

INVESTIGATION OF THE FOUNDRY PROPERTIES OF GIREI SAND DEPOSIT IN UPPER BENUE RIVER BASIN FOR CASTING PURPOSES

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ABSTRACT

Foundries for the metal-casting industry use large amounts of the foundry sand. Sand is the most crucial factor in the practice of foundry. It is therefore very essential to have better understanding of this material through the knowledge of its properties. This will greatly assist to determine the sand suitability for foundry use. This article presents an investigation to determine the foundry properties of sand deposit in Girei area of Upper River Benue Basin in Adamawa state, Nigeria. Sand samples containing 8% clay, 4% water and 88% sand were collected and prepared from which 8 specimens were produced and their physical and chemical properties analyzed to determine their suitability for use in casting industries. The results of the study show that the moisture content of the sand is 3.5%, the green shear strength is 1.8 kN/m², the green compression strength is 13.2, kN/m² dry shear strength is 40 kN/m² and the dry compression strength is 290 kN/m². Clay analysis showed that the percentage of clay in the sand is 5.6%. Sand permeability number was found to be 498 while sieve analysis indicates that the Grain Fineness Number (GFN) is 41.36. These results compare very well with American Foundry man's Society (AFS) standard for foundry sand. Therefore the Upper River Benue sand can be used in foundries for metal casting.

Keywords: Foundry sand, Casting, Compression strength, Moisture content, Clay content, Grain fineness number

1 INTRODUCTION

The strength of foundry rests on the fundamental quality of sand, which is basically use in pattern making and moulding or core making, as principal raw material or tool during casting process. The quality of casting produced depends largely on the pattern and core boxes, its materials, design and construction [1]. Mold and core molding sand must be readily moldable and produce defect free castings. Foundry sand is clean, uniformly sized, high quality silica sand used in foundry casting processes. The sand is bonded to form molds or patterns used for ferrous (iron and steel) and nonferrous (copper, aluminum, brass) metal castings [2]. Foundry sand for metal casting is usually sourced from either natural deposit or synthetic mix of refractory sand grain, binder and moisture [3]. In recent years, large deposits of suitable foundry sand and other related raw materials have been discovered in various parts of Nigeria. Amongst these foundry raw materials are dolomite found in Osara, Edo State, clay in Ibule and Ijapo both in Ondo State and naturally bonded foundry sand in River Osun, Osun State. Other States in the federation which have been found to have abundant deposits of bentonite include Abia, Taraba, Kogi and Enugu. According to them, the largest deposit of 70- 80 million metric tonnes of bentonite was also discovered in Afuze, Edo State. The Nigerian Mining Corporation has also confirmed the existence of bentonite clay reserve of 700 million metric tonnes in Nigeria. These avalanches of sand deposits and their associated raw materials are capable of boosting foundry activities in Nigeria coupled with prospect for export. Casting is the process of pouring molten metal into sand or metal molds in which they solidify and removing the metal from the mold. More than 80% of metal castings are poured into molds [4]. Since most casting are poured into sand molds, it is important to examine the characteristics of moulding sands. Sand is formed by the disintegration of rocks under the action of frost, wind and rain and since rocks vary

widely in composition, so also will be the resulting sands. Sand suitable for moulding consists largely of grains of silica (S_1O_2) together with sufficient clay, usually between 5 and 20% to act as a binding material [5]. A naturally occurring sand of this type need only be mixed with sufficient water to facilitate mould. Silica sand is more frequently employed than any other type of sand as quartz, Zirconium, fosterite etc. because of its lower cost and availability [6]. A good sand casting cannot be made without a mold. A good mold in turn can only be produced if the sand mixtures used to make the mold have the desired properties. This means that sand properties control is a very important factor in producing quality castings and reduction of production cost through minimizing casting defects. Several factors are important in the selection of sand for molds. Sand having fine grains can be closely packed and forms a smooth mould surface and enhances mold strength. They however said, the fine grains also lower permeability which allows gases and steam evolved during casting to escape easily [7, 8]. It is reported that for sand to be suitable for mould making its constituents have to be in correct proportions as to impart essential properties as green strength, dry comprehensive strength, gas permeability and mouldability [9]. The most suitable sand for foundry has sizes ranging between 53 and 400um and they are defined in terms of refractoriness and chemical composition [4]. A detailed experimental investigation was carried out by [10] on the characteristics of beach/river sand for foundry use. All the sands investigated except Lagos beach sand were of good quality for foundry use. This research aims at investigating the suitability of Upper Benue sand for foundry purposes. Because of inaccessibility or proximity of foundry shops to sand deposits and sometimes insufficient quality of the sand, huge amount of money is spent in transporting sand. Sometimes foundry operators resort to importation of the sand leading to spending of foreign exchange. The study of the properties of sand deposits will assist in setting up small and medium scale foundry shops. The high amount of foreign exchange use in importations can be conserved.

2 MATERIALS AND METHOD

Sand was collected from excavation sites in Girei, Adamawa state and transported to the National Metallurgical Development Centre (NMDC) Jos, Nigeria where the physical properties experiments were conducted. Sand samples for the determination of properties such as moisture content, clay content, grain size, green shear strength, green compression strength, dry compression strength and dry shear strength were prepared according to America foundry man's Standard [11].

2.1 Determination of Moisture content

Sand samples were prepared from 8% clay, 4% water and 88% sand on standard equipment. The sample was then carefully enclosed in a closed container to safeguard its moisture content. A measured amount of calcium carbide in a container along with a separate cap consisting 50g of the sand was kept in a moisture teller. The apparatus was shaken vigorously such that the following reaction represented by equation (1) takes place:



This raises the pressure of the sand. A calibrated pressure gauge connected to the apparatus directly read the amount of moisture in the sand.

2.2 Determination of Clay content

This is the ratio of the loss in weight to the original weight multiplied by 100%. A dried 25g sand sample was taken in a one litre glass flask with 250ml of distilled water and 25ml of a one percent caustic soda (NaOH). The sample was thoroughly stirred. After stirring for five minutes, the sample was diluted with fresh water up to a 150mm graduation mark and left undisturbed for 10 minutes to settle. The sand settled at the bottom and the clay particle washed from the sand floated in the water. This water was siphoned off the flask and it was again topped to the same level and allowed to settle for five minutes. This operation was repeated until water above the sand became clear, which is an indication that all the clay in the moulding sand has been removed. The sand was removed from the flask and dried by heat at 105 °C. The difference in weight of dried sand and wet sand was used to get the clay percentage in the moulding sand. The clay content was determined by equation (2)

$$\% \text{ Clay} = \frac{(W_1 - W_2) \times 100}{W_1} \quad (2)$$

Where: W_1 = Original Weight, W_2 = Weight after clay was removed

2.3 Determination of Sand grain size

A 100g dry sand grain was placed on the top sieve of a sieve which contains a series of sieves one upon the other with gradually decreasing mesh sizes. The sieves were shaken for a period of 15 minutes. After this shaking operation, sieves were taken apart and the sand left over on each of the sieves was carefully weighed. The grain size was determining using equation (3).

$$\text{Grain Finess Number (GFN)} = \frac{\text{Total Product}}{\text{Total sum of \% collected in each sieve}} \quad (3)$$

2.4 Determination of green compression strength

This is the stress required to rupture the sand specimen under compressive loading. The sand specimen was taken out of a specimen tube and immediately put in a strength testing machine which was then switched on. The force which caused compression failure was then read off.

2.5 Determination of green shear strength

The sample similar to the one above was prepared. An adapter was fitted to the universal strength testing machine so that loading was made for shearing of the sand. The stress at which the specimen was sheared was then read off at failure.

2.6 Determination of Dry compression strength

The sand specimen was dried in an oven at 105 °C for two hours. It was removed and allowed to cool. The specimen was then placed on the strength testing machine and the machine switched on. The force which caused rupture of the sand read off on the machine.

2.7 Determination of Dry shear strength

Remains of the dried specimen used for testing the compression strength was used as sample for determination of shear strength on the universal strength testing machine. The force which caused shear failure was read off and recorded.

2.8 Chemical Composition test

The chemical composition of the sand sample was determined using the X-Ray Fluorescence (XRF) spectroscopy technique at the National Geoscience Research Laboratories Centre, Kaduna, Nigeria. An x-ray tube was used to irradiate the sample with a primary beam of x-rays. By photoelectric effect some of the impinging primary x-rays are absorbed by the sample elements. The chemical composition of the sample was compared with Chelford (UK) sand.

2.9 Permeability test

Standard air pressure of $9.8 \times 10^2 \text{ N/m}^2$ was passed through the cylindrical specimen tube containing standard moulded green sand specimen placed in parameter of the permeability equipment. Each period for 2000 cm^3 of air to pass through the specimens was taken to determine permeability of each sand samples using relation (4) below.

$$\text{Permeability No} = \frac{V \cdot h}{p \cdot a \cdot t} \quad (4)$$

Where: V = Volume of air passing through the specimen cm^3 , h = Height of the specimen in cm (5.0cm), p = Pressure of air ($9.8 \times 10^2 \text{ N/m}^2$), a = Cross-sectional area of specimen in cm^2 (i.e. 20.26 cm^2 adopted standard value), t = Time for air to pass in minutes.

3 RESULTS AND DISCUSSION

Grain foundry number is a rapid method to express average grain sizes of a particular foundry sand and has an important bearing on the physical properties of sand grains and clay in foundry sand

[1]. From the sand analysis, it can be seen that Upper River Benue (Girei) sand is a high silica (synthetic) sand with GFN 41.36 which is within the standard range of GFN (28 – 79) which qualifies casting cast iron [12]. A similar result was also reported by [1]. The moisture content as obtained from the experiment is 3.5% for the sand sample (Table 1). This compares satisfactorily with American Foundry man’s Society (AFS) standard of 2 – 3.8% and ASTM D2216 standard of 0.1- 10.1. A sand mixture with this moisture content can be used for casting steel [12]. The strength of sand refers to the stress required to rupture the sand either under compression or shear. The test showed that the green shear strength of the sand is 1.8 kN/m², green compression strength 13.2 kN/m² while the dry shear strength is 40 kN/m² and dry compression strength is 290 kN/m² (Table 1). Comparing these values with the AFS standard shows that the sand is of high quality and has met AFS standard for foundry sand [13]. The implication of this result is that castings from this moulding sand are likely to be of fine surface finish with little or no defect if properly handled other necessary factors being equally satisfactory. Grain size affects refractoriness. The higher the green size, the higher the refractoriness and the more the sand resist high temperatures. Sand grains with GFN of 30 to 40 may have a high fusion point of the order of 1650 °C [12]. Girei sand which has a GFN of 41.36 and the refractoriness of 1670 °C fits into this category of high quality moulding sand. It can be seen from Table 2 that the major constituents of the specimens are SiO₂, Al₂O₃ and Fe₂O₃ (96.08%, 1.61% and 1.06% respectively) and are very close to that of Chelford and in line with the recommended mold sand chemical compositions in literature [1]

Table 1. Bulk Properties of Sand obtained after testing.

S/No.	Properties	Values
1	Green shear strength (GSS)	1.8 kN/m ²
2	Green compressive strength (GCS)	13.2 kN/m ²
3	Dry shear strength (DSS)	40 kN/m ²
4	Dry compressive strength (DCS)	290 kN/m ²
5	Permeability	498
6	Moisture Content	3.50%
7	Refractoriness	1670 °C
8	Clay content	5.50%
9	Grain size	GFN = 41.36

Table 2. Chemical composition of sand samples

Constituents	Girei sand %	Chelford sand % [9]
SiO ₂	96.08	97.91
Al ₂ O ₃	1.61	1.13
Fe ₂ O ₃	1.06	0.5
CaO	0.05	-
MgO		-
K ₂ O	0.2	0.25
Loss on ignition	1	0.21
Total	100	100

4 CONCLUSIONS

From the results and analysis, the following conclusions are drawn. The sand has analyzed good green compression strength and adequate permeability to produce good quality casting. The sieve analysis indicates that the sand can be used for casting steel and cast iron. It is high silica sand which can withstand high temperatures.

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