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Original Article

Evaluation of Potiskum Natural Sand's Acceptability as Foundry Moulding Material

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Abstract: *The addition of additives and changes in the quantity of certain materials and additions have an impact on the properties of molding sands. These additives include coal dust, clays, and corn flours; the materials mentioned are binders and water. The source of the natural molding sand was at Potiskum town, which is in the Potiskum Local Government Area of Yobe State, North Eastern Nigeria. This is where the sample was taken. The following tools are utilized to collect samples: pans, trowel, riddles, and shovels. The sand sample was subjected to basic foundry analysis using the following test equipment: X-ray fluorescence (Miniate PAN analytical, made by Philips), digital electronic weighing balance ± 0.01 g, rapid sand washer, sieve shaker/standard test sieves, laboratory sand mixer, quick moisture teller, and Universal sand testing machine, all manufactured by Ridsdale and Co. Ltd. UK. The analysis was conducted using the standard laboratory methods and procedures set forth by the American Foundrymens Society (AFS). Investigations were conducted into qualities including chemical composition, moisture content, dry and green compressive strength, permeability, flowability, moldability, refractoriness, and shatter index. The results of the chemical composition analysis of Potiskum moulding sand indicate that SiO2 makes up the majority of the sample (81.45%), followed by Al2O3 (12.71%), K2O 2.87%, TiO2 2.21%), and NaO2 1.16%. There are also trace amounts of other elements, such as MgO 0.81%, Fe2O3 0.76%, and CaO 1.07, all of which are within permissible bounds. I.e. Potiskum molding sand is a silica sand and can be used as such, according to the chemical compositions found in the analysis when compared to the typical suggested qualities of natural molding sands. The sample's grain fineness number, GFN = 138.40 AFS, is significantly higher than what is advised [20]. The physical characteristics results showed a clay concentration of 21.50%, which is significantly higher than the typical range of 5–11% [19] that is advised for natural moulding sands needed to produce high-quality aluminum castings. The moisture content (9.50-2.97%) and green sand strength (76.30KN/m^2) of the natural moulding sands were assessed as additional foundry (mechanical) qualities. The highest matching value was 5.98%. The best value for green compressive strength is 76.30 KN/m^2, while the best value for dry compressive strength at the lowest moisture level is 175.20 KN/m^2. Other optimal values include permeability and shatter index numbers up to 510 and 88.01, flowability and moldability at 95.0% and 99.90%, respectively, and refractoriness at 1550℃. This suggests that, as table 3 illustrates, a wider range of metals and alloys can be cast with greater control and balance on the permeability number and other parameters below 1500℃.*

Key Words: *Moulding Sand, Shatter Index, Permeability, Foundry.*

I. INTRODUCTION

The foundry business is crucial to the manufacturing sector since it supplies vital parts to a wide range of industries, such as the construction, automotive, and aerospace industries. Sand is a key component of the casting process, so selecting appropriate moulding materials is essential to the success of foundry operations. The integrity and functionality of the finished product are greatly impacted by the type and quality of sand used in foundry molding [1].

Northeastern Nigerian town Potiskum is well known for its enormous natural sand resources. The region's fundamental attributes for the moulding process make it a possible supply of foundry sand due to its geological characteristics. However, it is essential to carry out a thorough evaluation to determine Potiskum natural sand's compatibility and performance in relation to established foundry sand requirements before using it in foundry operations. For metal casting, foundry sand is often obtained from natural deposits or artificially created mixtures of refractory sand grains, binding agent, and moisture that create the ideal conditions for bonding reactions [1].

Every component plays a significant role in defining the properties of sand [2]. The composition and physical attributes of silica sand are considered when determining its suitability for industrial usage [3]. The addition of additives and changes in the quantity of certain materials and additions have an impact on the properties of molding sands. These additives include coal dust, clays, and corn flours; the materials mentioned are binders and water. Nigerian foundry companies produce their products with synthetic sand and imported binders. Higgins (1974) noted that different kinds of sand are used in foundries to make molds. Although suitable naturally occurring "green" sand is the most commonly used type, other types of sand are also used for specific applications, including dry sand, core sand, cement-bonded sand, and shell moulding sand. According to Ademoh (2018), the term "green" signifies that the mold has not been baked or dried and that there is still moisture present in the molding sand [5].

As per reference [6], sand that is appropriate for molding predominantly comprises silica (SiO_2) grains, with 5–11% clay serving as a binder. A necessary condition for the sand to work well for molding is its bindability, which is based on the amount of binder it contains. Refractory sand grains linked with clay directly from their deposit places make up natural moulding sands, as described by [7, 8, 9].

When water is added, these sands frequently acquire good molding qualities. Because of this, certain kinds of naturally occurring sands are used "as mined," requiring only a small amount of water to help with molding. This kind of naturally occurring sand just has to be combined with enough water to make molding easier. On the other hand, bentonite, water, powdered coal or grain, and pure quartz sand—free of clay or organic matter—make up synthetic moulding sands, which are utilized by the foundry industries. Because they can be processed considerably more closely, have a longer working life, and exhibit great compositional consistency, synthetic sands are increasingly frequently employed. Properties of the sand, such as its green compressive strength, dry strength, permeability, mold hardness, compatibility, and shatter resistance, have a major impact on the quality of casting for both naturally occurring and manufactured sand. index, wetness, and other factors. The aforementioned characteristics are contingent upon the binder's specifications, water content, and sand grain size [10].

Silica sand, moisture, and clay (as a binder) are the main components of molding sand. The varying amount of clay in natural molding sand serves as a connection between the sand grains. The kind of metal being cast, the need for consistency in the finished product, economics, and casting quality all influence the utilization of this kind of molding sand as a green sand molding media [11].

Molding sand needs to possess a variety of qualities in order to be considered good. Strength, permeability, refractoriness, thermal stability, flow ability, collapsibility, heat conductivity, reusability, and casting finish sand preparation and control are some of these characteristics [7].

The selection of appropriate molding sand and binder materials is a critical element in modern foundry operations that leads to increased productivity. Sand is the most changeable of the materials used in foundries because it has a wide range of chemical compositions in nature [12] and [13].

Sand used in foundry applications must therefore be assessed to make sure it is used wisely. Northern Nigeria has been a hub for the art of foundry for more than a century [14], but the nation has not yet reaped the rewards of this industry due to slow expansion, partially caused by a traditional knowledge gap between proprietors [15]. Nigeria must grow its foundry industry if it wants to advance industrially quickly, as foundry practices are deeply ingrained in the nation's culture. It is well knowledge that technical progress that is cut off from its cultural environment would inevitably develop soullessly [15].

In Nigeria, foundries have been found to be a significant source of economic independence and industrial emancipation [16]. According to an investigation, local foundry shops in Plateau state have been using Potiskum natural moulding sand without understanding its exact chemical and mechanical composition in locations like Jos and Bauchi. The availability of moulding sands is a key obstacle to the development of the foundry industry in Potiskum, which has enormous potential. Determining the chemical composition, physical characteristics, and mechanical/foundry properties of natural moulding sands from the deposit required investigation.

A. Location and Geography of the Study Area:

Yobe state is located in northeastern Nigeria l on latitude 11 North and longitude 13.5 , it was carved out of Borno State and was made to be a state on the 27th August 1991 by the then administration of Gen. Mohammed Babangida. The creation of Yobe as a state was made necessary due to the fact that the old Borno State was one of Nigeria's largest states in terms of land area and was therefore considered to be too large for easy administration and meaningful development. It has a total land area of 45,502 km^2 (17,568 sq mi). It is mainly an agricultural society and has one of the largest cattle markets in Africa located in Potiskum. Yobe state has the population of (2,321,339) as at 2006 census. The state borders four states: Bauchi, Borno, Gombe, and Jigawa, and lies mainly in the dry savanna belt. The climatic conditions are usually hot and dry for most of the year, with an average temperature of 37 °C (98.6 °F). Except in the southern part of the state which has more annual rainfall between the months of August and December. There is also an area of Sahel savanna, consisting of sandy soils and thorn scrub, which is located in the far north.

Figure 1: Map of Nigeria showing Yobe State. Source (Wikipedia 2023)

Figure 2: Map of Potiskum Yobe State. Source (Wikipedia 2023)

II. MATERIALS AND PROCEDURES

The source of the natural molding sand was at Potiskum town, which is in the Potiskum Local Government Area of Yobe State, North Eastern Nigeria. This is where the sample was taken. Moulding sands were gathered and prepared using simple sand sample collection and preparation tools such as pans, riddles, and shovels. The test instruments and equipment used are the following: a digital electronic weighing scale with an accuracy of ± 0.01 g, a fast sand washer, a sieve shaker and standard test sieves, a laboratory sand mixer, a quick moisture teller, and an X-ray fluorescence (Miniate PAN analytical, manufactured by Philips) for conducting chemical composition tests. Using a universal sand testing machine manufactured by Ridsdale and Co. Ltd. UK, a basic foundry examination was performed on the sample of sand. The physical and mechanical characteristics of the sand sample were ascertained by means of established laboratory tests and procedures set out by the American Foundrymens Society (AFS). Using measured standard test specimens and equipment in a standard foundry laboratory, Potiskum moulding sand was gathered for the trials, which examined its foundry qualities experimentally. Chemical composition, moisture content, dry and green compressive strength, permeability, flowability, moldability, refractoriness, and shatter index are among the attributes that are tested.

A. Experimental Methods:

a) Analysis of Chemicals:

For all assays, an AFS standard sample measuring 5.08 cm × 5.08 cm was used to prepare the sample for this study. The 2.5-meter-deep sand sample was taken from Potiskum town. A non-destructive technique for elemental analysis of solid and liquid sample materials, the ED-XRFS provides both quantitative and qualitative results. To fit through a 200–250 mesh sieve, 20g of the sand sample was powdered. After an hour of 1050C oven drying, the sample was combined with cellulose flakes as a binder in a 5g to 1g ratio. After being pelletized in the pelletizing machine at a pressure of 10–15 tons/inch2, the sample was stored in desiccators for analysis. After turning on and letting it warm up for roughly two hours, the ED-XRFS was used to evaluate the sample materials for the presence or absence of certain constituents of interest using the relevant programs.

b) Sieve Analysis:

To find the grain fineness number on a dry sand sample where all clay material has been eliminated, an AFS Sieve examination was performed. The sand was screened using a conventional testing sieve set. The sieves were arranged on a sieve shaker, starting with the coarsest sieve and working our way down. After 15 minutes of vibration, the weight of the sand maintained in each sieve was measured. Approximately 150g of sand was deposited at the top sieve. To find the product, the proportion of sand retained on each screen was multiplied by a multiplier to get the AFS grain fineness value. The AFS grain fineness number is calculated by taking the entire product added and dividing it by the total percentage of sand retained on the sieves.

c) Moisture Content Determination:

After weighing and adding about 6g of sand to the moisture content tester, two spoonfuls of granular calcium carbide were added, and the tester was shaken violently for two minutes before the dial gauge's reading was recorded in percentage.

d) Permeability Test:

The ease with which generated gasses can escape is measured for permeability in order to prevent casting problems like as porosity and gas inclusions. Grain characteristics such as size, shape, distribution, and binder content all play a role. AFS Standard sand specimens of 50 mm in diameter and 50 mm in height were created by using three standard rammer blows to compress the necessary 150g of sand into a smooth-surfaced tube. This sample was put in the permeability meter's mercury cup upside down. Once the arrow indicator was stable and represented the permeability number, the machine was turned on and the pressure lever was pressed. The readings were then recorded.

e) Dry Compression Strength Test:

This molding sand characteristic relates to the mold's strength during deformation while it's dry. It is the sand mold's capacity to tolerate the pressure of molten metal during the casting process. The specimen tube attachments and a conventional sand rammer were used to prepare the sample. After completely mixing the sand and clay on a roller for ten minutes, the mixture was molded into 50 mm by 50 mm specimens. Each specimen weighed 130g on average and had dimensions of 50 mm in diameter by 50 mm in height. Three 6.5kg dropping blows from a 50mm height were used to smash it. While the second and third test samples were bonded with different proportions of bentonite clay and kaolin clay, respectively, the first scheduled test sample was bonded with water alone. The AFS protocol a 50 mm by 50 mm sample was heated and dried in an oven at standard temperature 110°C for thirty minutes. The sample was then taken out and allowed to cool in the air to room temperature. The specimen was then put between two self-aligning compressions, and the load was increased until the sample failed at its ultimate compressive strength. The dry compressive strength was recorded at the point of failure.

f) Green Compression Strength Test:

This molding sand characteristic pertains to the mold's strength during its damp state during deformation. The degree of ramming, the sand's moisture content, and the sand's granulation makeup all affect strength. Specimen tube attachments and a regular sand rammer were used to prepare the specimen. The specimen measures 50 mm by 50 mm. On the universal testing apparatus, the specimen was positioned between two self-aligning compression heads. The magnetic rider was moved along the measuring scale with a weight that increased uniformly. The sample fails as soon as it reaches its peak strength. While the load was gradually released, the magnetic rider stayed in the ultimate strength position, and the sample's GCS was recorded from the magnet's position.

g) Shatter Index Test:

At National Metallurgical Development Center (NMDC) Jos, a shatter index tester was used to conduct the test. As in the case of permeability, a standard specimen of 50 mm in diameter and 50 mm in height was manufactured and stored in the steel tube. The apparatus had the tube containing the specimen fastened to it. The receiver, or plan, was positioned at the foot of the machine, exactly beneath the specimen, with its typical position set to zero. The specimen was discharged from the steel tube by pulling the plunger inside the mechanism's handle downward. Gravity caused the sand to fall and strike the anvil in the sieve above the receiver. The shatter index was calculated by measuring the mass of the sand in the receiver.

h) Refractoriness Test:

Refractoriness is a metric that indicates the kind of alloy that the sand is appropriate for casting by measuring the fusion point and thermal stability of the sand specimen [6]. A cuboid sand specimen with dimensions of 10.8 x 5.3 x 2.0 cm was made, bound with honey, and compressed at 300 pressure. The specimen was next heated to 1200°C and then progressively raised to 1700°C for two hours, during which time the alterations in size and appearance were noted. The refractoriness of 1,550°C was determined since the sand specimen sharing exhibits very little expansion and starts to shrink and distort at that temperature.

i) The Test for Flowability:

Sand may be efficiently molded to a consistent density by this ability to compact it. To ensure that the surface contours of the pattern are accurately replicated, it must have sufficient plasticity to react to the molding process. Typically, a percentage is used to express it.

j) Mouldability Test :

This refers to the sand's capacity to both form and hold its molded shape. This keeps it from warping when the molten metal is poured in or the design is removed. It has a percentage measurement as well.

III. RESULT AND DISCUSSION

The amount of silica, aluminum oxide, and other contaminants in the sand sample were determined by chemical analysis. The different chemical characteristics of the sample sand are displayed in Table 4.

Table 1: Potiskum Natural Moulding Sand Chemical Composition Analysis Result

Constituent	Values
SiO_2	81.45
Al_2O3	12.71
Fe_2O3	0.76
TiO_2	2.21
CaO	1.07
MgO	0.81
K_2O	2.87
NaO_2	1.16

Table 2: Potiskum Moulding Sand Sieve Analysis Result

S/No	Sieve Size(mm) AFS	Weight Retained(g)	Cumulative Retained (g)	Product
1.40	10	2.17	2.17	-----
1.00	16	2.95	5.12	29.50
0.71	22	3.30	8.42	52.80
0.50	30	2.78	11.20	61.16
0.355	44	3.17	14.37	95.10
0.250	60	4.97	19.34	218.68
0.180	100	6.67	26.01	400.20
0.125	150	22.15	48.16	2215.00
0.090	200	22.26	70.42	3339.00
0.063	300	18.93	89.35	3786.00
-0.063	350	10.25	99.60	3587.50
Total		**99.60**		**13784.94**

Grain Fineness Number (GFN) = product/cumulative weight retained =**13784.94/99.60 = 138.40**
GFN = 138.40 AFS

Table 3: Determination of Moisture Content on the Foundry Properties Potiskum Moulding Sand

Constituents	Values				
Moisture Content (%)	9.50	7.81	5.98	4.12	2.97
GCS (KN/m^2)	39.24	60.22	76.30	70.15	59.80
DCS (KN/m^2)	95.80	99.55	120.90	155.75420	175.20
P (mmWs)	325	370	450		510
Flowability (%)	86.55	89.00	92.95	96.70	95.00
Mouldability (%)	92.00	95.30	98.40	99.90	98.40
Shatter Index (No)	88.01	81.00	73.00	64.05	60.00

Table 4: Showing the Physical Properties of Potiskum Moulding Sand

Sand Sample	Result
Colour	Light Brown
Grain Shape	Sub-angular
Grain Size (mm)	0.25-0.10
AFS Grain Fineness Number	138.40
Clay Content (%)	21. 50
Loss on Ignition (%)	2.5
Refractoriness (^{o}C)	1550

Table 5: Showing Grading of Ranges of Sand Particles Size [17]

Sand Particles Size	Diameter Range (mm)
Gravel	2.0 and Larger
Very Coarse Sand	2.0 -1.0
Coarse Sand	1.0-0.5
Medium Sand	0.5-0.25
Fine Sand	0.25-0.10
Very Fine Sand	0.10-0.05
Fines	Less than 0.05

Table 6: Some Property Ranges for Foundry Moulding Sand [18]

Metals	Green Compressive Strength (KN/m^2)	Permeability (No)	Dry Compressive 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	45-55	20-60	210-550
Medium Grey Iron	70-105	40-80	350-800

Figure 3: Strength Test Sample Ready for Analysis

A. Chemical Composition Analysis of Potiskum Natural Moulding Sand:

Table 1 presents the XRF-derived chemical compositions of the specimen sand. It displays the concentration of silica in addition to contaminants like lime, manganese, alkalis, etc. This is undesirable because it significantly reduces the fusing point when large concentrations of lime, iron oxide, and alkali oxides are present [17]. Silica (SiO2), on the other hand, was discovered to be highly present up to 81.45%, which is in accordance with the basic sand molding ingredients that are advised [17]. Al2O3 ranked second with a significant amount of 12.71%, followed by K2O and TiO2 with around 2.87 and 2.21%, respectively. Other components, including sodium, calcium, and manganese oxides, are found to be present in trace amounts; as a result, refractoriness of roughly 1,550°C was obtained in returns.

B. Sieve Analysis:

AFS fineness number, which is the standard for reporting the grain size and distribution, was used to assess the particulate distributions as done by [6]. Grain sizes and their distribution in molding sand greatly influence the properties of the sand. The size and shape of the silica sand grains have a large bearing upon its strength and other general characteristics. Table 2 shows the various grains distribution of Potiskum sand which determines the likely surface finish of casting. Widely distributed sand is more compatible than narrowly distributed sand [17]. The mechanical sieve analysis in the table indicates that the sand is primarily medium, fine, and very fine sand because 70% of the sand size falls within the 0.18mm–0.75mm range on the sieve. Table 2 indicates that the sand size particle falls between 42% medium and 27% fine sand, which means it will provide a good surface finish to the cast material.

C. Refractoriness:

Refractoriness, a highly significant property of moulding sands, was determined to be at 1550°C for the natural sand sample from Potiskum moulding sand. This information provided was very helpful in understanding the thermal resistance of Potiskum natural moulding sand. Moulding sand with low refractoriness may burn on the casting surface, making it impossible to obtain a smooth casting surface. The shape, size, and SiO2 composition of the particle all affected how refractorily it formed. It demonstrates that ferrous alloy metals with melting points lower than 1,500°C and all varieties of non-ferrous alloy metals can be used with Potiskum sand.

D. Technical Specifications:

Permeability, green compression, dry compression, hardness, and the shatter index test are the mechanical characteristics of molding sand that are put to the most testing. The measured foundry characteristics of potiskum molding sand in its mined state, with changing moisture content, are displayed in Tables 3.

a) Compressive Strength (KN/m^2) of Green and Dry Sand:

Table 3 indicates that the dry compressive strength (DCS) has a maximum value of 175.20 KN/m^2 at least moisture level of 2.97%, while the green compressive strength (GCS) shows a maximum value of 76.30 KN/m^2 at moisture content of 5.98%. Sand next to metal that has been placed into a green mold dries, and when it is dry, the metal pressure and erosion shouldn't affect it. Dry strength is the strength of sand that has been baked or dried. The mold must be strong enough to support the flow and pressure of the molten metal at high temperatures throughout the pouring process; otherwise, the mold may expand, crack, wash out, or shatter.

b) Permeability:

At the lowest moisture level of 2.97%, the maximum permeability value of 510 was obtained. Determining the natural moulding sand's permeability and moisture content (MC) is necessary since they both have an impact on the caliber of castings made with the green sand method. Furthermore, the two have such a relationship that molding sand with a high moisture content (above 8%) will have a low permeability, and vice versa. For these reasons, it is necessary to ascertain their values in order to facilitate appropriate control over the properties of the moulding sand [16]. The amount of water in the molding sand combination, the amount of clay in the molding mixture, and the size and shape of the sand particles are some of the elements that affect green permeability [16]. Casting flaws include holes and pores are caused by the molding sand's inadequate porosity, or poor permeability.

c) Flowability and Mouldability Test:

As seen in Table 3, the value derived from the examination of potiskum natural moulding sand provides excellent results for both flowability and mouldability of nearly 100%.

d) Shatter Index:

The shatter index machine was also used to measure the mold's ability to collapse after casting. The investigation's findings indicate that a maximum value of 88.01 was obtained at the highest moisture level; as table 3 illustrates, the higher the moisture content, the higher the shatter index number.

IV. CONCLUSION

The chemical compositions of Potiskum moulding sand, when compared to the standard recommended properties of natural moulding sands, show that SiO2 is dominant in the sample with 81.45%, followed by Al2O3 12.71%, K2O 2.87%, TiO2 2.21%, and NaO2 1.16%, with traces of other elements like CaO 1.07, Fe2O3 0.76%, and MgO 0.81%, which are all within acceptable limits. The sample's grain fineness number (GFN) is 138.40 AFS, which is significantly higher than what is recommended [20]. The physical property results showed a clay concentration of 21.50%, which is significantly higher than the typical range of 5–11% [19] that is advised for natural moulding sands required to produce high-quality aluminum castings. The moisture content (9.50-2.97%) of the natural moulding sands was another foundry (mechanical) property that was investigated; the highest equivalent value, 5.98%, was 76.30KN/m^2 for strength of green sand. The ideal values for green compressive strength are 76.30 KN/m^2, dry compressive strength at the lowest moisture level of 2.97 KN/m^2, permeability, and shatter index number up to 510 and 88.01, respectively. Additionally, refractoriness of 1550°C and flowability and moldability are optimal at 95.00 and 99.90%, respectively. This suggests that, as table 3 illustrates, a wider range of metals and alloys can be cast with greater control and balance on the permeability number and other parameters below 1500°C.

V. REFERENCES

[1] Tipper, A. A. (1995). Naturally bonded or synthetic moulding sand IBF, London, pp 572 [3]

[2] Nigerian Foundries Limited, "The Fundamentals of Green sand technology". Foundry Africa Conference, 1995, pp 1-7 [4]

[3] Mclaws, I. J. (1971). "Uses and Specifications of Silica Sand", Research Council of Alberta Report 7, pp 1-4 [5]

[4] Higgins, R. A. Engineering Metallurgy, Edward Arnold, 1974, pp 37 [6]

[5] Ademoh, N. A. (2008). "Evaluation of the Foundry Properties of River Niger Sand Behind Ajaokuta Steel Company Limited, Ajaokuta," Nigeria American-Eurasian Journal of Scientific Research 3 (1) © IDOSI Publication, pp 75-83 [7]

[6] Ayoola, W. A., Adeosun, S. O., Oyetunji, A. and Oladoye, A. M. (2010). Suitability of Oshogbo Sand Deposit as Moulding Sand. The Kenyan Journal of Mechanical Engineering, 6(1): 33-41.

[7] Yekinni, A. A., Bello, S. K. Animasaun, L. A. and Olaiya, K. A. (2015). Assessment of Mechanical Properties of Foundry Moulding Sands. International Journal Engineering and Industrial Research, 4(2): 365-372.

[8] Ihom, A. P. (2012). Foundry Raw Materials for Sand Casting and Testing Procedures in Foundry, 1st Edition, A2P2 Transcendant Engineering, Publishers, Jos, Nigeria, pp. 1-127.

[9] Dietert, H.W. (1966). Foundry Core Practice 3rd edition, American Foundrymen's Society, Des plainesinc.

[10] Walton, C. F. and Opar, T. J. (1981). Iron Casting Handbook. Iron Casting Society Inc. New York, 15: 1286.

[11] NMDC. (2008). National Metallurgical Development Centre (NMDC) Jos Data Bank of Raw Materials for the Metallurgical Industry, 68

[12] Mshelia, Z. A. Abolarin, M. S. Abubakre O. K. and Ademoh, N. A. (2016). Characterization of Natural Moulding Sands from Selected Deposits in Maiduguri-Nigeria for Casting Applications. Arid Zone Journal of Engineering, Technology and Environment, Faculty Engineering University of Maiduguri. Vol. 12:110-121

[13] Adejuyigbe, S. B. (1998). Forecasting the Performance of the Manufacturing Industries. Nigerian Journal Engineering Management, 1 (2): 23-31.

[14] Essien, C. F. (2011). Empowering Indigenous Industries for National Development: A Review. Journal of Research in National Development, 9(1): 10-16.

[15] Ademulegun, F. (2008). Manufacturing Processes. Tess-Tech Educational Publisher, Ikeja, Nigeria, pp. 151-159.

[16] Ihom, A. P. and Offiong, A. (2014). Modelling of the Effect of Moulding Variable Parameters on some Properties of Clay- Bonded Sand. International Journal of Scientific and Engineering Research, 5(12): 1561-1571

[17] Turkeli, A. (2009). Foundry technology. London, Macmillan press publishers, Pg 432

[18] Mahmoud L.U., Apeh F. I., Shuaibu S. and Isheni Y., (2016). Application of Gwange Natural Sand as Foundry Moulding Material. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) Volume 20, No 1, pp 148-156

[19] Wikipedia, (2020, 2023).

[20] Clark, S. E., Thoman, C. W., Williams, R. and Krysiak, M. B. (1994). Evaluation of Reclaimed Green Sand for Use in various Core Processses, AFS Transactions Reprints, 102: 3-4