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ENGINEERING CHARACTERIZATION OF RIVER NIGER ONITSHA BEACH SAND FOR FOUNDRY APPLICATION

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Abstract
The Engineering Characterization of River Niger Onitsha Beach Sand has been undertaken with a view to finding its usefulness in the foundry industry. Chemical analysis was carried out using x-ray flurescence technique. Particle size analysis was conducted using electric sieve shaker. The mechanical properties of the moulding sand were tested using standard techniques (AFS). The mechanical properties tested were green compressive strength, green shear strength, dry compressive strength, refractoriness, moisture content and permeability. Results of the test obtained included: green compressive strength (31.65kN/m^2, 23.25kN/m^2), dry compressive strength (224kN/m^2, 220kN/m^2) permeability (141.15No, 143No), moisture content (3.80%, 3.55%), for bentonite and Ukpor clay respectively, with AFS grain fineness number (81.81), refractoriness (1388^{0}C) and fusion point (1390^{0}C) of River Niger Onitsha beach sand. From the result, it was found that 5% of bentonite and 5% of Ukpor clay respectively and then 5% water were most suitable for moulding river Niger Onitsha beach sand for application in non-ferrous foundry industry. These results demonstrated the possible utility of both binders for making sand casting moulds, and are therefore recommended for foundry application.
Keywords: *River Niger sand, Ukpor clay, bentonite, refractoriness, dry strength, casting.*

1.0 Introduction

Foundry sand mixtures for moulding purposes is expected to posses adequate green compression strength, permeability as well as dry strength (Onyeji, 2010). The required levels of these properties vary depending on the type of moulding, the types of metal cast, as well as the size and shape of casting (Mathew and Aku, 1983).

There have been various attempts by Nigerian researchers to develop local alternatives to imported foundry materials by determining their suitability for the production of sound castings. Most research in this area centred 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 (Ndaliman, 2002). Akinbode (1996) investigated the properties of termite hills as refractory material for furnace lining, and observed that the refractory properties of termite hill material like permeability, dimensional change and density were very similar to known refractory materials for furnace lining. Aliyu et al (2013), studied the chemical and physical characteristics of selected clay samples from three local government areas in Sokoto

State, Nigeria and found that the deposits could be processed for use in the paper and foundry industries.

The properties of moulding sand are influenced by the amount of additives such as coal dust, corn flours and clays and the ingredients such as binders and water (Ayoda et al, 2010). Foundry industries in Nigeria use imported binders and synthetic sand for production. According to Akintunde and Omole (2008), sand suitable for moulding consists largely of grains of silica (SiO_2) together with 5-6% clay to act as a binder. Binderbility of moulding sands, determined by the amount of binder present in it, is one of the requirements for effective performance of the sand for moulding. For both naturally occurring and synthetic sand moulds, the quality of casting is influenced significantly by sand properties such as green compression strength, dry compression strength, permeability, compactibility, moisture content and others. All these properties are in turn dependent on the sand parameters of the binder used, water and sand grain size (Ditert, 1966). Satisfactory mould property ranges for sand casings of various metal grades is shown in Table 2. Development of Igbokoda clay in the south western part of Nigeria as a binder for synthetic moulding sand was carried out by Loto and Motoso (1990). Their results confirmed that Igbokoda clay had good value as a binder for synthetic moulding sand. Aramide et al (2011) also investigated the effects of binders (bentonite and dextrin) and water on the properties of recycled foundry sand made from silica sand obtained from Ilaro sand deposit of Ogun State Nigeria. They discovered that with minimum additives of binders recycled Ilaro sand can be reused. Katsina el al (2013) studied the characterization of Beach/River sand for foundry application and discovered that samples from Ughelli River, Warri River and Ethiope River could be used effectively in the foundry. However, the sand from Lagos bar beach required to be sieved properly to remove the coarse fractions.

This work, seeks to address the suitability of River Niger Onitsha beach sand for possible foundry application using bentonite and Ukpor clay as binders.

2.0 Materials and Method

All the materials required for this research were sourced locally. The silica sand was sourced from River Niger beach Onitsha, while the binding clay was sourced from Ukpor in Nnewi South Local Government Area both in Anambra State. Each of the test specimens from the various mixtures were subjected to the relevant sand mould test such as chemical analysis of River Niger Onitsha beach sand, sieve analysis, green compression strength, green shear strength, dry compression strength, dry shear strength, moisture content, refractoriness and permeability tests.

2.1 Sieve Analysis

The stocks of sieve were arranged according to the sieve aperture with the largest aperture on top of the stock and the smallest aperture at the bottom. 1000g of sand dried in the air was put into the top sieve stock. The stocks were placed on a sieve shaker which was then switched on, and allowed to vibrate for a period of thirty (30) minutes. The sieves were removed one after the other beginning with the one on top. The quantity of sand remaining in each sieve was weighed. The weight was recorded for each sieve in the column corresponding to the sieve mesh serial number (1.00mm, 0.71mm, 0.50mm, 0.18mm, 0.125mm, 0.09mm and 0.063mm). Each sieve weight was multiplied by the corresponding sieve mesh number. The sum total of the product was divided by the total sample aligned and this produced the fineness number of the sand.

2.2 Chemical analysis

The chemical composition of the samples (River Niger sand and Ukpor clay) was determined sing X-ray florescence (XRF) spectroscopy technique. The samples were dried in an oven at 60^0C for 30mins and milled into powder sample of particle size 100mesh (0.15micron), recommended for XRF analysis. The equipment was allowed to run for 5 hours with the recommended voltage and current of 45volts and 40A respectively, to enable the standards and other mechanical parts responsible for analysis to stabilize and initialized for XRF test.

2.3 Determination of green compression strength

The green compression strength was carried out using universal sand strength testing machine (model: 6903). A prepared standard sample was positioned in the compression head already fixed into the machine. The sample was loaded gradually, while the magnetic rider moved along the measuring scale. As soon as the sample reached its maximum strength, the sample experienced failure and the magnetic rider remained in position of the ultimate strength (a value was noted), while the load was gradually released.

2.4 Determination of dry compression strength

A prepared standard sample of 5cm diameter x 5cm height was dried in the oven at a temperature of 110^oC for a period of 20minutes and then removed and allowed to cool in the air to ambient temperature. After cooling, the sample was fixed onto the universal sand-testing machine (model: 6903) with the compression head in place. The compressive load was applied and the samples failed at the ultimate compressive strength of the sample. The point at which the failure occurred was recorded at DCS

2.5 Determination of dry shear strength (DSS)

The prepared standard sample of 5cm diameter x 5cm height was dried in the oven at a temperature of 110^{o}C for 20 minutes and then removed from the oven to cool an air to ambient temperature. The same universal testing machine was used for dry compression strength. In this case, the shear head was replaced for the compression head. The shear strength was recorded at the point of failure of the standard test sample.

2.6 Determination of green shear strength (GSS)

The machine used for the GCS was also used for the determination of (GSS), except that the compression head was replaced with shear head in the machine. The green shear strength was recorded at the point of failure of the sample loaded

2.7 Determination of permeability

The permeability test was done on the standard sample specimen of 5cm diameter x 5cm height. The specimen, while still in the tube, was mounted on a permeability meter. The permeability meter is an electrical perimeter and it employed the orifice method for rapid determination of sand permeability. Air at a constant pressure was applied to the standard sample specimen, immediately after producing the sample and the drop in pressure was measured using a pressure gauge, calibrated directly in permeability numbers.

3.0 RESULTS AND DISCUSSION

Table 3 gives the chemical analysis result of the River Niger Onitsha beach sand, from the Table 3, it is evident that silica is the predominant component in the River Niger Onitsha beach sand. This is of good advantage since high percentages of silica in sand (Richard et al 1983), usually enhance its refractory and thermal stability, while it is noted that the presence of iron oxide, potassium oxide and sodium oxide can course objectionable lowering of the fussion point in sands. From the Table 3, the silica content of 94.49% compares well with the acceptable values of between 80% and 97% recommended for moulding (Jain, 2008), but cannot be used for ferrous castings because according of Mclaws (1971) ideal sand for ferrous castings should contain silica in the region of 98% - 99%. It can also be seen from the Table 1 that the percentage of SiO_2 content for Chelford, Warri and Ughellium River sand samples are very close to that of River Niger Onitsha beach sand sample. Table 4 and figure 1 showed the parameters of River Niger Onitsha beach sand and AFS grain fineness number, from the Table 4, it was shown that the grain fineness number falls within the acceptable range. According to the American foundrymen's society (AFS) Standard (1963) that 40 to 330 average fineness is suitable for foundry application. The River Niger Onitsha beach sand has average fineness number of 81.81 as shown in Table 4. From the figure 1, it was seen that the grain is distributed in all the screens and about 70.85 percent concentrations of the sand grains retained by the three adjacent sieves of 0.18mm, 0.125mm and 0.09mm.

Moulding experiments using Ukpor clay and bentonite as binder at varying composition were carried out to determine the basic mechanical properties such as the refractoriness, permeability, compactibility, dry compressive strength, dry shear strength, and moisture content of the moulded River Niger Onitsha beach sand. The variation of water content with the values of green compression strength increases with increase in percentage water addition as is shown figure 2. Green strength increases steadily from 15.90kN/m^2 at 1% water reaching a maximum value of 31.65kN/m^2 at 5% water content for bentonite sample. The maximum value of green compression strength of 23.25kN/m^2 was obtained at percentage water content of 5%. Dry compressive strength increased from 182.00kN/m^2 at 1% water content to 224.00kN/m^2 at 5% water content addition for bentonite sample, while Ukpr clay sample, increased from 180kN/m^2 at 1% water to 220.00kN/m^2 at 5% water content. This increase in the dry compressive strength with increase in water content shows that the sand can absorb more water.

These dry compressive values were in agreement with the American Foundrymen's Standard (AFS) shown in Table 2.

The green shear strength permeability and dry shear strength test were determined as shown in Tables 5 and 6. The moisture content values increased with increase in water concentration for both binders with bentonite sample having greater values as shown in figure 7 when mixed with 1% water, the moisture contents are 1.30% and 1.01% respectively for bentonite and Ukpor clay sample. These values increased to 3.80% and 3.55% at 5% water addition respectively for bentonite and Ukpor clay sample. These values increased to 3.80% and 3.55% at 5% water addition respectively for bentonite and Ukpor clay sample.

The variation of water content with the values of compactibility, increases with increase in percentage addition as shown in figure 8. From the figure, bentonite sample records higher values of 30.80% at 5% water addition compared to 27.40% recorded for Ukpor clay sample at 4% water addition. The bentonite sample shows a high value of compactibility number than the Ukpor clay sample by about 3.4%. The refractoriness of the pure silica sample is 1388^{0}C. The refractoriness gives important information about the thermal resistance of the sand. It showed that the sand is mainly suitable for non-ferrous metals with melting point lower than 1390^{0}C.

Table 1: Chemical Composition of some Foundry Sands

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

Source: (Dietert .1954)

Table 2: Satisfactory Mould Property Ranges for Sand Castings

Metal	Green compressive strength (kN/m^2)	Dry strength (kN/m^2)	Permeability (No)
Heavy steel	70 – 85	1000 – 2000	130 – 300
Light steel	70 – 85	400 – 1000	125 – 200
Heavy grey iron	70 - 105	50 – 800	70 – 120
Aluminium	50 – 70	200 – 550	10 – 30
Brass and Bronze	55 – 85	200 – 860	15 – 40
Light grey iron	50 – 85	200 – 550	20 – 50
Malleable iron	45 – 55	210 – 550	20 – 60
Medium grey iron	70 – 105	350 – 800	40 – 80

Source: (Dietert 1966)

Table 3: Chemical analysis of River Niger Onitsha beach sand

Compound	SiO_2	K_2O	CaO	TiO_2	V_2O_5	MnO	Fe_2O_3	NiO	CuO
Conc. unit	94.49 %	1.30 %	0.475 %	0.341 %	0.012 %	0.027 %	1.675 %	0.0058 %	0.001 %
Compound	Ag_2O	BaO	Nd_2O_3	OSO_4	Au	HgO			
Conc. unit	0.904 %	0.052 %	0.049 %	0.14 %	0.23 %	0.30 %			

Table 4: Parameters of River Niger Onitsha Beach sand and AFS fineness number

Sieve Serial No	Apperture size in (mm)	Sand Retained on each sieve(g)	Percentage of sand retained	Multiplier	Product
1	1.00	9.8	0.98	9	8.82
2	0.71	10.5	1.05	15	15.75
3	0.50	40.2	4.02	25	100.50
4	0.355	95.2	9.52	35	333.20
5	0.25	44.7	4.47	45	201.15
6	0.18	340.5	34.05	60	2043
7	0.125	205	20.50	81	1660.5
8	0.09	163	16.30	118	1923.4
9	0.063	55.0	5.50	164	902
10	Pan (-63)	36.1	3.61	275	992.75
11		1000	100		8181.07

$$A.F.S.\,grain\ fineness\ number = 81.81$$

Table 5: Properties of mould sand mixtures with 5% bentonite constant

Water%	1	2	3	4	5
Green strength(KN/m2)	15.90	23.10	27.88	28.00	31.65
Green shear strength(KN/m2)	4.06	5.07	6.48	6.80	7.09
Dry compressive strength(KN/m2)	182.00	190.00	212.00	217.00	224.00
Dry shear strength(KN/m2)	54.00	60.00	66.00	73.00	76.00
Permeability (No)	146.23	146.40	146.50	146.64	141.15
Moisture content (%)	1.30	1.80	2.00	3.11	3.80
Compactibility (%)	18.40	25.10	28.10	30.50	30.80

Table 6: Properties of mould sand mixture with 5% Ukpor clay constant.

Water%	1	2	3	4	5
Green strength (kN/m^2)	15.30	21.90	23.40	23.48	23.25
Green shear strength (kN/m^2)	2.80	4.00	4.00	4.91	4.90
Dry compressive strength (kN/m^2)	180.00	189.00	203.00	215.00	220.00
Dry shear strength (kN/m^2)	50.00	57.00	61.00	61.00	68.00
Permeability (No)	145.14	146.00	148.40	148.55	148.00
Moisture content (%)	1.01	1.30	1.41	2.94	3.55
Compactibility (%)	15.50	21.30	25.20	27.40	27.00

Refractoriness of pure silica sand: 1388^{0}C

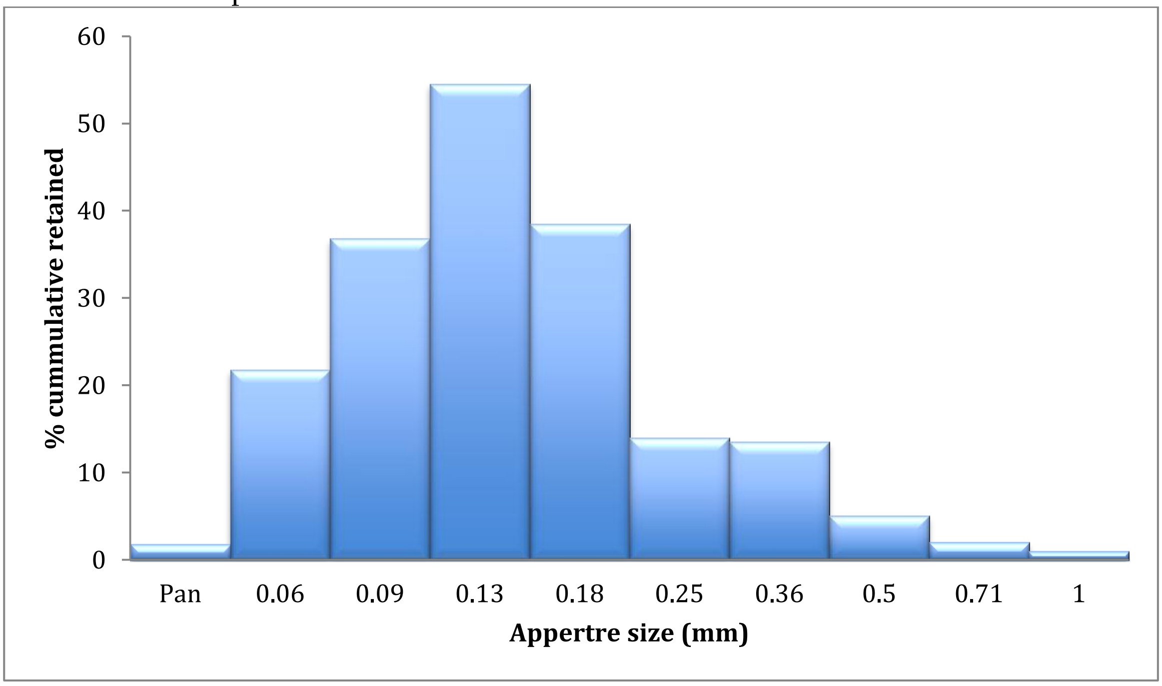

Fig. 1 shows the cumulative percentages retained on each aperture size

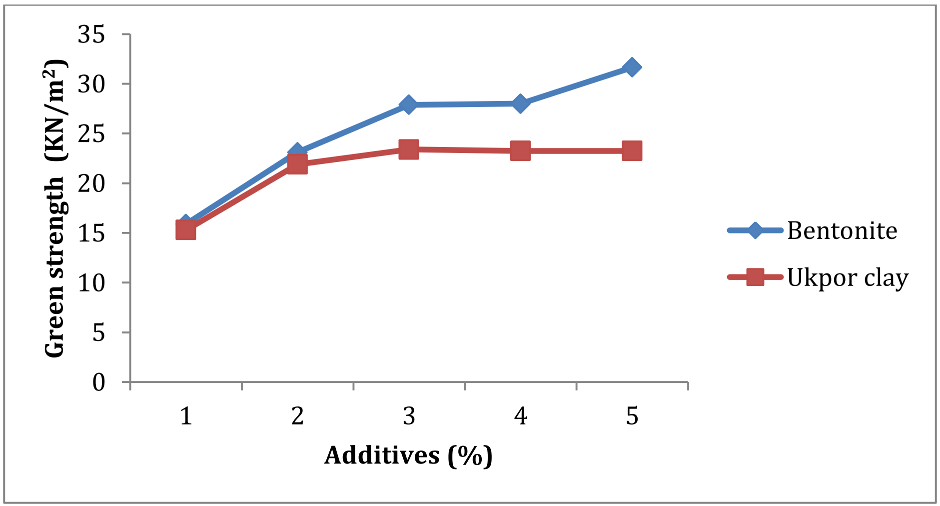

Fig 2: Effect of additives on the green compression strength and 5% water constant

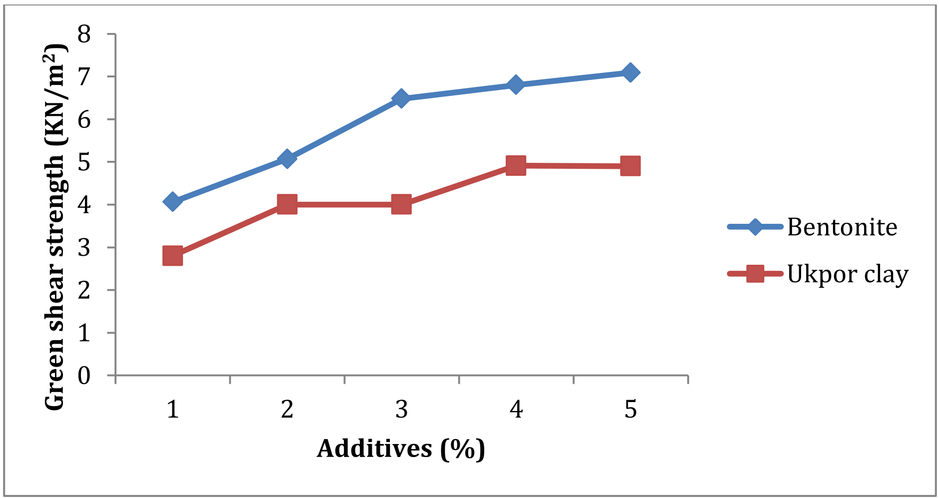

Fig 3: Effect of additives on the green shear strength and 5% water constant

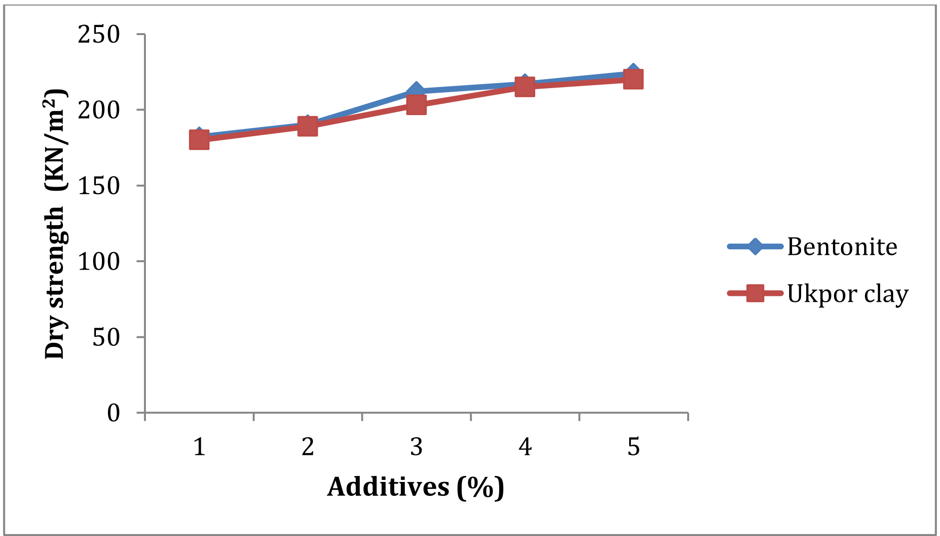

Fig 4: Effect of additives on the dry strength and 5% water constant

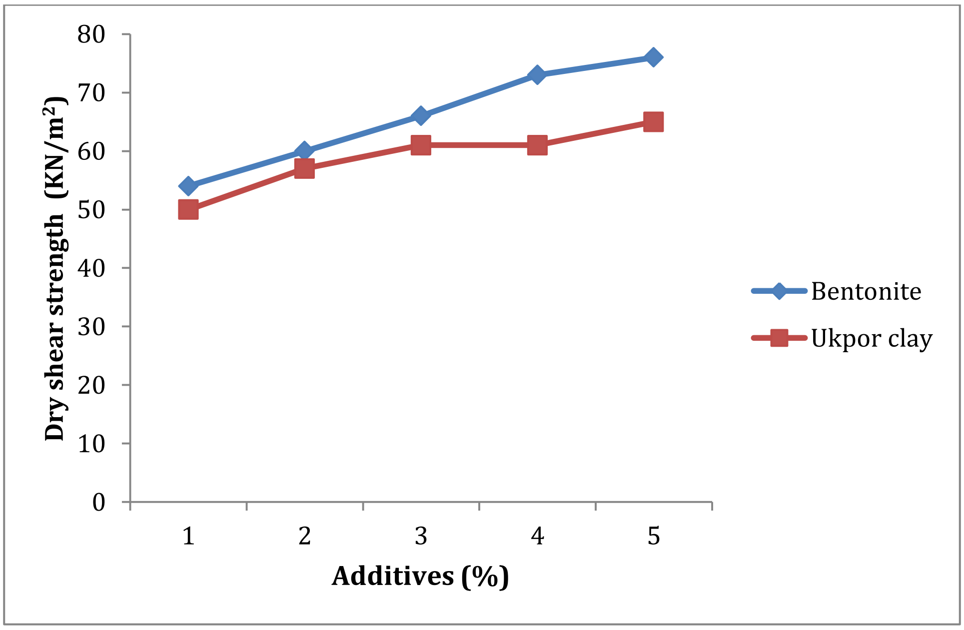

Fig 5: Effect of additives on the dry shear strength and 5% water constant

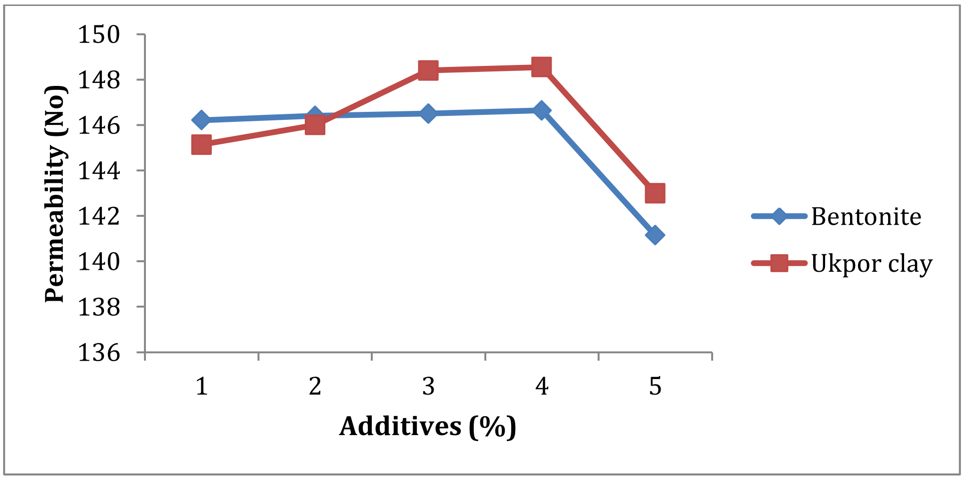

Fig 6: Effect of additives on the permeability and 5% water constant

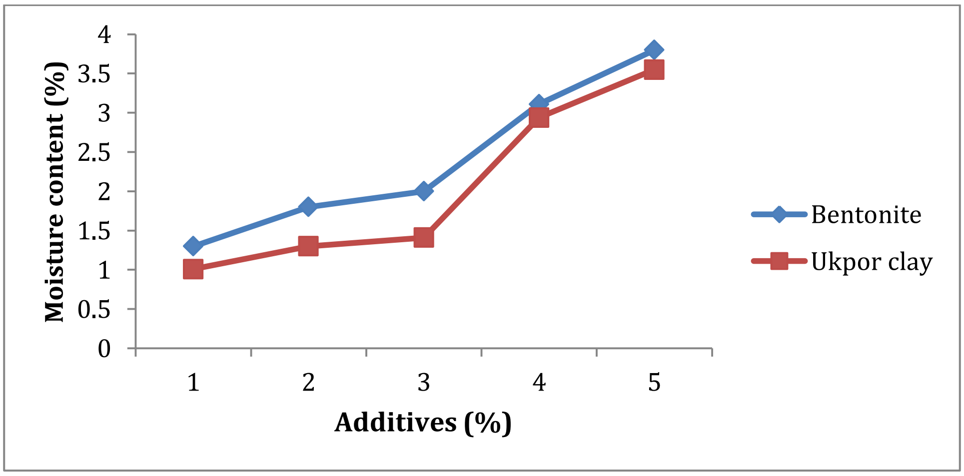

Fig 7: Effect of additives on moisture content and 5% water constant

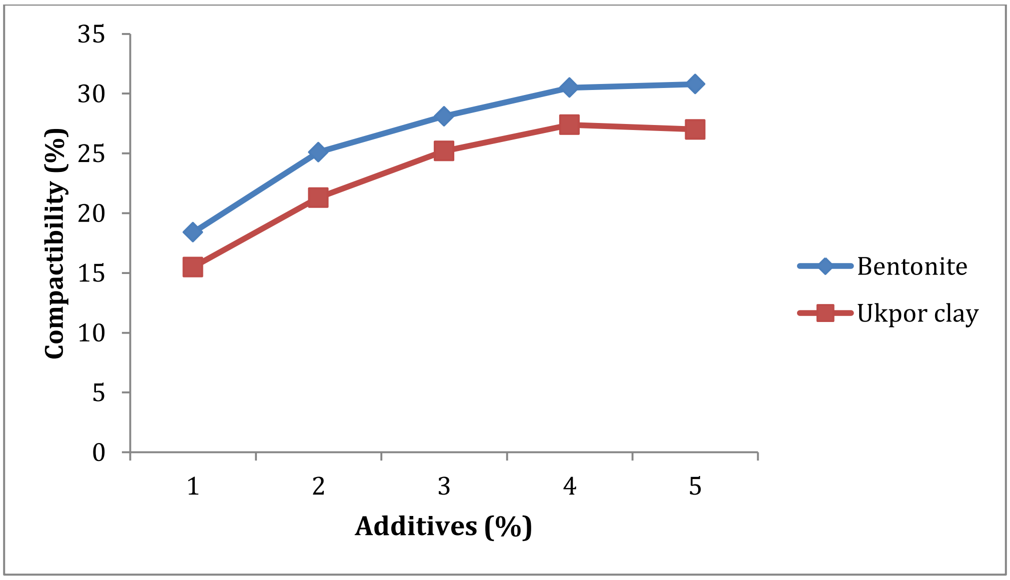

Fig 8: Effect of additives on compatability and 5% water constant

Conclusion

This study has shown that

- Ukpor clay is recommended for use in the foundry industry as replacement for imported bentonite
- The chemical analysis showed that the River Niger Onitsha beach sand is composed predominantly of silica (94.49%) but not in the range that could be used for steel and other heavy metals foundry
- The sand mix with 5% bentonite and 5% water content was the best followed by 5% Ukpor clay and 5% water content. These properties compared favourable with the proportion of the moulding sand currently used in foundries for casting of non-ferrous alloys.
- Further research aimed at determining the binding properties of other cheap locally available moulding materials is suggested.

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