Characterization of Beach/River Sand for Foundry Application

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Abstract

A detailed experimental investigation is been reported on the characterization of beach/river sand for foundry use. Bulk properties of the sand samples collected were evaluated. The experimental results were analyzed as per the American Foundry Society (AFS) standard. The analyses show that samples from Ughelli River, Warri River and Ethiope River could be used effectively in the foundry. The sample from Lagos bar beach requires to be sieved properly to remove the coarse fractions in order to make it suitable for foundry use.

Keywords

Sand; Moisture content; Grain size distribution; American Foundry Society (AFS) clay content; Refractoriness; Permeability; Green compression strength.

Introduction

There have been various researches by Nigerian researchers [1] in the area of developing local alternatives to foundry material to determine their suitability for the production of sound castings. But most of these works have been mostly on determining the refractory properties of various deposits of clays which are abundant in the country, and are used as binder in moulding sand.

Akinbode [2] carried out an investigation on the properties of termite hills as refractory material for furnace lining. In his report, he observed that the refractory properties of termite hill material which include porosity, density, dimensional change and permeability are very similar to known refractory materials for furnace lining.

Abolarin *et al* [3] studied the characteristics of Nigerian clays and discovered that the Barkin Ladi and Alkaleri clay sample were suitable for construction of furnaces and furnace lining.

Folaranmi [4] investigated the effect of additives (sawdust and ashes) on the thermal conductivity of clay; results obtained showed that with sawdust addition the clay was suitable as clay oven material as well as a good insulator.

Aramide *et al* [5] also investigated the effect of binders (bentonite and dextrin) and water on the properties of recycled foundry sand made from silica sand obtained from Ilaro deposit of ogun state Nigeria, they discovered that with minimum additives of binders recycled Ilaro sand can be reused.

Umaru and Aliyu [6] carried out the characterization and evaluation of refractory properties of some selected clay deposits in North Central, Nigeria to ascertain their suitability as refractory materials and for relevant application in Nigerian manufacturing industries.

Aliyu *et al* [7] studied the chemical and physical characteristics of selected clay samples from three local government areas of Sokoto state, Nigeria. Their findings showed that these deposits can be processed for use in the paper and foundry industries.

Sand casting is the most widely used casting process. It involves compacting sand round a metal, wood, or plastic pattern. The sand is relatively fine and is composed primarily of silica (SiO_2). Although there are various local deposits of sand, the suitability of particular sand in foundry depends on the casting, chemical composition, physical and mechanical properties in relation to its engineering application.

This paper is centered on the characterization of some beach/river sand, with a view to determining the chemical composition, moisture content, grain shape and distribution, AFS clay content, refractoriness, permeability, and green compression strength.

Material and Method

Samples of sand were collected from NNPC Terminal along Warri River, Egu along Ethiope River, Ogoregwekọ along Ughelli River all in Delta state of Nigeria, and from Lagos bar beach in Victoria Island of Lagos state. The following properties were evaluated:

1. Grain shape. Grain shape in foundry casting represents a compromise between permeability, bonding ability, and smoothness of the finished surface of the casted part. Generally, ideal foundry sand is sub angular in shape and allows individual grain the ability to interlock sufficiently well to form good mould and still providing necessary pore spaces for gases to escape without breaking the mould during casting process [8].
2. Grain size and its distribution. Grain size is determined by shaking a known amount of clean, dry sand downward through a set of 11 standard sieves for 15 minutes [5]. The amount of sand remaining on each sieve is weighed, and the weights are used to compute and A.F.S. (American Foundry Society) grain fineness index (GFI) [9].
3. Moisture content. This is determined by a special device that measures electrically conductivity of a small sample compressed sand. Or more directly by measuring the weight loss of 50g sample after it has been subjected to a temperature of about 110°C for sufficient time to drive off all the water [9].
4. Refractoriness. This is the resistance of sand to fusion and softening at high working temperatures. It is the maximum temperature a material can withstand after which it will fail (break). Refractoriness is measured by a standard technique and practically reported in pyrometric cone equivalents, (PCEs). The test measures the softening point of a refractory material by comparing the behaviour of its test cone with reference cones of standard composition [7].
5. AFS clay content. AFS clay content includes all particles finer than 20 microns in size, whether they are clay particles, silt or organic matter, (Jain, 2003). The total clay content in sand is determined by washing 50g sample of moulding sand using 475cm^3 of water and 25 cm^3 of standard sodium hydroxide (NaOH) in a jar. Several agitation and washing is required to fully remove the clay. The remaining sand then dried and weighed to determine the amount of clay removed from the original sample [9].
6. Chemical Composition. 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. This is a non-destructive analytical method in which x-ray tube is used to irradiate the sample with a primary beam of x-rays. Some of the impinging primary x-rays are absorbed by the sample elements in a process known as the photoelectric effect [7].

7. Green Compression Strength and Permeability. Sand sample of 500g was mixed with 6% sodium base bentonite and 4% water. Mixing was done in a laboratory Muller [10] for 5 minutes and standard cylindrical specimens (50 mm × 50 mm) were made using locally developed sand rammer [11] by ramming three times. The physical properties of the sand investigated using the standard tests methods was carried out at the National metallurgical and Development Centre (NMDC), Jos, Nigeria.

Results and Discussions

From Table 1, Warri, Ethiope, and Ughelli River sands high green compression strength as well as low permeability as compare to that of Lagos bar beach which is attributed to its coarse nature.

The results for refractoriness of all the samples conforms with the American Foundrymen Society [13] of 1200ºC fusion temperature needed for grey cast iron and certainly for non ferrous metals like aluminium, copper, and lead,

The clay content of the samples indicates that Lagos bar beach has the lowest value of 1.02%. However, the samples from Warri, Ethiope and Ughelli falls within the range of 1.15 – 1.55%.

The results of the various tests are presented in Table 1. And the chemical composition of the samples compared with Chelford (UK) sand [12] is presented in Table 2.

Table 1. Bulk properties of tested sand samples

S/no.	Bulk Properties	Warri River sand	Ethiope River sand	Ughelli River sand	Lagos Bar Beach sand
1.	Grain fineness number (GFI)	51.41	46.34	54.33	30.28
2.	Moisture content (%)	2.25	4.96	5.45	8.64
3.	Refractoriness (ºC)	1550	1600	1550	1500
4.	AFS Clay content (g)	1.32	1.38	1.44	1.02
5.	Permeability (l/min)	190	150	195	500
6.	Green Compression Strength (g/cm^2)	4.2	4.4	4.5	2.0

It can be seen from the Table 2 that the percentages of SiO_2, Al_2O_3 and Fe_2O_3 for samples from Warri, Ethiope and Ughelli are very close to that of Chelford. That of Lagos bar beach has lower percentage of SiO_2, and higher value for Al_2O_3 and Fe_2O_3.

Table 2. Chemical composition of sand samples

Constituent	Chelford	Warri River sand (%)	Ethiope River sand (%)	Ughelli River sand (%)	Lagos Bar Beach sand (%)
SiO_2	97.91	96.18	98.12	97.01	53.16
Al_2O_3	1.13	2.76	0.91	1.96	19.40
Fe_2O_3	0.50	0.06	0.16	0.13	4.70
CaO	-	-	-	-	2.66
MgO	-	-	-	-	2.08
K_2O	0.25	-	-	-	-
Loss on ignition	0.21	1.00	0.72	0.90	18.00
Total	100.00	100.00	100.00	100.00	100.00

From the analysis of results obtained for grain fineness and size distribution Figure 1, it shows that the samples are of three fractions: bulk, coarse and fine. The acceptable grade of sand has grain size between 0.18mm – 0.25mm [13]. Warri, Ethiope and Ughelli River sands conformed to this range. Lagos bar beach sand has coarse grains hence and it is out of acceptable range. Consequently, its foundry application will produce casting of poor surface finish.

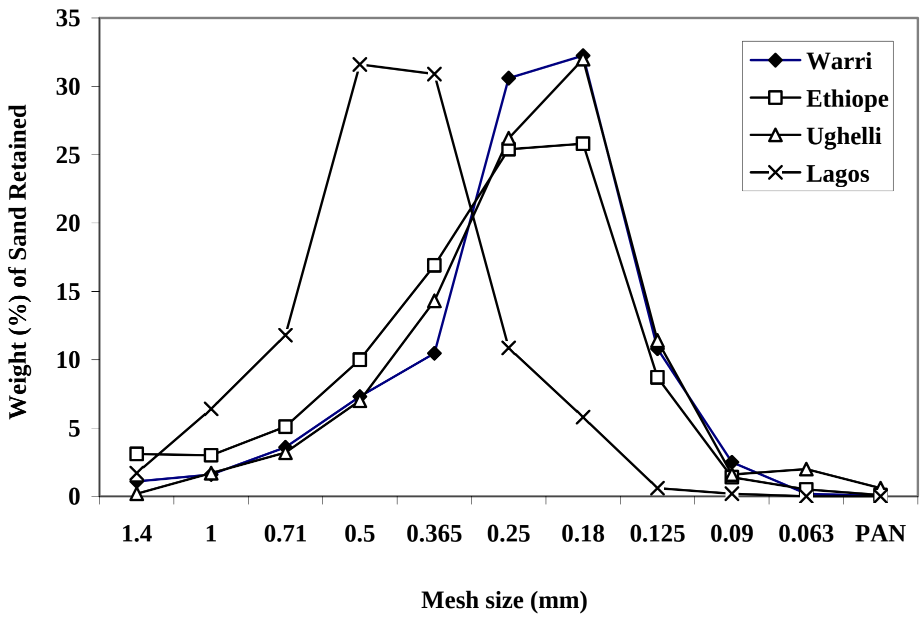

Figure 1. *Grain size distribution curves*

The moisture content of the samples shows that Lagos bar beach sand has the highest value 8.64%. This will require great amount of time and resources to prepare it for moulding operation.

Conclusions

An investigation into the properties of Warri river, Ethiope river, Ughelli river and Lagos bar beach sands for application in foundries has reveal that the first three samples have angular grain shapes which gives them greater interlocking strength as well as better venting properties. They have good green compression strength and adequate permeability to produce good quality casting. The permeability for Warri, Ethiope and Ughelli sand are moderate and therefore these can be used for light castings. Lagos bar beach sand was found to be coarse and therefore requires to be sieved to remove coarse fractions so that it could be used in foundries.

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