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Characteristic Foundry Properties of Kaduna River Sand

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ABSTRACT: *Kaduna is one of the foremost cities of growing economic activities in Nigeria. A lot of sand casting businesses whose overall economic importance is noteworthy, has been at various levels of undertaking in the city. The sand-cast products include domestic items such as pots, industrial parts, customized parts etc. The moulding sand is procured in close vicinity to the banks of river Kaduna and used green. A field survey of the cast products shows that they are generally of good and appreciative quality but basic information on the sand usage for optimal profitability with it is not documented. Optimum foundry production cannot be achieved without proper foundry practice and research. In this paper, a laboratory investigation of four critical foundry properties; green strength, dry strength, green permeability, and hardness of unmodified samples of the sand is presented. Its permeability compares favourably with the established practical values required for casting some of the common metals. The hardness of the sand is higher when its moisture content is low. The sand is weak in strength and does not meet the practical value for casting heavy metals. It is however found to be a cheap source of dependable moulding sand that can be easily controlled to yield particular practical foundry requirements for casting different types of metal in the city. The paper is intended to disseminate information on the sand for application interest of any corporate organization, individual, practitioner, researcher, student, and the general public.*

Keywords: *Casting, Kaduna river sand, use, desirable properties, profitability.*

I. Introduction

Casting is one of the important and versatile processes of manufacturing. Its prime purpose is to form solid or hollow objects, parts, etc of desired shapes, sizes, configurations, etc; by pouring a totally molten material into a prepared mould, to solidify and take up the shape of the mould cavity. 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, etc. These include (Doyle, 1969; Glownia, 1993; Jain, 2005).

- 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.
- vii 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, etc.

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. It consists of compacting sand around a metal or plastic pattern, which is latter removed to form a cavity. 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 half kilogramme to, 4.64 tonnes. Dry sand moulds are used for heavier casting. Sand casting is best suited to iron and steel at their high melting temperatures but also predominates for aluminum, brass, bronze, and magnesium. (Doyle, 1969; Jain 2005; Hindberg, 1977)

Incorrect sand condition can easily result in the production of scrap castings. It is for this reason that majority of foundries today operate efficient and costly laboratories for the control of existing foundry sands and for testing new sands to discover their foundry suitabilities. Foundry sand control can only really be effective it commences with the testing of all the raw materials; sands, binders, and additives prior to the preparation of the sand mix and after mixing (Doyle 1969). Sands found in different locations on the earth's surface can have wide variations in surface, physical, and chemical characteristics due to human; environmental; ecological; climatic; and geological factors; etc. Different sands have different foundry properties. One cannot therefore be sure of the suitability of a sand for casting a given metal until standard necessary laboratory tests are properly carried out on it.

Increasing freight charges have resulted in foundries utilizing sand deposiots nearest to their works (AFMS, 1963; Avalon and Baumeister, 1998). This could be the principal reason why Kaduna river sand is used for casting in the city of Kaduna, since the course of the river passes through the city dividing it into what is more or less called Kaduna North and Kaduna South. Anonymous (1990) and a survey conducted by Guma in 1996 show the following main places of foundry activities at the specified locations in the city that utilize the sand for casting:

i. Golden U. Foundry (GUF), in Television village.
ii. Kaduna Machine Works (KMW) Limited, in Kakuri
iii. Foundry Department of Defence Industries Co-operation of Nigeria (DICON).
iv. Panteka area, between Kaduna central market and CST Kaduna Polytechnic.

During the survey, some workers at these places who were familiar with foundry activities in their domain were interviewed on the subject to know what they do, prospects and problems that exist. Information obtained shows that the combined worth in the casting investment at these places is several millions of Nigerian Naira. The places also provide gainful employment to a good number of Nigerians. Casting at Panteka is of the jobbing type and is carried out at small shop level. It contributes appreciably to the small scale business energy of Kaduna. Over 40 shops are engaged in the casting here and many workers trade in the cast products within and to other parts of Nigeria. Those involved in the casting activities here are not engineers but mostly foundry artisans and those whose educational attainments are hardly above ordinary certificate level. Most of such workers lack proper scientific knowledge of the sand and its proper usage and control to achieve optimum foundry production and profit. Some of them had worked in some foundries before, where they acquired their foundry know-hows, while some through apprenticeship at Panteka itself or elsewhere. Comparatively GUF, KMW, and Foundry Department of DICON, are captive foundries. The castings produced by the three foundries are in the bulk of industrial spare parts such as those of; textile machines, machine tools, forming and production machines, equipment, agricultural machines, vehicles, etc. During the survey, it was also evident at the three foundries, that; the sand does undergo proper tests and particular controls before usage. However proper, applicable information from the tests and controls is not available to the public. There is therefore a need to contribute towards proper public-available information on the sand, for optimal foundry technology with it and benefit of all.

The shape, size, screen distribution and surface characteristics of a sand grains are the fundamental properties that determine whether it is suitable for 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. Of the properties, the first four are of more test importance, and hence the commonly tested ones (Anonymous, 1963; Avalon and Baumeister, 1998). This is because most sands, from test experience turn to have more variation and deficiency in the four properties. Moreover, the other properties depend to a great extent on the four (Jain 2005).

Sand moulds and cores may suffer physical damage during preparation and handling or during pouring, if the green strength is too low; leading to sand inclusions or mis-shapen castings. If the mould permeability is too low, air entrapment may occur and there is risk of porosity in the casting. However, where the permeability is too high, sand may burn on the casting especially if the sand has low refractoriness. Dry strength of a casting sand is necessary to resist bad pressure at high temperatures, erosion failure, undesirable mould expansion, and for storage and handling when the mould is dry. As the hardness of a sand increases, it also helps eliminate loose-sand inclusions and mould erosion. If the sand hardness it too high, its compactibility and flowability will be impaired, and hence ease of moulding with it will be reduced. On the other hand, hot strength of sand is necessary to avoid mould failure when hot metal is poured into it. A sand should have good collapsibility to enable moulds to be broken open to release castings from them. If refractoriness of a sand is low, it will melt when hot metal is poured into it, and this will result into mould failure and bad castings from it (Doyle, 1969; Avalon and Baumeister, 1998; Middleton, 1988). It is pertinent to know that each of the foundry properties depends on a combination of moisture content of the sand, amount and type of binder, size distribution of the sand grains, grain fineness, shapes of sand grains, amount of fine materials present and mulling time. The practical mixture of green sand mould consists of; sand 65% to 93%, clay 3 to 30%, water 2 to 8%, and additives (Doyle, 1969; Anonymous, 1963; Dietert, 1966). The clay with water acting as the bond or binder is the principal source of strength of a sand. In some locations, clay and sand occur in the right proportion for moulding and these mixtures are referred to as "natural moulding sand", In other cases, a clay for bonding must be added to the sand in order to develop the requisite cohesiveness and plasticity. There are several types of clays which are essentially aggregates of minute, activated, crystalline, flake-shaped particles. The clays may be bentonites, kaolinites or fire clays. Typically two or more of these clays may be used together in order to achieve the desired bond cohesiveness (Lindberg, 1977).

II. Methodology

2.1 Apparatus and Facilities

The following facilities were used for the experimental investigation of the sand properties (Guma, 1998).

i A standard speedy moisture tester, manufactured by Thomas Asworth & Co. Ltd Burnley England.
ii A 'Ridsdale-Dietert' universal sand strength machine.
iii A 'Ridsdale-Dietert' electric perameter and accessories
iv. A 'Ridsdale-Dietert' green hardness tester.
v. A 'Ridsdale-Dietert' specimen-ramming equipment.
vi. A Ventilated oven.
vii. Sand samples got on the bed and banks of river Kaduna.
viii. A weighing scale

2.2 The Experimental Investigation and Results

With the assistance of some artisan foundry workers at Panteka, sand samples were collected at different depths of up to two metres in several locations covering a distance of 16 kilometers on the bed and banks of river Kaduna, bank strip width of about 200 metres in the closest vicinity to Kaduna city, and then mixed thoroughly to have a representative sample. Standard sand test specimens of diameter 5.08cm and height 5.08cm, recommended by the American Foundry-men Society (AFS) (Anonymous, 1962) for various room temperature tests were each made by dropping a standard weight of 6.35kg three times through a standard height of 5.08cm on the representative sample filled to an appropriate level in a standard steel tube container, using the specimen ramming equipment. Five standard specimens of various moisture contents – A, B, C, D and E; were each made from a differently quantified and properly water-mixed sand in three sets each for the hardness, green strength and dry strength tests.

Moisture content of each prepared standard specimen was measured using the standard speedy moisture tester. This was accomplished by compressing a small sand portion of known mass, and unknown given moisture content from which the specimen was made between the two prongs of the moisture tester. The instrument instantly indicated the amount of water present in the small sand sample in centilitres of water by its designed capability. The result was used to determine the mass content of water present in the specimen and hence its percentage moisture content. The permeability of the sand was measured using the permeability testing equipment by blowing a standard air pressure of 9.8 x 10^2N/m^2 through the standard tube of the perameter containing the green sand specimen of given moisture content. The perameter instantly indicated the permability of the sand in units of number [No].

The green compressive strength was determined by separately placing each prepared test specimen of a given moisture content in a set appropriately on the universal sand strength machine, and applying a steadily increasing compressive force on it, until it just fractured. The strength at that instance was then read from the machine scale. The dry strength of the sand was similarly measured, but only after heating and drying each specimen of the prepared second set in an oven at a standard temperature of 105^{o}C and cooling it to room temperature.

The green hardness of the each prepared sand specimen of the third set was determined by pressing a standard steel ball on the specimen's surface using a standard setting on the hardness tester. The depth of penetration of the steel ball gave the hardness of the specimen on the direct reading dial.

III. Results And Discussion

Test-obtained results of the four foundry properties of the sand at moisture contents of; 2.4, 3.3, 4.1, 5.2 and 6.1% are shown in table 1, and graphically in figures 1 to 4. The properties are compared with practical values required for casting different metals in accordance with Dietert (1966) as shown in table 2, and similar other test results by Jain (2005). From the results of the tests, the green strength of the sand decreases with increase its moisture content in a typical manner shown in Fig. 1. Analysis of the results vis-à-vis the required practical values shows that the green strength required for casting the heavy metals cannot be achieved with the sand under any moisture content. The trend of dry strength variation of the sand under various moisture contents is shown in Fig. 2. From the figure, it is apparent that the dry strength of the sand increases with increase in its moisture content up to a maximum value at a content of about 4.1%; thereafter, it decreases with further increase in the moisture content. The dry strength of the unmodified sand falls below the practical values required for casting most metals as can be inferred from table 2.. The trend of variation of the green permeability of the sand with its moisture content is shown in Fig.3. From the figure, it can be observed that the permeability of the sand increases with increase in its moisture content up to an optimum value of about 52 [No] at a content of about 3.4%. Thereafter, it decreases with increase in moisture content. Comparing the test values with the various practical requirements shown in table 2, it can be seen that the sand has good natural green permeability for casting a good number of ferrous and non-ferrous metals.

The trend of variation of the hardness of the unmodified sand under various moisture contents is shown in Fig.4. From the figure, it is clear that the hardness of the sand decreases with increase in its moisture content. According to Jain (2005), the hardness numbers for moulding sand are in the orders of; 100,125, and 175 for; soft rammed moulds, medium rammed moulds, and hard rammed moulds respectively. From the results it is clear that the hardness of the sand is in the order of soft rammed moulds.

Finally, the trends of variation of the four foundry properties are similar to most other sands obtained in different locations of the world and similarly tested and presented by Doyle (1969), Anonymous (1963); Middleton (1998). The specific values presented here are however typical of Kaduna river sand around the region of the city. The results show that with a percentage, moisture content in the range of 2 to 6%, the unmodified sand can be used to produce small and medium castings of good quality from lighter metals such as aluminum. The river sand has good surface characteristics, fine and almost uniform grain size distribution. The deposits of the sand can be found in large quantities in several locations along the course of the river and its banks. The results also indicate that with minimal control, the sand can serve as a sustainable cheap source of satisfactory sand required for casting a wide range of metals.

IV. Conclusion

Test results indicate that the green permeability of the unmodified Kaduna river sand is satisfactory for casting a wide range of metals or their alloys. The hardness of the sand is higher at lower moisture contents. The natural sand is however inadequate in strength, and is not recommended for casting heavy metals or their alloys, such as steel without the necessary modifications. The result give a true indication of the foundry properties of any sand associated with the river in close vicinity to Kaduna city; covering a distance of eight kilometre up and down its course from the city centre, depths of up to about two metres, and bank strip width of about 200 metres. It is also apparent from the results that with little control the sand can meet particular foundry requirements in its usage for casting different types of metals or their alloys.

V. Rrecommendation

The presented test results of the foundry properties of Kaduna river sand and other information on it in this paper are for public education and are hereby recommended to be considered or exploited appropriately for optimal foundry production and profitability with the sand and for other related research purposes.

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Table 1 Experimentally measured foundry properties of Kaduna river sand

Sample	**A**	**B**	**C**	**D**	**E**
Moisture contents [%]	2.4	3.3	4.1	5.2	6.1
Green strength [kN/m^2]	51	47	44	38	32
Dry strength [kN/m^2]	160	178	179	173	168
Green permeability [NO]	57	52	48	41	38
Green hardness [NO]	62	61	59	56	54

Table 2: Some satisfactory sand properties ranges for various types of casting by Dietert (1966)

Metal	**Green Compression Strength[KN/m^2]**	**Permeability [NO]**	**Dry Strength [KN/m^2]**
Heavy steel	70 – 85	130 – 300	1000 – 2000
Light steel	70 – 85	125 – 200	400 – 1000
Heavy grey iron	70 – 105	70 – 120	350 – 800
Aluminum	50 – 70	10 – 30	200 – 550
Brass & 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

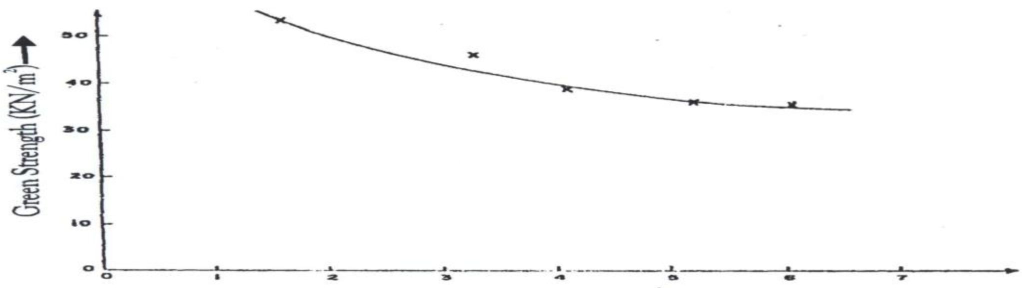

Fig. 1: Green Strength Vs Moisture Content

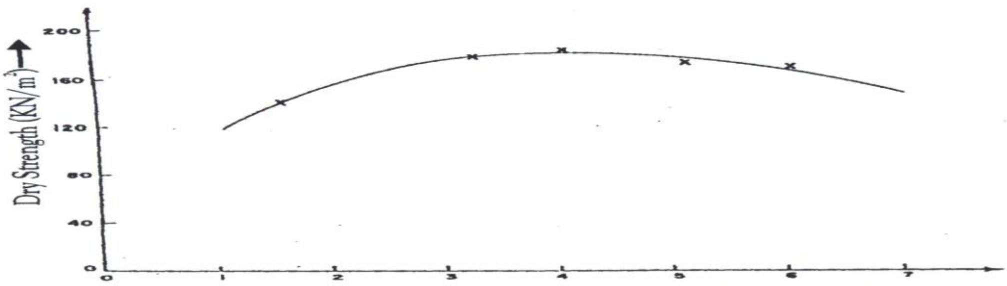

Fig. 2: Dry Strength Vs Moisture Content

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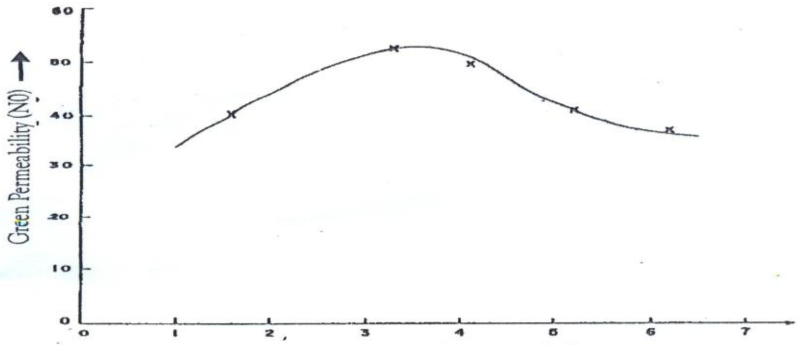

Fig. 3: Green Permeability Vs Moisture Content

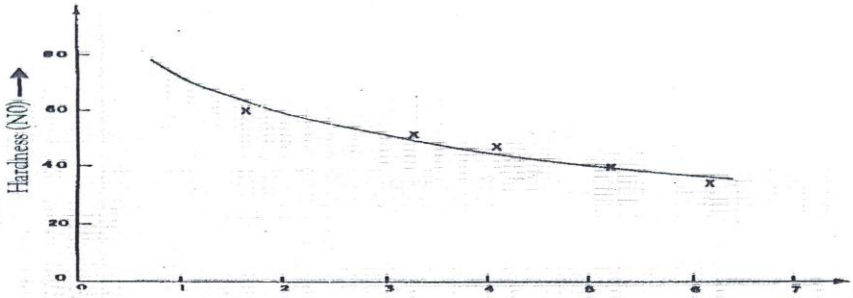

Fig. 4: Hardness Vs Moisture Content

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