Iyoloko clay in the sand mixture increases as in Figures 4 and 5, these means that as the percentage of Iyoloko clay increased the sand develop strong bounding.

3.7 Compression strength and Shear strength

Figures 6 and 7 shows the compression strength and shear strength variation with Iyoloko clay, it shows that both the green and dry strength increases as increasing percentage of Iyoloko clay from 5% to 25% addition respectively. For example, the green compression strength increased from 19 to 42KN/m^2 and shear strength increased from 12 to 31KN/m^2

The baking strength also increased at the percentage of the Iyoloko clay increased in the sand mixture, it means that the higher the Iyoloko clay, the more strength developed with the sand. Figure 7 shows that increased the percentage of Iyoloko clay beyond 20%wt do not resulted to any further increases in strength of the sand. The increases in compression strength of green sands containing 20%wt Iyoloko clay indicate its binder properties.

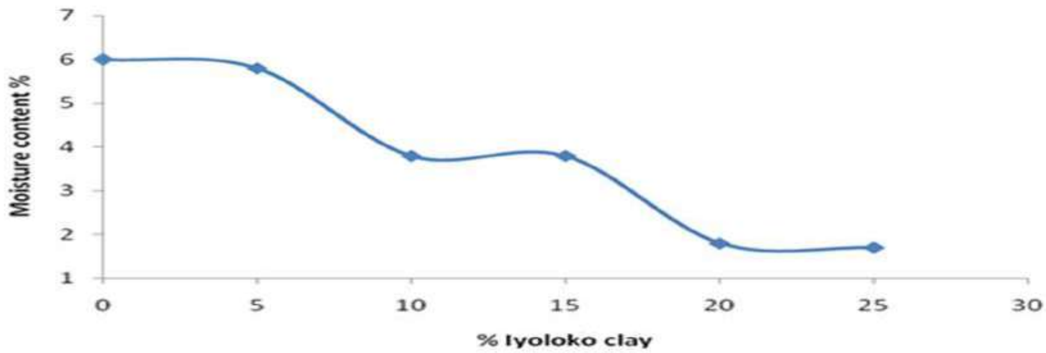

Figure1, Variation of % Moisture content with % of Iyoloko clay.

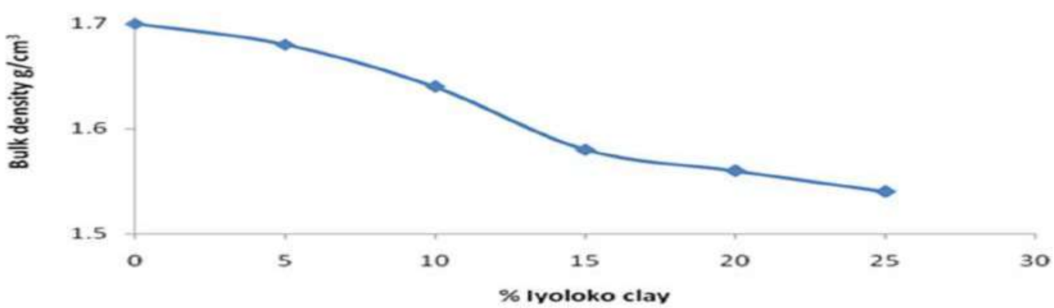

Figure 2, Variation of Bulk Density with % of Iyoloko clay.

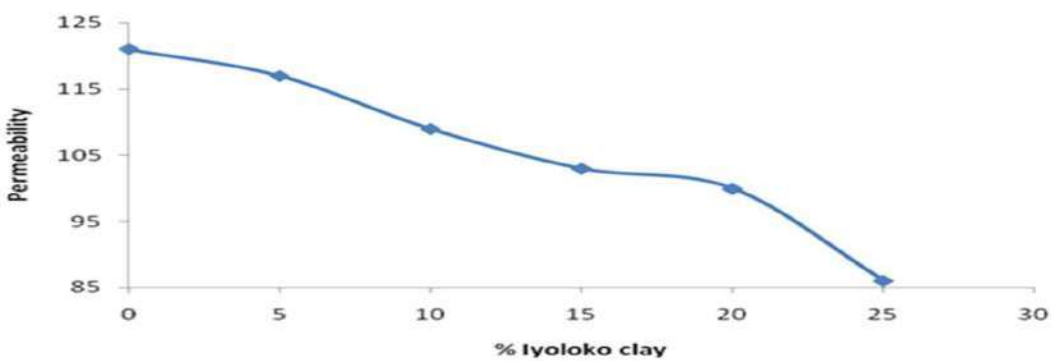

Figure 3, Variation of Permeability with % of Iyoloko clay.

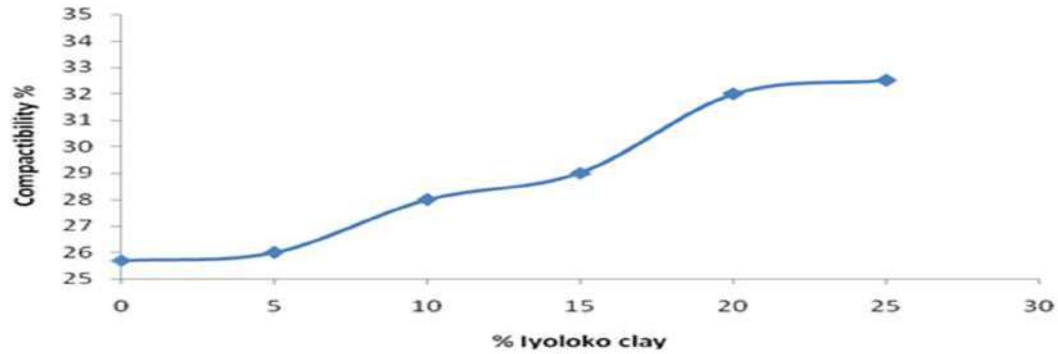

Figure 4, Variation of Compatibility with % of Iyoloko clay.

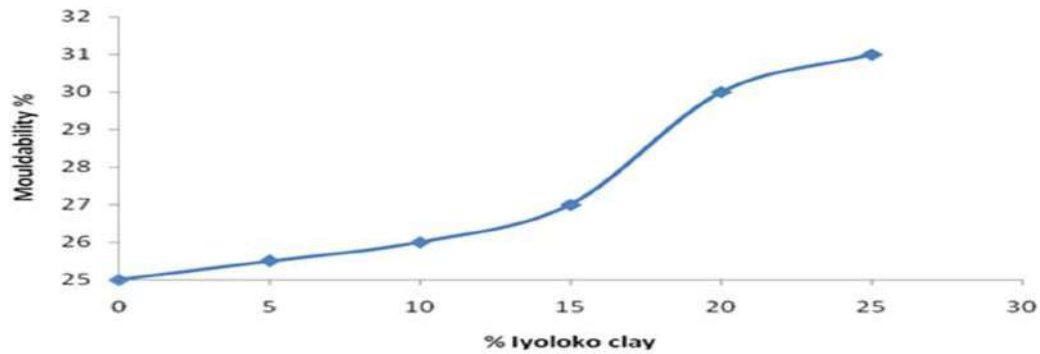

Figure 5, Variation of Mouldability with % Iyoloko clay.

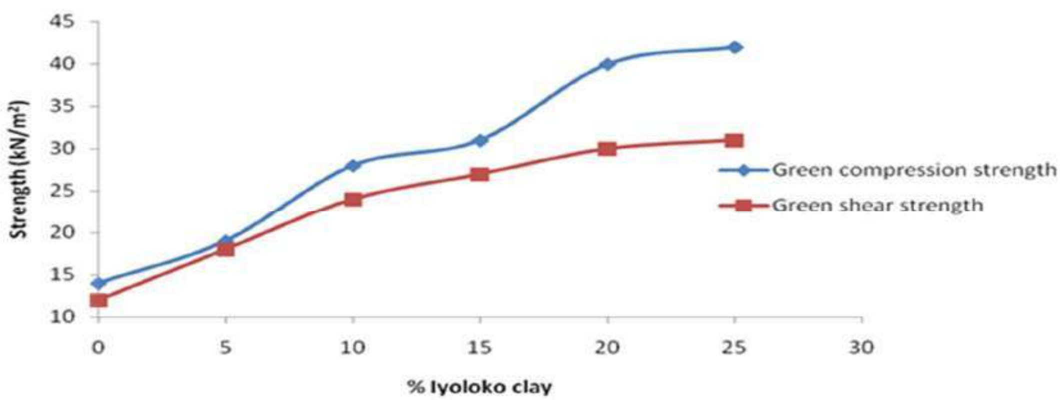

Figure 6, Variation of Green Strength with % of Iyoloko clay.

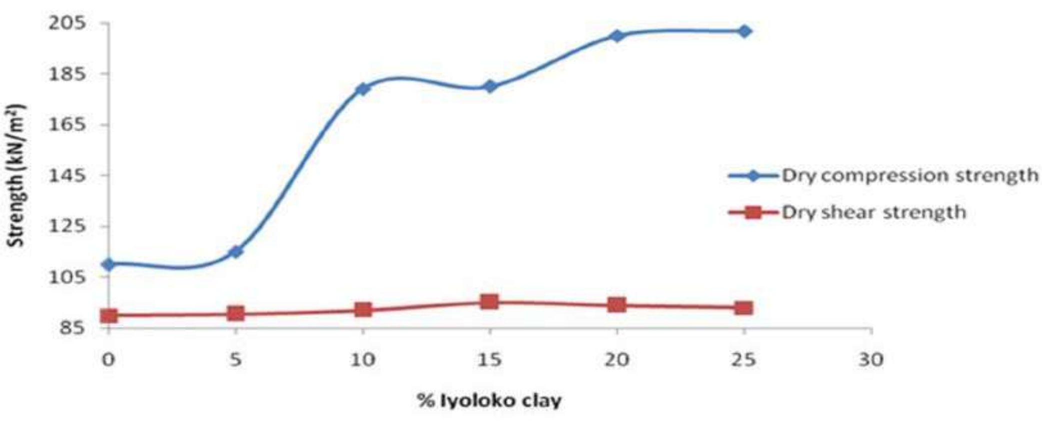

Figure 7, Variation of Dry Strength with % of rice husk ash.

4.0 Conclusions

This study revealed that river Niger sand taken from River Niger at Itobe is alumino – silicate with physio – chemical properties that are suitable for non – ferrous alloy casting of low melting point because of its low refractoriness (1093^{0}C). It responded well to "Iyoloko" clay binder that gave good mechanical properties to sand mould specimens. All investigated clay were found capable of being added up to amounts of 20% with their technological properties remaining at sufficient levels which provides an opportunity for obtaining casting of satisfactory quality from sand casting.

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