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Assessment and Characterization of NKPOLOGU Sand Deposit in UZO-UWANI Local Government Area of ENUGU State, NIGERIA Using CASSAVA STARCH as a Binder for MOUID Production

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ABSTACT: This paper investigated the effect of cassava starch binder and water on the Nkpologu Silica Sand in Uzo-Uwani, Local Government Area, Enugu State, as moulding sand. The assessment and characterization analysis carried out divulges the composition of oxides present in the silica sand and shows that it is good for foundry mould production specifically for casting of non-ferrous metals. The result of X-Ray Diffraction (XRD) confirmed the presence of phases such as, Quartz (SiO_2), Allophane (Al_2O_3. $2SiO_2$. $3H_2O$) Kaolinite ($Al_2Si_2O_5$ $(OH)_4$) and zirconium silicate (Zr (SiO_4) with diffraction major peaks of 27^{o}C, 27^{o}C, 25^{o}C, and 27^{o}C respectively. The X-Ray Fluorescence (XRF) analysis showed the oxide composition of the Nkpologu Silica Sand as follows: SiO_2 (75.21%), Al_2O_3 (16.5%), Fe_2O_3 (0.794%), TiO_2 (0.93%) as major oxides were found to be present. The present of compound like SiO_2, Al_2O_3, suggested that, the Nkpologu Sand can be used for foundry application. This result of XRF is in agreement with the result of XRD obtained. Addition of cassava starch as a binder in the silica sand gave it a special prosperities, with particular reference to the fineness.

KEYWORDS: Nkpologu Silica Sand, Cassava Starch, casting, XRD and XRF Analysis

I.INTRODUCTION

Foundry process is one of the momentous part of engineering meadow, where most of the intricate shape or part of designed dimensions are produced which might be very difficult to produced by any other production method such as, fabrication method, machining method, forging method, drawing method, extrusion etc. Foundry as a production industry is concerned mainly with casting alone. Foundry industry is one of the basic industries and is also considered to be the mother of all other production industries in this world of contemporary. The eventual achievement of industrial emancipation and economic self reliance in many countries hinges on the success of foundry industries.

The moulding sand most usually used is foundry operation is silica sand. Despite the fact that sand is available and obtainable everywhere around the world, which means different things to different people depending on the area or perspective one find it. Wikipedia, the free encyclopedia defined sand “as a naturally occurring granular material composed of finely divided rock and mineral particles.” The composition of sand is highly variable depending on the local rock sources and conditions. But the most common constituents of sand in in-land continental settings and non-tropical coastal settings is silica (silicon dioxide (SiO_2),) usually in the form of quartz. The second most common form of sand is calcium carbonate, for example aragonite, which has mostly been created over the past half a billion years, by various forms of life, like coral and shellfish. It is for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem. But it is mostly not used for foundry moulds.

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Most of the sand that used in foundry for moulds production or for casting must possess the following characteristics;

1. Permeability to gases.
2. Cohesiveness or strength, and
3. Refractoriness or ability to withstand high temperature.

Silica sand has been proved to have some many industrial applications, but getting suitable silica sand that will give out best application for different manufacturing has been a greater challenges. This research work was designed to source alternative and suitable silica sand for industrial applications.

II.MATERIALS COLLECTION AND METHOD OF PREPARATION.

The sand sample was collected from its occurrence or deposit at Uzouwani local government area, in Enugu state. In the course of this project evaluation or work, the materials used were all in their raw state, especially the cassava starch and the silica sand from Nkpologu sand deposit. The materials made to undergo the required preparation processes before been used for production.

The silica sand used was obtained from Nkpologu sand deposit in Uzo-uwani Local Government Area, Eungu State. The silica "Nkpologu sand deposit" was washed thoroughly to remove all the impurities and unwanted inclusion or materials that are presence in the sand deposit. Thereafter, it was allowed to dry under the sun for a period or an interval of 3-days, before it is been collected back and processed for sieving analysis. The sample was taking for further process, which is sieving operation. The sample was sieved for a period of fifteen minutes to determine the quantity of the sample retained in each sieve. The cassava starch used as a binder was also gotten raw.

A.CASSAVA STARCH EXTRACTION:

Cassava tubers were peeled and properly washed. The washed tubers were pounded followed by grinding into pulp. Water was then added to easy the extraction of starch. On the addition of water, it formed suspension which was left to stay for 2 hours before the water above was decanted. The starch residue was properly dried to white, odorless and tasteless powder in accordance with Anonim,2009, Oyetunji and Seidu, 2012 and Narayana, 2002.

B.SIEVE ANALYSIS :

The silica sand was taken to a stack of sieves arranged in descending or downward order of magnitude on a shaking table that is accountable for the vibration of the sieves that aids in sieving. The sizes of the sieves in the stack are listed as follows: 1.6mm, 1.0mm, 0.710µm, 0.400µm and 0.315µm respectively and their arrangement was in descending order of magnitude to allow lower sizes of the silica sand to seep into easily. The arranged sieves were then placed on a sieve shaker whose function is to cause vibration of the stack of sieves and aid in allowing respective sizes of the silica sand to percolate through the sieves.

C.CHEMICAL ANALYSIS:

The chemical analysis was carried out to determine the various elements and oxides contained in the sand sample "Nkpologu Sand Deposit".

Preparation: The sand was washed and then dried for about three days, pulverized into appropriate fine particles size and sieved to have a large surface of reaction (0.10mm in diameter); the chemical analysis is an operation which contains many processes.

The sample was sieved 120mm mesh. 1gram of the crucible and 6gram of anhydrous sodium carbonate (Na_2CO_3) is added and thoroughly mixed using a class rod. The crucible containing the sample was headed in a muffle furnace to a temperature of 100^{o}c for a period of one hour for fusion to take place. It was allowed to cool after heating, before it was transferred into an evaporating dish and 1gram of Hcl was added. Sufficient time was given for the sample to be loosened so that it can be moved from the crucible.

More Hcl (1g) was added and taken to an ultraviolet lamb (u.v lamb) to enable the sample to dry appropriately. A fumeless sample was noticed with the application of ammonium solution. The sample was removed from the lamb after some times, before another 1gram of Hcl was added and placed on a hot plate stirred until the sample got dissolved. This was fittered after being removed from hot pot plate into a beaker using filter paper. The weight of the silica present will be known from the residue, whilst Fe2O3 from the filtration. It was from the Fe2O3 that we determined the

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weight of calcium oxide (Cao), magnesium oxide (Mgo), total iron, titanium oxide (Tio2), and some other oxides that were present from the result of chemical analysis of Nkpologu Sand Deposit.

D.PHYSICAL ANALYSIS:
The purpose of sand control tests is simply to predict the behavior of sand or sand mixture during moulding and casting operation. The following physical tests were carried out and the result was obtained as shown below:

E.GREEN COMPRESSION:
The green compression strength test was carried out in a universal sand strength machine. A quantity of about 100g was measured and poured inside a cup and then fixed in a ramming machine. The sand was rammed about three times and was placed between the compression head and a head wheel was used to load the specimen. The loading continues gradually until the specimen cracks and the loading is expected to stop for the reading of the strength to be taken from the calibrated scale.

F.DRY COMPRESSION STRENGTH:
In this test, the specimen before testing was heated at a temperature of about 200^{o}c for a period of 2-3 hours and cooled in air to allow the removal of available moisture content in the sand test. The strength of the dry compression strength was known by taking the reading in the calibrated scale marked dry compression at the point of fracture.

G.SHEAR STRENGTH:
The dry and green strength was carried out in the same process as explained in the compression test. The only difference was that the flat head of the compression head was replaced by the shear head and the reading was taken from the scale.

H.REFRACTORINESS:
The refractoriness of Nkpologu Sand Deposit was carried in crucible furnace at Federal Polytechnic, Idah, Kogi State in Foundry workshop. The test was carried out by pouring some sand sample into the cup of the sand rammer and rammed. The test was carried out on 100g of the specimen placed inside a crucible and heated. Different temperature ranges are recorded as the sample is constantly being observed, until the final temperature range in which cracks began to be identified in the specimen which was recorded. The final temperature which was about 1200oc in range becomes the temperature on which the sand can withstand without cracking. This refractoriness tests has already shown that Nkpologu Sand Deposit is good for moulding production, especially in casting of materials whose its temperature is below the final temperature of the sand; such as Aluminum, whose its melting point is about 650^{o}C.

III. RESULT

SIEVE ANALYSIS OF NKPOLOGU SILICA SAND (100G)
THE SIEVE ANALYSIS OF NKPOLOGU SAND DEPOSIT IN ENUGU STATE

S/N	Mesh (mm)	Multiplier	%Wt Retained (g)	Cumulative %Passing	Product
1	1.60	6	3.4	3.4	20.4
2	1.00	9	6.7	10.1	60.3
3	0.710	15	11.85	21.95	177.76
4	0.630	25	6.6	28.55	165
5	0.400	35	25.99	54.54	909.65
6	0.315	45	12.2	66.74	549
7	0.200	60	20.79	87.53	1247.4
7	0.160	81	6.98	94.51	565.35
9	0.125	118	3.39	97.90	400.02
10	0.100	164	1.17	99.07	191.88
11	0.080	275	0.93	100	255.75
TOTAL			100	100	4542.53

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The grain fineness number of Nkpologu Sand deposit was determined using eduation …….4.1

Grain Finest Number is = $\frac{\text{total product}}{\text{total sum percentage sieved}}$ equation…..4.1

G.F= 4542.53/100=45.43

A.THE GRAPH OF SIEVE ANALYSIS OF NKPOLOGU SILICA SAND DEPOSIT, PLOTTED %WT RETAINED AGAINST APERTURE SIZE (MM)

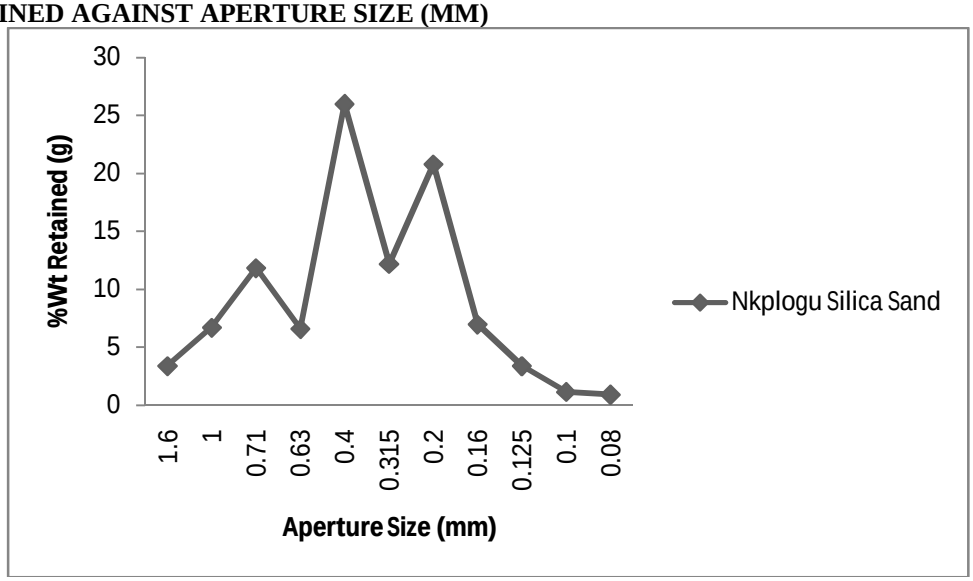

Figure 1: Variation of %Weight retained with Aperture size for 100% Nkpologu Sand Deposit.

B.The Graph of Sieve Analysis of Nkpologu Silica Sand Deposit, Plotted Cumulative %passing against Aperture size (mm)

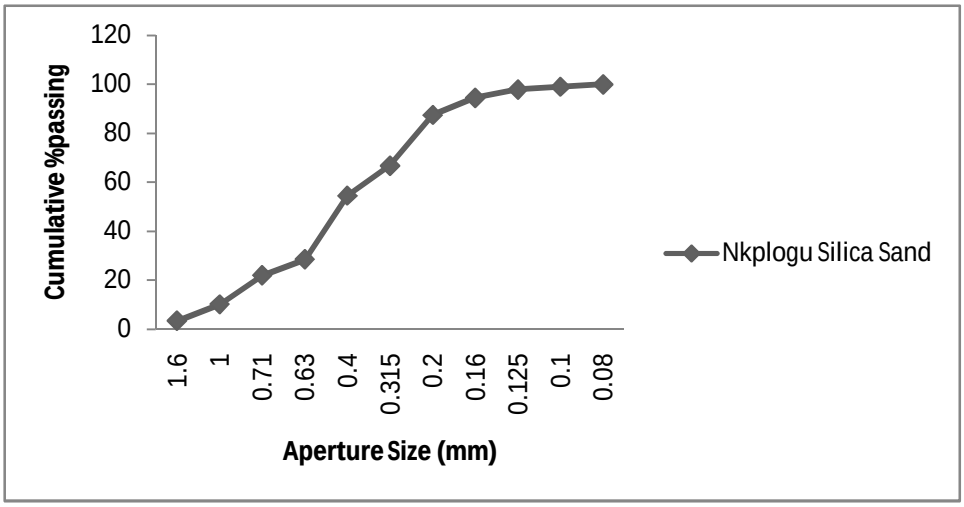

Figure 1.1: Variation of Cumulative %Passing with Aperture size for 100% Nkpologu Sand Deposit

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IV. PHYSICAL ANALYSIS OF NKPOLOGU SILICA SAND

S/N	TESTS	RESULTS
1	Green compression strength	0.0475pa
2	Green shear strength	-
3	Dry compression strength	2.24pa
4	Dry shear strength	0.330pa
5	Permeability	$310m^2$
6	Compatibility	43.3%

Evaluation of the sand with 70% silica sand, 22% cassava starch, and 8% moisture content.

V.REFRACTORINESS TESTS

S/N	Firing Temperature ^oc	Observed change in the sample
1	200	No crack
2	400	No crack
3	600	No crack
4	800	No crack
5	1000	No crack
6	1200	No crack
7	1400	Little crack
8	1600	Crack initiated in a big quantity

VI.CHEMICAL ANALYSIS OF NKPOLOGU SILICA SAND

X-RAY FLUORESCENCE SPECTROMETER (XRF) FOR NKPOLOGU SILICA SAND

Oxide Composition	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO
Percentage(%)	75.21	0.930	16.50	0.794	0.135	0.18	0.47	1.23	0.0001

Oxide Composition	$V2O_5$	Cv_2O_3	NiO	CuO	PbO
Percentage(%)	0.024	0.0051	0,0099	0.0066	0.37

VII.X-RAY DIFFRACTION RESULTS FOR NKPOLOGU SILICA SAND

s/n	Oxide Name	Peak	d(A)	2Theta(deg)	I (%)
1	**Quartz (SiO_2)**	27^oc	1.14060	84.962	0.2
2	**Allophone ($Al_2O_3.2SiO_2.3H_2O$)**	27^oc	-	-	-
3	**Kaolinite ($Al_2Si_2O_5$ $(OH)_4$)**	25^oc	-	-	-
4	**Zirconium silicate $Zr(SiO_4)$**	27^oc	1.16660	82.645	1.9

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VIII.DISCUSSION

ANALYSIS OF XRD AND XRF RESULT

The XRD patterns of Nkpologu sand is showed in the Figure below. The particle size of the samples has been calculated by employing the Scherres equation:

$$D=\frac{K\lambda}{\beta Cos\theta}$$

Where θ is the angle between the incident and diffracted beams (degree), β the full with half maximum (rad.), D the particle size of the sample (nm) and λ is the wavelength of the X-ray. The results of XRD confirmed the formation of Quartz (SiO_2), Allophane ($Al_2O_3.SiO_2.3H_2O$), Kaolinite $Al_2Si_2O_5(HO)_4$) and Zirconium silicate ($Zr(SiO_4$) with a diffraction major peaks of 27°C, 27°C, 25°C, 27°C, with a crystal structure of Hexagonal, Anorthic and Tetragonal respectively. It was clearly observed that the diffraction major peaks of all the phases occurred at 27°C which mean that the pattern corresponding to phase with good crystalline nature. Quartz has the higher numbers of peaks, then the kaolinite and Zirconium silicate which confirmed the sand is high in silica content. XRF analysis confirmed that SiO_2 (75.21%), Al_2O_3 (16.5%) were found to be major constituents of the sand. Fe_2O_3 (0.794%), TiO_2 (0.93%) were also found to be present in traces. The presence of elements like Si, Al suggested that, the Nkpologu sand can be use as material in Foundry. This result of XRF is in agreement with the result of XRD obtained. Therefore, the present work shown the possibility of using Nkpologu sand as materials in mould making since the chemical composition has close similarity with the XRF analysis of others sand used.

IX.CONCLUSIONS

The results of the investigation showed that the Nkpologu silica sand exhibit good properties for mould production and casting of non-ferrous and ferrous metals such as aluminum and cast iron. Addition of water up to 8% and cassava starch (22%) to the Nkpologu silica sand respectively possess high compressive strength and compactibility and would produce sound castings. There is close agreement in the values of green and dry compression strengths, shatter index, compactibility and permeability obtained.

The chemical and physical analysis showed that the present of elements like Si, Al in sand suggested that, the Nkpologu sand can be use as material in the foundry work. The results of XRD confirmed the formation of Quartz (SiO_2), Allophane ($Al_2O_3.2SiO_2.3H_2O$), Kaolinite ($Al_2Si_2O_5$ (HO) $_4$) and Zirconium silicate ($Zr(SiO_4$) with a diffraction major peaks of 27°C, 27°C, 25°C, 27°C, with a crystal structure of Hexagonal, Anorthic and Tetragonal respectively. It was clearly observed that the diffraction major peaks of all the phases occurred at 27°C which mean that the pattern corresponding to phase with good crystalline nature. Quartz has the higher numbers of peaks, then the kaolinite and Zirconium silicate which confirmed the sand is high in silica content. XRF analysis confirmed that SiO_2 (75.21%), Al_2O_3 (16.5%) were found to be major constituents of the sand. Fe_2O_3 (0.794%), TiO_2 (0.93%) were also found to be present in traces. This result of XRF is in agreement with the result of XRD obtained. Therefore, the present work shown the possibility of using Nkpologu sand as materials in mould making since the chemical composition has close similarity with the XRF analysis of others sand used.

Conclusively, Nkpologu silica sand is recommended for mould production and casting of non-ferrous and ferrous metals. The addition of binder to Nkpologu silica sand is necessary in order to obtain a good surface finish in the cast and to improve the mechanical strength of the product.

X.RECOMMENDATIONS

a. I recommended that Nkpologu silica sand deposit should be used for production and casting of ferrous and non-ferrous metals such as aluminum.
b. Binder such as cassava starch should be used in the mixture of the sand deposit to ensure good surface finish.
c. The present of high silica content in the sand gives it a special moulding property.
d. I also recommend this sand for many foundry industries in the country as it will be magnificent to their production.

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XI.AUTHORS CONTRIBUTIONS

Udeh JN, collected the materials used for this research work in its raw state and carried out all the experiment and research analysis under the supervision of Engr. E.O Attama. While Engr. Ekera, JT, and Ozioko C.C, proofread the work and organized the manuscript.

XII.ACKNOWLEDGMENT

On behalf of the entire author, I Udeh JN, thank those that contributed for the actualization of this great work. May God Almighty reward you all handsomely.

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