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Examination of Numan natural clay bonded silica sand deposit for green moulding sand

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Abstract:
Local founding in Adamawa State imports green moulding sand from other states of the federation, to reduce dependence on externally sourced materials, there is need to search for indigenous moulding sand. Examination of Numen natural clay bonded silica sand deposit for green moulding sand was carried out by physicochemical analysis *of the sand deposit. The result shows that the deposit is made up of silica sand and kaolinite clay of 78.51% and 14.80% respectively and traces of other oxides. The bonded sand has the physical properties of pH of 6.80, loss on ignition of 1.67 %, specific gravity of 2.42, conductivity of 131.20 W/mK, clay content of 16.80%, refractoriness of 1300.00 ^{0}C. The physical properties show that the natural clay bonded silica sand deposit is neutral which is safe to handle, refractive, conducts heat to full molten metal solidification and self-binding. The natural clay bonded silica sand was tempered with water and conditioned for casting simple bushings. The green mould was seen to possess strength, shape and stability. The bushings were seen to have satisfied dimensions. Thus, the clay bonded silica sand is self- binding which makes the deposit suitable for green moulding sand.*

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1. Introduction

Raw materials development is the bedrock for nation technological advancement [1, 2, 3]. According to [1, 2, 4], technological development of Nigeria is at low pace due to inadequate attention paid to the development of national raw materials especially founding materials that could be used by the national foundry industries to manufacture equipment which would boost its ailing economy. Founding is a metal casting process which causes molten metals to take desired shape and size such as the manufacture of combustion engines, gear boxes, axles, cars, agricultural trucks, tools, heavy trucks, industrial equipment and parts, etc. that will serve the need of man [5, 6]. To manufacture this equipment, there is need to search for low cost material such as self-binding sand. Self-binding sand is one in which the sand grains are associated with clay in its natural deposit. Such natural deposit is called natural clay bonded sand. In situation where the sand grain is silica, the deposit is termed as natural clay bonded silica sand. Silica sand provides the mould major properties such as refractoriness, strength, permeability, conductivity, grain shape, size, and distribution, etc. [1, 7, 8, 9], while clay provides the bond strength [1, 10]. Natural clay bounded silica sand is the most simplest and low-cost moulding sand used to shape molten metals to useful end [2, 6, 8, 9]. Founding workers in Adamawa State have been importing natural clay bonded silica sand from Katsina and other States of the federation which makes casts produced in the state expensive to the end users. In order to reduce casts production cost in the State, there is need to source for natural clay bonded silica sand deposit within the State [4]. This work examines the foundry properties of Numan natural clay bonded silica sand deposit for green moulding sand.

2. Materials and Method

2.1 Materials

Ten kilograms of natural clay bonded silica sand, one kilogram of aluminium based scraps, water for tempering the sand, etc. Natural clay bonded silica sand was mined from River Gongola bank at Numan, Adamawa State, Nigeria. The moisture content of the sample representative was removed in an electric oven at pre-set temperature of 105 ^{0}C for an hour and pulverized to 75 μm fineness. The ground sample was packed into sample bags for mineralogical composition, chemical and physical property tests.

2.2 Physicochemical analysis

2.2.1 Mineralogical composition analysis

The mineralogical composition of the sand was determined by X-ray diffraction machine. Five grams of the pulverized sample was analysed. The sample was picked into the X-ray diffraction analysis unit by the machine robot. Generated electrons from the X- cathode ray accelerated towards the sample and bombarded it. As the sample and the detector were rotated, the intensity of the reflected Xrays was recorded. Once all the d_b-spacings of the sample have been determined, automated search/match routines compare the d_b-spacings of the unknown sample to those of the known materials from the International Centre for Diffraction mineral data bank. The sample diffractogramme was presented as peak positions at 2 theter and X-ray counts (intensity) in the form of x-y plot. The result was displayed on the computer screen which was printed out in hard copy and the soft copy was saved for future use. The analysis was completed within eighty seconds. On the completion of the analysis, the machine robot returned the sample back to its former position on the stage holder [9].

2.2.2 Chemical composition analysis

The chemical composition analysis of the sand was determined by X-ray Fluorescence machine. Twenty grams of the pulverised sample was put into the machine and measure option was highlighted. The X-ray Fluorescence machine automatically displayed the sample chemical composition on the computer screen which was printed out in hard copy. The soft copy was saved for future use. The time of measurement of each sample was one hundred seconds [6].

2.2.3 Loss on ignition

One gram of the pulverized sample was placed into platinum crucible. The sample was heated in electric carbolated furnace at 1000 ^{0}C for an hour. The heated sample was removed from the furnace and cooled in desiccator to room temperature. The weight of the cooled sample was taken. The loss on ignition (LOI) was computed using equation 1 as reported in [8]:

$$LOI = (W1 - W2)/W1\% \qquad (1)$$

Where W_1 is the sample mass and crucible before heating and W_2 is the sample mass and crucible after heating.

2.2.4 Conductivity

Ten grams of sample was soaked in 100 ml of distilled water for 24 hours. The conductivity electrode was inserted into the soaked sample. The conductivity machine automatically displayed the result [5].

2.2.5 Ph Value

Ten grams of the sample was soaked in 100 ml of distilled water for 24 hours. The pH electrode was inserted into the soaked sample. The acidity machine automatically displayed the result [3, 9].

2.2.6 Refractoriness

The pyrometric cone equivalence (PCE) method was used in determining the refractoriness of the sample. The sample was made in form of Segar cone. The sample was thoroughly mixed and then formed in suitable mould. The test piece was mounted at the centre of the refractory plague. The test piece and the appropriate pyrometric cone number was placed in the furnace and heated to an estimated temperature of 2000 ^{0}C. The temperature was checked by means of an optical pyrometer. The test was in progress until when the tip of the cone had bent over and levelled with the disc base. The plague bearing the specimen was removed from the furnace and the test piece was examined when cold. The refractoriness was the number of the pyrometric cone that had bent over to the test cone. The temperature was then read off from the equivalence of the cone number [8].

2.2.7 Specific gravity

Weight of empty sample bottle was taken. Weight of one third sample and empty density bottle b was taken. Weight of one third sample and empty density bottle full water c was taken. Weight of density bottle full with water d was taken. The sample specific gravity (SG) is shown in equation 1 as reported in [3]:

$$SG = (b - a)/(b + d) - (a + c) \qquad (2)$$

Where SG is the specific gravity, a is the weight of empty sample bottle, b is the weight of one third sample and empty density bottle, c is the weight of one third sample and empty density bottle full of water and d is the weight of density bottle full of water

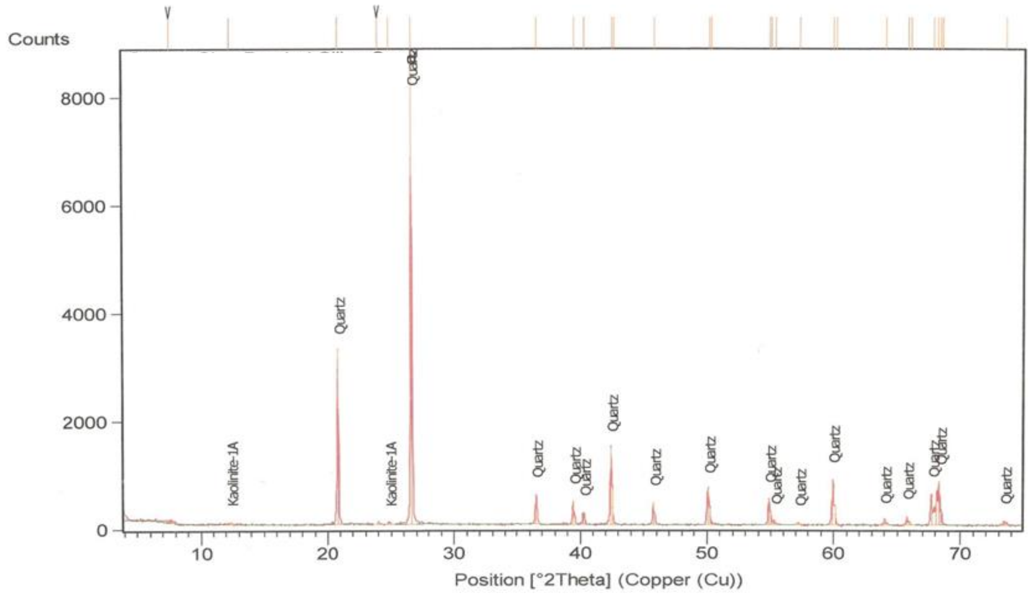
3. Results and discussion

Figure 1 shows Numan natural clay bonded silica sand in dry powder form. Physical examination shows that the sand is composed of brown- grey fine sand.

Figure 1: Numan Natural clay bonded silica sand

Figure 2 shows XRD diffractogramme of the clay bonded silica sand. From the figure, it could be observed that the sample is made up of two main minerals, namely: quartz (silicon oxide) and kaolinite clay which indicates that the deposit is made up of silica sand and clay whose compound name is aluminum silicate hydroxide with chemical formula of $Al_2Si_2O_5(OH)_4$.

Figure 3 shows the bar chart representation of the chemical composition of the natural clay bonded silica sand deposit. From the chart, it could observed that the deposit is mainly composed of 78.51% silica sand grains and 14.80% kaolinite clay which makes the mineral (aluminum silicate hydroxide) concentration of 93.31%. The sand grains are the mould major ingredients which are responsible for refractoriness, porosity, etc., while the clay is responsible for binding the silica sand grains for strength, shape and stability.



Diffractive key:
Mineral name: kaolinite,
Compound name: Aluminum Silicate Hydroxide
Chemical formula: $Al_2Si_2O_5(OH)_4$

Figure 2: XRD Diffractogramme of Numan natural clay bonded silica sand

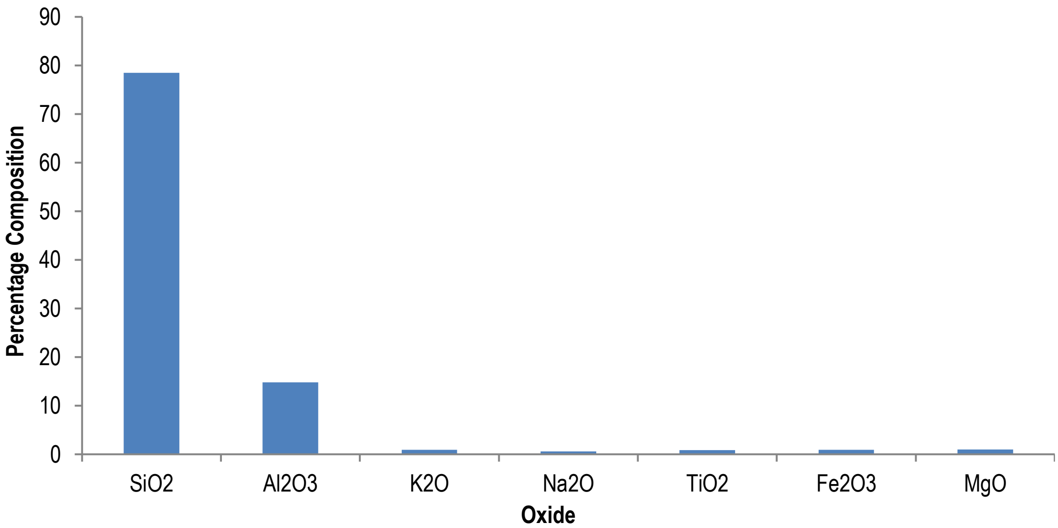


Figure 3: Chemical Composition of Numan Natural Clay Bonded Silica Sand

Table 1 shows the physical properties of the clay bonded silica sand. The sand physical properties show that the clay bonded silica sand deposit is base which is safe to handle

Table 1: Physical Properties of Numan Natural Clay Bonded Silica Sand

S/No.	Parameters	Values
1	Loss on ignition %	1.67
2	Specific gravity	2.42
3	Conductivity W/mK	131.20
4	Clay Content %	16.80
5	Refractoriness ^{0}C	1300:00
6	pH	6.80

The carbonaceous materials (loss on ignition) associated with the deposit improves mould permeability and consequently fast collapsibility of the mould/core during demoulding as the carbonaceous materials decomposes on heating during casting operations. The specific gravity (SG > 1) ensures mould stability which also aids core print in supporting the sand core in the desired position, conducts heat to provide mould/core chilling to full molten solidification and sufficient clay content to bind the sand grains. The refractoriness is good for non-ferrous castings. Thus, the natural clay bonded silica sand was observed to be satisfactory for non-ferrous green moulding sand. Green moulding was made to cast simple bushings. About 4 percent of water was added to the clay bonded silica sand. The mixture was mixed thoroughly by muller mixer machine. The pattern was placed on the centre of the moulding board and the drag flask was placed on the moulding board. The drag flask was filled with the green moulding sand and rammed. The drag flask was inverted.

Both the board and the pattern were removed, thus leaving an impression in the drag mould. In similar manner, another impression was made in the cope mould. An impression of ingate/pouring channel was made. On completing the moulding process, the green sand cores were preheated to expel moisture. The moisture free sand cores were inserted into the drag flask. The drag and the cope flaks were assembled together to receive the molten metal. Aluminium based metal was melted and poured into the mould flaks. The moulds were opened after the solidification of the casts. The casts were removed and allowed to cool to room temperature. The fins of the casts were cut off. The cast were machined. Figure 4 shows the moulding process.

(a) (b) (c) (d)

Figure 4: Green Moulding Process (a) Green mould flasks in closed position with solidified cast, (b) Green mould drag with cast, (c) Cast with fins and (d) Completed bushing

4. Conclusion

Examination of foundry properties of Numan natural clay bonded silica sand deposit was made. The result of the foundry properties were found to be in conformity to the acknowledged standard natural clay bonded silica sand data. The natural clay bonded silica sand as mined directly from the deposit was moulded for casting simple bushings. The green mould was found to have good dimension which means that the natural clay bonded silica sand is self-binding since the mould/core has the required strength and shape stability.

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