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SUITABILITY OF SAND FROM RIVER UBUH IN DELTA STATE FOR METAL CASTING

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ABSTRACT
This Research on suitability of sand from rivers Ubuh in Delta state for metal casting purposes with binding clay and water. The sand is put to use for metal casting which includes ferrous and non ferrous material components for foundry purposes with a view of possible replacement of the imported products. The sample is subjected to physical and mechanical tests. These include permeability, green and dry compression strength tests. Green and dry shear strength shattered index and refractoriness tests will also be carried out on the samples. The samples investigation consisted of washed and unwashed sands prepared from control sample moulding sand. The results obtained shows the existence of peak values for the green compressive strength of the washed and unwashed sand, and peak values for the permeability and shatter index of the washed sand, with set amounts of binding clay as well as water in both cases. In addition, the working range for each type of property was seen to vary with the amount of water present in the sand. Samples containing 23–32% clay were found to possess adequate permeability, good strength and refractoriness suitable for casting of both ferrous and non-ferrous alloys. The results demonstrated the possible utility of the sand for making of sand casting moulds.

Keywords: Green and dry compressive strength; Green and dry shear strength Permeability; Shatter index

INTRODUCTION
Metal casting is a modern process with ancient roots. It is defined as the process in which molten metal is poured into a mould that contains a hollow cavity of a desired geometrical shape and allowed to cool down to form a solidified part. Casting is also used to describe the part made by the casting process which dates back 6000 years. Historically it is used to make complex and or large parts, which would have been difficult or expensive to manufacture using other manufacturing processes. In the metal casting process, metal shapes are formed by pouring molten metal into a mold cavity, where it is cooled and later extracted from the mold. Metal casting is arguably the earliest and most influential industrial process in history. It's used to make many of the metal objects used in our daily lives: automotive parts, train wheels, lamp posts, school bus pedals, and much more. Plus, metal casting foundries rely on metal recycling as a cost-efficient source of raw material, significantly reducing wasted scrap metal that might end up in landfills.
Casting is a method where a solid material is dissolved, heated to suitable temperature (generally treated to change its chemical structure), and is then added into a mold or cavity, which keeps it in a proper form during solidification. As a result, in just one step, complex or simple designs can be created from any material that can be dissolved. The end product can have nearly any setting the designer needs.

- For any casting procedure, choice of right alloy, sizing, shape, thickness, tolerance, structure, and weight, is really important.
- Special needs such as, magnetism, deterioration, stress distribution also have an impact on the selection of metal casting process.
- Opinions of the tooling manufacturer; foundry / machine house requirements, customer's exact product needs, and secondary procedures like paint work, must be addressed before choosing the right metal casting process.

Casting is a metal shaping process by pouring the molten metal into a mould and allowing it to solidify The basic simplicity of this, the most direct of all metallurgical processes, has provided the foundation for the growth of a vast industry with a wide diversity of products. To obtain a true perspective of the casting process, however, its characteristics must be seen in relation to the whole range of processes available for the production of metal structures. Foundry serves a variety of industries that cut across oil and gas, construction, mines and mineral processing, glass manufacturing, flour milling, marine and shipping, etc. A foundry is a metal factory where castings are produced. Metals are cast into shapes by melting them into a liquid, pouring the metal into a mould, and removing the mould material or casting after the metal has solidified as it cools. Sand casting is relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. There are numerous metal casting processes implemented in the manufacturing of parts. Two main divisions can be identified by the fundamental nature of a mold they use. There is expendable casting and long-lasting mold casting. Expendable molds are utilized for a single metal casting while long-lasting molds are utilized for several. Nearly every engineering product we use from washing machines to pillar drills, cars to bicycles are manufactured using metal parts which are most likely to be made using one of the metal casting processes. This age-old manufacturing process has improved its precision and tolerances over time. Typically, castings are used to make car engine blocks, crankshafts, power tool housings such as, pillar drills, plumbing parts, turbine blades, metal statues, some gears and gearbox housings. Metal casting is one of the important net shape manufacturing technologies. Others include net shape forging, stamping of sheet metal, additive manufacturing and metal injection moulding. It dates back to the ancient time and has certain advantages over the other processes of shape-producing desired components or parts such as forging, rolling, extrusion, powder metallurgy, machining.

i Ease and economy in adaptability to the requirements of mass production.

ii Certain metals and alloys such as highly creep resistant metal-based alloys for gas turbines can't be worked mechanically and can be cast only.

iii Heavy pieces of complicated shapes of several tonnes can be cast while it would be difficult to make these in any other way.

iv Casting is often the cheapest and most direct way of producing a shape with certain desired mechanical properties. Desired mechanical properties can be attained by operations such as; suitable control of alloy composition, grain structure and heat treatment.

v Castings are often cheaper than forgings and weldments; depending on the quantity, type of material used and fixture for weldments. Where this is the case they are logical choices for engineering structures or parts.

vi Castings have specific important engineering properties, these may be metallurgical, physical and economic. Intricate shapes having internal openings and complex sectional variations can be produced quickly and economically by casting since liquid metals can flow into any form, whereas tooling and machine cost in mechanical working would be too high to produce them.

vii Casting is best suited for composite components requiring different properties in different sections. These are made by incorporating prefabricated inserts in a casting, some examples are; steel screw threads in zinc die castings, aluminum conductors into slots in iron armatures for electric motors, wear resistant skins into shock resistant components, There are various types of moulding processes and two types of moulds, namely permanent and expendable; are used for casting. Sand casting employs the use of expendable moulds. It is the most widely used and adaptable casting process. The process is well suited to a whole variety of miscellaneous castings in sizes as low as individual teeth in a zipper to several tonnes such as the huge stern frames of ocean liners. The sand is composed primarily of silica (SiO_2). Green sand moulding is the most popular and widely used process in the foundry industry. The process is well suited to a whole variety of miscellaneous casting in sizes of less than 0.5- 4.64 kg. Dry sand moulds are used for heavier casting. Sand casting is best suited to ferrous and non ferrous metals at their high melting temperatures but also predominates for aluminum, brass, bronze, and magnesium. (Doyle, 1969; Jain 2005; Lindberg, 1977)

MATERIALS AND METHODS

Materials used for this work were locally sourced. The sand was sourced from River Ubuh in Ogwashi Uku, Aniocha South Local Government Area Delta State Nigeria. The clay was sourced from Umuekete clay deposit, in Ossissa Ndokwa East LGA all in Delta State. The test specimen from the various mixture were subjected to the relevant test such Green Compression Strength, Green Shear Strength, Dry Compression Strength, Dry Shear Strength and permeability test All the tests were carried out with the sand testing equipment at the Federal Institute of Industrial Research (FIIRO) Oshodi, Lagos State, Test sample specimens were prepared for laboratory experiment from various moulding sand mixtures as shown in Table 1.

SAMPLE PREPARATION

The required quantity of the sand, clay and water for each of the samples 1-5 were measured in accordance with the varying proportion and put into the laboratory mixer and then mixed for about five minutes. When thoroughly mixed, the mixture was discharged from the mixer through the discharge opening at the bottom of the sand mixer. These was done to achieve the required size of 5cm diameter x 5cm height was weighed on the weigh-balance and then poured into the specimen tube. The tube with the sand sample inside it was positioned in the specimen rammer and then rammed with three drop of the standard weight of 6.6kg. After ramming, the specimen was ejected from the tube with the aid of specimen extractor. This procedure was repeated for the preparation of the standard test specimens for the various compositions of the moulding mixtures.

Table 2. CHEMICAL COMPOSITION /ANALYSIS OF SILICA SAMPLE

Constituent	Ubuh River sand (%) C
SiO_2	89.27
Al_2O_3	4.12
Fe_2O_3	3.46
CaO	0.58
Na_2O	0.15
K_2O	0.01
TiO_2	0.80
Loss on ignition	1.42
Total	**100.00**

Determination of Grain Size Distribution

The stocks of sieve were arranged according to the sieve aperture with the largest aperture on top of the stock and then smallest aperture at the bottom (on top of pan). Some quantity of sand were dried in the air and 100g of the sand sample was taken on to the top of sieve stock and stocks were placed on a sieve shaker and then switched on, the time was set to allow for vibration for a period of fifteen (15) minutes and after vibrating for a period of 15minutes, the vibration stopped automatically. The sieves were removed one after the other beginning with one on top. The quantity of sand remaining on each sieve was weighed. The weight was recorded accordingly on each sieve in the column corresponding to the sieve mesh number, i.e. British Standard Sieve number (BSS). Each separate sieve weight was multiplied by the preceding sieve mesh number. The sum total of the product was divided by the total sample aligned and this produced the fineness number of the sand. Table 2 shows the results obtained

Table 2. Grain Size Analysis.

Screen size μm	BS Sieve no	% Sand retained on sieve	Multiplied by previous sieve no	Product
425	10	0.15	1.5	1.5
300	16	3.26	52.16	53.66
250	22	6.61	145.42	199.08
212	30	9.21	276.3	475.39
180	44	23.98	1055.12	1530.5
150	60	38.76	2325.6	3856.1
106	100	12.72	1272	5128.1
75	150	3.36	504	5632.1
-75	200	0.86	172	5804.1

	TOTAL	**100**		**5804.1**

Source: study 2020

AFS Grain fineness number = 5804.1/100 =58.04 ≈ 58 AFS

Determination of Green Compression Strength

The Green Compression Strength was carried out using the universal sand strength testing machine. In the sand mixture, 150g was weighted and poured in the specimen tube or core box which is placed beneath the ramming head on the ramming machine. Three ramming blow is applied and removed. The rammed sample is place in the compression heads in the lower position of the strength tester machine. Load is applied simultaneously until the sample collapse. Using the magnetic rider on the scale readings were taken in $KN/m^{2.}$ A prepared standard sample was positioned in the compression head which was already fixed into the machine. The sample was loaded gradually, while the magnetic rider moved along the measuring scale. As soon as the sample reached its maximum strength, the sample experienced failure and the magnetic rider remain in position of the ultimate strength, while the load was gradually released. This experiment was repeated for clay content varied thus; 10%, 15%, 20%, 25%, and 30%.for the three rivers sand and It was discovered that the Green Compression Strength (GCS) reduced with increase percentage of clay content in the sample as shown in Table 3,

Table 3 UBUH RIVER SAND DISTRIBUTION OF VARIOUS PROPERTIES

Sand %	Clay %	Water %	Permeability (l/min)	Green Compressive Strength KN/M²	Green Shear Strength KN/M²	Dry Compressive Strength KN/M²	Dry Shear Strength KN/M²	Moisture Content %	Compactability
84	10	6	170.09	45	2.0	100.5	50.5	6	34.42
79	15	6	135.16	65	2.5	175.0	92.5	6	52.90
74	20	6	144.72	95	3.35	187.5	105.0	6	49.87
69	25	6	123.91	102	4.0	115.0	117.5	4	56.07
64	30	6	131.49	114	4.75	155.5	127.5	6	48.41

Sand original Clay Content = 4%

Determination of Green Shear Strength

The Green Shear Strength (GSS) which is the measure of the shear strength of the prepared sample, when shear load is applied in its green state. The machine used for the GCS was also used for the determination of green shear strength (GSS), except that the compression head was replaced with shear head in the machine. Samples were prepared in the way as in the green compressive strength. But this the rammed sample is placed in the shear heads in the lower position of the ramming machine where simultaneous head was applied until it shears. The reading was taken using the magnetic rider.

The shear strength was recorded at the point of failures of the sample loaded. The GSS decreased as shown in Table 3A,.

Determination of Permeability

Permeability is defined by the **A.F.S.** as that physical property of moulded sand which allows gas to pass through it. It is determined by measuring the rate of flow of air through the **A.F.S.** Standard rammed specimen under standard pressure. Gas permeability of a moulding sand is the ability of the sand mould to allow the passage of gaseous product from the mould cavity to the atmosphere. The permeability test was carried out on the standard sample specimen of 5cm diameter x 5cm height. The specimen, while still in the tube, was mounted on permeability meter. The permeability meter is an electrical perimeter and it employed the orifice method for rapid determination of sand permeability. Air at a constant pressure is applied to the standard sample specimen, immediately after producing the sample and the drop in pressure was measured on the pressure gauge, which is calibrated directly in permeability numbers.

The general formula for calculating permeability is:

$$P = \frac{V * h}{\rho * a * t}$$

Where ρ = permeability number
V = Vol of passing through the specimen
h = Height of the specimen in cm
p = Pressure of the air in cm of water
a =Area of cross-sectional of specimen in cm^2
t = Time in minutes

Determination of Dry Shear Strength

The prepared standard sample of 5cm diameter x 5cm height was dried in an oven at a temperature of 110^0C for 30 minutes and then removed from the oven to cool in an air to ambient temperature.

The same universal testing machine was used for dry compression strength. In this case, the shear head was replaced for the compression head. The shear strength was recorded at the point of failures of the standard test sample. The failed sample due shear load is shown in Table 3

Determination of Dry Compression Strength

The prepared standard sample of 5cm diameter x 5cm height was dried in an oven at a temperature of 110^OC for a period of 30minutes and then removed and allowed to cool in the air to ambient temperature. After cooling, the sample was fixed into the universal sand-testing machine with the compression head in place. The compressive load was applied and the samples failed at the ultimate compressive strength of the sample. The point at which the failure occurs was recorded at GCS and it is shown in Table 3

RESULTS AND DISCUSSION

The Green Compression Strength (GCS) of the moulding sand mixture for the three specimen increased from ($3.45KN/m^2$) to ($15.5KN/m^2$) for Ubuh river in 6% water addition respectively. This shows that Umuekete clay has good bonding characteristic even in little addition of water. Metals can be cast with 1-6% water addition to the moulding sand mixture, mould wall erosion could occur during pouring of hot liquid metal as a result of friable nature of the mould.

The Green Shear Strength (GSS) of the moulding sand mixture was observed to be increasing from (45 KN/m^2 to114 KN/m^2) with 1% and 10% water addition respectively. The Dry Compression strength increased from (100.5KN/m^2 to 155.5KN/m^2) in Ubuh river sand with increase of clay content from 5% to 30% for 6% water content. And this value increases with further increase in moisture content. The dry shear strength of samples of moulding mixture was observed to increase from 50.5KN/m^2 to 127.5KN/m^2 with moisture content of 6% as shown in Table 3.

River Ubuh is brownish. Umuekete clay is very fine clay and has a high plastic in nature when mixed with water. This characteristic of the clay makes it suitable for foundry application as a binder. The grain fineness number of River Ubuh sands has AFS fineness number of 58 respectively. This grade of fineness number is suitable for all types of alloys steel as this belongs to the group of fineness number that has a wide range of application. The other grades of the sand are very much available within the shore of the river. The selection of the appropriate grade of grain size for a specific application largely depends on experience and the nature of the alloy production in a particular foundry industry.

River Adofi, River Ubuh, and River Ologodo sand and Umuekete clay when mixed together with varying percentage of water produce a plastic mass with varying degree of strength. In the green state of the mixtures; the strength decrease with increasing moisture content. The level of strength reach between 2% to 6% water additions conforms to the standard specification for metal casting moulding sands. Although the strength level of 8% and 10% water addition are relatively lower enough these levels of moisture content are considerably much higher for some alloys such as ferrous alloys, under green application.

When mould is applied under dry condition, high moisture content could be an advantage as in the casting of various parts as shown in Figs. 2.1 - 2.4 hence strength is one of the major factors to be considered in casting. These important properties, such as permeability, green compression strength, and dry compression strength of these sand samples attain their highest value with moisture of 2% and 6% water addition. This makes 2% and 6% water addition more suitable for optimum moulding properties requirement. Water and clay are the major property variables that influence the strength of the moulding (Jain 1986; Uhvotu 2006)

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