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Adaptation of Ushafa clay, Abuja, as a suitable replacement for bentonite in the foundry industry

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ABSTRACT

This work investigated the possible use of Ushafa clay in Abuja, Nigeria as a suitable replacement for bentonite clay in foundry use. Moulding sand mixes with compositions of 8,10 and 13 % Ushafa clay, silica sand and 5, 7,8,9,10 and 11 % coal dust additives were mulled. From each mix, cylindrical specimens were prepared and subjected to permeability, shatter index, compression and shear strength tests. The results from the Ushafa mix were compared with results from Bentonite mixes. The results showed that moulding sand compositions having 13 % Ushafa clay, and coal dust additions of 8 % produced specimens with good permeability, dry strength, green strength and collapsibility for foundry use. This work has confirmed the possible use of Ushafa clay as suitable replacement for bentonite binder in foundry.

Keywords: *Abuja Ushafa clay; moulding-sand binder; bentonite replacement; foundry*

INTRODUCTION

Clays are defined essentially, as aggregates of extremely minute crystalline, usually flake-shaped particles that can be classified on the basis of their structure and composition into a few groups which are known as clay minerals. Some clays are composed of particles of a single clay mineral, whereas others are mixtures of clay minerals. Some clays are composed entirely of clay minerals, while others contain mixtures of quartz, pyrite, and organic matter [1-5].

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Clay minerals used as bonding additions to sands are western and southern bentonites(montmorillonites), fire clays (kaolinites) and special clays (halloysites, illites, attapulquites). Bentonite is the most used for binding in many foundries[6] including Nigerian foundries. Bentonite clay, used in Nigerian foundries is mined in North America. With Nigeria's nascent foundry industry, there is the need to minimise material costs if the industry is to compete favourably with foreign imports whose quality and source cannot be guaranteed. The use of locally produced foundry binders will help to relieve some of these problems. Local clay is abundant and can serve as a cheap source of binder if the right quality is sourced.

The present work concentrated on the possible use of Ushafa clay in Abuja an alternative binder to bentonite clay using moulding sand properties as a guide. Mineralogical studies will be done in a separate paper.

MATERIALS AND METHOD

Materials

Silica sand used, for the present study was obtained from Opa River in Ile-ife, Osun State. It was sieved to remove inorganic matter and other undesirable materials present. Clay was obtained from Ushafa, in Abuja, and coal was purchased for the molding sand mix.

Method

Drying,communition and sieving

The silica sand was sun-dried for two weeks. The clay was also dried for about two and a half weeks to ensure complete removal of moisture and to ensure that thorough dripping can be achieved. The dried clay and coal were communited by crushing and grinding in a mill.
The dried and communited clay, coal dust and silica sand were then sieved. Fine particles measuring 300 μ were collected for the experimental work.

Weighing And Mixing

All the materials (clay, silica sand and coal dust) were weighed, each time, for the preparation of each sample, using the desired percentages for each composition to make up 1 kg. Moulding sand mixes were composed of 8,10 and 13 % Ushafa clay, silica sand and 5, 7,8,9,10 and 11 % coal dust additives. Coal dust additives were used in order to reduce the high dry shear and compression strengths that often accompany high bonding clays. Thorough mixing of the materials was done using rotating rollers for milling and mixing(sand muller).

Sample preparation and testing

Cylindrical specimens 5cm in height, by 5cm in diameter were produced by impact ramming using a laboratory rammer able to deliver 6.5 kg ramming weight. The samples were subjected to standard tests; namely: permeability, dry compressive strength, dry shear strength, green compressive strength and shatter index test following standard procedures [7-11].

Bentonite Clay –binded Sand Mix

Moulding sand mixed with 10 % Bentonite clay with no coal dust additives was also subjected to standard moulding sand tests listed in section 2.2.3. These results swere used for comparative analyses of the moulding sand mixes with Ushafa clay.

RESULTS AND DISCUSSION

Results

The results obtained are presented in Figures 1-5 below. Table I shows the grain fineness number(GFN) for both Opa sand and Ushafa clay as bwellas the result dry compression results for Ushafa clay-binded sand mixes. Properties of moulding sand mixed with bentonite clay without coal dust additives are presented in Table II. The sieve analyses of both Opa sand and Ushafa clay are presented in Fig. 1. Figures 2-5 present the effects of varying Ushafa clay percentages in moulding sand with charcoal additive on various properties of the sand.

Table I: Grain Finess Number (GFN) of Opa sand and Ushafa clay and Dry Compressive strength.

Opa Sand Grain Fineness Number	67.84
Ushafa Clay Grain Fineness Number	*50.78*
Dry Compressive Strength for all Ushafa clay-binded sand mixes	*>650KN/m²*

Table II: Bentonite mixed sand properties without coal dust additive

% Bentonite in sand mix	10
Permeability	140
Shatter Index	78
Green Compressive Strength(KN/m^2)	465
Dry Compressive Strength(KN/m^2)	645
Dry Shear Strength(KN/m^2)	308

DISCUSSION

Sieve Analysis

The results of the sieve analysis tests are presented in figure1. The bulk fraction can be identified from the cumulative percentage curve, and it is the middle portion of the curve. The fineness number of Opa sand and Ushafa clay were calculated and found to be 67.84 and 50.78 which are good for medium castings.

Permeability

It could be observed from fig.2 that for all the sand mixes, permeability generally decreased with increase in amount of coal dust till about 8 % coal dust addition after which permeability started on an upward trend albeit very marginally. This showed that the pore-binding effect of the coal dust was maximum at about 8 % after which increased additions acted in the creation of pores albeit on a minute scale. For all the mixtures, the minimum permeability occurred at about 8 % coal dust addition, and the highest permeability was observed in sand mixtures containing 10 % clay content. Sand mixes with 13 % Ushafa clay were observed to have lowest permeability. Comparison with Bentonite mixed sand showed that the sands with Ushafa clay had higher permeability than all the sands with Bentonite clay(Table II). Permeability is therefore adjudged good for Ushafa clay mixes.

Dry Compressive Strength

The dry compressive strength was measured relative to the dry strength for the Bentonite mix. All the Ushafa clay – binded sand mixes had strengths above 650 KN/m^2(Table II).

Shatter Index

It was observed that the shatter index values increased as clay percentage increased(Fig.3). Also shatter index generally increased as coal dust additive increased till about 7 and 8 % coal addition after which different variations in shatter index values with coal dust addition could be observed. This confirms as well the observation noted under permeability that there seems to be a maximum pore- binding influence at about 8% coal dust addition. Since shatter index represents the inverse measurements of the degree of collapsibility, it therefore means that collapsibility decreased as the clay content increased and as coal dust additive increased with of course the different variants observed after 7 and 8 % coal additions.

Comparing these values (Fig. 3) with values obtained from bentonite-mixed sand(Table 2), it was observed that the collapsibility of the Ushafa clay mixes are very high compared with Bentonite-bound sand mix. However, increasing coal additives gives better binding properties especially with 13% Ushafa clay mix and 8% coal dust additive.

Green Compressive Strength

Green strength values were observed to generally increase with increasing coal dust additions(Fig.4). Also, green strength increased with increasing clay additions till 7 % when strengths for 13 % clay – sand mixes increased above the 10 % clay-sand mixes.

The green strength values at high coal additions greater than 7 % coal dust addition were observed to be comparable to those of Bentonite mixed sand especially the 10 % Ushafa clay-binded sand mixes.

Dry Shear Strength

Dry shear strength like the Dry compressive strength decreased as coal dust additive increased. Also it was observed that dry shear strength generally decreased as clay content increased.

Comparison with Bentonite mixed sand showed that 8 % coal dust added sands had same dry shear strengths with bentonite- binded sand.

CONCLUSION

From the results discussed above, the following conclusions were derived;

i) Permeability was good for all Ushafa clay-binded sand mixes.

ii) Collapsibility was low for all Ushafa clay-binded sands but best for 13 % Ushafa clay- binded sand mix with 8 % coal dust additive.

iii) Dry compressive strengths obtained for all Ushafa clay-binded sand mixes with 8% coal dust additions were comparable with the strength of Bentonite clay –binded sand mix.

iv) Green strength values at coal-dust additions greater than 7 % coal dust addition were observed to be comparable to those of Bentonite mixed sands especially the 10 % Ushafa clay-binded sand mixes.

v) Ushafa clay binded sand mixes with 8 % coal dust addition had comparable dry shear strengths with with bentonite- binded sand.

vi) Mould mixes containing 8 % coal dust additive and 13 % Ushafa clay content gave good moulding sand properties

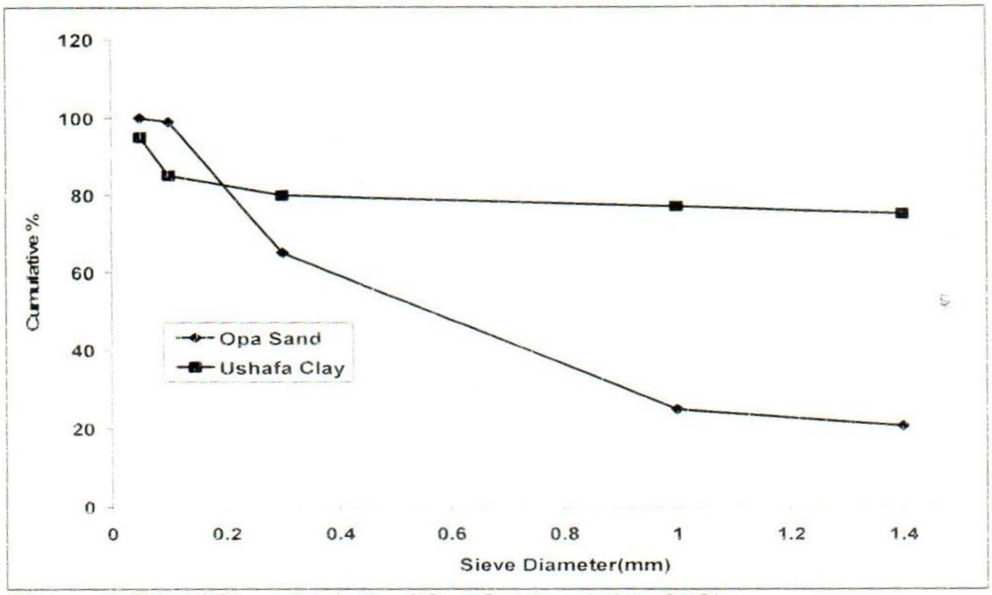

Figure.1: *Plot of Sieve Analysis of Opa Sand and Ushafa Clay*

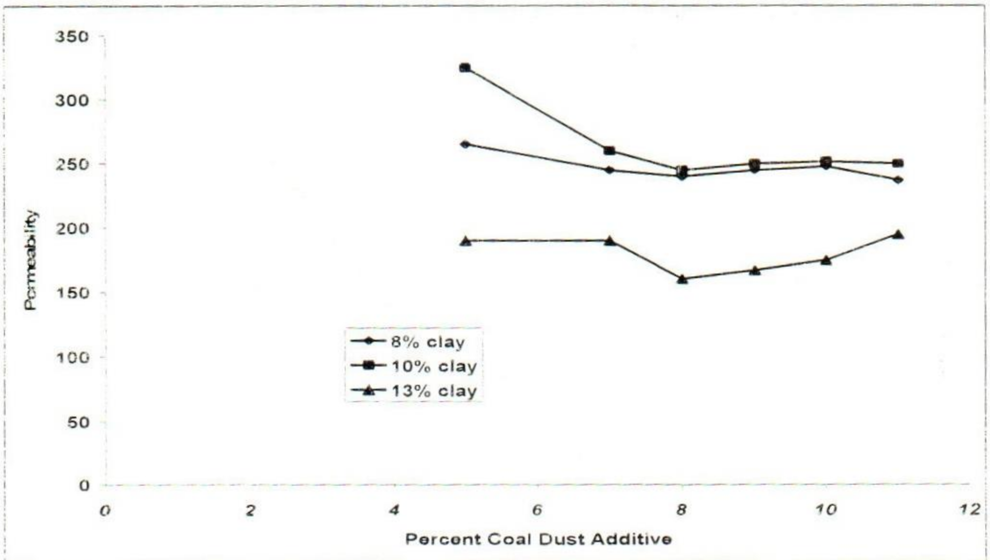

Figure 2: *Plots of Permeability variations with coal dust additives for sand mixtures containing 8%. 10% and 13% clay with 5% moisture respectively*

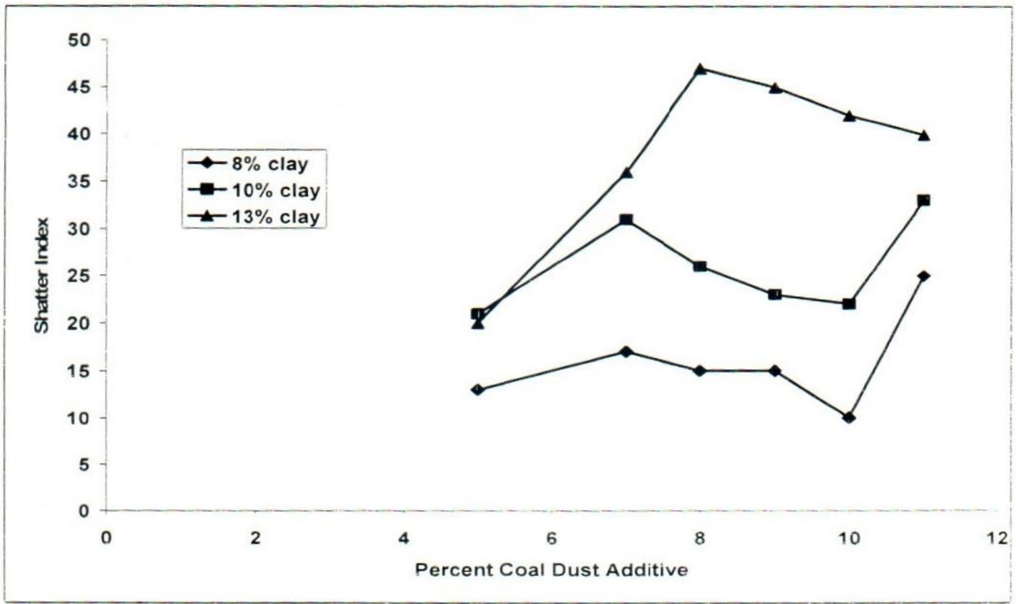

Figure 3: *Plots of Shatter Index variations with coal dust additives for sand mixtures containing 8%, 10% and 13% clay, with 5% moisture content respectively*

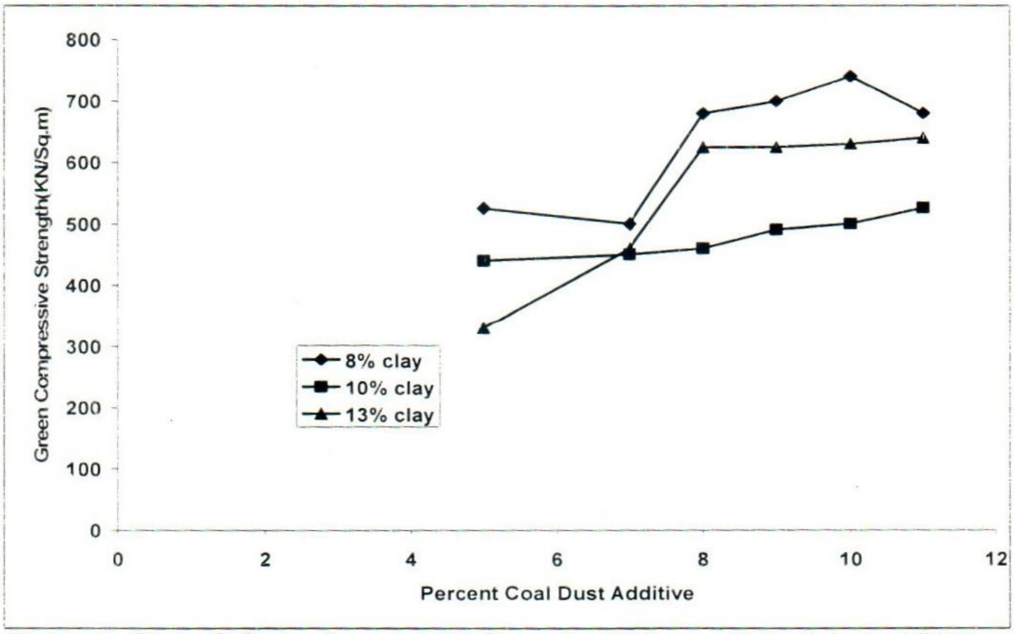

Figure 4: *Plots of Green Compressive Strength variations with coal dust additives for sand mixtures containing 8%, 10% and 13% clay, with 5% moisture respectively*

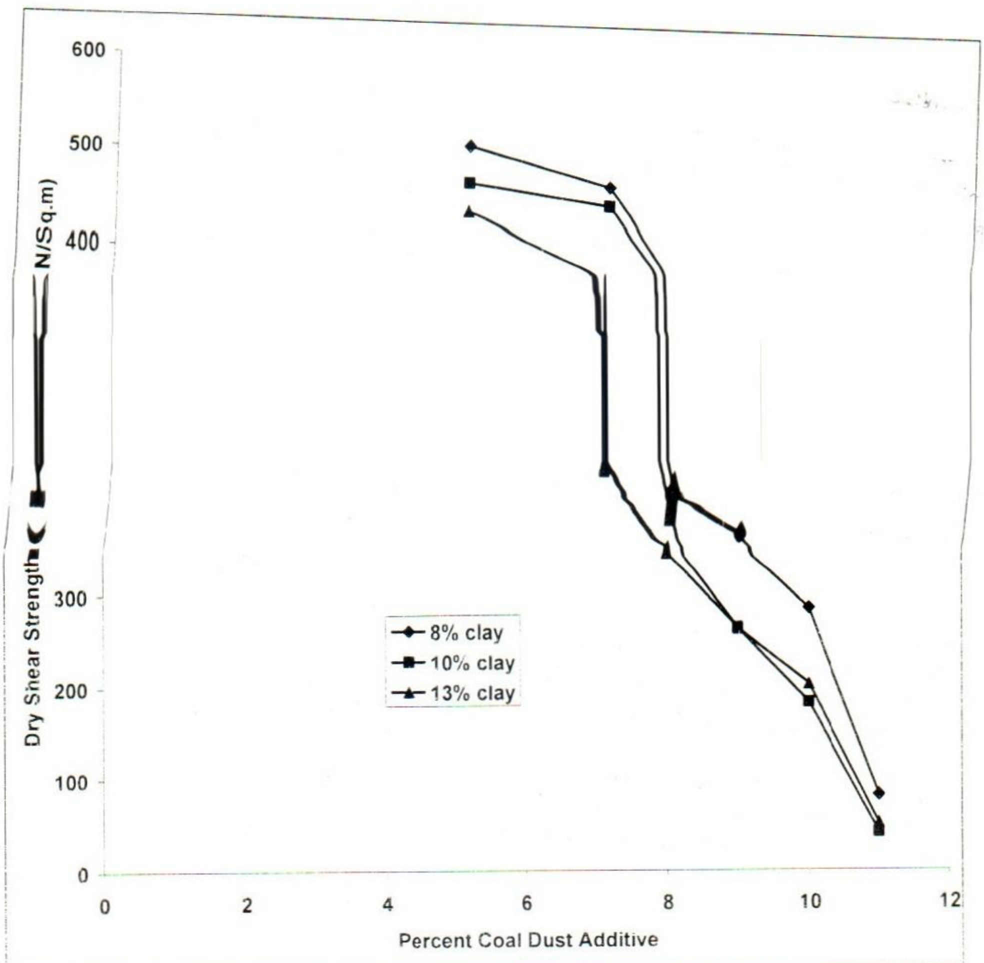

Figure 5: *Plot of Dry Shear Strength variations with coal dust for sand mixtures containing 8%, 10% and 13% clay, with 5% moisture content respectively*

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