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Application of Gwange Natural Sand as Foundry Moulding Material

Mahmoud L.U. [a*], Apeh F. I.[b], Shuaibu S.[c], Isheni Y.[d]

[a,b,d]*Engineering Material Research Department, Nigerian Building and Road Research Institute, PMB, 1055, Km 10, Ota, Ogun State.*

[c]*Department of Automobile Engineering, Abubakar Tafawa Balewa University, Bauchi, Bauchi State.*

[a]*Email: lawalmu@gmail.com*

Abstract

Foundry remains a vital base for rapid industrial development of any nation.The foundry sectors produce spare parts for other industries and are mostly affected in the source of local readily usable processing materials to facilitate the production of spare parts for other industries. Foundry sand is one of these materials which needed to be developed for its application in the sectors. Gwange Sand from Maiduguri, Borno State in North-Eastern Nigeria was collected at 3, 4, 5 & 6 meters depth and characterized to ascertain its suitability for use as natural sand in foundry industry. Foundry laboratory testing equipment were used in carrying out the tests and the results obtained were compared with American Foundry Men Society Standard (AFS). It was discovered that quantity of moisture and clay content has effect on foundry properties of the sand. The moulding sand has about 30-40% clay content with an average of 35% clay content as the optimal use with satisfactory green compressive strength of 57.06KN/m^{2}and other properties at moisture content less than 3%. The study also revealed that, the favourable results obtained for compression strength, permeability, mouldability, Shatter Index, refractoriness etc., makes Gwange sand as natural moulding sand suitable for casting of some metals components and its alloys.

Keywords: foundry; natural moulding sand; compressive strength; permeability; clay; casting.

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* Corresponding author.

1. Introduction

The use of sand in foundry industry is indispensable as it applicability to all type of castings with exception of few types. Sand casting is versatile as it is used for both ferrous and non-ferrous metals castings.

Silica sand (SiO_2) is the commonly used in foundry but not all sand are suitable for casting. This is because there are certain properties that are required before they can be used, these properties include: green compression strength (GCS), dry compression strength (DCS), permeability (P), shatter index (SI), mouldability (M) refractoriness, moisture content (MC), etc. Refractoriness is the ability of the moulding sand to easily withstand the high temperature of molten metal and as such will not fuse during the pouring operation, [1] discovered that moulding sands with poor refractoriness may burn when the molten metal is poured into the mould cavity.

The chemical resistivity of moulding sand, which helps it not to chemically react or combine with molten metal and as well as pave ways for possible re-use of the foundry materials, is very important. The materials should have high degree of permeability, which allows air and gases to escape from the mould cavity when liquid metal is been poured without interfering with the rigidly and cohesiveness of the mould. Good moulding sand is the one that facilitates the economics production of defects free castings. The cheapest of the moulding sand is the one containing all property components in correct proportions in the natural state [1]. Thermo physical properties of the moulding mixtures determine the rate and sequence of solidification of the poured metal and the conditions of its cooling [2].

Nigeria, like other countries of the world is blessed with abundant minerals resources and silica sand is one of them, with large deposit of over 150million tons have been discovered in Benue, Kogi, Ondo, Borno, Niger, Enugu, Delta, Lagos, Bayelsa, Kano, Katsina, Imo, Abia, Cross-River, States, etc. The material is also used in the production of glass, fused silica as fillers in automobiles tires, rubbers and in footwear soles [3].

Foundry sand (Base sand) consist of primarily of clean, uniformly sized high proportion of silica and have bonding quality which depend on the presence of some kind of clay material which can be baked to form bonded mould for ferrous (iron and steel) and non-ferrous (copper, aluminium, brass,etc.) metal casting. Most silica contains impurities which cause scabbing of the casting surfaces when used [4]. The impurities in the sand affect foundry properties of the moulding sand. Table 1 shows some properties ranges for sand casting.

Binder (clay) is the second major constituent of foundry sand; it constitutes about 5 to 11% in moulding sand. Clay (bentonite) in particular are added to give cohesion to moulding sand and it provides strength to the moulding sand and enables it to retain its shape after forming the mould cavity. Bentonite is a form of clay that is widely used in not only foundry but also find its application in petro-chemical industries as a seal [5]. Binders are added to based sand to bond or glue the sand particle together in other to make it easily mouldable, which also gives it sufficient strength and plasticity when mixed with the right quantity of water [6]. Other types of clay materials in use include kaolinites and special clays (illites, hallosites, and atalpugites). Bentonites and kaolinites are the one commonly in used in foundry practice. In Nigeria, there is the tendency of the big tour

drew, especially, the ones owned by government to rely almost solely on the imported bentonite. Hence, there is need to investigate the foundry properties of Gwange natural moulding sand for its possible application in foundry industry to reduce the burden of foundry materials sourcing.

Table 1: Some Property Ranges for Sand Casting

Metal	**Green Compression Strength (KN/m^2)**	**Permeability (No)**	**Dry (Compression Strength (KN/m^2)**
Heavy Steel	70-85	130-300	1000-2000
Light Steel	70-85	125-200	400-1000
Heavy Grey iron	70-100	70-120	350-800
Aluminium	50-70	10-30	200-550
Brass and Bronze	55-85	15-40	200-860
Light Grey Iron	50-85	20-50	200-550
Malleable Iron	45-55	20-60	210-550
Medium Grey Iron	70-105	40-80	350-800

Source: AFS (1989)

2. Material and methods

In carrying out the experiments, Gwange silica sand was collected and its foundry properties were experimentally investigated using measured standard test specimen and equipment in a standard foundry laboratory. The properties measured include: moisture content, green and dry compression strength, permeability, mouldability, refractoriness and shatter index.

2.1 Research Materials and Equipment

Gwange river sand collected was sieved using standard sieve size 40-70 mesh. The sand contained 30-40% clay. The grain fineness can be obtained as follow:

Grain Fineness Number GFN= Product/ Cumulative of GFN ==133.26

GFN: 133.26 AFS

Tests using AFS Standard was used forcarrying out the experiment. The sand collected from the river bank of the Gwange community, Maiduguri, Borno State at a depth of 3, 4, 5 and 6 meters respectively were prepared accordingly. The experimental test equipment include: laboratory sand mixer, sand rammer, universal strength test machine, permeability-meter, hardness tester, dry oven shatter index machine, mouldability machine and as well as quick moisture teller.

2.2 Specimen Preparation and Test Procedure

The entire tests conducted in this work were in accordance with the American Foundry Men Society Standards [7].

The sand specimen was weighed (2kg), and then washed, oven dried at 110^{o}C to remove free water. It is then re-weighed in order to calculate the clay content. The quantity was sieved using AFS standard to obtain required grains of 40-70 mesh, (see Table 2). Sample sand specimen was then prepared using a standard sand rammer that model Type 'N': Ridsdale Dieter T & Co Ltd Middles Brough England, Serial No:8421, which produced a compaction of three blow, 6.5kg to form a height of 50.4mm. Each specimen after three compaction blow measured 50.4mm in height by 50.4mm in diameter of the average weight of 130g. Majorly, specimens are classified into green and dry compression. A speedy teller model Type 'C2', Riddle Dieter T Co. Ltd Middles Brough England was used to test and read the moisture content of the specimen. The instantaneous moisture content in percentage was recorded.

In carrying out the permeability test, standard air pressure of 9.8 x 102N/m^2 was passed thought cylindrical specimen tube containing standard moulded green sand specimen placed in parameter of the perm-meter and the time taken for 2000cm^3 of air to pass through the specimen was determined. The dry and green compressive strength tests were carried out with the universal strength testing machine model Ridsdale Dieter T & Co Ltd Middles Brough England, Serial number-M8415. Steady increase in compressive force was applied on test specimen until failure occurred and strength in KN/m^2 was recorded instantaneously. The dry compressive specimens were first oven dry at 110^{o}C for one hour and allowed to cool with the oven before the test was conducted. A shatter test apparatus model Ridsdale Dieter T & Co Ltd Middles Brough England Serial No: 8451 was used to measure shatter index of the specimens.

The most widely used method of measuring the softening behaviour of moulding sand at high temperatures has been the determination of the Pyrometric Cone Equivalent (PCE) of a particular material against the virgin material and as such the refractoriness value of the virgin material was determined using Pyrometric Cone Equivalents (PCE) in a Furnace of model: NETZSCH 428 PCE Furnace. 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 100^{o}C per minute until the tip of the test cone (Gwange Sand) bent over level with the base. At the end of the experiment, the final temperatures were recorded.

3. Results and discussion

The sieve analysis carried out on the material is shown on Table 2. From the Table, it shows that, the result obtained from sieve analysis of Gwange moulding sand which was aimed at determining the grain fineness number (GFN), that is, the ratio of the product to the cumulative weight retained was found to be 133.26 AFS standard as GNF. The grain fineness number has a significant role in terms of the passage of gasses generated on introduction of the molten metal to the mould cavity. The result obtained is within the recommended range of AFS Standard (see Table 2).

Table 2: Sieve Analysis of the Materials

S/N	Sieve Aperture(mm)	AFS	Weight retained(g)	Cumulative weight (g)	Product
1	1.40	10	2.17	2.17	-
2	1.0	16	2.95	5.12	29.5
3	0.71	22	3.30	8.42	52.8
4	0.51	30	2.78	11.24	61.16
5	0.355	44	3.17	14.37	95.10
6	0.250	60	4.97	19.34	218.68
7	0.180	100	6.67	26.01	400.20
8	0.125	150	22.5	48.16	22.5
9	0.090	200	22.26	70.42	3339
10	0.063	300	18.93	89.35	3786
11	-0.063	350	10.25	99.60	3075
			99.60		**13272.44**

The sand collected is light brown in colour, sub-angular in shape and has an average clay content of 35% at 4meters depth as the optimal. Table 3 shows the result of the physical properties.

Table 3: Physical Properties of Gwange Moulding Sand

S/N	SAND SAMPLE	
1	Colour	Light Brown
2	Grain Shape	Sub- Angular
3	AFS Grain Fineness	133.26

Gwange natural molding sand has about 30 to 40% natural clay. The green compression strength of sand shows a high value in the green compression strength of 57.27KN/m^2 at moisture content of 2.2% and lower value of the green compression strength of 33.95KN/m^2 at the highest moisture content of 4.7% (see Table 4). From the result obtained, it indicates that metals, such as, aluminum, brass, bronze, malleable iron and light grey iron can be cast with Gwange natural moulding sand without any addition of binder, as the green compression strength at the its maximum fall within the acceptable range. Below in Figures 1& 2, are the samples prepared with less than 3% and above 3% moisture content, while Table 4 shows the Effect of Moisture Content on some foundry properties.

Figure 1: Sample Prepared for Moisture Content < 3% Figure **2:** Sample prepared for test at Moisture content above 3%

Table 4: Effect of Moisture Content on Some Foundry Properties

Properties	**MC (%)**				
	4.7	3.6	2.8	2.2	1.9
GCS (KN/m^2)	33.95	43.47	51.82	57.27	57.06
DCS (KN/m^2)	93.5	94.5	105.5	146.5	152.5
P (mmWs)	340	390	410	430	440
M (%)	92.00	95.30	98.40	99.90	99.80
SI (No)	88.0	81.0	73.0	64.0	60.0

The results of dry compression strength test show a low value of 152.5KN/m^2 at 1.9 moisture content. From the Table 4, it indicates that, the higher the moisture content the lower the GCS and DCS. This indicate that Gwange moulding sand has poor dry compression strength and therefore cannot be used as dry mould, rather it can be used in green state based on the AFS standard.

The result of the permeability test shows an increase in the permeability number with decrease in moisture content with a value of 440mmWs at 1.9% moisture content. It was further revealed that the moulding sand when used for casting, the cast component(s) will be free from major and minor defects, such as, blown holes, porosity, scars, etc.

The results of the mouldability test carried out indicated that, at various moisture contents excellent mouldability of almost 100% were achieved. Figure 1 shows the samples prepared for compression strength, permeability and mouldability tests at a control moisture content of less than 3%. This mix was also used for the test mould for casting of aluminum plates. It was discovered that the cast products came out fine (see Figure 3),

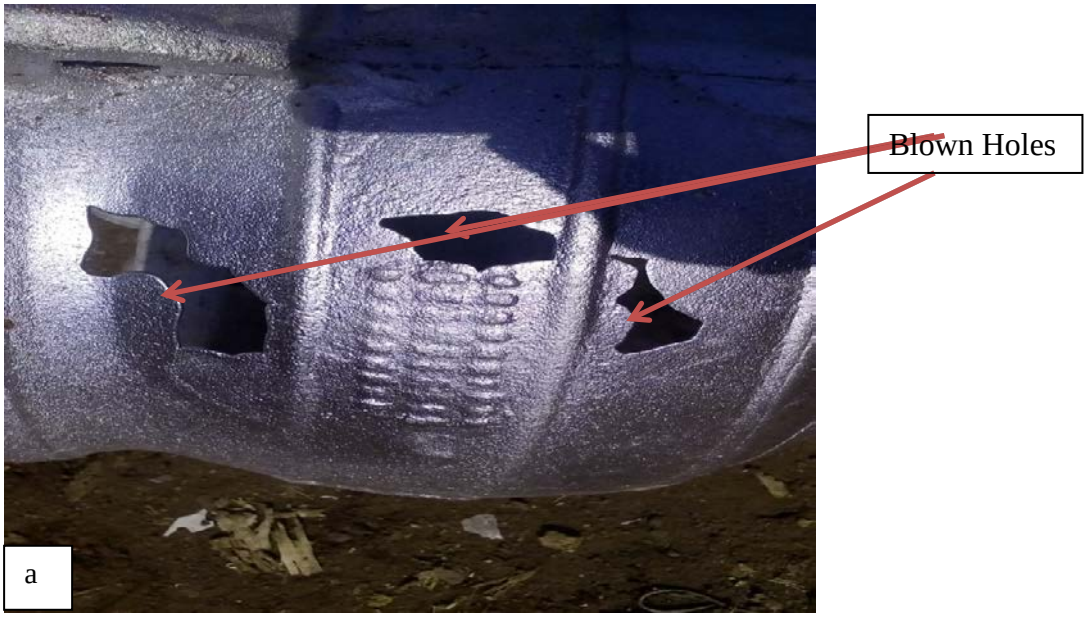
while sample prepared using moisture content above 3% used for casting of aluminum plates came out with some defects, such as, blown holes, shrinkage porosity, etc., as shown in Figures 4a &b.

Shatter Index, which is the ability of the mould to collapse after casting was also access using the shatter index machine, the result of the investigation reveals that the higher the moisture content the higher the shatter index number as shown in table 4.

From the results obtained, it is cleared that high percentage of moisture in the moulding sand is not advisable, as the resultant effect will lead to temperature reduction during the process of pouring in of the molten metal. During the process, large volume of gasses will be released which equally facilitates the rate of cooling and at the same time obstruct the flow of the molten metal leading to the defects recorded.

The refractoriness value of moulding sand is $1{,}370^{0}$C and this implies that the material can be used for aluminum, brass, bronze, malleable cast iron and light grey cast iron products.

Figure 3: Cast Aluminum Plate from Moulding Sand with less than 3% Moisture Content



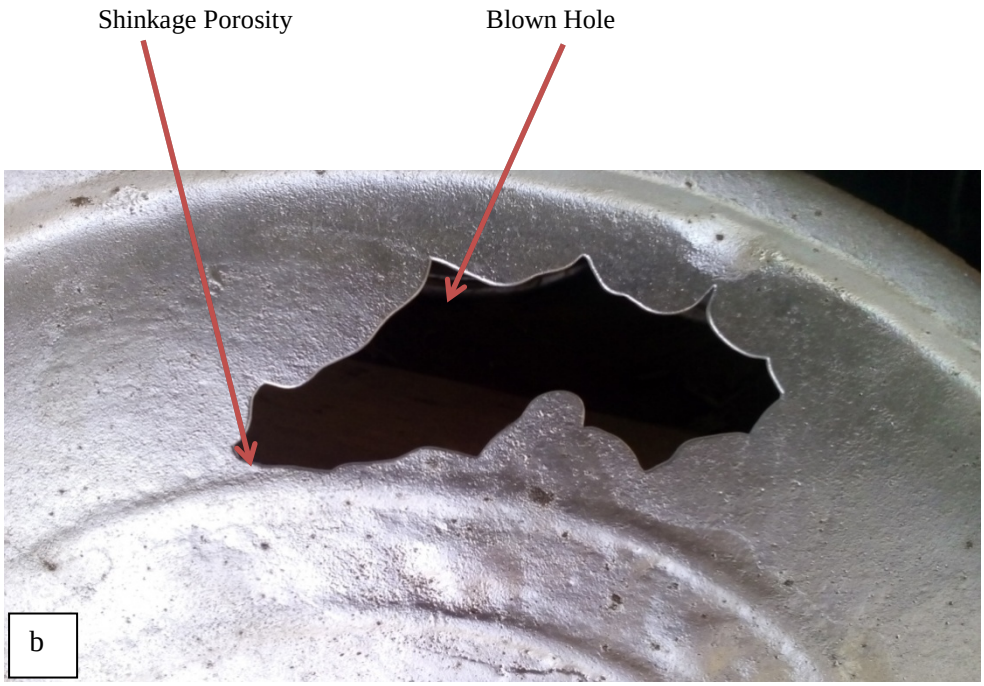


Figure 4 (a & b): Cast Components showing some Defects

4. Conclusion

Research on the application of Gwange Natural Sand as Foundry Moulding Material has been carried out. Foundry laboratory tests conducted on the materials collected indicated its potential to be used as foundry sand in green state. From the results obtained it was discovered that, quantity of moisture and clay contents has effect on foundry properties. The moulding sand has about 30to 40% clay content with an average of 35% clay content as the optimal use with satisfactory green compressive strength of 57.06KN/m^2 at moisture content less than 3%. From the results obtained for compression strength, permeability, mouldability and refractoriness Gwange Sand can be used as natural moulding sand suitable for casting of some metals components (brass, bronze, aluminum, malleable cast iron and as well as light grey cast iron) and its alloys.

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