SADI International journal of Science, Engineering and Technology
ISSN: 2837-1941| Impact Factor : 6.26
Volume. 11, Number 2; April-June, 2024;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis Ave Los Angeles, California
https://sadijournals.org/index.php/sijset|editorial@sadijournals.org

SUITABILITY OF NYAMA RIVER SAND FOR FOUNDRY APPLICATIONS USING EDDA CLAY AS BINDER

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DOI: https://doi.org/10.5281/zenodo.10961096

Abstract: Study on the suitability of Nyama River sand for foundry applications using Edda clay as binder has been successfully investigated. The chemical analysis was conducted using X-ray diffractometer (XRD) and X-ray florescence (XRF). The XRD test results conducted showed that Nyama River sand indicated the presence of quartz and sodalite as its predominant mineral, while Edda clay has kaolinite and quartz as its predominant mineral. The XRF tests conducted showed that Nyama River has 73.64% SiO_2, 7.98% Al_2O_3 and 1.45% MgO as its predominant oxides. The mechanical properties of the moulding sand were tested using standard techniques (AFS). The mechanical properties conducted were green compressive strength, green shear strength, dry compressive strength, dry shear strength, permeability No and compactibility test. The results of the mechanical properties tests were: green compressive strength (36.21KN/m^2); green shear strength (12.28KN/m^2); dry compressive strength (252.20KN/m^2); dry shear strength (89.40KN/m^2); compactibility (30.10KN/m^2), permeability value (145.50 No) and moisture content of (27.0%). From the results, it was observed that 6% Edda clay content and 5% water content were most suitable for moulding of Nyama River Sand for application in non-ferrous foundry as they improved the foundry properties of the sand.

Keywords: Application, suitability, Nyama River, sand, binders, clay

1.0 INTRODUCTION

Sand is the major material used to create or manufacture moulds. When blended with water and a biding material. The major ingredients of moulding sand include silica sand grain, clay and water content (Mathew et al., 2010). The silica sand grains is of paramount importance in moulding sand because it induced chemical resistivity, permeability, refractoriness to the sand.

The foundry industry in Nigeria uses imported binders and synthetic sand for moulding. The quality of casting is influenced significantly by sand properties such as green compressive strength, dry strength, permeability, compactibility, refractoriness, moisture content and others as stated by Mahesh et al (2008).

Some researcher have investigated the suitability of Nigeriann clay deposits for foundry preparations (Ayoola et al, 2010). Development of Igbokoda clay in the South Western part of Nigeria as a binder for synthetic moulding sand was carried out by Loto and Omotoso (1990).Their results confirmed that Igbokoda clay had good value as a binder for synthetic moulding sand.

The naturally bonded sand grains are normally coated with clay, which becomes sticky when water is added to it. The clay in the sand is used to cohesively bond sand particles giving it some binding strength. The resulting sand-clay mixture thus has enough strength to hold the shape when pressed against a pattern producing good sand casting products. Abolarin et al (2007) produced some samples of brake disc and impeller blade using silica sand without any additives and found that the cast yield was high with minimal surface defects. Solenicki et al (2009) concluded that the knowledge of the heating rates of sand moulds would help reduce the occurrence of defects generated by internal stresses due to high operational temperature.

2.0 Materials and Method

The materials used for the research work were locally. The silica sand used was sourced from Nyama River sand located at Enugu South local government area of Enugu State. While the binding material was sourced from Edda located at Afikpo South local government area of Ebonyi State.

2.1 Preparation and Determination of Grain Size

The silica sand was washed, oven-dried at 110^0C and sieved to remove coarse and dusty materials. The size and distribution of sand grain was determined with sieve analysis. 1000g of dried silica sand was measured on a weighing balance. The weighed sand was then placed on top of a set of sieve of decreasing aperture. (1.0-0.063mm) size contained in a shaker. The shaker was switched on for a period of 30mins, after which the sand retained in each sieve and the bottom pan was weighed and recorded against the sieve aperture size and their percentages to obtain the grain size according to the equation 1. The tests were all carried out according to American Foundry Society (AFS) standard for foundry sands.

$$AFS\ grain\ fineness\ number\ = \frac{product}{amount\ retained\ (\%)}$$

2.2 Determination of Green Compression Strength

The green compression strength was determined using universal sand strength testing machine. A prepared standard sample (5 diameter x 5cm height) 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 which its value was recorded.

2.3 Determination of Dry Compression Strength

A prepared standard sample of 5cm diameter x 5cm height was dried in the oven at a temperature of 110^0C for a period of 20 minutes 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 with the compression head in place. The compressive load was applied and the samples failed at the maximum load capacity of the sample. The point at which the failure occurred was recorded at DCS.

2.4 Determination of Dry Shear Strength

The prepared standard sample of 5cm diameter x 5cm height was dried in the oven at a temperature of 110^0C for 20 minutes and then removed from the oven to cool in air to ambient temperature. The same universal testing machine used for dry compression strength was also used. In this case, the shear head was replaced with the compression head. The shear strength was recorded at the point of failure of the standard test sample.

2.5 Determination of Green Shear Strength

The machine used for the GCS was also used for the determination of green shear strength (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.

2.6 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 the permeability meter. Air at a constant pressure was applied to the standard specimen, and the drop in pressure was measured using a pressure gauge, calibrated directly in permeability numbers,

2.7 Refractoriness

The sand for the refractory test was mixed with the desired quantities of alkali free dextrin and water. The mixture was moulded into cone shaped and then dried in oven at 110^0C. Followed by sintering the cone shaped sample in the furnace to a temperature of 1000^0C. The standard pyrometric cones of known softening temperature and the prepared sample were arranged in furnace to test for the refractoriness. The cones are heated gradually until softening of the cones are observed in the furnace. 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 occur was measured as the refractoriness.

3.0 Results and Discussion

The results of the research investigated were presented in Tables 3.1 – 3.3 and figures 3.1 – 3.6.

Table 3.1 and fig 3.2 – 3.6 shows the foundry properties results of Nyama River sand using 7% Edda clay as binder.

Fig. 3.2 shows the effect of green compressive strength on varying percentages of water content addition on the constant 7% clay content. From the fig. 3.2, it was shown that the green compressive strength increases from 21.90KN/m^2 at 2% water content to 34.78% at 6% water. From the fig. 3.3 below, it was shown that the dry compressive strength of Nyama River sand increased with increase in water content and from the fig. 3.3, it was shown that dry compressive strength increased from 197.17KN/m^2 at 2% water content to 259.11KN/m^2 at 6% water content addition.

From figure 3.4, it was shown that the maximum permeability of Nyama River sand sample was obtained at 7% clay content with 4% water content as shown in Table 3.1 and fig. 3.4 below.

Fig. 3.5 shows the effect of water content addition on the moisture content of Nyama River sand. From the fig. 3.5, it was shown that moisture content increased as the percentage water content addition increased. The moisture content increased from 1.40% at 2% water content addition to 3.84% at 6% water content addition as shown in Table 3.1.

Fig. 3.6 shows the compactibility of Nyama River sand, from the figure 3.6, it was shown that the compactibility of Nyama River sand increased as the percentage water content addition increases upto a certain maximum value after which decreased. The compactibility increased from 16.20% at 2% water content to 30.10% at 5% water content after which decreased to 29.50% at 6% water content addition as shown in the Table 3.1.

The chemical analysis of Nyama River sand carried out using X-ray florescence (XRF) showed that Nyama River sand composed predominantly of silica (73.64%) which is below the range recommended for steel and other heavy metal foundry according to Mclaws (1971). The X-Ray Diffraction (XRD) analysis showed that the Nyama

River sand consist of quartz and sodalite as its predominant minerals with muscovite and albite as minor mineral. While Edda clay has kaolinite and quartz as its predominant mineral with Halloysite as minor mineral as shown in Fig. 3.1. The X-Ray diffraction results of Edda clay deposit were shown in the fig 3.1.

Table 3.1: Foundry properties result of Nyama River sand using 6% clay as binder

Water (%)	Green Compressive strength (KN/m^2)	Green shear strength (KN/m^2)	Dry compressive strength (KN/m^2)	Dry shear strength (KN/m^2)	Permeability (No)	Compatibility	Moisture content (%)
2	21.90	11.70	197.17	70.21	153.15	16.20	1.40
3	29.50	12.02	207.00	75.20	156.6	22.80	1.50
4	33.00	12.25	227.54	84.90	149.80	26.40	2.58
5	36.21	12.28	252.20	89.40	145.50	30.10	2.70
6	34.78	12.26	259.11	92.00	145.10	29.50	3.84

Table 3.2: Chemical composition of Edda clay

	%	Peaks		%	Peaks
Fe_2O_3	0.7229 %	2732	V_2O_5	0.0343 %	147
NiO	0.00337 %	21	Cr_2O_3	0.01962 %	161
CuO	0.00442 %	26	MnO	0.01229 %	56
ZnO	0.00984 %	80	Rb_2O	0.00236 %	11
Ga_2O_3	0.00984 %	136	Y_2O_3	0.00419 %	25
Ta_2O_5	0.00283 %	3	ZrO_2	0.2213 %	369
WO_3	0.00992 %	9	SnO_2	1.245 %	8
MgO	3.72 %	5	PbO	0.0293 %	13
Al_2O_3	33.34 %	523	Bi_2O_3	0.02567 %	1
SiO_2	56.0 %	2883	ThO_2	0.00533 %	6
P_2O_5	0.1714 %	41	Ag_2O	0.00075 %	2
SO_3	0.0812 %	98	Sb_2O_3	[0.054] %	2
Cl	0.0208 %	10	I	0.000835 %	12
K_2O	0.2720 %	282			
CaO	0.02873 %	45	Cs_2O	0.00044 %	2
TiO2	2.0824 %	7647			

Table 3.3: Chemical Composition of Nyama River sand

Oxides	Concentration	Peaks(cps/mA)
Fe_2O_3	1.3842 %	5232
NiO	0.00178 %	11
CuO	0.07551 %	448
ZnO	0.08288 %	677
Ga_2O_3	0.000695 %	10
Lu_2O_3	[0.000018] %	2
Ta_2O_5	0.0059 %	6
WO_3	0.01373 %	33
MgO	1.45 %	2
Al_2O_3	7.984 %	125
SiO_2	73.641 %	5645
P_2O_5	0.2650 %	63
SO_3	0.0686 %	83
Cl	0.0391 %	20
K_2O	0.0746 %	77
CaO	0.0904 %	140
TiO_2	0.1714 %	629
V_2O_5	0.00483 %	21
Cr_2O_3	0.00226 %	18

Oxides	Concentration	Peaks(cps/mA)
MnO	0.04170 %	189
Br	0.00027 %	1
Rb_2O	0.00102 %	5
Y_2O_3	0.001926 %	2
ZrO_2	0.0420 %	88
SnO_2	1.222 %	3
PbO	0.01188 %	5
Bi_2O_3	0.02431 %	0
Ag_2O	0.00085 %	2
Sb_2O_3	[-0] %	0
I	0.000523 %	0
Cs_2O	0.00032 %	3

Table 3.3b: Standard Properties for sand castings in Foundry Industries

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

Source: (Ademo & Abdullahi, 2009)

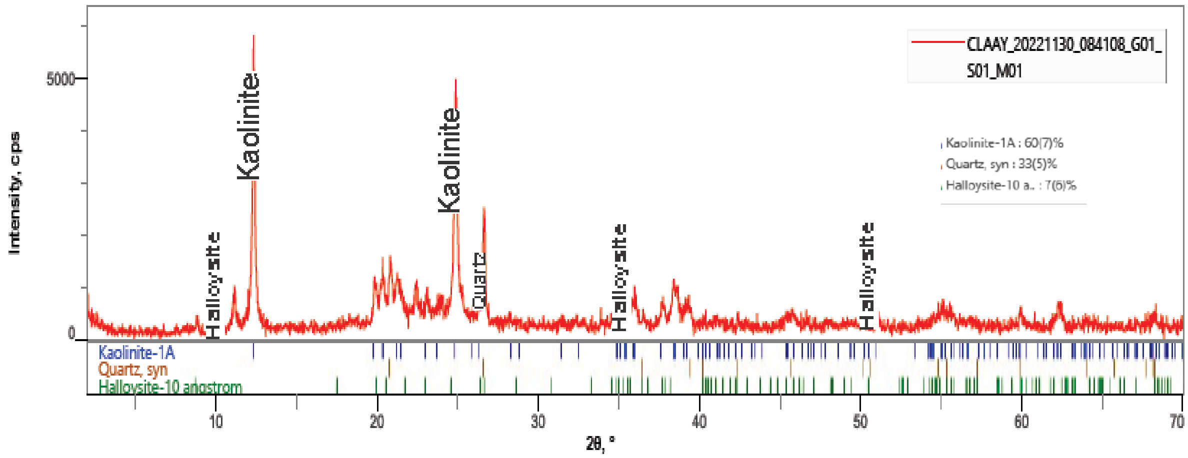

Fig. 3.1: XRD Result of Edda Clay

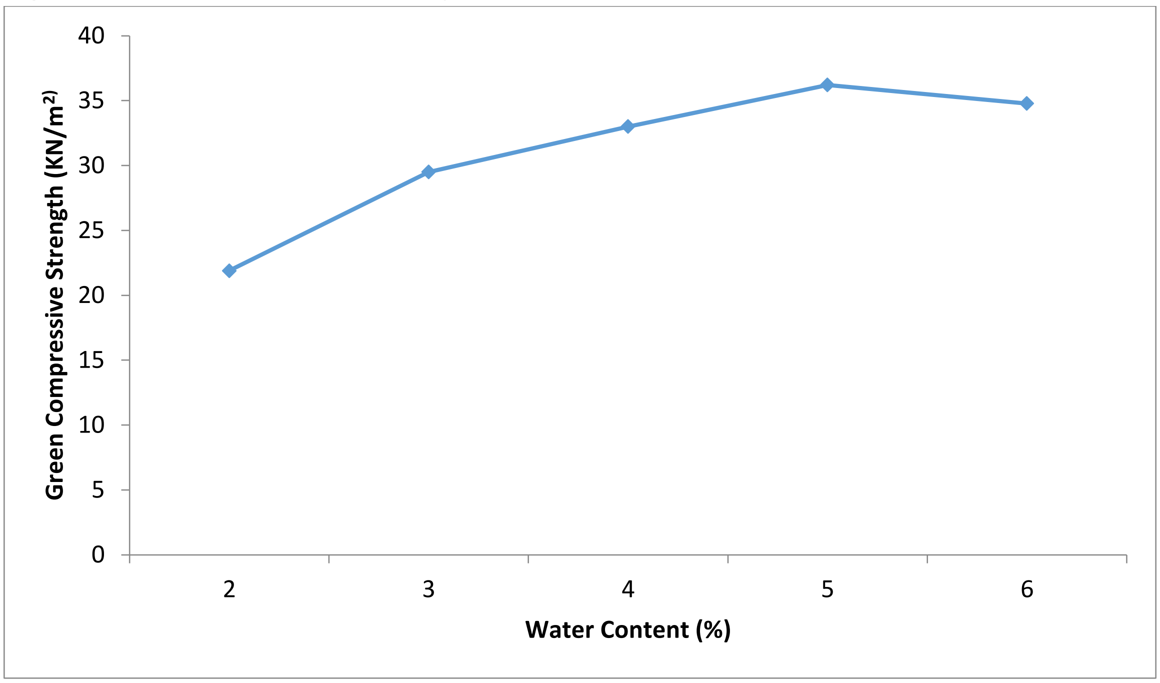

Fig. 3.2: Effect of Water content on the Green Compressive Strength of Nyama River Sand

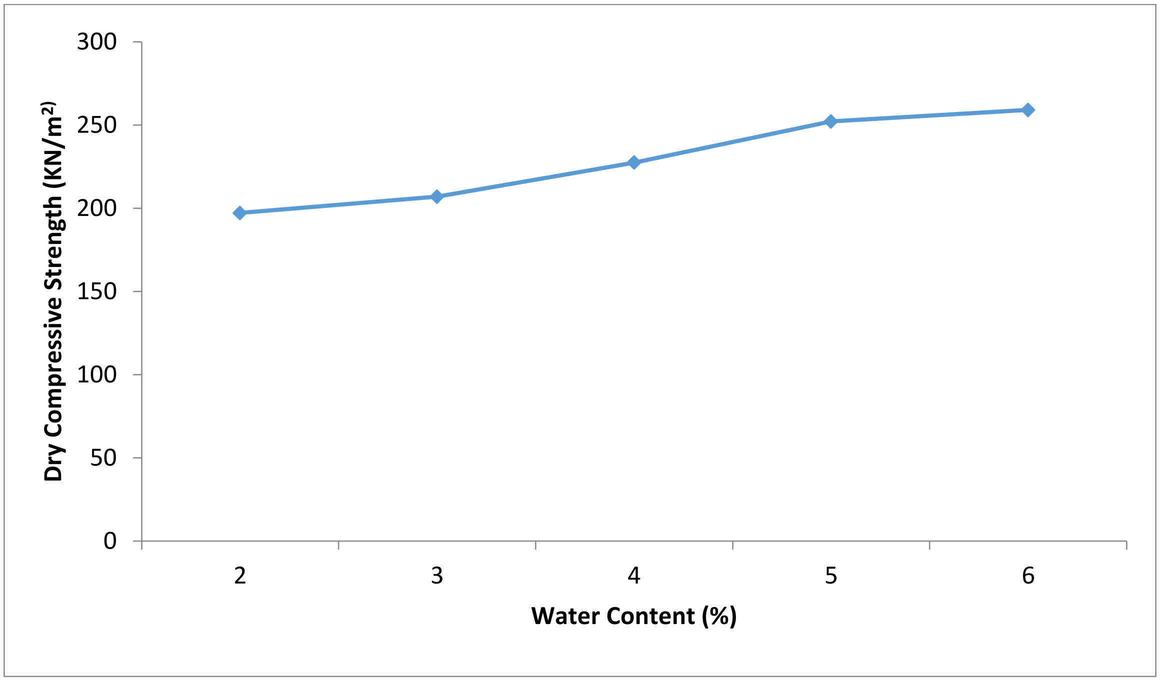

Fig. 3.3: Effect of Water content on the Dry Compressive Strength of Nyama River Sand

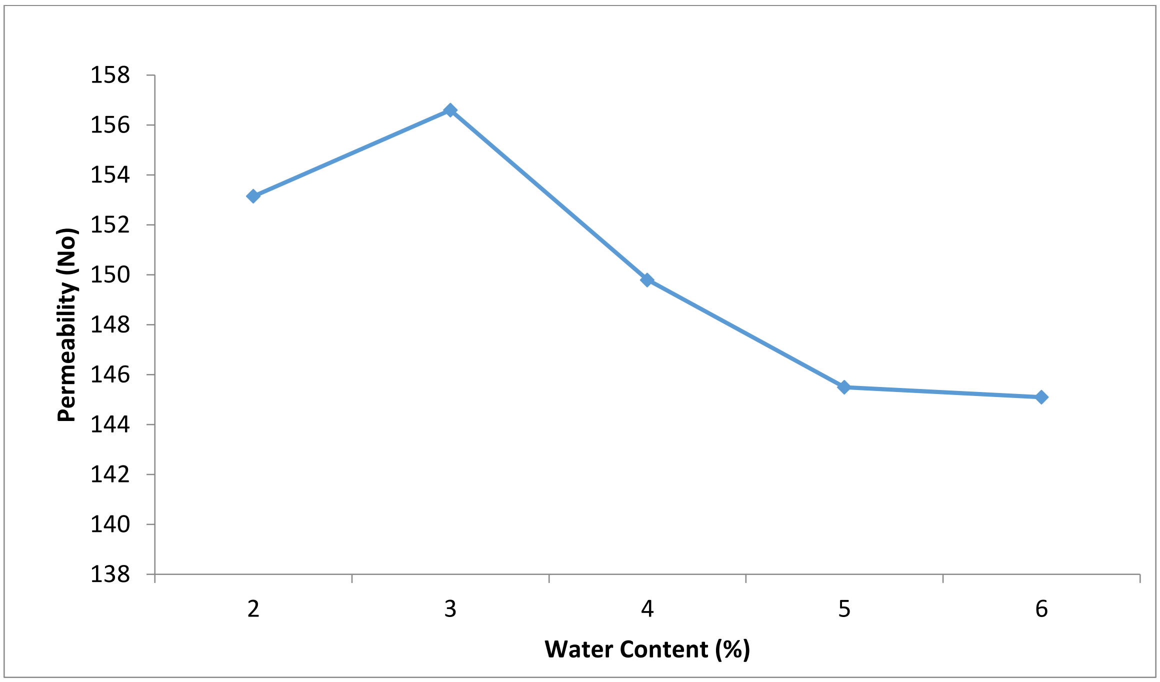

Fig. 3.4: Effect of Water content on the Pemeability of Nyama River Sand

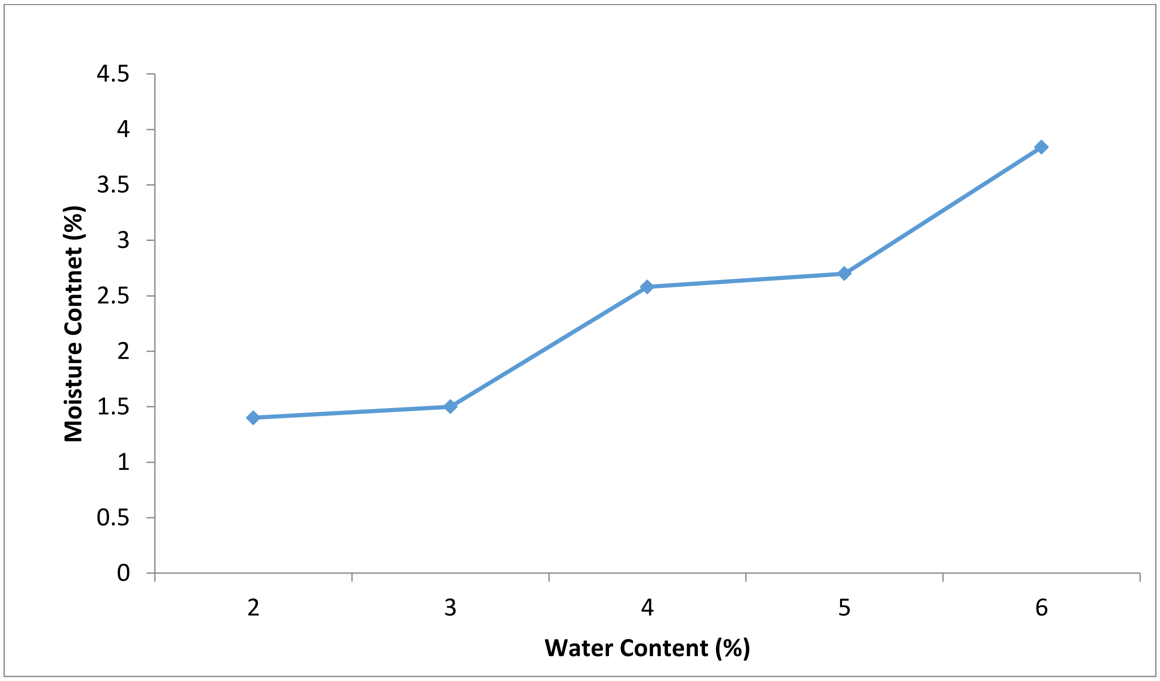

Fig. 3.5: Effect of Water content on the Moisture Content of Nyama River Sand

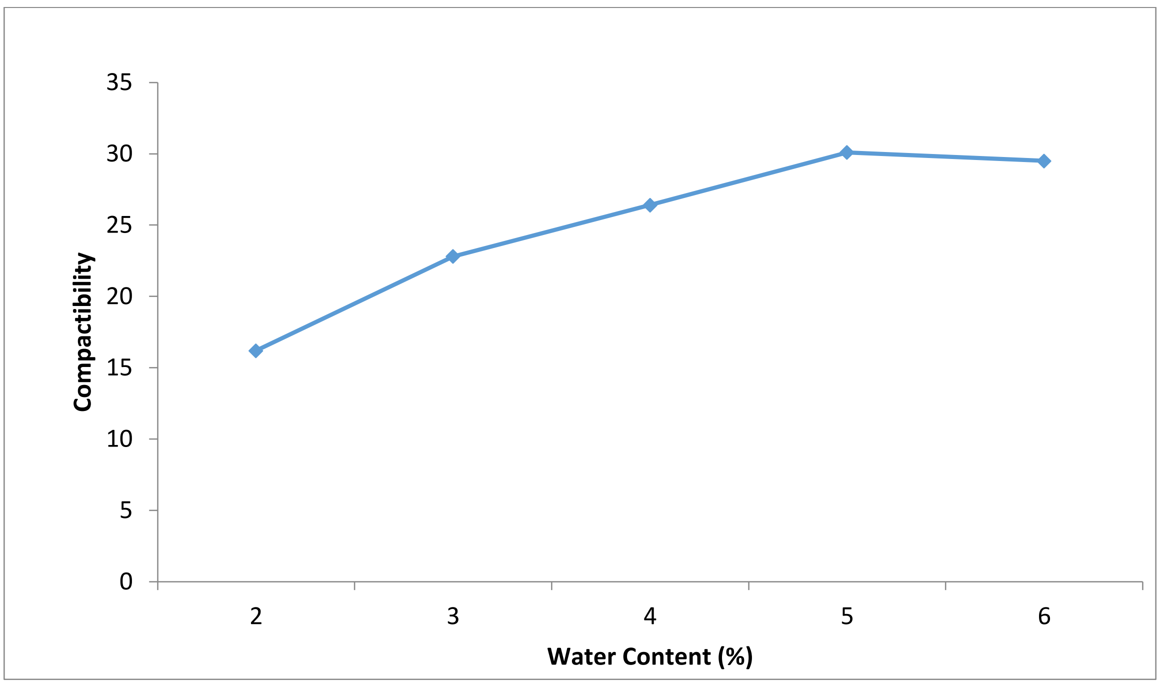

Fig. 3.6: Effect of Water content on the Compactibility of Nyama River Sand

4.0 Conclusion

The results of the mechanical properties of Nyama River sand were compared to the existing foundry standard and it was found to be very suitable for non ferrous alloy casting at 5% water content addition and 7% Edda clay content as binder.

The X-ray diffraction analysis of Nyama River sand showed that the sand consists of quartz and sodalite as its predominant minerals with muscovite and albite as minor minerals.

The X-ray diffraction results of Edda clay showed that the clay consists of kaolinite and quartz as its major mineral with Halloysite as minor mineral.

References

Abolarin M. S., Olugboji O. A. and Ogunwole O. A. (2007), Casting of brake disc and impeller from aluminium scrap using silica sand; Electronic Journal of Practices and Technologies. Vol. 6, No. 10, pp. 145-150.

Ayoola W. A., Adeosun S. O., Oetunji A. Oladoye. Suitability of Oshogbo sand deposit as moulding sand. The Kenya Journal of Mechanical Engineering 2010, 6:33-41.

Loto C. A., Omotoso E. O. (1990). Analysis and development of Igbokoda clay as a binder for synthetic moulding sand. Applied clay science 5(1): 85-97.

Mahesh B, Parappagoudar DK, Practinar A; Dattai E.L. (2008). Forward and Revers Mapping in Green sand mould system using Neutral Networds Elsvier Science. 8: 239-260.

Matthew S. A., Sunday A. L., Abdul R.A.S. Effect of moisture content on the moulding properties of River Niger Sand within Lokoja under Murtala Mohammed Bridge. Assumption University Journal Thailand 290: 13(3): 170-174.

MacLaws I. J. (1971). Uses and Specification of Silica and Edmond, Alberta pg. 35-68.

Solenicki G. Budie I and Ciglar D. (2009). Determination of thermal conductivity in foundry mould mixtures, METABK, vol. 49 No. 1, pp. 3-7.