Investigating the Foundry Properties of Eagle Island Sand and Clay

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Abstract

Sand, an important refractory material in founding, significantly influences the properties of the mould and quality of the cast. This work investigates the qualities of sand and clay from Eagle Island (behind Rivers State University of Science and Technology, Port Harcourt, Nigeria). The physical and chemical properties of the sand were examined using sieves, mortar and piston, compaction loading machine, electron meter, ph meter, etc. The test was in accordance with American Foundry Man's Society specification. Results show the sand and clay to be good for foundry industries.

Keywords: Sand, mould, silica, chemical, ph meter

INTRODUCTION

Foundry sand is used in foundries to make moulds and cores for metal castings. The castings can be done in either permanent moulds or expendable refractory moulds. Since the properties of the moulding materials are for production of sound and dimensionally accurate crucial castings, the selection and testing of the sand becomes very important.

Sand occurs naturally as pure silica or naturally bonded with clay. The use of sand for casting is advantageous as it can be reused after casting, once the characteristics of the sand have been restored. Although sand is important in founding, it can not function effectively unless its properties are suitably controlled. The moisture content, bond strength, permeability of air, crushing, strength, grain size and chemical composition are important for producing high quality castings.

Four major types of sands are commonly used in the foundry industry. These includes: silica sands (SiO_2), olivine sands (($(MgFe)_2$, SiO_4), Zircon sand ($ZrSiO_4$) and chromate sands ($FeCr_2O5$ or $FeCr_2O_4$). The most common forms of natural sands are the high silica sand and the naturally occurring green sand, which contains a proportion of clay.

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The basic requirements for the foundry sand are:

i. Dimensional and thermal stability at elevated temperatures,
ii. Suitable particle size and shape,
iii. Chemical inertness with molten metals,
iv. Not readily wetted by molten metals,
v. Freedom from volatiles that produce gas upon heating,
vi. Economic availability,
vii. Consistent purity and pH,
viii. Compatibility with binder systems.

Only few sands possess all these. In order to satisfy the requirement for mould properties for producing superior quality castings, artificial improvement of poor minerals is of major concern.

To achieve this objective, the work focused on plasticity test, bond strength test, permeability, Atteberg limits, refractoriness, compressive strength, moisture content, chemical properties and analysis of the result.

EXPERIMENTAL METHODS AND MATERIALS

The samples were collected from under water using shovel and head pan. The samples were put in airtight bags and taken to Civil Engineering Laboratory of Rivers State University of Science and Technology, Port Harcourt, foundry workshop of Rivers State Polytechnic, Bori and Nigeria Agip Oil Company (NAOC), Green Rivers Project Laboratory, Obirikom for analysis

Some of the samples were dried in oven while some others were used in natural wet form. The samples were broken and crushed and some were mixed with water as would be appropriate for the test.

Particle Size Distribution:

165g of the sample was crushed using mortar and piston and poured into sieves arranged in order of their sizes – 425, 300, 150 and 75 μm using receiving pan. The arrangement was shaken for 15min and weight of retained sand in each sieve recorded. Percentage of total sample passing each sieve was calculated.

Plasticity:

The plasticity of sand is its ability to change shape on the application of load and to retain that shape when load is removed. The most convenient guide to plasticity levels of moulding sand is the shatter index.

$$\text{Shatter index} = \frac{\text{weight of sand on anvil and sieve}}{\text{original weight of cylinder of sand}}$$

Bond Strength:

Bond strength is the measure of the mould behaviour when subjected to stresses from heat and quantity of metal and indication of ease of pattern withdrawal.

Compaction test was used. Cylinder of height 11.35cm and diameter 10.16cm, 2.5kg standard harmer, compaction loading machine, beam balance, trowel and mortar and piston were used for the test.

2500g of the sample was weighed on beam balance and crushed using mortar and piston. The crushed sand was emptied into a rectangular tray and 12% water added and mixed properly. It was compacted into the cylinder ramming with 25 blows of the harmer. The mould was removed and the sample was crushed using the compaction loading machine. The values of the crushing load were recorded at point of collapse.

$$\text{Bond strength} = \frac{\text{Maximum load}}{\text{Cross sectional area}}$$

Moisture Content:

The apparatus used for the investigation are a can of 6.80g, beam balance, drying oven. Wet samples in the can was weighed using the beam balanced. It was then placed in the oven and allowed for 24 hours to dry. Sample was removed from oven and weighed

$$\text{Moisture content, } W = \frac{M_2 - M_3}{M_3 - M_1} \times 100$$

Where M_1 is mass of container

M_2 is mass of container + wet sand

M_3 is mass of container + dry sand

Clay Content:

This test aims at determining the amount of fine material in the sand. 50g of the sample was weighed in the beam balance. The sample was crushed, placed in a glass jar containing water and stirred with a glass stirrer. Weight of the sand which settled fast was determined and recorded.

The percentage of weighed quantity is evaluated as:

$$\frac{50 - W}{50} \times 100$$

Where, W is weight of clay in 50gm standard weight

Liquid and Plastic Limits

The samples were crushed using mortar and piston and passed through 425μm sieve. The fine particles through the sieve were collected in a pan and properly mixed with water. The wet sample was placed in the casangrandle device with the up resting on a platform. A cut was made from top to bottom using the v-shaped tool along the length. The cup was lifted up and down through a pulley mechanism till the groove closed up. The number of blow to close the groove was recorded.

Some quantity of the wet sample were rolled into many 3mm diameter and placed in 5.2g can. The weight of wet sample and container was taken. The sample was dried and weight taken.

The plastic index (PI) is expressed as:

$$PI = \text{LL} - \text{PL}$$

where, LL is liquid limit

PL is plastic limit

Green Compressive Strength

A fresh sample was compacted into a cylinder 7.82cm high ad 3.75cm diameter. The compacted cylinder was pushed into an air-tight rubber and both ends covered with caps. The assemblage was placed in the compression machine vertically. The pressure of the machine was increased from Zero and the failure loads were recorded.

Refractoriness

This is of great importance in casting high melting point alloys, especially steel. The test was carried on the silt particles alone. The samples were crushed, sieved and washed to remove clay particles. The sample was placed in a dish which was placed on a sintering boat and heated. Observations were made at different intervals of time until the sample started sticking together. The sand grains were found to cohere at temperatures above 1300^{o}C on different tests.

RESULTS AND ANALYSIS

Table1: Particle Size Distribution

S.No	Size of sieve (Nm)	Wt. of Sample retained (5)	Cum. Wt of samples retained (3)	% wt. of Sample retained sample $^{w}/_{105}$ x 100	Cum. % wt. of retained samples	% wt. pass in through sieve
		Sample 1				
1	425	64	64	39	39	61
2	300	50	114	30	69	31
3	150	19	133	12	81	19
4	75	20	153	12	93	7
5	Pan	10	163	6	99	1
	Total	163		99		
		Sample 2				
1	425	53	53	11	11	89
2	300	53	106	11	22	78
3	150	253	359	51	73	87
4	75	71	430	14	87	13
5	Pan	30	460	6	93	7
	Total	460		93		

The results of particle size distribution is shown in Table 1 above. The percentage of samples retained on each sieve and the ones passing through each sieve are also recorded. Results shows adequate combination of both clay and silt particles of both samples.

Table 2 Liquid and Plastic Limits (Atteberg Limit)

Contents	Liquid limit						Plastic Limit			
	Sample 1			Sample 2			Sample 1		Sample 2	
No of Blow	32	26	19	12	22	39				
Wt. of Wet Sand + can	33.7	29.0	28.3	69.8	73.4	91.5	15.1	14.0	15.0	14.8
Wt of dry Sample + can	24.0	21.0	19.8	33.6	35.4	44.0	13.4	12.5	13.4	12.4
Wt of can	5.2	5.2	5.2	5.2	5.2	5.2	6.8	6.8	6.8	6.8
Wt of dry sample	18.8	15.8	14.1	28.4	30.2	38.8	6.6	5.7	6.6	5.6
Wt of moisture	9.7	8.0	8.5	26.3	28.4	36.5	1.7	1.5	4.6	4.4
Moisture content (%)	52.0	51.0	60.0	92.7	94.0	95.3	26	26	70	80
Average	54.3			94.0						

The result of liquid limit shows that Sample 1 (red clay) has lower liquid limit than Sample 2 (white clay). Less water would be added when mixing the red clay.

Table 3: Bond Strength

Rate of Compaction	Sample 1		Sample 2	
	Load (N)	Bond strength (KN/m^2)	Load (N)	Bond strength (KN/m^2)
Wet (green compaction)	2955	256	2317	201
After one day	4610	400	3191	277
After 3 days	7683	666	6265	543
After 7 days	8510	738	6974	605

Result showed that the red sample (1) has higher bond strength than the white sample (2)

Table 4: Shatter Index and Green Compressible Strength (GCS)

Moisture content	Sample 1					
	Shatter Index			Green Compressive Strength		
	30g clay to 500g sand	40g clay to 500g sand	50g clay to 500g sand	30g clay to 500g sand	40g clay to 500g sand	50g clay to 500g sand
3.0	19	35	37	32	36.5	–
3.5	39	48	53	26.8	31.0	40.1
4.0	47	52	57	21.0	25.4	48.4
4.5	40	44	48	17.3	21.8	37.4
5.0	31	33	39	11.8	16.0	31.4
	Sample 2					
	Shatter Index			Green Compressible Strength		
	30g clay to 500g sand	40g clay to 500g sand	50g clay to 500g sand	30g clay to 500g sand	40g clay to 500g sand	50g clay to 500g sand
2.0	25	32	36	27.8	30.0	–
2.5	33	40	43	24.3	25.7	39.6
3.0	40	46	49	15.7	21.6	44.4
3.5	32	41	42	12.0	16.8	27.5
4.0	26	28	30	9.1	11.2	21.7
4.5	20	22	25	–	7.0	17.7

Result showed that the red sample (sample 1) has higher shatter index and can make a better binder material.

The shatter index peaks at certain moisture contents but the green compressive strength shows increase in strength with increasing binder content and decrease with increasing moisture content for particular clay content.

Table5: Moisture Content

	Sample 1		**Sample 2**	
Wt. of West S. and can (g)	56.8	76.8	67.4	58.9
Wt of dry Samp. and can (g)	54.0	73.5	63.5	55.5
Wt of can (g)	6.8	6.8	6.8	6.8
Wt of moisture (g)	2.8	3.3	3.9	3.4
Wt of dry sand (g)	47.2	66.7	56.7	48.7
% Moisture content	5.9	4.9	6.9	7.0
Average	5.4		6.95	

The moisture content of sample 1 (red sample) is lower than that of sample 2 (white sample) although both fall within acceptable levels (4 – 7%)

Table 6 Refractoriness

Sample 1		**Sample 2**	
Tempt ^{o}C	Appearance	Tempt ^{o}C	Appearance
900	A	800	A
1000	A	900	A
1100	A	1000	A
1200	A	1100	A
1300	B	1200	B
1400	B	1300	B
1450	C	1400	C
1500	D	1450	D

A – No reaction; B – Sticking together; C – Sintering; D – Glazing

The refractory tests were performed on silica sand and the temperature at which the particles get deformed corresponds to those at which the grains begin to stick together when viewed under microscope. Sintering temperature for moist silica sands are between 1100^{o}C and 1600^{o}C. The obtained results of 1450^{o}C and 1400^{o}C are, therefore, within acceptable range.

Conclusion

In this study, an investigation was carried out on Eagle Island sand and clay to determine if they meet the requirements for foundry use. It was observed that the compressive strength of the samples decreases with increase in moisture content and the shatter indices show they are good for binder and good for foundry application, for steel and cast iron casting.

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