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# Influence OfBentonite On The Foundry Moulding Properties Of River Niger Onitsha Beach Sand

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***ABSTRACT***
*The efficacy of moisture content and possibility of improving the bonding capacity of the River Niger OnitshaBeach sand using bentonite wereinvestigated. Chemical analysis was conducted using the X-ray florescence technique. The mechanical properties of the moulding sand were tested using standard techniques. The mechanical properties tested were green compressive strength, green shear strength, dry compressive strength, dry shear strength, conpactibility,refractoriness and permeability test using American Foundrymen Society Standard. The results obtained showed that green compressive strength was 25.8kN/m$^3$,green shear strength was 5.2kN/m$^2$, dry compressive strength was 213.00kN/m$^2$, dry shear strength was 74.00kN/m$^2$, Refractoriness was 1388$^0$C, permeability 152.00 (No), compactability was 27.10%. From the results, it was found that 4% bentonite and 4% water content were suitable for moulding River Niger Onitsha Beach sand for application in non-ferrous foundry, as they improved the foundry properties of the sand.*

***KEYWORDS:*** *Moisture content, moulding sand, improvement, dry compressive strength, binder.*

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## I. INTRODUCTION

Mouldingsand is made up of silica groups. The mineral silica ($SiO_2$) is characterized by high refractoriness with melting point of 1710$^0$C – 1713$^0$C,high hardnessand good chemical stability. For this reason, silica sand is the main component part of most mouldingmixtures[1]. Foundry sand mixtures for moulding purposes should possess certain properties like green compressive strength, dry shear strength, dry compressive strength, dry shear strength, permeability[2].

The required levels of these properties vary depending on the type of moulding, the type of metal casting, as well as the size and shape of casting[3]. Foundry sand for metal casting is usually sourced from either natural deposit or synthetic mix of refractory sand grain, binder and moisture[4]. Each of the mix constituent is important in determining the characteristics of sand[5]. The binding agent is responsible for bindability thereby determining the size of voids by sand grain while moisture level determines the plasticity of the mouldingsand[6]. Development of Igbokoda clay in the south western part of Nigeria as a binder for synthetic mouldng sand was carried out by Loto and Omotoso (1990)[7]. Their results confirmed that Igbokoda clay had good value as a binder for synthetic moulding sand. Fatai et al (2011)[8] also investigated the effects of binders (bentoniteand dextrin) and water on the properties of recycled foundry sand made from silica sand obtained from Ilaro sand deposit of Ogun state, Nigeria. They found that with minimum additives of binders recycled Ilaro sand can be reused.

Katsina and Reyazul (2013)[9] studied the characteristics of Beach/River sand for foundry application and observed that samples from Ughelli River, Warri River and Ethiope River could be used effectively in the foundry and the sample from Lagos bar beach required to be sieved properly to remove the coarse fractions in order to make it suitable for foundry uses.

Ayoda et al (2010)[10] investigated the suitability of Oshogbo sand deposit as moulding sand. The samples, investigated consisted of washed and unwashed sands prepared from control moulding sand sample. The result, obtained showed peak values for the green compressive strength of the washed and unwashed sand, and peak values for the permeability and shatter index of the washed sand, with set amount of binding bentoniteand coal dust additives as well as water in both cases and thus demonstrated the possible utilization of the sand for making sand casting moulds.

This work seeks to address the suitability of River Niger Onitsha Beach sand for possible foundry uses using bentonite as binder.

## II. MATERIALS AND METHOD

### 2.0 Materials

The silicon sand used for this research was obtained from the River Niger Onitsha Beach sand. The bentonite used as binder was purchased from Ogbete Main Market Enugu, in Enugu North Local Government Area, Enugu State-Nigeria. The tests 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.

### 2.2 Method:

### 2.3 Chemical analysis

The chemical analysis of the samples was determined using X-ray florescence (XRF) spectroscopy technique. The samples were dried in an oven at $60^0$C 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.

### 2.4 Determination of green compression strength GCS

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.

### 2.5 Determination of dry compression strength

A prepared standard sample of 5cm diameter x 5cm height was dried in the oven at a temperature of $110^o$C 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

### 2.6 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.

### 2.7 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

### 2.8 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.

### 2.9 Refractoriness

The sand for the refractory test was mixed with the desired quantities of binders and water. The mixture was moulded into cone shape and then dried in oven at $110^0$C. This was followed by sintering the cone shaped sample in the furnace to a temperature of $1000^0$C. The standard pyrometric cones of known softening temperature and the prepared sample were arranged in the furnace to test for the refractoriness. The cones were heated gradually until softening of the cones was observed. The softening point of the pyrometric cones which corresponded with the time of the softening of the test sample was recorded. The temperature at which this occurred was recorded as the refractoriness. After this, the fusion point was also observed and noted.

## III. RESULTS AND DISCUSSION

The results of the tests conducted are presented in Tables 2-3 and figures 1-7. Table 2 and fig. 1 show the result of the chemical analysis of the River Niger Onitsha Beach sand. From fig. 1, it was indicated that the River Niger Beach sand contains 94.49% $SiO_2$, 1.30% $K_2O$ and 1.675% $Fe_2O_3$ as the major components. The silica content of 94.4% compared very well with the accepted standard values of between 80% and 97% recommended for moulding (Jain, 2008)[11}, but cannot be used for ferrous castings because according to Mclaws (1971)[12] ideal sand for ferrous castings should contain silica in the range of 98% - 99%. Silica being the predominant component in the River Niger Onitsha Beach sand is of good advantage, since higher percentages of silica in sand according to Richard et al (1983)[13] usually enhance its refractoriness and thermal stability. It was a measure of refractoriness and thermal stability that dictates the alloy the sand will be suitable for casting. This implies that River Niger Onitsha Beach sand mainly will be suitable for casting metals and alloys with melting point lower than $1390^0$C. It can also be seen from the Table 1 that the percentage of $SiO_2$ content for Chelford, Warri and Ughellium River sand sample are very close to that of River Niger Onitsha Beach sand sample.

Result of the moulding experiment using 4% bentonite and varying percentages of water is presented in Table 3. This was carried out to determine the efficacy of moisture content on the basic mechanical properties such as the green compressive strength, green shear strength, dry compressive strength, dry shear strength, permeability and compactibility of the moulded River Niger Onitsha Beach sand. Green compressive strength increased with increase in moisture content, reaching a maximum at 4% water content. Thereafter, it decreased as shown in Table 3. and figure 2. The green strength increased from 16.08KN/$m^2$ at 1% water content to 25.80KN/$m^2$ at 4% water content, thereafter decreased to 25.72 KN/$m^2$ at 5% water content. Further increase in the percentage of water content above 4% led to reduction in the green compressive strength. Reduction in green compressive strength with increase in water content suggested the presence of excess moisture in the sand mould. The maximum moisture content of 4% is adequate to produce sand cast product with 4% bentonite content base on green sand property.

The green shear strength of the moulded River Niger Beach sand mixture increased as the water content introduced increased, thereby decreased as shown in Table 3 and figure 3. The green shear strength was observed to increase from 4.0KN/$m^2$ at 1% water content to 5.20 KN/$m^2$at 4% water content addition. Thereafter, it decreased to 5.15 KN/$m^2$ at 5% water content.

The dry compressive strength of the moulding mixture was observed to increase from 170.75 KN/$m^2$ at 1% water content to 213.00 KN/$m^2$ at 5% water content. This indicated that sand in dry condition can withstand the pressure of 200 KN/$m^2$ of the molten metal during the period of solidification in the mould, once the mouldingwater was at the maximum content. This makes the dry moulding sand to be more suitable for large castings. This property evaluated is in agreement with the American Foundrymen society standard AFS. The dry shear strength of the mixture was observed to increase with the increase in the water content addition reaching a maximum value of 74.00 KN/$m^2$ at 5% water content (fig. 5). Fig. 6 shows the effect of moisture content on the permeability of the moulded sand mixture, as the percentage water content increased. The permeability was observed to increase from 150.00 (No) at 1% water to 152.00 (No) at 2% water content, thereafter decreased to 140.00(n) at 5% water content addition. This behaviour could be attributed to the fact that water acts as blockage to the air pores in the sand thereby impedingthe free passage of air through the sand. As water content increased, the excess moisture available occupies the pores in the sand mould thus, leading to a corresponding decrease in the permeability of the sand. Fig 7 shows the effect of moisture content on the compatibilityof the moulded sand mixture. It was observed that the compatibility test increased as the water content introduced increased, thereafter decreased as shown in the fig. 7

The compatibility increased from 18.60% at 1% water content to 27.10% at 4% water content, thereafter decreased to 25.05% at 5% water content.

**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: 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 3: Properties of moulding sand mixture with 4% bentonite content**

| Water % | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Green compressive strength ($KN/m^2$) | 16.08 | 23.05 | 25.70 | 25.80 | 28.72 |
| Green shear strength ($KN/m^2$) | 4.0 | 5.07 | 5.10 | 5.20 | 5.15 |
| Dry compressive strength ($KN/m^2$) | 170.75 | 185.00 | 194.00 | 210.00 | 213.00 |
| Dry shear strength ($KN/m^2$) | 53.00 | 58.00 | 64.00 | 68.00 | 74.00 |
| Permeability (No) | 150.00 | 152.00 | 151.00 | 146.90 | 140.00 |
| Compactibility (%) | 18.60 | 24.20 | 27.10 | 27.10 | 25.05 |
| Refractoriness | $1388^0C$ | | | | |
| Fusion point | $1390^0C$ | | | | |

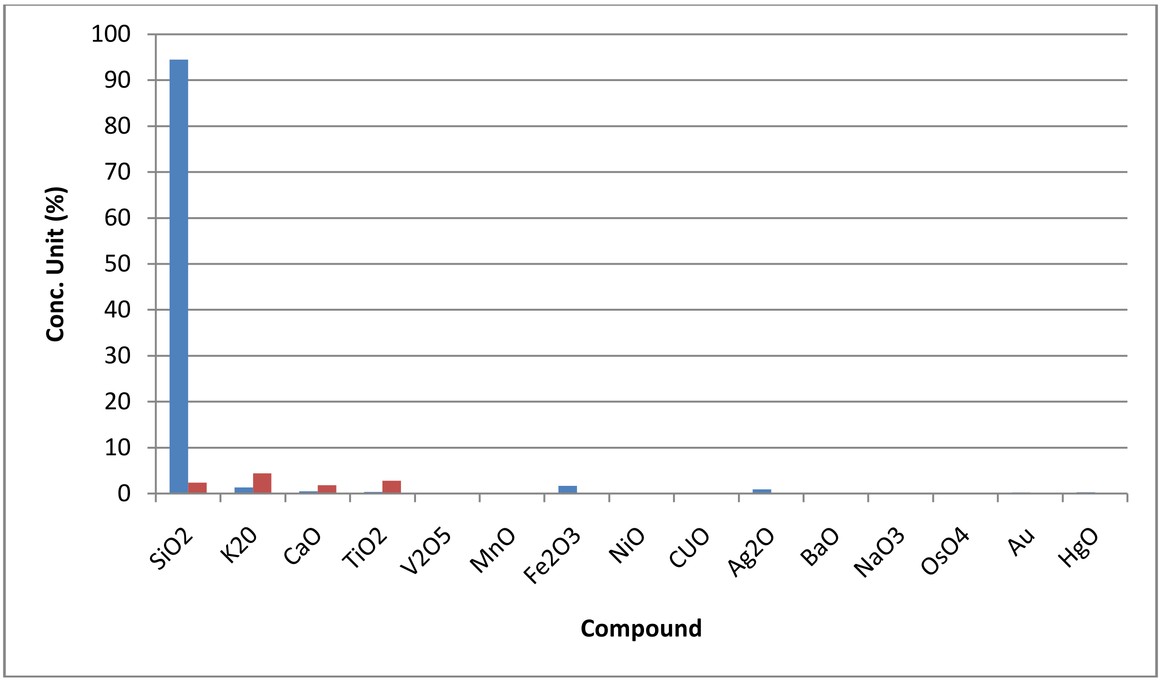


**Fig. 1: Chemical composition of River Niger Ontisha Beach Sand**

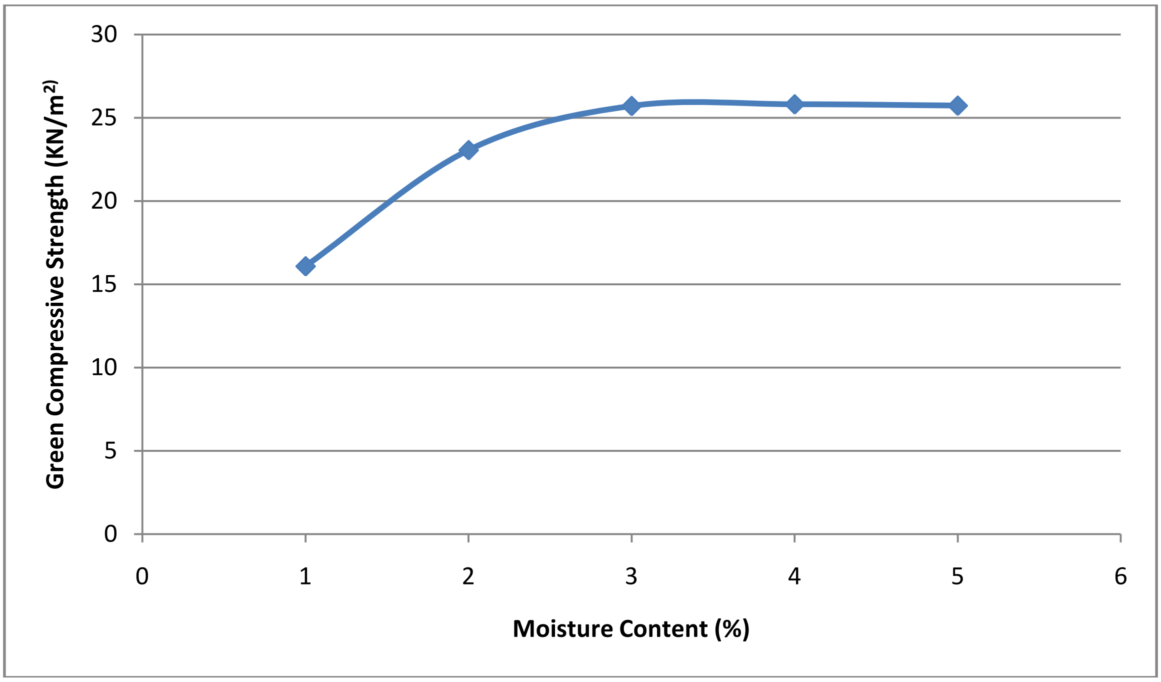


**Fig 2: Effect of moisture content on green compressive strength of River Niger Onitsha beach sand**

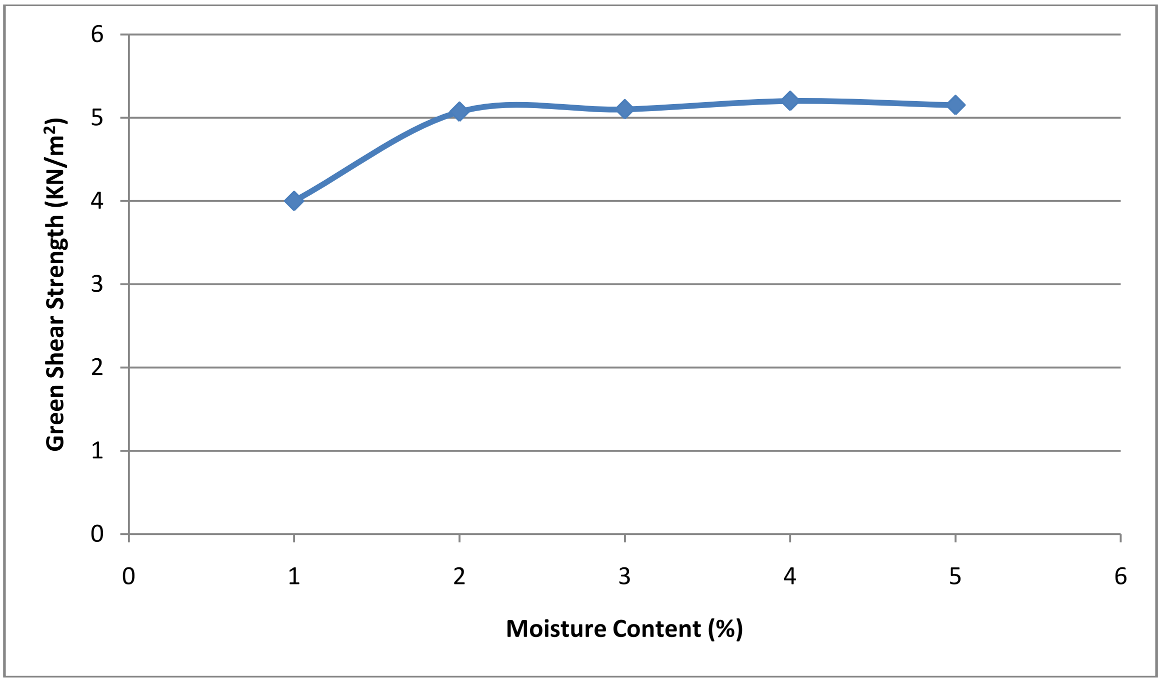


**Fig 3: Effect of moisture content on green shear strength of River Niger Onitsha beach sand**

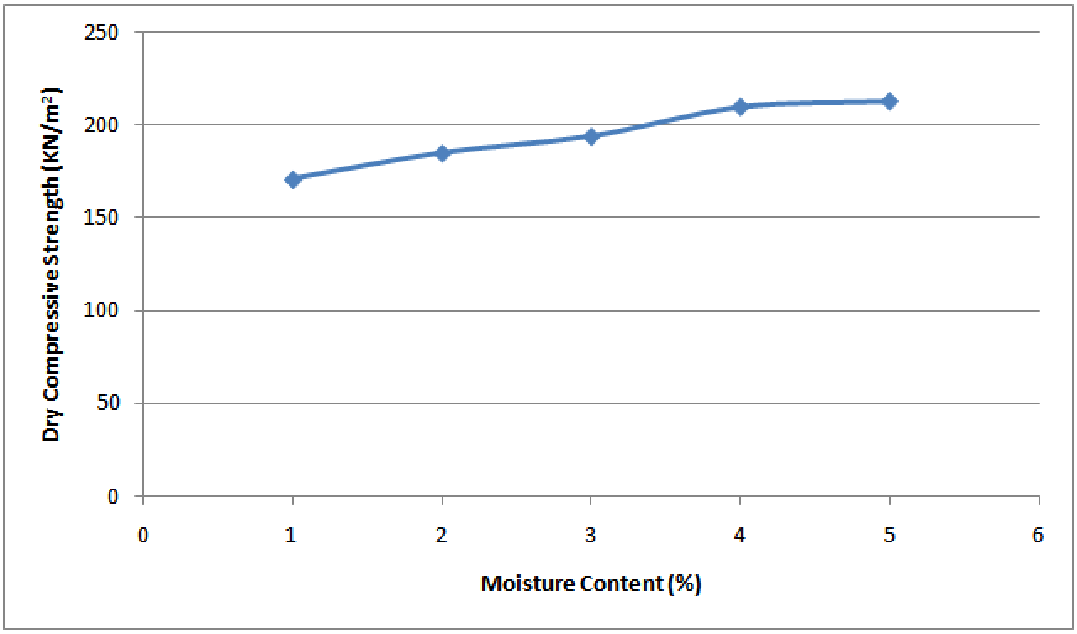


**Fig 4: Effect of moisture content on dry compressive strength of River Niger Onitsha beach sand**

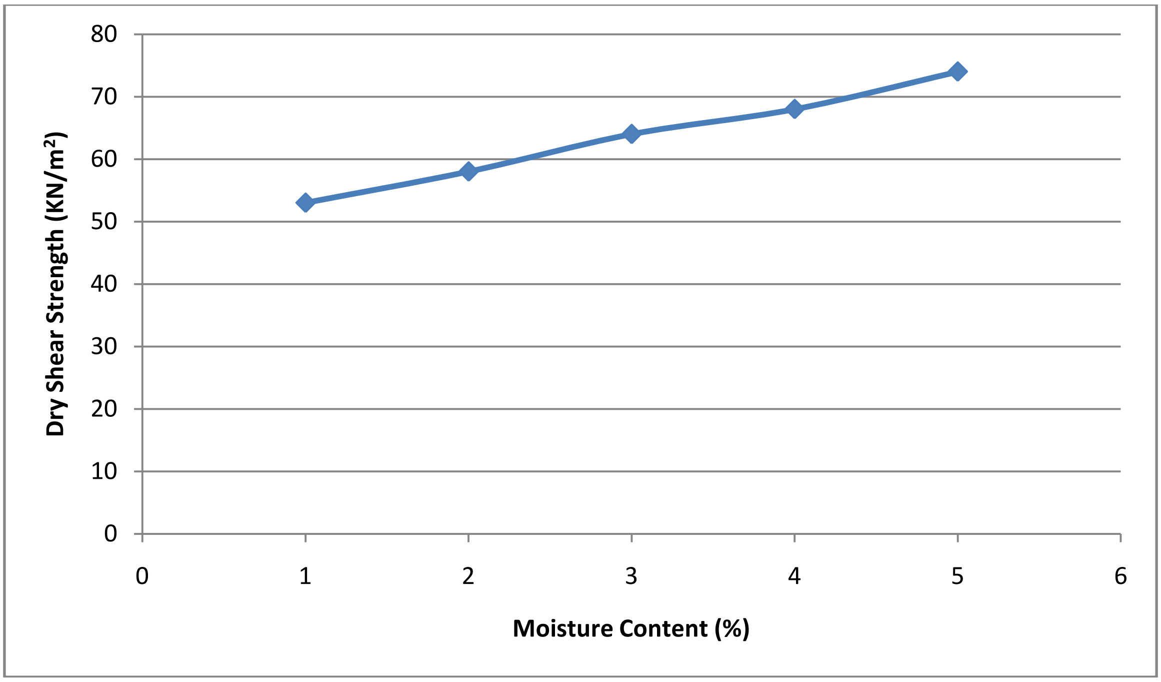


**Fig 5: Effect of moisture content on Dry shear strength of River Niger Onitsha beach sand**

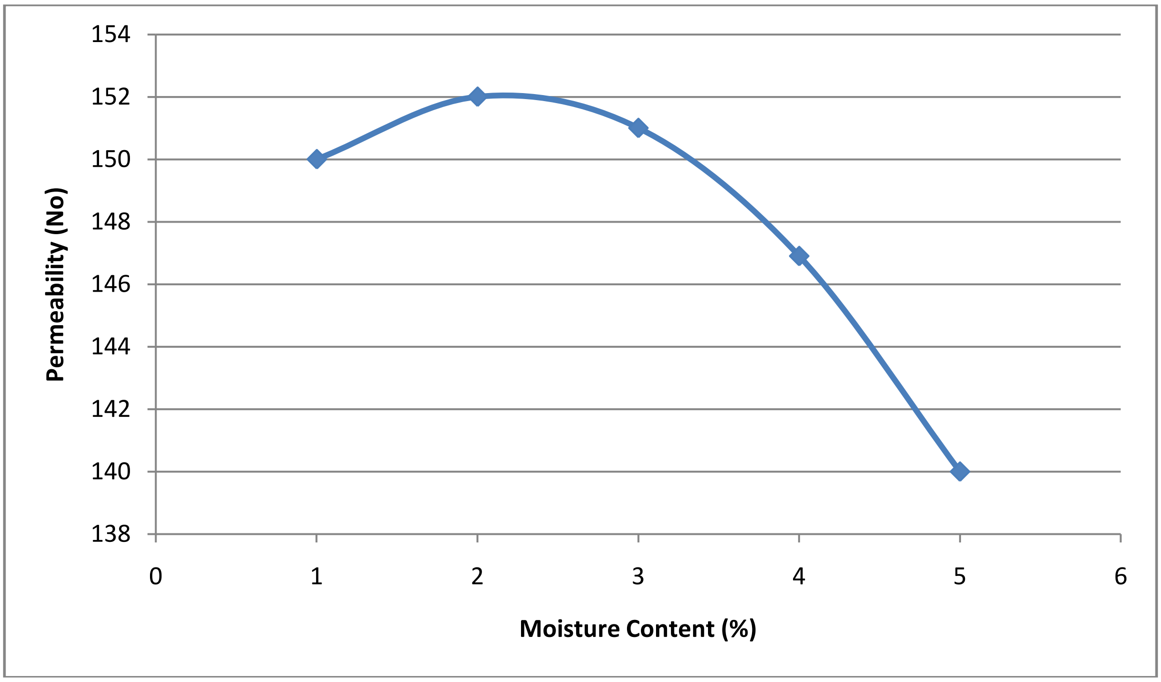


**Fig 6: Effect of moisture content on permeability of River Niger Onitsha beach sand**

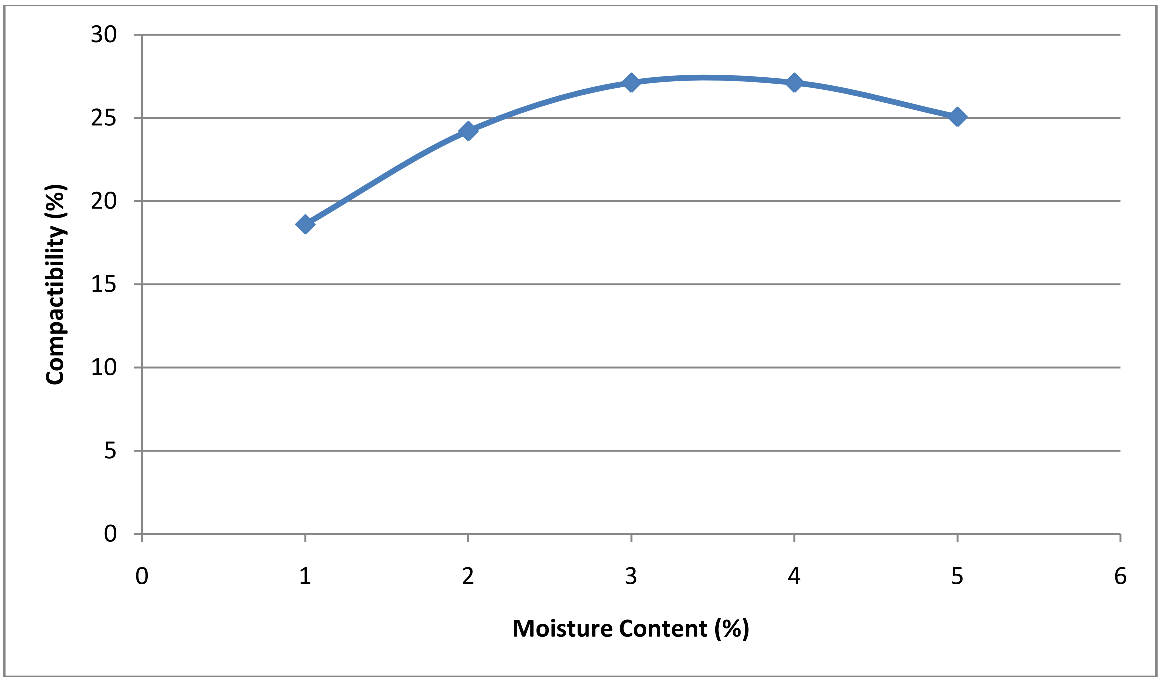


**Fig 7: Effect of moisture content on Compactibility of River Niger Onitsha beach sand**

## IV. CONCLUSIONS

From the results of the analysis presented, the following conclusions were drawn

1. The chemical analysis showed that the River Niger OnitshaBeach sand is composed predominantly of silica (94.49%), but not in therange that could be used for steel and other heavy metals foundry.
2. Moisture has a very strong influence on the foundry properties of the River Niger Onitsha Beach sand. These properties include the green compressive strength, green shear strength, dry compressive strength, dry shear strength, permeability and compactibility tests, all of which attend their maximum value with a moisture content of 4%. Hence 4% moisture content is most suitable for maximummoulding properties required as shown in figures 2-7.
3. The result of the mechanical properties of the sand as compared to the existing foundry standard was found to be very suitable for non-ferrous alloy castings at moulding mixture of 4% bentonite and 4% water.

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