SAJSET
ISSN: 2992-3581

Savannah Journal of Science and Engineering Technology
Volume: 02; Issue: 05; Pages: 288-292; 2024.
www.sajsetjournal.com.ng

DOI: xx.xxxx.x/sajset-02-2024-0039

SAJSET
ISSN: 2992-3581

Characterization of foundry properties of river Gongola silica sand deposit for manufacture of centrifugal pump impeller

Zhengwuvi, L. B.
[1]*Department of Mechanical Engineering, Modibbo Adama University, Yola Adamawa State, Nigeria*

Paper History
Received: 09th Sept., 2024
Accepted: 20th Sept., 2024
Published: September, 2024

Corresponding author
Zhengwubi, L. B.
zhengwuvi@mau.edu.ng

Abstract

Foundry sand such as silica sand has been imported into the country for manufacture of equipment which makes parts produced expensive to the end users. To manufacture affordable goods/parts to the end users, there is need to source for local silica sand deposit for the national founding industries. The aim of the study is to characterise the river gongola silica sand deposit to determine its suitability for foundry operations. The deposit has 93.63% concentration of silica sand and minor traces of other oxides. The sand deposit has pH scale of 7.50 which is neutral. It suggests that the sand deposit is friendly and safe to handle. The silica sand deposit has loss on ignition of 0.52 %, specific gravity of 2.83, conductivity of 153.80 W/mK, clay content of 0.80 %, refractoriness of 1500.00 ^{0}C, grain average size of 210 μm, AFS grain fineness number of 57, grain size distribution of 4 sieves, shape is angular and colour is white-brown. The foundry properties of the silica sand were compared with the American foundry society *AFS standard. The result showed that the foundry parameter results are in conformity to the standard ones. Thus, the silica sand deposit was observed to be satisfactory for founding works. The silica sand was used as major mould/core ingredients in sodium silicate glass-carbon dioxide process to cast an impeller of a centrifugal pump. The manufactured impeller was observed to possess the required shape and size. The pump was tested and observed to perform well as the imported ones.*

Keywords: *Characterization, Foundry, Manufacture, Silica sand*

1. Introduction

Silica sand is the product of disintegration of rocks principally by the actions of frost, wind and rain [1, 2]. It is found on the earth's surface like beaches, under waters like rivers and lakes, and subsurface deposits of different geological formations [1, 2]. Silica sand is the most abundant mineral in nature [1 - 6]. It is the most readily available, cheap and long life moulding material [1, 7]. Foundry industries utilize silica sand to manufacture parts/equipment in order to save cost in production [1, 8, 9, 10]. Foundry silica sand has a particular size and shape requirement which makes not every sand deposit qualifies for foundry works [1, 11, 12, 13]. A careful search for these requirements was necessary and made among the Adamawa State drainage systems (Benue, Yadzaram and Gongola Rivers).

It was facially observed that River Gongola silica sand deposit at Numan where it is about to terminate into River Benue met up these requirements. The deposit has fine grain size and shape, and homogenous in distribution which makes the deposit attractive for further works. The attractiveness of this site made the researcher in partnership with the staff of Dangote Sugar Company (formally called Savanah Sugar) Numan, Adamawa State to embark on this work. This work is to ascertain the suitability of the deposit and foundry properties of the sand for the manufacture of equipment/parts such as centrifugal pump impeller.

2. Materials and method

2.1 Materials

The material used in the study include five kilograms of silica sand, carbon dioxide, sodium silicate, moulding materials, etc.

2.2 Material collection

Silica sand was mined from River Gongola bed at Numan about five hundred meters away from the confluence (where River Benue and River Gongola meet). In order to obtain good representation of the deposit, the silica sand was mined across the breadth and length of the river bed and mixed thoroughly before forwarding for test.

2.3 Material test

Test on the silica sand deposit was carried out as follows:

2.3.1 Mineralogical composition analysis

The mineralogical composition of the silica sand was determined by X-ray diffraction machine. Five grams of moisture free and pulverized sample was analysed. The sample was placed in the machine. The machine robot picked the sample into the X-ray diffraction analysis unit. Generated electrons from the X- cathode ray accelerated toward the sample and bombarded it. As the sample and the detector were rotated, the intensity of the reflected X-rays was recorded. Once all the d_b-spacings have been determined, automated search/match routines compare the d_b-spacings of the unknown sample to those of the known materials from the International Centre for Diffraction mineral data bank. The sample diffractogramme was presented as peak positions at 2 thete and X-ray counts (intensity) in the form of x-y plot. The result was printed out in hard copy and the soft copy was saved for future use. The analysis was completed within eighty seconds. On the completion of the analysis, the machine robot returned the sample back to its former position on the stage [12].

2.3.2 Chemical composition analysis

The chemical composition analysis of the silica sand was determined by X-ray fluorescence machine. Twenty grams of the pulverised sample was put into the machine. The machine cabinet was closed and measure option was highlighted. The X-ray Fluorescence machine automatically displayed the sample chemical composition on the computer screen which was printed out in hard copy. The soft copy was saved for future use. The time of measurement of each sample was one hundred seconds [12].

2.3.3 Loss on ignition

One gram of the pulverized sample was placed into platinum crucible. The sample was heated in electric carbolated furnace at 1000 ^{0}C for an hour. The heated sample was removed from the furnace and cooled in desiccator to room temperature. The weight of the cooled sample was taken. The loss on ignition (LOI) was computed as reported in Zhengwuvi and Ibhadode [2] as shown in equation 1:

$$LOI = (W1 - W2)/\, W1\% \qquad (1)$$

Where W_1 sample mass and crucible before heating and W_2 sample mass and crucible after heating

2.3.4 Conductivity

Ten grams of sample was soaked in 100 ml of distilled water for 24 hours. The conductivity electrode was inserted into the soaked sample. The conductivity machine automatically displayed the result [2,12].

2.3.5 pH Value

Ten grams of the sample was soaked in 100 ml of distilled water for 24 hours. The pH electrode was inserted into the soaked sample. The acidity machine automatically displayed the result [2].

2.3.6 Refractoriness

The pyrometric cone equivalence (PCE) method was used in determining the refractoriness of the silica sand. The silica sand sample was made in form of Segar cone. The sample was thoroughly mixed and then formed in suitable mould. The test piece was mounted at the centre of the refractory plague. The test piece and the appropriate pyrometric cone number was placed in the furnace and heated to an estimated temperature of 2000 ^{0}C at the rate of 10 ^{0}C to 15 ^{0}C per fifteen minutes. The temperature was checked by means of an optical pyrometer. The test was in progress until when the tip of the cone had bent over and levelled with the disc base. The plague bearing the specimen was removed from the furnace and the test piece was examined when cold. The refractoriness was the number of the pyrometric cone that had bent over to the test cone. The temperature was then read off from the equivalence of the cone number [12].

2.3.7 Clay content analysis

50 grams of dry sand grains was poured into beaker containing 250 ml of distilled water. 10 ml of sodium hydroxide was added to the content in the beaker. The sodium hydroxide accelerated the separation of the clay substance from the sand grains. The content of the beaker was stirred with mechanical stirrer for about 30-50 minutes. The content was allowed to rest for about ten minutes to allow the sand grains settle to the bottom of the beaker while the clay particles remained in suspension. The suspended clay particles in the solution were decanted by means of siphoning. More distilled water was added followed by stirring and then allowed for another ten minutes and then decanted by siphoning. Additional water was added and this continued until clean water (free from suspended clay particles) was observed. At this stage, the holding time was reduced to about five minutes. At the final stage of washing, the water was decanted and the sand grains were dried under the sun until no water was present. The sand grains were thereafter dried in an oven at about 105 ^{0}C for an hour. After drying, the final mass was taken. The clay content was calculated as percentage difference between the initial mass and the final mass to that of the initial mass [12].

2.3.8 Specific gravity

Weight of empty sample bottle was taken. Weight of one third sample and empty density bottle b was taken. Weight of one third sample and empty density bottle full water c was taken. Weight of density bottle full with water d was taken. The sample's specific gravity (SG) as given in Zhengwuvi and Ibhadode [2] as shown in equation 2:

$$SG = (b - a)/(b + d) - (a + c) \qquad (2)$$

Where SG is the specific gravity, a is the weight of empty sample bottle, b is the weight of one third sample and empty density bottle, c is the weight of one third sample and empty density bottle full of water and d is the weight of density bottle full of water

2.3.9 Sieve analysis

100 grams of clean dry sample was introduced into a set of sieves arranged in descending order of fineness. The shaker machine was in operation for recommended shaking time of fifteen minutes in order to achieve

complete classification of the sand. At the end of shaking, the sieves were removed one after the other beginning with the one on top. The mass retained on each sieve was recorded [2, 12].

3. Results and discussion

Figure 1 shows the silica sand grains in granular form. The sand is white-brown in colour and the grain shape is angular. Figure 2 shows the X-RD diffractogramme of the sand deposit.

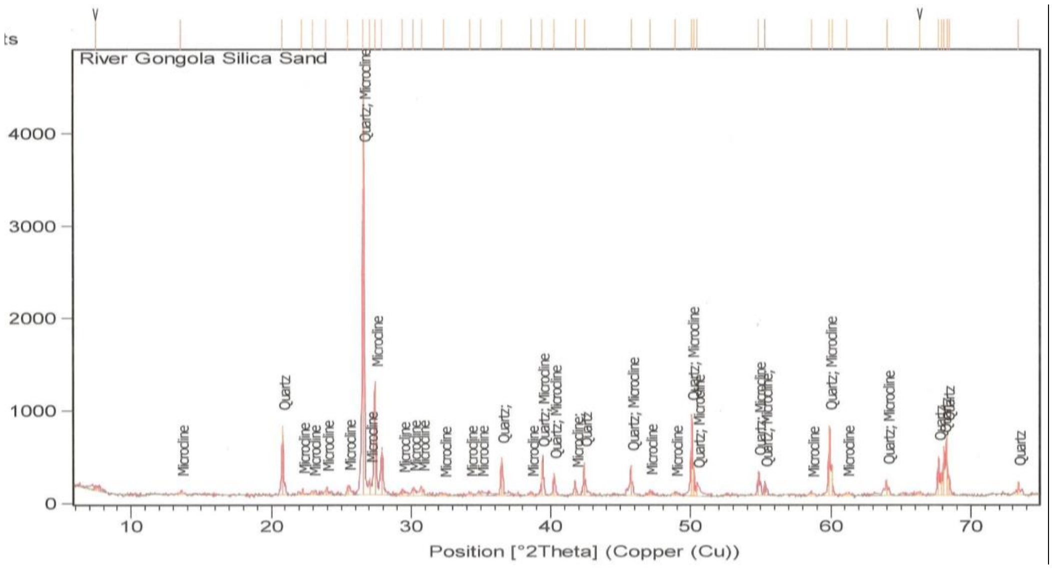
Figure 1: River Gongola silica sand

The adjacent angular grains would create void space which will accommodate the smaller grains and the binder for strong bond during moulding process. These features would suggest that the grain size is homogeneous in distribution. The silica sand deposit is observed to satisfactory for foundry works.

The diffractogramme shows the mineralogical composition of the sand deposit. It shows that the leading deposit mineral name is quartz who's chemical and empirical formula is silicon oxide (SiO_2) which confirms that the deposit silica sand. Figure 3 shows the bar chat representation of the chemical composition/oxide elemental analysis of the silica sand deposit.

From the ~~chat~~ Figure 3 and Table 3, it could be observed that the deposit is composed of 93.63% concentration of silica sand and minor traces of other oxides. According to Brown [12], the silica sand concentration is satisfactory for foundry works as moulding/core sand major ingredient.

The sand grain does not require further processing for molding. It can be used directly as mined from the deposit with chemical or non-chemical binder. Table 1 shows the physical properties of the silica sand deposit.



Diffractive key: Mineral name-quartz,
Compound name: Silicon oxide,
Chemical formula: SiO_2

Figure 2: XRD Diffractogramme of river Gongola silica sand deposit

Table 1: Physical Properties of River Gongola Silica Sand Deposit

S/No.	Items	Values
1	Loss on ignition %	0.52
2	Specific gravity	2.83
3	Conductivity W/mK	153.80
4	Clay Content %	0.80
5	Refractoriness ^0C	1500.00
6	pH	7.50

The deposit has pH scale of 7.50 which is base-safe and friendly to handle; loss on ignition of 0.52 % which represents the presence of carbonaceous materials associated with the deposit. Lower percentage of the carbonaceous materials is good for foundry works since it indicates the possibility of good permeability of moulding/core sand. As the carbonaceous materials decomposes during molten metal pouring and solidification which consequently enhances mould/core collapsibility during demoulding process. Clay content of 0.80 % means that the clay associated with the sand grain deposit is minimal. The sand will require small amount of binder to achieve strong bond of mould/core. Specific gravity of 2.83 indicates that the mould/core stability to withstand the pressure of the molten metal pouring and mould cavity filling so that moulding /core sand floating is arrested.

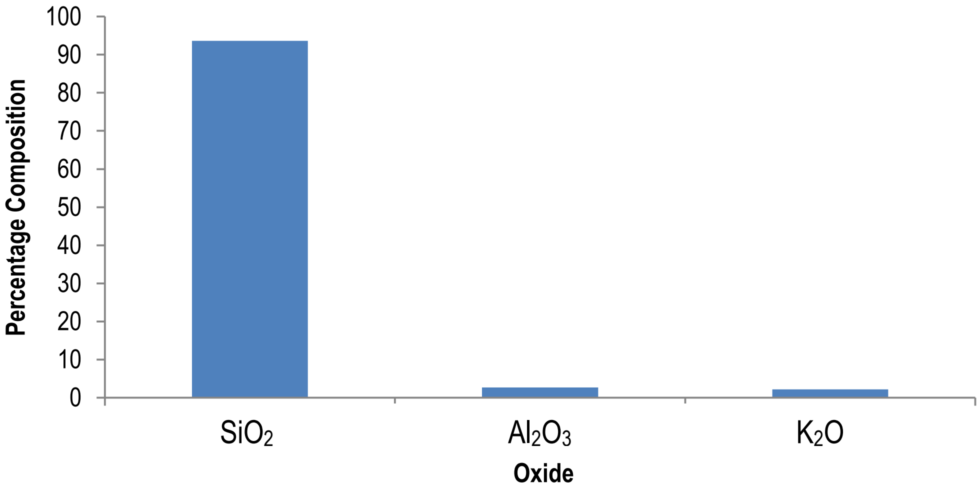


Figure 3: Chemical composition of river Gongola silica sand deposit

Conductivity of 153.80 W/mK indicates the capability of the sand grains to conduct heat properly and provide mould/core chilling effect so that casting defects such as cold or short run is completely avoided during mould cavity filling and solidification. Refractoriness of 1500.00 ^{0}C. The refractoriness of the sand shows that the sand would be able to withstand molten metal temperature up to 1500.00 ^{0}C without melting. Thus, the sand grain is capable to be used in foundry works as moulding/core sand for both ferrous and non-ferrous metal casting. Table 2 shows the silica sand sieve analysis. The sieve analysis helps in classifying the sand grains. The analysis shows that the silica sand has grain average size of 210 µm, fineness number of 62 AFS and distribution of 4 screens. According to Brown [12], the sand grain classification is seen to be satisfactory for moulding/core sand.

Table 2: River Gongola Silica Sand Sieve Analysis

S/No.	BS sieve number	Aperture (µm)	Multiplier	% mass retained	Product
1	6	3350	3	-	-
2	10	1400	5	-	-
3	22	700	10	-	-
4	30	500	20	-	-
5	44	355	30	3.80	114.00
6	52	300	40	9.50	380.00
7	60	250	50	25.80	1290.00
8	100	150	70	56.50	3955
9	150	106	100	2.70	270.00
10	200	75	145	0.50	72.50
11	Pan	-	300	0.20	60
12	Total			99.00	6141.50
13		AFS grain fineness number	62	(6141.50/99.00)	
14		Average grain size		210 µm	
15		Grain distribution		4 sieves	

Table 3 shows the comparison between the researched silica sand properties and the AFS standard values. From the table it could be observed that all the silica sand parameter values are in conformity to the standard except for the slightly high values of aluminum and potassium oxides which would have tend to affect the sand purity and refractoriness. However, the sand purity (93.63% concentration) and the refractoriness (1500.00 ^{0}C) were realized regardless of the presence of the two slightly high oxides. On satisfactory performance of the silica sand characterization, the sand was mixed with sodium silicate glass. The mixture was used to mould the pump impeller core and as well as the moulding sand. Carbon dioxide was introduced into the mould for fast curing. Molten metal was poured into the moulding flasks. On solidification of the cast, the mould flask was disassembled. The impeller was removed. The casting was thoroughly examined and found to be sound with the required shape and size. The pump was tested and found to perform well.

4. Conclusion

River Gongola silica sand deposit was characterized for the manufacture of centrifugal pump impeller. Within the experimental error, the characterization result was observed to be satisfactory. The silica sand directly from the deposit was used to cast the impeller. The pump was tested and found to perform well as the imported ones. Thus, the silica sand as directly mined from the deposit could be used for moulding/core sand without further processing. Foundry workers/firms such as Dangote Sugar Company may not need to import silica sand for its foundry activities since this deposit has met up with the foundry properties requirement for casting both ferrous and non-ferrous metals.

Table 3: Comparison of the Silica Sand Deposit with Standard

S/No.	Chemical Purity (%)	Percentage Composition	AFS Standard [12]	Remark
1	SiO_2	93.63	96	Good
2	Al_2O_3	2.71	0.11	Slightly high
3	K_2O	2.13	0.5	Slightly high
4	Na_2O	0.02	0.5	Good
5	CaO	0.18	--	Good
6	TiO_2	0.19	--	Good
7	$V_2\ O_5$	0.02	--	Good
8	MnO	0.001	--	Good
9	Fe_2O_3	0.38	0.5	Good
10	MgO	0.06	--	Good
11	BaO	0.12	--	Good
	Physical Properties			
12	Loss on ignition %	0.52	0.5	Good
13	Specific gravity	2.83	2.65	Good
14	Conductivity W/Mk	153.80	--	Good
15	Clay Content %	0.80	0.5	Good
16	Refractoriness ^{0}C	1500.00	1450	Good
17	pH	7.50	>7.00	Good
18	AFS grain fineness number	62	35-90	Good
19	Average grain size	210 µm	390-150	Good
20	Grain distribution	4 sieves	3-5	Good

Acknowledgement

The author wishes to acknowledge the assistance rendered by the staff of National Geosciences Laboratory Kaduna, Dangote Sugar Company Numan, Adamawa State and Ahmadu Bello University, Zaria.

References

[1]. Thio, R. P. and Konan, D. K., (2020). Characterization of raw silica sand from the ivorian sedimentary basin for silica glass making, *Journal of Material Enviromental Science*, 11(12), 2016-2024.

[2]. Zhengwuvi, L. B. and Ibhadode, A. O. A., (2017). Characterization of sand deposits in adamawa state for foundry core making, A Ph. D, Thesis Submitted to the School of Postgraduate Studies, University of Benin, Benin-City.

[3]. Alemaka, A. M. and Abdulahi, A. M., (2021). Characterization of Makoda silica sand deposit in Kano State North West Nigeria for use in glass manufacturing. *Journal of Science Technology and Education*, 9(2), 1-7.

[4]. Saeed, U. A., Muhammad, I. A., Dukku, M. M., Elhusien, G. (2020). Suitability of northeast Nigeria molding status for foundry use-A review. *European Journal of Mechanical Engineering Research,* Vol 9, Issue 1, pp 12-20

[5]. Daulaay, S., Yuwono, A. H., Ismail, I. and Sofyan, S., (2024). Fabrication and characterization of silica nanoparticles from beach sand. *Engineering Chemistry Journal*, 6, 53-58.

[6]. Malu, S. P., Edem, C. A. and Ita, B. L., (2023). Chemical characterization of silica sand deposit from river Katsina-Ala North Central of Nigeria. *Global Journal of Pure and Applied Physics*, 3(1), 26-37.

[7]. Apeh, F. I., Mahmoud, L. U., Shuaibu, S. and Fabiyi, M. O., (2022). Impact of moisture variation on some foundry properties of fori silica sand, *Journal of Materials Characterization and Engineering*, 10(5), 5-13.

[8]. Ogheneova, A., Chigozie, N. R. and Jude, V. O., (2023). Estimation of the variation of silica sand deposits in chosen communities in parts of Niger Delta, Southern Nigeria using geophysical techniques, *Solid Earth Sciences Journal*, 8(4), 267-282.

[9]. Osman, R. A., (2021). Assessment of chemical and minerology and features on silica sand and its potential industrial applications at Elwadi Elgedid Western Desert, Egypt. *International Journal of Innovotion Science Engineering and Technology*, 8(10), 12-20.

[10]. Rana, M. S., Alam, M. S., Shahrlar, M. S., Hossain, M. I. S., Biswas, P. K. and Zaman, M. N., (2023). Evaluation of foundry properties of brahmaputra river sand and its prospects, *Archiews of foundry Engineering*, 20(2), 80-90.

[11]. Salihu, S. A., Usman, A. and Suleiman, I. Y., (2020). Effect of variation of different additives on some selected properties of silica sand mould for aluminium casting. *Journal of Engineering and Technology Researh*, 2(1), 24-30.

[12]. Brown, J. R. (2000). America Foundry Society Handbook, Butterworth-Heinemann Linacre House, Jordan Hill, Oxford.

[13]. Ramana, M. V. (2016). Process parameter optimization of CO_2 gas cured sodium silicate molding process for better compression strength. *International Journal of Latest Trends in Engineering and Technology*, 6(3), 5-11.