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Investigation into the Suitability of Lere River Bank Sand for Green Sand Casting

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Abstract: *An investigation into the suitability of Lere river bank sand for use in green sand casting process was conducted. The samples of sand were tested for Refractoriness, Sieve analysis, Clay content, Moisture content, Shatter index, Dry and Green strength as well as Chemical analysis. The sand was divided into four specimens and tested with different percentages of bentonite clay as a binder which responded well. The result of the mechanical properties analysis was compared to existing foundry standard and it was found to be very suitable for all types of non ferrous alloy casting. The result showed that Lere river bank sand is alumina silicate with physio-chemical properties that are suitable for non-ferrous alloy casting because of its low refractoriness.*
Keywords: *green sand, silica sand, bentonite, non-ferrous alloys, sieve analysis.*

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I. INTRODUCTION

Foundries serves a variety of industries that cut across oil and gas, construction, mines and mineral processing, glass manufacturing, flour milling, marine and shipping, etc[10]. A foundry is a factory metal where castings are produced. Metals are cast into shapes by melting them into a liquid, pouring the metal into a mould, and removing the mould material or casting after the metal has solidified as it cools. Foundries all over the world are classified according to the product obtained from them such as Cast iron foundries, Steel foundries and Non-ferrous metal foundries.

Molten metal is poured into a mould cavity formed out of sand (natural or synthetic). Over 70% of all metal castings are produced via sand casting processes [3]. Sand casting is relatively cheap, and in addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and also make the aggregate suitable for moulding. These expendable moulds are made of wet sand that is used to make the mould's shape.

There are many recipes for the proportion of clay, but they all strike different balances between mould ability, surface finish, and ability of the hot molten metal to degas. Moulding sand, also known as foundry sand, are defined by eight characteristics: refractoriness, chemical inertness, permeability, surface finish, cohesiveness, flow ability, collapsibility and availability/cost [3].

II. MATERIAL AND METHOD

2.1 Apparatus

1. Standard laboratory pan mill.
2. Laboratory Rammer.
3. Moisture teller.
4. Permeability meter
5. Universal green compression testing machine.
6. Mechanical sieve shaker
7. Shatter index equipment
8. Furnace with Controller (RUL/CIC 421 E/9)

2.2 Methods

Determination of chemical composition

The chemical composition of the sand sample was determined using the X-Ray Fluorescence (XRF) and atomic absorption spectrophotometer (AAS) at the National Geoscience Research Laboratories Centre, Kaduna, Nigeria. The results are shown in table 1.

Sieve Analysis

300g of the River sand was weighed and dried in an oven; 100g of the natural sand was weighed and introduced into a set of BS Sieve with a ranging No 16 - 200; the nest of sieves were arranged from the largest aperture to the smallest. The nest of sieve was then mounted on a sieve shaker and vibrated for 15 minutes. The result was tabulated and used in finding the grain distribution and fineness number of the river sand as shown in table 2.

Clay Content Test

The clay content of the sand was calculated after tabulating the sieve analysis of the sand by using the formulae below;

$$Silt/clay\ content = \frac{(total\ weight) - (lost\ cumulative\ value)of\ sieved\ sand}{total\ weight} x\ 100^{(2)}$$

$$= \frac{100 - 99.97}{100} x\ 100$$

$$= 0.03$$

The dried sand sample was placed on the balance and the weight was multiplied by two to give the moisture content.

Permeability, Moisture Content, Shatter Index, Green and Dry Sand Compressive Strength Test

A standard laboratory pan mill was used to mix the sand for sampling (Sample A, B, C and D) for the various tests carried out. An American Foundry Society standard 50mm diameter specimen was prepared in a precision specimen tube and the weight of the sand specimen was recorded.

The permeability meter was used to carry out the permeability test measuring the rate of flow of air through the AFS. Standard rammed specimen under a standard pressure with the descent of the air drum timed between the zero and the 2000ml march with a stop watch and the pressure indicated on the manometer was recorded at different time.

According to RRD (2012), the general formula for the calculation of permeability is expressed as:

$$P = \frac{v \times h}{p \times a \times t} \quad \text{--- (1)}$$

Where: P = Permeability number

v = Volume of air in ml passing through the specimen

h = Height of test specimen in cm.

p = Pressure of air in cm of water.

a = Area of cross-section of specimen in cm^2

t = Time in seconds.

By substituting values for v, h, and a, and measuring the time in seconds, the formula becomes:

$$P = \frac{30072}{p \times t} \quad \text{--- (2)}$$

The value of the permeability was determined by applying the formula in equation 2 above, using bentonite clay binder and 3% water.

Sample A: $P = \frac{30072}{10cm \times 25s} = 120.3$

Sample B: $P = \frac{30072}{10cm \times 26s} = 115.7$

Sample C: $P = \frac{30072}{10cm \times 27s} = 111.4$

Sample D: $P = \frac{30072}{10cm \times 28s} = 107.4$

Moisture content test was performed with the moisture taller equipment.

The green and dry sand compression test machine was used to carry out the compression strength test of the prepared sand specimens. The Shatter index value of the specimen was determined by allowing the specimen to fall freely from a height of 1.83 meters unto a steel anvil. The degree of disintegration of each specimen was measured, from which the toughness or plasticity of the sand was determined.

III. RESULTS AND DISCUSSION

3.1 Results

Table 1: Chemical analysis of river Lere bank sand

Lere river bank sand	SiO_2	Al_2O_3	CaO	MgO	Na_2O	Fe_2O_3	TiO_2	K_2O	MnO	H_2O+
Comp by weight%	71.66	19.50	3.65	1.20	1.20	0.79	0.10	0.11	0.01	0.85

H_2O^+ = lost on ignition; fluxing agent = sodium hydroxide, Fusion point of the Lere River bank sand = 1380^{o}c

Table 2: Mechanical Sieve analysis of Lere River bank sand

S\No	BS sieve No	Retained (%)	Cumulative (%)
1	16	00.04	00.04
2	30	22.57	22.61
3	40	61.96	84.57
4	54	00.01	84.58
5	60	00.02	84.60
6	72	15.20	99.80
7	100	00.03	99.83
8	150	00.02	99.85
9	200	00.08	99.93
10	pan	00.04	99.97
11	clay	00.03	100.00

Table 3: Calculation of AFS grain fineness number for sand

S\N	BS sieve No	Sand retained (%)	multiplier	Product
1	16	0.04	10	0.40
2	30	22.57	20	451.40
3	4 0	61.96	30	1858.80
4	52	0.01	40	0.40
5	60	0.02	52	1.040
6	72	15.20	60	912.00
7	100	0.03	72	2.160
8	150	0.02	100	2.00
9	200	0.08	150	12.00
10	pan\clay	0.07	200	14.00
Total		100.00		3254.20

AFS Grain Fineness Number

The AFS fineness number which is the standard for reporting the grain size and distribution of sand was used to assess the particles [7]. This was applied to the sieve result as in Table 6 to obtain the AFS number.

From the table, $grain\ fineness = \frac{total\ product}{\%\ sand\ substan\ ce}$

$$= \frac{3241}{100}$$
$$= 32.4$$

The sieve analysis for two other samples gave AFS numbers 32.1 and 31.9 organic contaminants or residual clay in the sand after washing.

Table 3: Measured Foundry properties of Lere river sand using varying percentage of water.

Sample: water used as binder for sand	A	B	C	D
Added water (%)	2.0	3.0	4.0	5.5
Moisture content (%)	3.0	3.0	4.0	4.0
Green strength ($kN\backslash m^2$)	-	-	-	-
Dry strength ($kN\backslash m^2$)	-	-	-	-
Green permeability (no)	-	-	-	-
Shatter index (no)	7.6	6.6	3.8	3.4

Table 4: Measured foundry properties of Lere River sand using varying percentages of bentonite clay binder with a constant 3% of water.

Sample: bentonite clay used as binder	A	B	C	D
Clay content (%)	0.4	1.0	1.4	2.0
Moisture content (%)	3.0	3.0	2.8	2.8
Green strength(kN\m^2)	11.0	13.0	20.0	22.0
Dry strength (kN\m^2)	161.0	167.0	182.0	196.0
Green permeability (no)	120.3	115.7	111.4	107.4
Shatter index (no)	90.0	86.0	83.0	75.0

2.2 DISCUSSION OF RESULTS

Chemical analysis

Table 1 shows content in percentage by weight of various mineral oxides. It also reveals that the sand is coarse as can be seen from the lower AFS number. The fusion point measures the refractoriness and gave very useful information about the thermal resistance of the river Lere bank sand. It showed that the sand is mainly suitable for non-ferrous metals with melting point lower than 1380^{o}c.

Sieve Analysis

61.96% of the sand is in medium grade (BS no.36, 44, 52 & 60) and about 15.31% is in the fine grade (BS no. 72, 85, 100, 120 & 150). The grain distribution is within acceptable standard. This means that the experiment used sand grains in BS sieves 40 – 72, implying a mixture of 70% medium and 30% fine sand.

Mechanical analysis of mould sand specimens

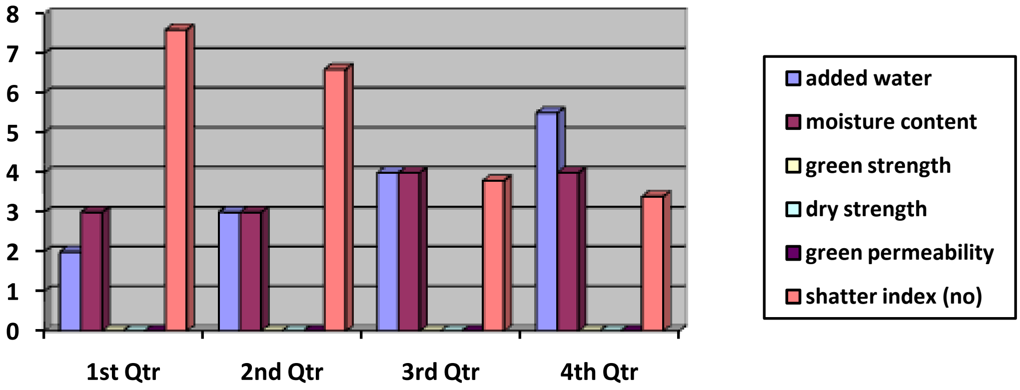

Fig. A: Measured Foundry properties of Lere river sand using varying percentages of water

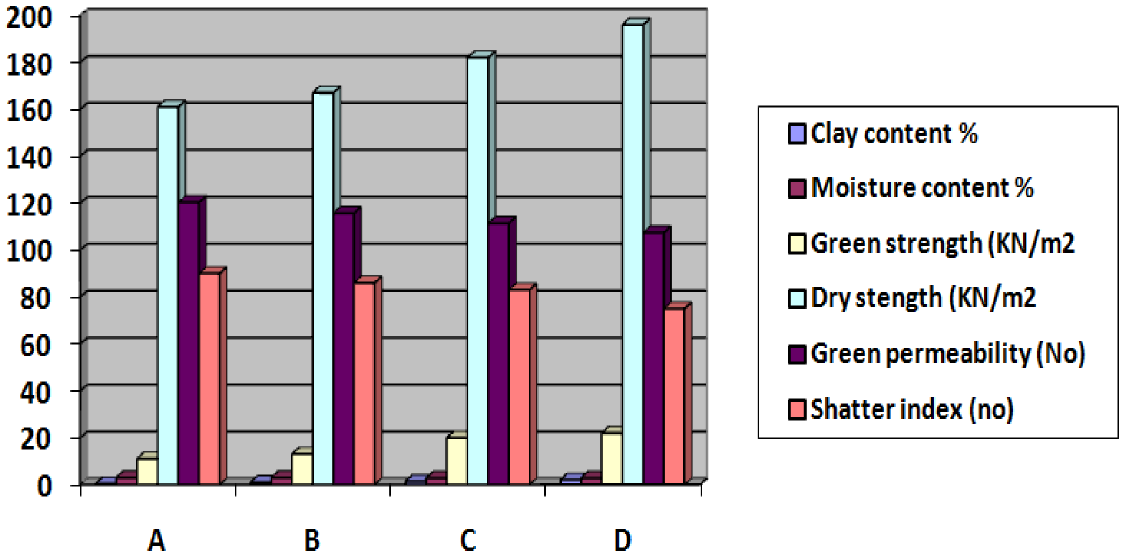

Fig. B: measured foundry properties of Lere River bank sand using varying percentages of bentonite clay binder with 3% of water.

Figure A-B shows the green compressive strength, dry compressive strength, permeability, moisture content, clay content and shatter index for sand specimen using varying percentages of bentonite clay binder with 3% of water. The washed and dried Lere River sand bonded with varying percentage by weight of ordinary water showed that without binder the sand could not bond together into test mould as shown in Table 3. This confirmed that it is alumino-silicate of quartzite origin. Silica (SiO_2) is dominant of the oxides present. Sodium oxide is high causing reduction in refractoriness as it fluxes at high temperature. The sand is mostly suitable for non ferrous castings.

The results of the property analysis when compared with foundry standard showed that it is suitable for all categories of non-ferrous alloy casting in green or dry sand moulds from 1.5% bentonite clay with about 2% moisture. The limitation to application of the sand is due mainly to low refractoriness of the sand caused by presence of low melting point oxide like sodium oxide that fluxes out as sodium hydroxide at high temperature.

IV. CONCLUSION

This study revealed that Lere river sand is alumino-silicate with physio-chemical properties that are suitable for non-ferrous alloy casting. It responded well to bentonite clay binder that gave good mechanical properties to sand mould specimens. The result of the mechanical properties analysis of the sand was compared to existing foundry standard and it was discovered to be very suitable to all types of non ferrous alloy castings at 2.5% bentonite clay with about 2% moisture content.

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