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Effect of Moisture Content on Nasarawu Natural Foundry Sand

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Abstract

This study was aimed at investigating the effect of moisture content of Nasarawu natural foundry sand. The moisture content was varied from 2 to 10% to determine its effect on green compressive strength, dry compressive strength, green shear strength, shatter index and green permeability. The particle size distribution, the grain fineness number and the clay content of the natural sand were also determined. The results indicated that the dry compression strength increased with moisture content, and an optimum value 99.7 psi was obtained at 10% moisture content. At the same time, 6% of moisture content gave the optimum green compressive strength of 118.6KN/m^2. Nasarawu natural sand had an average grain size of 138.73microns, clay content of 25.2% and refractoriness value of 1400^{0}C. A sand mixture containing 6% moisture was prepared and used to produce a test casting with aluminium scraps, and the cast was sound. This shows that Nasarawu natural moulding sand is suitable for a wide range of non-ferrous metal casting.

Keywords - *Moisture Content, Green Compressive, Shatter Index, Green Sheer*

I. INTRODUCTION

Foundry is the field of engineering that deals with the production of castings. It is an essential source of industrial emancipation and economic self-reliance in Nigeria [1]. Casting plays essential roles in the production of modern equipment for transportation, communication, power, agriculture, agro-allied, construction, space, chemical and petrochemical, and other industries. It makes it easy to produce devices and equipment that are very difficult in other engineering processes. In castings, sand is mixed with clay and water in appropriate proportion to prepare a mould for the production of industrial agricultural, automobile and municipal cast components [2].

Sand is the general name applied to comparatively finely divided, unconsolidated grains of rock, minerals, or slag. Although this report is concerned primarily with foundry sand, it is perhaps well to consider briefly other essential uses of sand. Concrete, plaster and similar sands used in construction represent by far the enormous consumption of sand. Foundry sands rank next to construction sand in a volume of output. For steelwork, a high silica content is essential for proper refractory qualities, some moulding sands for the non-ferrous metals contain no more than sixty or seventy per cent of silica. Sand grains is a heat resistant material with a particle size above 0.02 mm, has the main volume weight apportioned in a mixture. It forms a material skeleton of moulds and cores; therefore angularity and granulometry of particles is among its most essential properties asides the activity of grain surfaces [3, 2]

The shape, size, size distribution and surface characteristics of sand grains are the fundamental properties that determine whether it is suitable for the production of castings. Its desirable foundry properties are green strength, permeability, dry strength, hardness, hot strength, flowability, plasticity, adhesiveness, cohesiveness, binding property, thermal stability with respect to cracks; buckling; flaking; and thermal shocks, adequate refractoriness, good mouldability, good collapsibility, chemical resistivity, reusability, ability to produce castings with good surface finish, and ease of preparation and moulding with it [4, 2].

[5] investigated the effects of moisture content on the foundry properties of Yola naturals and. They found out that for optimum green compression strength, the moisture content should be 5% while for high dry compression strength, moisture contents between 59% should be used. The authors concluded that the moisture content of 5% produces a quality casting of aluminium using aluminium alloy scraps. [6] carried out the characteristic foundry properties of Kaduna River sand. He found out that the sand is weak in strength and does not meet the practical value for casting heavy metals. [7] investigated the suitability of Lere river bank sand for green sand casting. Their investigation revealed that the riverbank sand is alumino-silicate with Physico-chemical properties that are suitable for non-ferrous alloy casting. It responded well to bentonite clay binder that gave good mechanical properties to sand mould specimens. The result of the mechanical properties analysis of the sand as compared to existing foundry standard and it was discovered to be very suitable to all types of non-ferrous alloy castings.

This research is of utmost importance in the area of foundry application with the applicability of the Nasarawu natural sand as a moulding material. The local foundry men have been using this sand without the knowledge of its properties. Except for these scientific properties of the sand is known, it will be complicated to use the sand and achieve its full potential. As such, this research aimed at determining and analyzing the physical and mechanical properties of Nasarawu natural sand for foundry application.

II. EXPERIMENTAL PROCEDURE

The Nasarawu sand sample was collected at three different depths of 0.5m, 1.0m, 1.5m and mixed thoroughly to have a mixed representative. For moisture content test, the sample was collected in waterproof material. The physical and mechanical properties of the sand were analyzed using American Foundry Men Society (AFS) Standards [8].

PHYSICAL PROPERTIES OF THE SAND

i. Sieve Analysis

300g of the Nasarawu foundry sand was weighed and dried in an oven; 100g of the natural sand was weighed and introduced into a set of the sieve with a ranging 1.40 – 0.063mm; the nest of sieves were arranged from the largest aperture to the smallest. The nest of the sieve was then mounted on a sieve shaker and vibrated for 15 minutes [7]. The result was tabulated and used in finding the grain distribution and fineness number of the sand, as shown in table 1.

Plate 1: Mechanical shaker with a set of sieve

ii. Clay Content

50g of the Nasarawu dry sand sample was transferred into a wash bottle, and 475 ml was added into distilled water and 25ml of 3% NaOH solution. The mixture was agitated for 10 mins, then suspended clay particles in the solution were decanted by means siphon. Additional water was introduced, followed by stirring and decantation. This was repeated until clear water; free from suspended clay particles was observed. The sample then dries in an oven at 300^{o}C, the sample was then allowed to get cold and weigh. [6, 9]

Initial sample weight = X_1

Final sample weight of dry sand = X_2

Clay content = $\frac{X1-X2}{X1} \times 100$ … (1)

iii. Moisture Content Test

The dried sample of the Nasarawu sand was weighed out on the speedy moisture content weighing balance, the sand was poured into the moisture tester, and two spoons of calcium carbide powder was poured as well. The knob tightened properly then shaken for 2mins, and the reading on the moisture content of the dry sand was taken as expressed in percentage (this indicates the water of crystallization) The same procedure was repeated for varying moisture addition of (2% to10%)[10].

Plate 2: Measuring moisture content

MECHANICAL PROPERTIES OF THE MOULD

i. Green Compressive Strength

Sand samples were weighed and were rammed using laboratory Muller for 3mins, and 150g of the mixed specimen was weighed out using a sensitive tabletop digital scale. The weighed samples were poured into a cylindrical ramming drum and rammed using a mechanical rammer to obtain a 50mm X 50mm cylindrical test specimen. The specimen was removed from the cylinder with the aid of a sample remover. The

sample was placed into the machine using a compression head. The machine was switch on, and a Steady increased compressive force was applied to the test specimen until failure occurred. The value was recorded as the green compressive strength. This procedure was repeated by varying water (2% to 10%) [8].

ii. Green shear Strength

Sand samples were weighed and were rammed using laboratory Muller for 3mins, and 150g of the mixed specimen was weighed out using a sensitive tabletop digital scale. The weighed sample was poured into a cylindrical ramming drum and rammed using a mechanical rammer to obtain a 50mm X 50mm cylindrical test specimen. The specimen was removed from the cylinder with the aid of a sample remover. The sample was placed into the machine using compression shear head. The machine was switch on, and a Steady increased compressive force was applied to the test specimen until failure occurred and was recorded as the green shear strength. This procedure was repeated varying water (2% to 10%) [8, 9].

iii. Dry compressive strength

Sand samples were weighed and were rammed using laboratory Muller for 3mins, and 150g of the mixed specimen was weighed out using a sensitive tabletop digital scale. The weighed sample was poured into a cylindrical ramming drum and rammed using a mechanical rammer to obtain a 50mm X 50mm cylindrical test specimen. The specimen was removed from the cylinder with the aid of a sample remover. The sample was dried in an oven for 30min at 160^{o}C and was placed into the machine using a compression head. The machine was switch on, and a Steadily increased force was applied to the test specimen until failure occurred and was recorded as the dry shear strength. This procedure was repeated varying water (2% to 10%) [9, 10].

iv. Dry Shear Strength

Sand samples were weighed and were rammed using laboratory Muller for 3mins, and 150g of the mixed specimen was weighed out using a sensitive tabletop digital scale. The weighed sample was poured into a cylindrical ramming drum and rammed using a mechanical rammer to obtain a 50mm X 50mm cylindrical test specimen. The specimen was removed from the cylinder with the aid of a sample remover. The sample was dried in an oven for 30min at 160^{o}C and was placed into the machine using the shear head. The machine was switch on, and a Steadily increased force was applied to the test specimen until failure occurred and was recorded as the dry shear strength. This procedure was repeated varying water (2% to 10%) [11]

Plate 3: Universal strength testing machine

v. Green Permeability

The rammed specimen inside the cylindrical drum was placed into the tester, and the knob was tightened. The machine pressure knob was opened, and equipment turned on to read the result, the principle behind this test is that the specimen was subjected to a standard pressure of 9.8x10N/m^2. The amount of air passed through is shown on the dial reading expressed in psi (pounds per square inch), which indicates how suitable the sand is for moulding. The air nozzle used for this experiment was the small orifice, and reading was taken from the small orifice [14].

Plate 4: Permeability tester

vi. Refractoriness

A furnace (model: NETZSCH 428 PCE Furnace) will be used in order to obtain the refractoriness of the sand. The test pieces mounted on a refractory plaque along with some standard cones whose melting point are slightly above or slightly below that expected of the test cones

were placed in the furnace. The temperature of the furnace was raised at a rate of 100ºC per minute until the tip of the test cone bent over level with the base. At the end of the experiment, the final temperatures were recorded [10]

vi. Shatter Index

A shatter test apparatus was used to measure shatter index of the specimens [11]. The index value of the specimen was determined by allowing the specimen to fall freely from a height of 1.83 meters unto a steel anvil placed on the sieve (12.5mm mesh). The degree of disintegration of each specimen was measured.

III. DISCUSSION OF RESULT

RESULTS

Table 1: Sieve analysis

S/N	Sieve size (mm)	Wt Retained (g)	Wt(%) Retained	(%) passing finer	Cumm (%) Retained	Multiplier	Product
1	1.40	2.39	2.39	100.00	2.39	12	28.68
2	1.00	3.85	3.85	97.61	6.24	16	61.60
3	0.71	3.42	3.42	93.76	9.66	22	75.24
4	0.50	3.55	3.55	90.34	13.21	30	106.5
5	0.355	3.75	3.75	86.79	16.96	44	165
6	0.25	15.53	15.53	83.04	32.49	60	931.8
7	0.18	13.09	13.09	67.51	45.58	85	1112.65
8	0.125	18.58	18.58	54.42	64.16	120	2229.6
9	0.09	13.30	13.30	35.84	77.46	170	2261
10	0.063	8.90	8.90	22.54	86.36	240	2136
11	Pan	13.60	13.60	13.64	99.96	350	4760
	TOTAL	**99.96**		**0.04**			**13868.07**

$$AFS = \frac{\text{PRODUCT}}{\text{wt\% RETAINED}} = \frac{13868.07}{99.96} = 138.73 \quad \ldots (2)$$

Table 2: Some properties of Nasarawu natural sand

Sample Properties	GFN	Grain Shape	Clay Content	Refractoriness Value
Results	138.73AFS	angular	25.2%	1400^0C

Table 3: Shattered Index

% Moisture	2%	4%	6%	8%	10%
Shatter Index	Nil	45.86	82.25	113.66	134.22

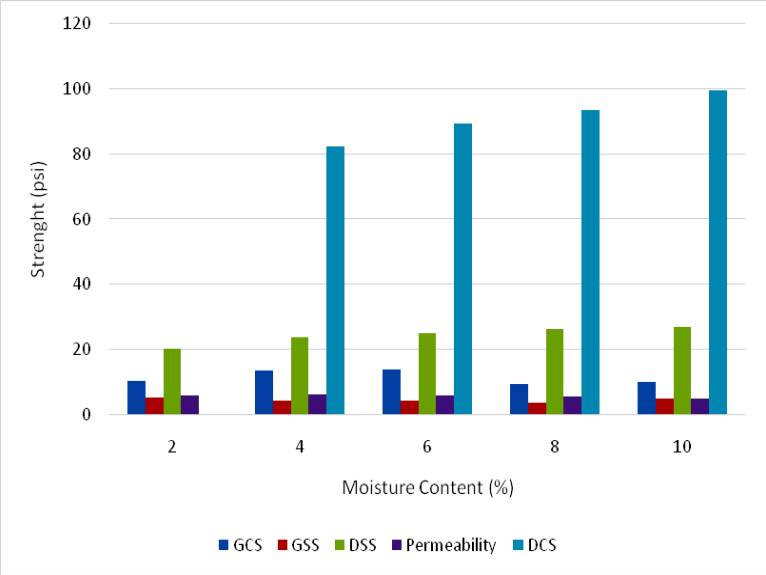

Figure 1: Effect of Moisture Content on Mechanical Properties of Nasarawu Natural Sand

DISCUSSION OF RESULT

Table 1 shows the sieve analysis of the Nasarawu foundry sand with AFS 138.73. Foundry sand is usually grouped into the range of 150- 400um and 220-250um being the most commonly used. This has a significant role in terms of the passage of gasses generated on the introduction of the molten metal to the mould cavity. Hence, the result obtained is within the recommended range of AFS Standard, as reported [10].

Furthermore, Nasarawu natural moulding sand has a natural clay content of 25.2% as can be seen in Table2. The refractoriness value of the moulding sand was found to be 1400^0C. This implies that the material can be used for aluminium, brass, bronze, malleable cast iron and light grey cast iron products according to AFS standard [9].

As shown in Fig. 1, permeability increases with increase in moisture content from 2% to 6% and after 6% of moisture content. The permeability starts decreasing significantly. According [5], the permeability increases as the moisture content increases in a nearly linear manner due to the swelling action of the clay particles, thereby pushing the sand particles further apart and making more room for air passages just as in the case of this natural sand. With the high permeability value of 6 Psi at a moisture content of 2%, this revealed that the moulding is good enough for casting, the cast components will be free from major and minor defects, such as, blown holes, porosity, scars [10].

From Fig. 2, the effect of moisture content on Nasarawu natural sand revealed that as the moisture content increases the green compressive strength increases to an optimum value of 13.6 Psi at a moisture content of 6% after which the strength starts decreasing and dry compressive strength of the material increases with the increased in moisture content, from 2% to 10% moisture content with the strength of 82.6 Psi to 99.7 Psi respectively. This is above Lere river sand (22 KN/m^2), but quite far below Yola natural foundry sand (118.6KN/m^2) at 5% moisture content, Asa Dam foundry sand (290 KN/m^2), Ita-Amo moulding sand (350KN/m^2) and Okelele foundry sand (298 KN/m^2) [5, 7, 11]. From the result obtained when compared with the recommended AFS standard, it indicates that metals, such as aluminium, brass, bronze, malleable iron and light grey iron can be cast with Nasarawu natural moulding sand, as the green compression strength at the maximum falls within the acceptable range [8, 11].

The effect of moisture content on Nasarawu natural sand revealed that as the moisture content reduces the green shear strength decrease while dry shear strength increases with the increased of moisture content (see Fig. 2). The green shear strength of the natural sand decreases with increase in moisture content, 5Psi at a moisture content of 2% and 5.75 Psi at 10% moisture content, while that of dry shear strength shows a high value at 10% moisture content with a strength of 26.7 Psi and a low value at 2% with a strength 20 Psi. This strength of the sand is sufficient enough to prevent the shear of the mould as molten metal is poured into the mould [14].

Casting

A test casting was made using aluminium scrap and mould preparation using Nasarawu natural sand. The result showed that the casting had a good surface finish and of good quality.

Plate 5: An Aluminium Cast Products using Nasarawu Natural Sand at 6% Moisture Content

An Aluminium casting was conducted using Nasarawu Natural sand at 6% moisture content in order to demonstrate the suitability of the sand. This can be seen in Plate 5 above. The cast product was found to be free of any defect.

IV. CONCLUSION

Nasarawu natural sand indicates its potential to be used as a foundry sand in the green state. It was discovered that it required 6 % of moisture for optimum performance, after varying the moisture content from 2% - 10%. From the results of the mechanical properties obtained, Nasarawu natural sand can be used as foundry sand suitable of casting metals components such as brass, bronze, aluminium and its alloys at a lower moisture content of 6%, but not suitable for casting of higher temperature (above $1{,}400^0$C) melting metals like iron and steel.

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