International Journal of Research in Advanced Engineering and Technology
Online ISSN: 2455-0876
www.engineeringresearchjournal.com
Volume 1; Issue 3; December 2015; Page No. 12-16

Effect of Ukpor clay content on the properties of synthetic moulding sand produced from River Niger sand

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Abstract
The effect of binder content on the moulding properties of Onitsha beach river Niger sand bonded with sUkpor clay has been studied. The samples were sourced from their deposits. Impurities and other foreign objects were removed by washing and sorting. The experimental samples were sieved and mixed in a Ridsdale laboratory sand mixer (Serial No: 845). AFS standard test specimens (50mm diameter by 50mm height) were prepared using Ridsdale laboratory sand rammer and six key moulding properties; green compression strength, dry compression strength, green shear strength, dry shear strength, green permeability and Mouldability were determined using a motor driven universal sand strength testing machine (Serial No: M8415), electric permeability meter (Serial No: 872) and mouldability tester. The results obtained showed a remarkable increase in green and dry strengths as the quantity of binder was increased from 10% to 12%. Further increase in the quantity of binder from 12% to 22% yielded a gradual increase in the strengths. High percentages of mouldability (90.57% to 97.36%) were obtained when the clay content was increased from 14% to 22%. The green permeability number showed a steady decrease from 11.00 to 7.00 as the quantity of the clay was increased from 10% to 22%. The results of moulding sand tests obtained from the produced synthetic moulding sand indicated that the sand could be used in the production of cast iron and non-ferrous alloys castings.

Keywords: Binder; dry strength; green strength; mouldability; Permeability.

1. Introduction
Moulding sand for ferrous and non-ferrous metals and alloys casting is usually sourced from natural deposit or from synthetic mix of refractory sand grains, binder and moisture (Tipper, 1958 and Ademoh *et al*, 2008) [17, 1, 2]. Each constituent is important in determining the properties of the moulding sand. With the use of natural sand, there is limitation and constraint to the extent of control on the principal ingredients of moulding sand; but with synthetic sand, the three major constituents are well-sellected to give desired properties within acceptable limits (Ademoh *et al*, 2008) [1, 2]. It has been demonstrated that the quality of casting is influenced significantly by moulding sand properties such as; green compressive strength, dry compressive strength, permeability and compactibility . All these properties invariably depend on such parameters as the quantity of binder used, amount of water and sand grain size (AFS, 1968, Ayoola *et al*, 2010 and Atanda *et al*, 2012) [3, 6, 5].

The function of the bonding material is to produce cohesion between the refractory sand grains in green or dry state. Bonding materials are not necessarily highly refractory, thus, the required strength must be obtained with minimum possible addition (Beeley, 2001) [7]. Many substances possess bonding quality, for example clays, starch compounds, silicates and numerous organic resins and oils, which may either be synthetic or natural. They may be used singly or in combination. Clay bonded sands are distinguished by the fact that they can be recycled in closed systems and the bond regenerated by the addition of water, while the action of most other binders is irreversible and the mould material has to be discarded after one production cycle (Beeley, 2001) [7]. The bonding materials are normally either in liquid form or much finer than the sand grains. There is generally a fall in permeability and rise in strength with increasing binder content, hence the reason for restricting the addition to the minimum consistent with adequate green and dry strengths (Grim *et al*, 1945) [11].

Moulding sands for traditional green and dry sand practice are commonly bonded with clay. Plasticity and bond strength are developed by the addition of required quantity of water. On drying, loss of adsorbed water produces shrinkage of the lattice and further strengthening of the bond, therefore, clay binders are effective in both green and dry condition (Beeley, 2001) [7]. According to the American Foundrymen's Society (AFS, 1968) [3] clays normally used in sand moulding are of three general types, depending on the chemical compositions, viz; montmorillonite or bentonite clays, kaolinite or fireclay, and illite. Efforts have been made by various researchers to characterise some local clays and suggest suitable areas of applications (Nnuka *et al*, 2003) [14].

2. Materials and Methods
2.1 Materials
Green silica sand from the Onitsha bank of river Niger and Ukpor clay were used to compose the moulding sand. The equipment used included 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 and laboratory core baking oven (with temperature range of 40 ^oC to 240 ^oC).

2.2 Methods

Impurities such as hard lumps, metals, stones and other foreign objects were removed from the natural silica sand by sorting and washing, while the lumps of the dried Ukpor clay were crushed and finely ground to pass through a 200 – 250 mesh size. The sand sample was sieved using a stack of standard test sieves mounted on a sieve shaker. 840 g of the sieved silica sand was placed in the laboratory sand mixer and the required quantity of the clay was sprinkled over it. The mill was started and the dry ingredients mixed for about 5minutes before the addition of required quantity of water. After mixing operation, AFS standard test specimens were prepared using Ridsdale laboratory sand rammer. Dry and green strengths (compression and shear) tests were carried out accordingly 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.

3. Results and Discussion

The results of the tests are shown in Tables 1 to 4 and figures 1 to 6.

Table 1: Sieve analysis and AFS grain fineness number (GFN) of Onitsha beach sand

S/N	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

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

The result from the sieve analysis (Table 1) indicated that more than 95% of the bulk sand was retained on the first few sieves. Thus, the sand deposit have met the American Foundrymen's Society (AFS) standard specification for sand casting (AFS, 1963 and Mclaws, 1971) [3, 13]. The grain fineness number (GFN) of the sand deposit is 40.01 and this grade of fineness number is suitable for most types of alloy steels and nonferrous metals as this belongs to the group of fineness number that has wide range of application according to Brown (1994) [8].

Table 2: Effects of clay content on the properties of moulding sand.

Clay Content (%) / Properties	10	12	14	16	18	20	22
GCS (KN/m^2)	17.50	30.80	34.30	35.70	42.70	56.70	57.40
DCS (KN/m^2)	255.50	567.00	577.50	591.50	609.00	609.00	637.00
GSS (KN/m^2)	17.50	18.20	20.30	21.00	21.00	38.50	38.50
DSS (KN/m^2)	70.00	73.50	77.00	77.00	80.50	82.00	84.00
Green Permeability No	11.00	9.50	8.50	7.80	7.50	7.40	7.00
Mouldability (%)	67.37	67.71	90.57	94.37	94.40	96.90	97.36

Note: GCS, DCS, GSS and DSS represent Green compression strength, Dry compression strength, Green shear strength, and Dry shear strength respectively.

Table 3: Moulding properties of the natural sand.

Sample	GCS (KN/m^2)	DCS (KN/m^2)	GSS (KN/m^2)	DSS (KN/m^2)	Green Permeability No	Mouldability (%)
Natural sand	19.25	70.10	56.00	87.50	8.00	97.75

The result presented in Table 2 revealed that the green permeability of the synthetic sand decreased from 11.00 at 10% Ukpor clay to 7.00 at 22% Ukpor clay, showing that permeability decreased with increasing binder content. This has been reported in recent research findings. (Nwajagu *et al*, 1989; Eze *et al*, 1993; Ademoh *et al*, 2008; Olasupo *et al*, 2009 and Khandelwal *et al*, 2014) [15, 10, 2, 16, 12].

The green and dry strengths (compression and shear) increased with increasing clay content. The dry compression strength exhibited a rapid increase from 255.50 KN/m^2 at 10% clay content to 567.00 KN/m^2 at 12% clay content and then displayed a gradual increase (567.00KN/m^2 to 637.00KN/m^2) from 12% to 22% clay content. Comparing the result with the standard property range for sand casting by Dietert (1966) [9] shows that from 12% clay content, the moulding sand is suitable for green and dry mould casting of aluminium and its alloys, brass, bronze, malleable and light grey iron. Figures 1 to 4 compared favourably to that given by Grim and Cuthbert (1945) [11] on the influence of binder content on strength of silica sand bonded with bentonites and this suggests inter-changeability of both binders.

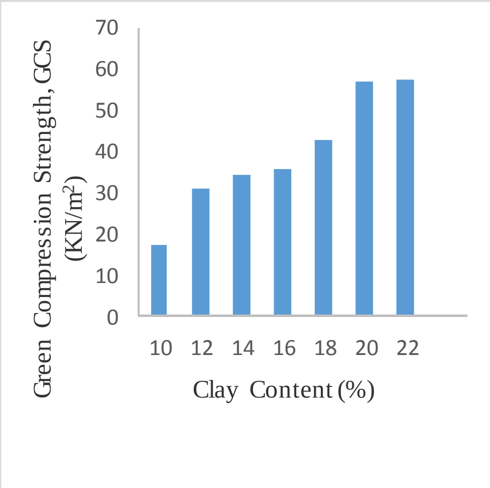

Fig 1: Effect of clay content on green compression strength (GCS)

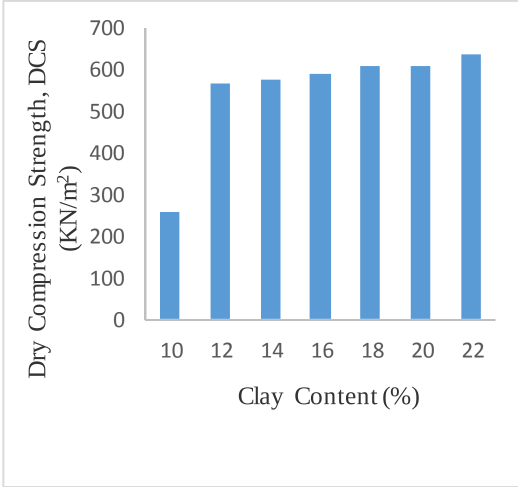

Fig 2: Effect of clay content on dry compression strength (DCS)

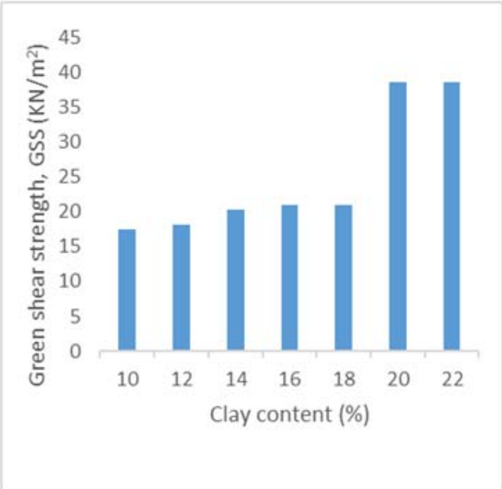

Fig 3: Effect of clay content on green shear strength (GSS)

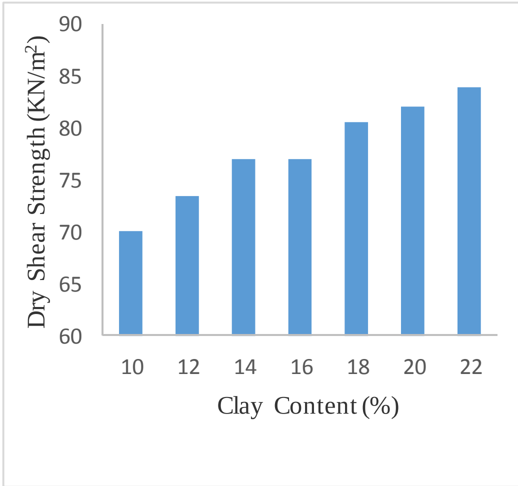

Fig 4: Effect of clay content on dry shear strength (DSS)

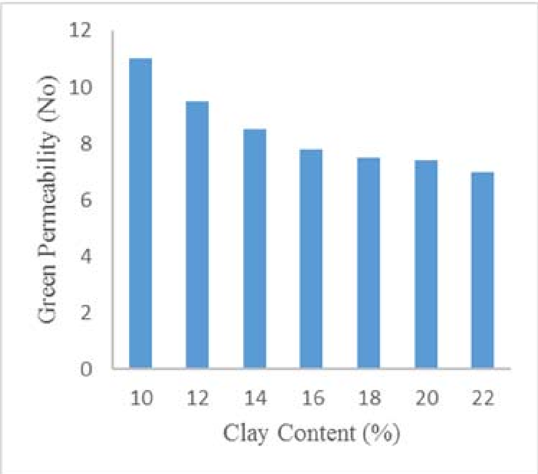

Fig 5: Effect of clay content on green permeability

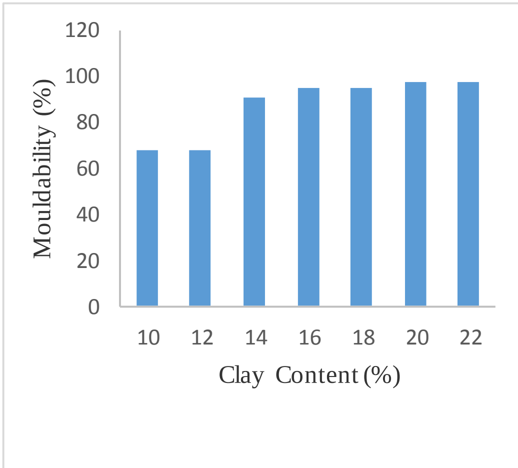

Fig 6: Effect of clay content on mouldability.

The mouldability also increased with increasing binder content showing the tendency to conform to moulding processes as the clay content is increased.

Table 4: Standard property range for sand casting of different alloys. (Dietert, 1966)

Metal	Green Compression Strength (kN/m^2)	Permeability (No)	Dry compression Strength (kN/m^2)
Heavy steel	70 - 85	130 - 300	1000 - 2000
Light steel	70 - 85	125 - 200	4000 - 1000
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 Grey Iron	50 - 85	20 - 50	200 - 550
Malleable iron	45 - 55	20 - 60	210 - 550
Medium Grey Iron	70 - 105	40 - 80	350 - 800

4. Conclusion and Recommendations

4.1 Conclusion

The following conclusions were made from the results of this investigation.

1. The amount of Ukpor clay used as binder affected the moulding properties of the foundry sand. The green and dry strength increased as the clay content increased from 10% to 22%. There was a remarkable increase in strength as soon as the clay content increased from 10% to 12%, then, a gradual increase in strength from 12% to 22% clay content. Results showed that improved properties of the mould were obtained when the sand was bonded with Ukpor clay than when the natural sand only was used.
2. The green permeability decreased steadily from 11.00 to 7.00 as the clay content was increased from 10% to 22%.
3. The mouldability of the foundry sand bonded with Ukpor clay increased as the clay content increased from 10% to 22%. High percentages of mouldability were recorded from 14% to 22% clay addition.
4. The grain size analysis showed that more than 95% of the bulk sand was retained on the first few consecutive sieves. Thus, river Niger silica sand (Onitsha deposit) met the AFS standard specification for foundry sand. The grain fineness number (GFN) of the sand deposit fell within the range recommended for wide application in sand casting.

4.2 Recommendations

Having studied the effects of this variable (clay content) on the moulding properties of moulds produced from River Niger sand (Onitsha deposit) bonded with Ukpor clay, some recommendations and new areas of research have been identified.

1. That Ukpor clay as a binder for river Niger sand (Onitsha deposit) is suitable for both dry and green sand mould casting of ferrous and nonferrous alloys from a minimum of 12% clay content to about 20% clay content.
2. Research should be carried out on the sand deposit using bentonite as binder to determine the effect on the properties of this sand.
3. The foundry sand prepared from river Niger sand (Onitsha deposit) and Ukpor clay should be used to produce ferrous and non-ferrous casting components and mechanical tests carried out on those components to determine the characteristics of the sand at both high and low temperatures and the effect on the mechanical properties.

5. Acknowledgement

The authors wish to acknowledge the assistance of National Metallurgical Development Centre (NMDC), Jos.

6. References

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