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Moulding Properties of Kaduna River Bank Sand for Application in Foundry Workshop

Aminu Zakari Yushau
Department of Foundry Engineering Technology,
Kaduna Polytechnic,
Kaduna, Nigeria.

Hayatuddeeen Abdullahi Ibrahim
Department of Foundry Engineering Technology,
Kaduna Polytechnic,
Kaduna, Nigeria.

Abdussalam Mamoon
Department of Foundry Engineering Technology,
Kaduna Polytechnic,
Kaduna, Nigeria.

***Abstract* — The properties of some locations in Kaduna river bank molding sands were examined. The research involves analyses of the chemical and molding properties of Kaduna river bank sand. Samples were obtained from three different locations of the river bank sand and were experimentally investigated. The chemical compositions of the sand were analyzed and determined using X-ray Fluorescence (XRF). Similarly, the physico-mechanical properties were also examined according to American Foundry Society (AFS) standards. The results of the chemical analysis indicated that the sand constituents mainly contain Silica and Aluminium Oxide with value of 80.12 – 82.40% and 9.52 – 13.34% respectively. All sand from the three locations were found to have shown the grain fineness (AFS-GFN) values and other properties within the acceptable molding sand standards. The results indicate that sands within the acceptable molding sand standard. These results indicate that sands within the river Kaduna bank exhibit appropriate casting properties and are suitable to be used for application in foundry workshop of Kaduna Polytechnic.**

***Keywords*—foundry; moulding; properties; river bank; sand**

I. INTRODUCTION

Foundry is the field of engineering that deals with production of castings. It has been found to be an important source of industrial emancipation and economic self-reliance in Nigeria. Foundry technology is one of the vital bases for rapid industrial development of any nation. These rapid industrial developments are very essential in positively addressing the problem of economic recession, high rate of unemployment, and the over dependence on the importation of goods (durable and non-durable) into Nigeria. The Nigerian foundry industry is developing at a very slow pace. The major foundry raw material known to man is sand, and one of the main difficulties confronting both small and medium scale foundry enterprises at present is with respect to this raw material.

In manufacturing of engineering goods such as engine blocks, piston, cylinder heads and valve, metal casting is usually employed. In metal casting, sand casting is the most widely and is found to be relatively cheap and adequate utilization of sand as a resources will help towards enhancing Nigeria as an industrialized nation. Until recently, sands and binders were still freely imported and used by notable foundry companies in Nigeria. These raw materials are being progressively substituted by locally available materials. The need for identification and information on sources of suitable substitutes and standardization in the supply of sands, binders and other materials need not be over-emphasized.

Naturally bonded molding sands are found in various locations of the world and the only challenge is the evaluation of the sand's deposits for appropriate grading, adequate amount of clay content and the correct proportion of optimum water to be added for desirable foundry products. A lot of researches have been conducted on the assessment and investigation of the molding properties of different sands across Nigeria. The casting quality is depended on many properties of molding sand like dry compressive strength, wet tensile strength, permeability, etc. and these properties are dependent more or less on parameters like setting/curing time, resin amount, hardener amount, content of moisture and so on.

The source of good foundry sand is a universal problem. Foundry sand is being transported from area with good quality sand to areas where the foundry plant is located. Even though silica sand is relatively of low value, the cost of transportation over a long distance could contribute significantly to high cost of production in foundry. This has mandated some foundry operators to locate their industries closer to the source of this very important raw material. Some foundries that could not locate a good sand deposit will have to process the poor sand within the environment to meet the standard requirement for foundry practice.

Garba and Alhaji (2019) investigated the molding properties of River Niger bank sand at Jebba for use in Foundry. Standard laboratory test specimens were produced and tested from the sand samples collected along the river bank. The result from their tests indicate that the sand is permeable, has high clay content and low refractoriness, as such is suitable for non-ferrous casting. Similarly, they also examine the effect of

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grain size and clay content of the same river Niger bank sand and concluded that the sand is fine grained and contain considerable amount of clay.

Rajan et al., (2021) studied the strength of mold of the silica sand specimen by using the Taguchi technique. They conducted random experiments using L9 orthogonal array and it is observed that the setting time and granite powder are the parameters dominant for quality of mold and strength. Shuaib-Babata et al., (2017) evaluated the chemical and physico-mechanical properties of Ado-Ekiti natural molding sand for foundry applications. Some natural sand samples were obtained and their chemical compositions and physico-mechanical properties were determined. It was found out that the sand can be used naturally as a core and the properties of the sand was found to fall within the required values for casting of most ferrous and non-ferrous metals. Similarly, Shuaib-Babata Y. L. (2014) investigated the Ilorin sand molding properties for foundry applications. They analyzed the chemical and mechanical molding sand properties using standard foundry laboratory test equipment. The results of the experimental test indicate that the natural sands within the Ilorin metropolis exhibit appropriate casting properties for non-ferrous and ferrous metals.

Oke and Omidiji (2016) investigated the molding properties of Isase River sand bonded with Ipetumodu clay. Standard cylindrical specimens were prepared from various sand and clay ratio with water content. The result showed that the sand and clay mixture can be used to cast ferrous and non-ferrous alloys. Aweda and Jimoh (2009) assessed the mechanical and permeability sand in Ilorin and Ilesha. The optimum moisture content for appropriate foundry works was determined. The results obtained from the tests indicate that with the addition of water in the range of 8-9%, the natural sand exhibit appropriate casting properties for non-ferrous metals. Finally, Shuaib-Babata et al., 2017 conducted suitability analysis of Ado-Ekiti natural molding sands for use as foundry sands. Samples of natural molding sands were collected from three different molding sand deposit within Ado-Ekiti metropolis. The samples were used to produce aluminium alloy cast specimens and their mechanical properties evaluated. The result revealed that the properties compare favorably with standard values.

II. MATERIAL AND METHODS

A. Material

The material for this research is sand samples collected from three different locations within River Kaduna bank in Kaduna metropolis

B. Methods

The sand samples collected from the three (3) different location were prepared by washing and sun dried for 3 days to remove the moisture in the sand, and sieved in order to separate the debris that were collected with them. A quantity of the sand was sieved through 2 mm British Standard (BS) sieve to obtain grain size required for the experiment. The samples were molded in a specimen tube to produce standard test specimen of diameter 50mm by average height of 50 mm using standard sand rammer. The specimens were then classified and kept in a desiccator for further various foundry laboratory tests and analysis. Furthermore, the chemical constituents of the sand samples were determined using X-ray Fluorescence (XRF).

1) Moisture Content Test

The moisture content of the moulding sand was determined by weight loss method. 50-gram sample of tempered sand is weighed, dried from 105°C to 110°C. It is then cooled to room temperature in a desiccator and reweighed. The difference in the weight of the sample (in gram) is divided by the total weight of the sample taken (50-gram) to obtain the moisture content of the sample.

2) Clay Content Test

The clay content is determined by the loss of weight after washing of the sample. A 50-gram sample of previously dried sand is weighed. It is then placed in a mixing device and treated with a standard sodium hydroxide solution under controlled conditions. After a thorough washing, residue is dried and reweighed. The loss of weight is a measure of the clay substance

3) Grain Size or Fineness Test

The test is carried out to determine the percentage distribution of grain sizes in the sand. The test was performed on a dried-sand sample of weight 50-gram, from which all the clay content is removed by washing the sand. The sand is subsequently dried, and is placed on different sizes of sieves with the coarsest at the top and is vibrated or shake for a specified duration. Finally, the weight of sand retained on each sieve is obtained and converted to a percentage basis.

4) Permeability Test

A standard specimen according to AFS was placed on the perm-meter, while still in cylindrical sample tube. The perm-meter was switched on and blows a standard pressure of 9.8 X 10^2 N/m^2 through the standard tube containing green sand. The permeability level of the sand was indicated on the dial-gauge of the perm-meter in mms. The procedure was repeated for all the samples.

5) Green and Dry Compressive Test

The green strength of moulding sand was determined through the application of gradual load under a universal strength tensile machine until failure of the mould occurred and the corresponding value of the strength in KN/m^2 was instantaneously recorded. Similarly, the specimens for the dry compressive strength test were dried at 110°C for about 2 hours and cooled at room temperature before subjected to gradual application of load until failure occurred and the corresponding value of the strength in KN/m^2 was also instantaneously recorded.

III. RESULTS

A. Chemical Composition of River Bank Sand

The result of the chemical composition analysis for the selected River Kaduna Bank sands are presented in Table 1. From the result, it can be seen that the major constituents in all the sand specimens are oxide of Silicon (silica) and Aluminium with values ranging from 80.12 – 82.40 % and 9.52 – 13.34 % respectively. Other substances of small proportion were found.

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Table 1: Chemical Composition of River Kaduna Bank Sand

S/No	Element	Composition by Weight (%)		
		A	B	C
1	SiO_2	82.40	80.80	80.12
2	Al_2O_3	10.47	9.52	13.34
3	CaO	2.00	1.98	0.31
4	MgO	0.70	0.77	0.90
5	Na_2O	1.22	1.31	0.89
6	Fe_2O_3	1.20	1.24	1.03
7	TiO_2	1.03	1.35	0.65
8	K_2O	0.24	0.25	0.45
9	MnO	0.25	1.20	0.77
10	LOI	0.29	0.90	0.85

B. Grain Size or Fineness Results

The result of the AFS Grain Fineness Number (AFS-GFN) for the three sand specimens is tabulated in Table 2. It is a very important result in the selection of sand for foundry use, as the size distribution of sand affects the quality and properties of castings produced.

Table 2: AFS-GFN Result of River Bank Sand

S/No	Sieve No	Sieve Size Openings (mm)	Amount Retained on Sieve (%)		
			Sample A	Sample B	Sample C
1	8	2.060	7.20	1.07	5.33
2	10	1.680	22.20	4.16	72.48
3	16	1.000	66.44	144.02	99.30
4	22	0.853	334.66	524.04	170.67
5	60	0.250	1040.40	560.93	683.40
6	100	0.147	1750.00	808.90	628.80
7	150	0.100	1613.10	1710.90	1590.20
8	200	0.074	2046.7	2326.66	2853.00
9	Clay Pan		760.00	260.00	992.00
10	Total		7580.7	6340.62	7095.18
11	AFS-GFN		75.81	63.41	70.95

C. Properties of River Bank Moulding Sand

The molding properties of the river bank, which include the moisture content, clay content, permeability, and strength (green and dry) of the sand are presented in Table 3.

Sample	Moisture Content (%)	Clay Content (%)	Permeability (%)	Green Strength (kN/m^2)	Dry Strength (kN/m^2)
A	7.17	16.10	107.40	122.10	242.30
B	6.31	18.03	110.40	117.70	279.27
C	6.45	18.59	116.73	108.33	327.83

IV. DISCUSSIONS

The elemental composition analysis presented in Table 1 shows the major and minor constituents found in the samples of the three river bank sand. The values obtained from the analysis are in line with the recommended molding sand constituents in literature. Similarly, the analysis of the grain size distribution is tabulated in Table 2. From the table, it can be seen that the grain fineness number for sample A, B and C are 75.81%, 63.41% and 70.95% respectively. All the AFS-GFN values obtained fall between the standard value of 35-90. This indicate that the sand from these locations are therefore suitable for casting both medium and heavy steel castings. Normally, the higher the fineness of a sand ensures greater suitability of such sand for foundry use.

The properties of the Kaduna river bank sand across three (3) different locations is presented in Table 3. The properties values obtained were compared with the standard satisfactory mold sand properties in order to evaluate the sand's suitability for use in foundry workshop, precisely for sand casting. All the three sand's moisture content ranges from 6.31 to 7.17%, fall within the satisfactory AFS molding sand moisture content for various castings (i.e. 4-8.5%). Similarly, the clay content of all the samples ranged between 16.10 and 18.59%, whereas the specified clay content for a molding sand is between 10-12%; while the American Foundry Men's Association satisfactory proved values for aluminium, brass and bronze, iron and steel castings is between 12 and 18% clay contents. This indicate that the amount of clay in all the samples is sufficient and does not require the addition of binder.

The green and dry compressive strength in Table 3 showed that the results obtained for all the samples are within the acceptable standard ranges for most ferrous and non-ferrous metals, and therefore meet the need for their casting applications. This implies that all the sand samples possess adequate strength that will retain its shape and will not distort or collapse even after the pattern has been removed from the molding box. Finally, permeability is that property of molding sand that permits the escape of steam and other gases generated in the mold during hot metal pouring. The permeability test results presented in Table 3 ranged between 107.40 and 116.73%. It can be seen from the result that permeability decreases as the clay content increases, which may be attributed to the clay filling up the spaces between the sand grains.

V. CONCLUSIONS

The following conclusions were arrived at the end of the study:

1. The river Kaduna bank sand samples possessed chemical composition which are within the AFS acceptable limits for molding sands. Silica oxide and aluminium oxides are the major constituents in the sand.
2. All the physico-mechanical and AFS-GFN results obtained in this research indicate it is in close agreement when compared to established standard values.
3. The river Kaduna bank sand has potential to be used as a foundry material, which will greatly enhance possibility of creating both small and medium foundry workshops.

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