International Journal of Advanced Engineering and Technology
ISSN: 2456-7655
www.newengineeringjournal.com
Volume 1; Issue 1; March 2017; Page No. 28-31

Preparation of synthetic moulding sand using local raw materials

[1] Edoziuno FO, [2] Oyibo AO, [3] Nwaeju CC

[1] Department of Metallurgical Engineering, Delta State Polytechnic, Ogwashi-Uku, Nigeria
[2] Department of Welding and Fabrication Technology, Delta State Polytechnic, Ogwashi-Uku, Nigeria
[3] Department of Metallurgical & Materials Engineering, Nnamdi Azikiwe University, Awka. Nigeria

Abstract
Efforts have variously been made to develop synthetic moulding sand for foundry mould production from locally sourced ingredients. This research investigates the suitability of using river Niger sand (Onitsha deposit) and Ukpor clay to compose moulding sand. Laboratory Foundry sand tests were carried out on American Foundrymen's Society (AFS) standard test specimens (50mm diameter by 50mm height) prepared with a ridsdale laboratory sand rammer, to determine their moulding properties in both dry and green conditions. The results of chemical analysis of the sand and the clay samples indicated that the sand is of high silica content (89.9%) and the clay is rich in both silica and alumina contents (67.2% and 24.5%) which is an indication of their suitability for use in foundry mould production and other refractory applications. The result of sieve analysis for the sand deposit revealed a grain fineness number (GFN) of 40.01 and an average grain size of 421.70µm, which is within the range widely used in sandcasting. Over 99% bulk of the sieved sand was retained after few consecutive sieves, which confirms that the sand met AFS standard specification for foundry sand. The results of the moulding sand properties obtained compared favourably with the standard property range required for the sandcasting of various ferrous and non-ferrous metals and alloys.

Keywords: Sandcasting, synthetic moulding sand, grain fineness, sieve analysis

1. Introduction

Nigeria is endowed with abundant natural deposits of silica sand and kaolin clay. These minerals have several areas of application. One such areas of application is as constituents in the preparation of moulding sand for foundry mould production. Effective application of these local raw materials in moulding sand production demands that its moulding properties must be known and compared with the standard properties required for such application. For this reason it is considered necessary to study the moulding properties of synthetic moulding sand produced using river Niger sand (Onitsha deposit) and Ukpor clay with a view to recommending to the needy local industries. The main source of moulding sand ingredients for our foundries has been overseas. The cost of procuring and transporting these materials into the country has been enormous. Production is often delayed or disrupted consequent upon unforeseen interruptions in the supply chain. Furthermore, the major beneficial aspect of government job creation programme and diversification from a mono-economy driven by oil to a robust poly-economy driven by agriculture, mining and steels development, is the inward search for indigenous industrial inputs especially in the raw materials for metals sector.

There had been a concerted effort made by various researchers to characterize and study the moulding properties of some local clays and silica sand deposits [1, 2]. Synthetic moulding sand had also been prepared from those suitable for foundry mould production [3].

Moulding sand may be classified basically into two different types according to the type of base sand used; the natural moulding sand and the synthetic moulding sand [4, 5, 6]. Moulding sand for high and low temperature sandcasting of metals and alloys is usually obtained from natural deposit or from synthetic composition of silica sand particles, binder and moisture [3, 7]. Synthetic sands are basically high silica sands containing little or no clay binder in the natural form. The desired strength and bonding properties of these sands are developed by separate additions of clay and other additives. This allows for greater flexibility in the control and adjustment of the properties of synthetic moulding sands [5, 6, 8, 9]. The control of the quantity of the principal constituents of synthetic foundry sand is key to determining the properties of the moulding sand [8, 10, 11, 12]. The use of synthetic sand in foundry mould production is increasing due to increased reclamation rates and this has reduced the costs associated with dumping spent sand [13].

2. Materials and Methods

2.1. Materials and equipment

The local materials used to compose the synthetic moulding sand were green silica sand from the Onitsha bank of river Niger and Ukpor clay. The instruments used included set of standard test sieves mounted on a sieve shaker, standard sand rammer (Serial No: 845), motor driven universal sand strength machine (Serial No: M8415), electric permeability meter (Serial No: 872), mouldability tester, laboratory core baking oven (40ºC to 240ºC), laboratory sand mixer and Energy Dispersive X-ray fluorescence Spectrometer (ED-XRFS mini PAL model © 2005).

2.2. Experimental Methods

Impurities such as metallic objects, stones, hard lumps and other unwanted objects were removed from the silica sand collected from the deposit by sorting and washing. The hard lumps of the dried clay were crushed and finely ground to pass through a 200-250 mesh sieve size. The sand sample was sieved using a stack of standard test sieves mounted on a timed sieve shaker. 840g of the sieved silica sand (80%) was placed in the laboratory sand mixer and 168g of the dried clay (16%) was sprinkled over it. The sand milling operation was started and the dry ingredients were mixed for 5minutes before the addition of 42g of water (4%) and further mixed for 3minutes.

After the mixing operation, AFS standard test specimens were prepared using laboratory sand rammer. Dry and green strengths (compression and shear) tests were conducted on the standard specimen using a motor driven universal sand strength machine, while the percentage mouldability and green permeability number were determined using the mouldability tester and electric permeability meter respectively. Separate specimens of the silica sand and the clay samples were collected and used for the chemical analysis using Energy Dispersive X-Ray fluorescence Spectrometer (ED-XRFS).

3. Results and Discussion

The quantitative and qualitative results of the tests conducted are shown in Tables 3.1 to 3.6.

Table 1: Chemical composition of Onitsha beach silica sand.

Compound	SiO_2	K_2O	CaO	Fe_2O_3	Ag_2O	TiO_2	SeO_2	BaO	HgO	MnO	GeO_2	CuO
Conc %	89.9	3.00	2.63	1.767	1.83	0.319	0.16	0.14	0.10	0.039	0.02	0.0087

Table 2: Chemical composition of Ukpor clay.

Compound	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	Ag_2O	CaO	V_2O_5	OsO_4	K_2O	SeO_2	MnO	Cr_2O_3	Ga_2O_3
Conc %	67.2	24.5	4.271	2.039	1.44	0.166	0.139	0.059	0.042	0.094	0.025	0.024	0.010

The results of chemical analysis (Tables 3.1 and 3.2) indicated that the sand is of high silica content (89.9%) while the clay is rich in silica and alumina contents (67.20% and 24.50% respectively). The clay, therefore, belongs to the aluminosilicate class.

The purity of sand grains influence their refractoriness. It is evident that silica is the predominant component in the sand sample. This is desirable since high percentage of silica in moulding sand, usually enhance its refractoriness, thermal stability and chemical inertness [8, 14]. It have also been noted that the presence of oxides of alkali metals in high proportions cause objectionable lowering of the fusion point of foundry sand from 1690°C to about 1200°C [15]. Where maximum refractoriness is required, as in steel moulding, high purity silica sand are used.

Table 3: Sieve analysis and AFS grain fineness number (GFN) of Onitsha beach silica sand.

S. No	Sieve Aperture (μm)	% Sand Retained	BS Sieve No	Product
1	1400	2.48	12	0.00
2	1000	1.40	16	16.80
3	710	4.32	22	69.12
4	500	13.82	30	304.04
5	355	25.91	44	777.30
6	250	28.55	60	1256.20
7	180	16.96	85	1017.60
8	125	5.84	120	496.40
9	pan	0.44	-	52.80
Total		99.72		3990.26

$$GFN = \frac{Total\ Product}{Total\ \%Sand\ Retained} = \frac{3990.26}{99.72} = 40.01 \quad 3.1$$

Table 4: Calculation of average grain size.

Sieve Aperture (μm)	% Sand Retained	Multiplier	Product
1400	2.48	1180	2,926.40
1000	1.40	1180	1,652
710	4.32	1180	5,097.60
500	13.82	600	8,292
355	25.91	425	11,011.75
250	28.55	300	8,565
180	16.96	212	3,595.52
125	5.84	150	876
Total	99.72		42,052.27

$$Average\ Grain\ Size = \frac{Total\ Product}{Total\ \%Sand\ Retained} = \frac{42052.27}{99.72} = 421.70\mu m \quad 3.2$$

The result of the sand grain size analysis showed that more than 99% of the bulk sand was retained on the first few consecutive sieves. Thus, the sand deposit met the American Foundrymen's Society (AFS) Standard specification for sand casting [10, 14]. The grain fineness number (GFN) and average grain size of the sand deposit are 40.01 and 421.70μm respectively. This grade of fineness number is suitable for most types of alloy steels and nonferrous metal as this belongs to the group of fineness number that has wide range of application in sandcasting. The average grain size of the sand falls within the common foundry sand range of 150-400μm [8]. It should be noted that while average grain size and AFS grain fineness number are useful parameters, choice of sand should be based on particle size distribution, as the size distribution affects the quality and properties of casting produced.

Table 5: Moulding properties of the synthetic foundry sand.

Properties	GCS (KN/m²)	DCS (KN/m²)	GSS (KN/m²)	DSS (KN/m²)	Green Permeability No	Mouldability (%)
Value	35.70	591.50	21.00	77.00	7.80	94.37

Where GCS, DCS, GSS and DSS represent green compression strength, dry compression strength, green shear strength, and dry shear strength respectively.

Table 6: Standard property ranges for sand casting of different alloys (Dietert, 1966).

Metal	GCS (kN/m²)	Permeability (No)	DCS (kN/m²)
Heavy steel	70 - 85	130 - 300	1000 - 2000
Light steel	70 - 85	125 - 200	1000 – 4000
Heavy Grey iron	70 -105	70 - 120	350 - 800
Aluminum	50 - 70	10 - 30	200 - 550
Brass and Bronze	55 - 85	15 - 40	200 - 860
Light GreyIron	50 - 85	20 - 50	200 - 550
Malleable iron	45 - 55	20 - 60	210 – 550
Medium Grey Iron	70 - 105	40 - 80	350 - 800

From the results of moulding sand properties tested (Table 3.5), it would be observed that the % mouldability is high showing an increase in the tendency of the moulding sand prepared from this locally sourced raw materials to conform to the moulding processes. This is as a result of the moulding sand being more plastic and pliable, thus increasing the ability and ease with which the sand can fill intricate mould cavity and reproduce in fine details the embedded pattern.
The green permeability was high enough to allow the easy escape gases and forestall defects in casting. The moulding sand was not so compacted or strongly bonded that the porosity and shakeout time are hampered [3, 16, 17]. The green permeability value obtained can also be linked to the low green strength (compression and shear) recorded. The dry strength was high enough to withstand the metallostatic pressure of the molten metal during pouring and subsequent solidification processes. Comparing the results with the standard property range specified for sand casting (Table 3.6), it will be seen that the moulding sand is suitable for dry mould casting of aluminium and alloys, bronze, heavy grey iron, lighy grey iron, malleable grey iron and medium grey iron.

4. Conclusion and Recommendations

4.1 Conclusion

The suitability of preparing synthetic moulding sand using these local silica sand and clay deposits has been investigated in this research work and the following conclusions are made:

- Synthetic moulding sand produced from Ukpor clay and river Niger sand (Onitsha deposit) is suitable for dry mould casting of ferrous and non-ferrous alloys.
- The grain size analysis showed that more than 99% of the bulk sand was retained on the first few consecutive sieves. Thus, the sand deposit met the AFS standard specification for foundry sand. The grain fineness number (GFN) and average grain size of the sand deposit also fall within the recommended range for wide application in sand casting.
- The results of chemical analysis for the silica sand and the clay samples indicated that both have the required purity for enhanced refractoriness, thermal stability and chemical inertness of moulding sand.

4.2. Recommendations

In the course of this investigation, some pertinent recommendations are made and further research areas have been identified.

- It is recommended that Onitsha deposit of river Niger sand and Ukpor clay be used as components for synthetic moulding sand preparation.
- Foundry moulds produced from this synthetic moulding sand should be employed in the dry mould casting of both ferrous and non-ferrous alloys components.
- Mechanical tests should be carried out on the ferrous and non-ferrous alloy components cast with this locally produced synthetic moulding sand to determine the effects of the moulding sand on the components' mechanical properties.

5. Acknowledgement

The authors wish to sincerely appreciate the technical assistance of National Metallurgical Development Centre (NMDC), Jos and Engr. Nicholas Agbo of the Defence Industry Corporation of Nigeria (DICON), Kaduna.

6. References

1. Nnuka EE, Ogo DUI, Oseni MI. Characteristics and the Application of some Indigenous Clays in Nigeria. Journal of Agriculture Science and Technology. 2003; 13(2):128-135.
2. Nwajagu CO, Okafor ICI. A study of the Moulding Properties of Sand Bonded by Ukpor Clay. Applied clay Sciences. 1989; 4(3):211-223.
3. Edoziuno FO, Odo JU, Nnuka EE. Effect of Ukpor Clay Content on the Properties of Synthetic Moulding Sand Produced from River Niger Sand. International Journal of Research in Advanced Engineering and Technology. 2015; 1(3):12-16.
4. Rundman KB. Metal Casting Reference Book for MY. 2000; 41(30):11-16.
5. Beeley PR. Foundry Technology, Butterworth-Heinmann. 2001; 4:178-236.
6. Edoziuno FO. Effects of Particle Size, Clay and Moisture Contents on the Properties of Moulding Sand.

Unpublished Master of Engineering (M. Eng) Thesis, Nnamdi Azikiwe University, Awka, Nigeria. 2016, 1-65.
7. Ademoh NA, Ahmed AT. Estimation of the Effect of Kaolin Clay Addition on the Mechanical Properties of Foundry Moulding Sand Bonded with Grade 3 and 4 Nigerian Gun Arabic (Acacia Species). Middle East Journal of Scientific Research. 2008; 3(3):126-133.
8. Brown JR. Foseco Ferrous Foundryman Handbook, Butterworth- Heinemann Publishers, Oxford. 1994, 3-6, 15-17, 27-85.
9. Jain PL. Principles of Foundry Technology, Tata McGraw-Hill Publishing Company Ltd, New Delhi. 2006; 3:55-151.
10. American Foundrymen's Society, AFS. Foundry Sand Handbook; the American Foundrymen's Society. Des Plaines, Illinois, 7th ed. 1963, 1-216.
11. Atanda PO, Olorunniwo OE, Alonge K, Oluwole OO. Comparison of Bentonite and Cassava Starch on the Moulding Properties of Silica Sand. International Journal of Materials and Chemistry. 2012; 2(4):132-136.
12. Ayoola WA, Adeosun SO, Oyetunji A, Oladoye AM. Suitability of Oshogbo Sand Deposit as moulding sand. The Kenya Journal of Mechanical Engineering. 2010; 6(1):33-41.
13. Okada T, Ikeuchi T. Characteristic of Synthetic Sand and Application of Refractory Coating. Foundry Practice 258, Foseco Japan Ltd, Magazine. 2013, 1-4.
14. Mclaws IJ. Uses and Specifications of Silica Sand. Research Council of Alberta, Report. 1971; 71(4):21-28.
15. Ayoola WA, Adeosun SO, Oyetunji A. Investigation into Foundry Properties of Oshogbo and Saki Silica Sand Deposits. Annals of Faculty of Engineering Hunedoara-International Journal of Engineering. 2013; 11(3):213-218.
16. Eze EO, Alli A, Thompson EO. Foundry Qualities and Application of Local Synthetic Sand Mixtures. Applied Clay Science. 1993; 7(6):493-507.
17. Ademoh NA, Abdullahi AT. Effect of the Variation of Moisture Content on the Properties of Nigerian Gum Arabic Bonded Foundry Sand Moulds. American-Eurasian Journal of Scientific Research. 2008; 3(2):205-211.