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Suitability Evaluation of River Benue Bank Sand Around Vinikilang, Adamawa State, Nigeria, for Foundry Applications

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ABSTRACT

This study investigated the suitability of River Benue bank sand around Vinikilang, Girei Local Government Area, Adamawa State, Nigeria, for foundry applications. Standard laboratory tests, including sieve analysis, green permeability, green and dry compression strength, and green and dry shear strength tests, were conducted. The results showed that the sand had a grain fineness number of 56.91 AFS No. The green permeability ranged from 57–67 AFS No., with an optimum value obtained at 5% moisture content. Green compression strength ranged from 31.0–127.5 kN/m², with the optimum value of 127.5 kN/m² obtained at 12% clay and 5% moisture content. Dry compression strength ranged from 259.1–624.6 kN/m², while green and dry shear strengths ranged from 23.8–41.3 kN/m² and 131.3–250.6 kN/m², respectively. The obtained results showed good agreement with established American Foundrymen's Society (AFS) standards, indicating that the River Benue bank sand is suitable for foundry applications.

KEYWORDS: *foundry sand; River Benue sand; moulding properties; grain fineness number; permeability; compression strength; shear strength.*

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1. INTRODUCTION

Foundry technology is one of the oldest manufacturing processes, dating back to about 3600 BC, and remains an important technology for industrial development. It provides a means of producing components and spare parts from both ferrous and non-ferrous metals and is therefore essential to industrialization and technological self-reliance. In Nigeria, however, the development of the foundry industry has remained relatively slow, contributing to the continued dependence on imported components and spare parts [1, 2].

Sand is one of the most widely used materials for mould production because of its availability, low cost, and ability to withstand molten-metal temperatures. The performance of a sand mould depends largely on the physical and mechanical properties of the moulding sand, binder, moisture content, and additives. In green sand moulding, properties such as grain fineness, permeability, compression strength, and shear strength are particularly important for producing sound castings. Inadequate control of these properties can result in defects such as mould collapse, cracking, erosion, and poor surface finish. Consequently, proper testing and evaluation of moulding sands are necessary to ensure satisfactory casting performance [3, 4, 5].

Nigeria possesses abundant deposits of natural sand suitable for potential foundry applications; however, only a limited proportion of these resources has been adequately characterized and utilized for foundry purposes. The shortage of suitable local moulding sand has contributed to the reliance of some foundries on externally sourced materials, with associated economic implications. The properties of natural sands also vary according to their geological, environmental, ecological, and climatic conditions, making the characterization of individual deposits necessary before their application in foundry practice [6, 7, 8].

Previous studies have evaluated locally available sands and demonstrated their potential for foundry applications [9, 1, 10, 11 etc.]. However, the

suitability of River Benue bank sand around Vinikilang, Girei Local Government Area, Adamawa State, for green sand moulding has not been adequately established. Characterizing this locally available resource could provide useful information on its moulding performance and potential application in foundry practice.

Therefore, this study investigates the suitability of River Benue bank sand around Vinikilang for foundry applications. The study evaluates its grain fineness, green permeability, green and dry compression strengths, and green and dry shear strengths at different clay and moisture contents. The results are compared with established foundry requirements to assess the potential of the sand as a locally available moulding material.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this study comprised sand obtained directly from the bank of River Benue around Vinikilang, Girei Local Government Area, Adamawa State, Nigeria, and bentonite used as the binder. The experimental work was conducted at the National Metallurgical Development Centre, Jos.

2.2. Equipment and Tools

The equipment used in the study included a universal sand strength testing machine fitted with compression and shear heads, an electric permeability meter, a specimen ramming machine, an electric oven, a standard cylindrical specimen tube with an internal diameter of 50 mm, a weighing balance, a stopwatch, eight sets of sieve racks, and a mechanical sieve shaker.

2.3. Methods

2.3.1. Test Sample Preparation

The required proportions of sand, bentonite, and water were measured and mechanically mixed for 5 min. From each of the twelve moulding sand compositions, 160 g of the mixture was compacted in a standard specimen tube using three blows of a 6.6 kg rammer to produce cylindrical specimens of 50 mm diameter × 50 mm height. The compacted specimens were subsequently ejected using a specimen extractor and prepared for testing [10].

Table 1. Composition by Weight of Samples

S/N	Sample	Composition by Weight (%)		
		Sand	Bentonite	Water
1	A1	92	4	4
2	B1	91	4	5
3	C1	90	4	6
4	D1	89	4	7
5	A2	88	8	4
6	B2	87	8	5
7	C2	86	8	6
8	D2	85	8	7
9	A3	84	12	4
10	B3	83	12	5
11	C3	82	12	6
12	D3	81	12	7



Figure 1: A collection of some of the standard cylindrical test specimens before the test.

2.3.2. Sieve Analysis and Grain Fineness Number

The sand was repeatedly washed with water to remove clay, plant debris, and organic matter, and then sun-dried for 24 h. A 500 g portion of the dried sample was subjected to sieve analysis using eight sieves arranged in descending order of aperture size, from 2000 to 75 µm. The sample was mechanically sieved for 15 min, after which the mass retained on each sieve and the bottom pan was determined and expressed as a percentage of the total sample mass. The percentage retained on each sieve was multiplied by its corresponding sieve multiplying factor, and the Grain Fineness Number (GFN) was calculated as the sum of these products divided by the total percentage retained [5].

$$R = \left(\frac{M_1}{M_0}\right)100\% \quad (1)$$

Where, M_0 = Total mass of sand sample
M_1 = Weight of sand retained on each sieve
R = Percentage weight of sand sample retained

$$GFN = \frac{\sum_{i=1}^{n} K_i R_i}{\sum_{i=1}^{n} R_i} \quad (2)$$

Where, GFN = Grain Fineness Number
K_i = multiplying factor for the i_{th} sieve (Sieve mesh No.)
R_i = Percentage of sand sample retained for i_{th} sieve.

2.3.3. Green Permeability Test

Standard cylindrical specimens measuring 50 mm in diameter × 50 mm in height were prepared by compacting the moulding sand with three ramming blows. Each specimen was retained in the sample tube and positioned centrally on the permeability meter. A constant air pressure was passed through the specimen, and the resulting pressure drop was measured using the calibrated pressure gauge. The permeability was directly read and recorded as the AFS permeability number. The procedure was repeated for all the prepared sand compositions [12].

2.3.4. Green Compression Strength Test

Standard 50 mm × 50 mm cylindrical specimens were prepared by three successive ramming blows and tested in a universal testing machine. Compressive load was progressively applied until failure, and the maximum strength was recorded in psi as the green compression strength (GCS) [13, 12,].

2.3.5. Dry Compression Strength Test

The green compression strength procedure was repeated after oven-drying the specimens at 110°C for 1 h. The specimens were cooled to room temperature before testing.

2.3.6. Green Shear Strength Test

Standard 50 mm × 50 mm specimens were prepared and tested using a universal testing machine fitted with a shear head. A progressively increasing shear load was applied until failure, and the maximum shear strength was recorded as the green shear strength (GSS). The test was repeated for all samples. [10]

2.3.7. Dry Shear Strength Test

The green shear strength procedure was repeated after oven-drying the specimens at 110°C for 1 h. The specimens were cooled to room temperature and tested using the shear head.

3. RESULTS AND DISCUSSION

3.1. Sieve Analysis and Grain Fineness Number

Table 2. Sieve Analysis of the Composite Sand Sample

S/N	Sieve Size (µm)	K=Sieve Mesh Number	Weight Retained (g)	R=Weight Retained (%)	Cumulative Weight Retained (%)	KR=Product
1	2000	10	5.70	1.14	1.14	11.40
2	1180	14	16.50	3.30	4.44	46.20
3	1000	16	10.10	2.02	6.46	32.32
4	425	40	219.70	43.94	50.40	1757.60
5	212	70	198.60	39.72	90.12	2780.40
6	150	100	42.70	8.54	98.66	854.00

7	125	120	3.30	0.66	99.32	79.20
8	75	200	2.50	0.50	99.82	100.00
9	-75 (Pan)	350	0.30	0.06	99.88	21.00
Total				**= 99.88**		**= 5683.92**

Source: Research data, 2017.

AFS Grain Fineness Number (GFN) = $\frac{\sum_{i=1}^{n} K_i R_i}{\sum_{i=1}^{n} R_i}$

$\sum_{i=1}^{n} K_i R_i = 5683.92$

$\sum_{i=1}^{n} R_i = 99.88$

GFN = $\frac{5683.92}{99.88}$

GFN = 56.91 AFS No.

Table 4.1 presents the result of the sieve analysis. The sand had a grain fineness number (GFN) of 56.91 AFS, which falls within the American Foundrymen's Society (AFS) range of 28–79 [14] and is within the range commonly used by foundries. This fineness grade is suitable for casting various alloys, as it provides a wide range of applications and can produce good surface finishes at relatively low binder levels.

3.2. Permeability, Green and Dry Compression Strength, Green and Dry Shear Strength

The measured moulding properties of the River Benue sand at different clay and moisture contents are presented in Table 3.1

Table 3.1 Moulding Properties of Sand Mixtures at Different Clay and Moisture Contents

Sample	Composition by Weight (%)			Green Permeability (AFS NO.)	Green Compression Strength kN/m²	Green Shear Strength kN/m²	Dry Compression Strength kN/m²	Dry Shear Strength kN/m²
	Clay	Water	Sand					
A_1	4	4	92	66.5	36.5	25.8	259.1	131.3
B_1	4	5	91	67	38.6	27.6	310.1	137.8
C_1	4	6	90	66	35.5	27.6	320.7	137.8
D_1	4	7	89	61	31.0	23.8	325.1	148.6
A_2	8	4	88	58	81.6	31.0	282.5	172.3
B_2	8	5	87	66	89.9	29.9	361.8	189.5
C_2	8	6	86	58	88.2	28.1	475.3	197.8
D_2	8	7	85	57	74.4	25.8	519.6	208.9
A_3	12	4	84	60	109.2	41.3	561.5	189.5
B_3	12	5	83	61	127.5	37.6	589.1	206.1
C_3	12	6	82	60	112.3	34.1	613.9	241.2
D_3	12	7	81	58	103.35	29.5	624.6	250.6

Source: Research data, 2017

3.2.1. Permeability

Table 3.1 presents the green permeability of the moulding sand. As shown in Figure 2, the permeability of the samples containing 4%, 8%, and 12% clay increased with moisture content from 4–5%, followed by a gradual decrease as the moisture content increased from 5–7%. The permeability of the sand has a maximum value of 67 AFS No at 4% clay and 5% water content. The permeability values ranged from 57–67 AFS No., which fall within the standard range recommended for casting medium grey iron and malleable iron [8]. The initial increase in permeability may be attributed to the swelling of clay particles, which separates the sand grains and creates additional passages for air flow. Beyond the moisture saturation point of the clay, excess water occupies the void spaces between the sand grains, resulting in a reduction in permeability [11].

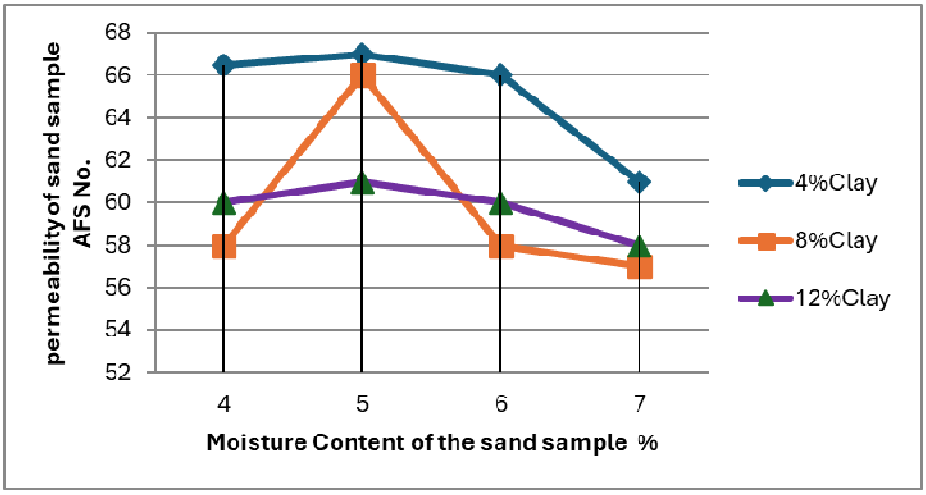


Figure 2: Green permeability with moisture content at 4%, 8%, and 12% clay content.

3.2.2. Green Compression Strength

Table 4.3 presents the green compression strength of the moulding sand. As shown in Figure 3, green compression strength increased with increasing clay content. For all clay contents, the strength increased with moisture content from 4–5% and decreased beyond 5%, indicating that 5% moisture content produced the optimum green compression strength. The optimum values for 4%, 8%, and 12% clay were 38.6, 89.9, and 127.5 kN/m², respectively. Overall, the green compression strength ranged from 31.0 to 127.5 kN/m² for clay contents of 4–12% and moisture contents of 4–7%. The obtained values satisfy the American Foundrymen's Society (AFS) standards and fall within the recommended range for casting medium grey iron, malleable iron, light grey iron, aluminium, brass, and bronze [3, 8]. The increase in strength with clay content indicates improved bonding between the sand particles, while the reduction beyond 5% moisture may be associated with excess moisture weakening the sand bond.

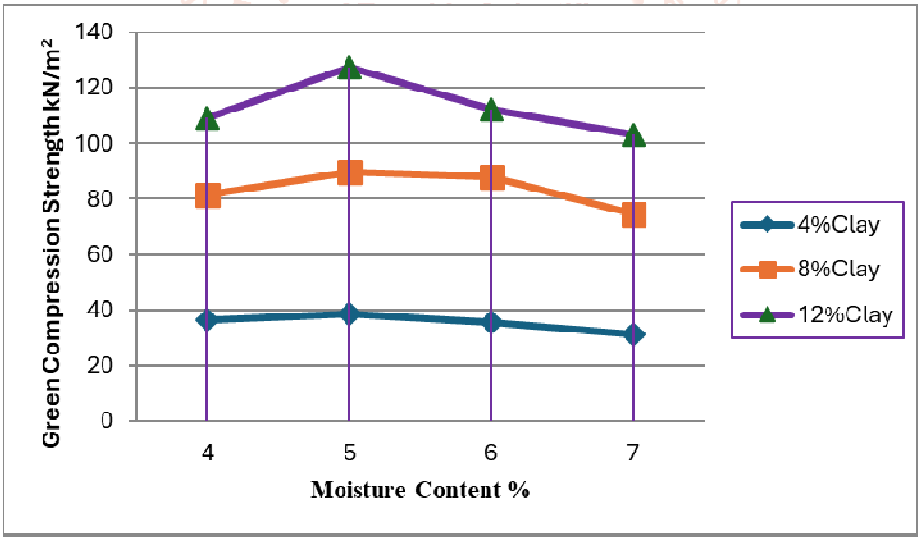


Figure 3: Green compression strength with moisture content at 4%, 8%, and 12% clay content.

3.2.3. Dry Compression Strength

Table 3.1 presents the dry compression strength of the moulding sand. As shown in Figure 4, the dry compression strength increased with increasing moisture and clay contents. For clay contents of 4%, 8%, and 12% and moisture contents ranging from 4–7%, the dry compression strength varied from 259.1 to 624.6 kN/m². The obtained values satisfy the American Foundrymen's Society (AFS) foundry standards and fall within the recommended range for casting medium grey iron, malleable iron, light grey iron, aluminium, brass, and bronze [15]. The relatively high dry compression strength indicates that the moulding sand can withstand compressive stresses imposed on the mould walls during casting. Higher dry compression strength may be achieved by increasing the clay and moisture contents beyond 12% and 7%, respectively. Adequate dry strength is important during molten-metal pouring to minimize mould collapse, cracking, and erosion and thereby improve casting quality.

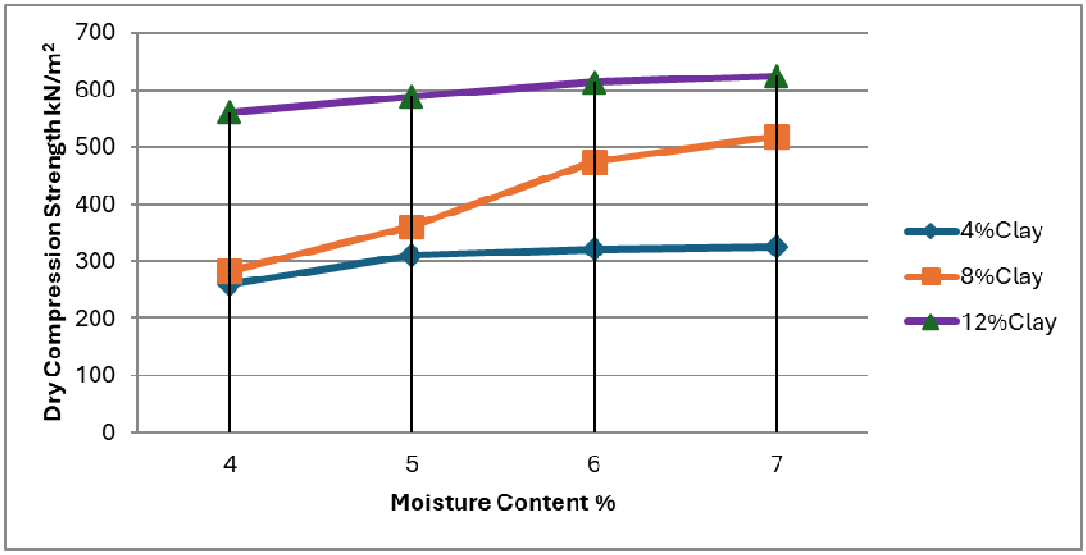


Figure 4: Dry compression strength with moisture content at 4%, 8%, and 12% clay content.

3.2.4. Green Shear Strength

Table 3.1 presents the green shear strength (GSS) of the moulding sand. For the sample containing 4% clay, the GSS increased from 23.8 to 27.6 kN/m² as the moisture content increased from 4–6%, after which it gradually decreased with further increases in moisture content. In contrast, the GSS of the samples containing 8% and 12% clay generally decreased as the moisture content increased from 4–7%. The maximum GSS of 41.3 kN/m² was obtained at 12% clay and 4% moisture content as shown in figure 4.

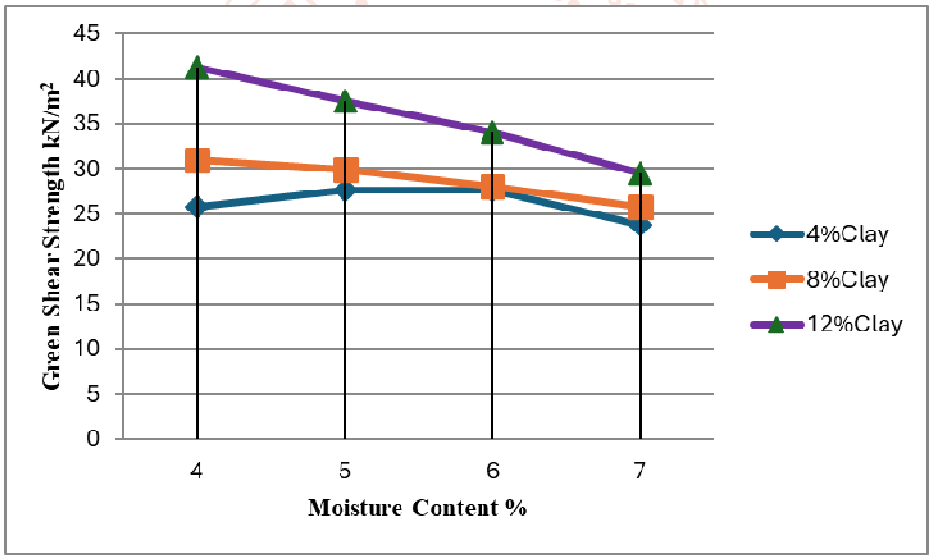


Figure 4: Green shear strength with moisture content at 4%, 8%, and 12% clay content.

3.2.5. Dry Shear Strength

Table 3.1 presents the dry shear strength of the moulding sand. As shown in Figure 5, the dry shear strength increased with increasing clay and moisture contents. For clay contents of 4%, 8%, and 12% and moisture contents ranging from 4–7%, the dry shear strength varied from 131.3 to 250.6 kN/m².

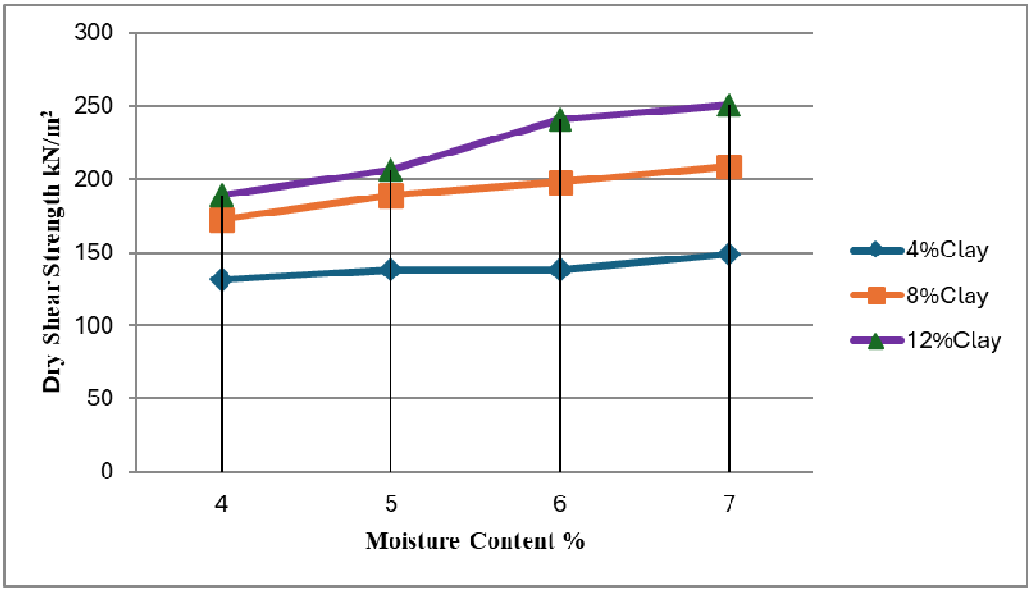


Figure 5: Dry shear strength with moisture content at 4%, 8%, and 12% clay content.

Conclusion

The results obtained in this study showed good agreement with the established American Foundrymen's Society (AFS) standards for foundry moulding sands. The investigated River Benue sand exhibited satisfactory moulding properties and was found to be suitable for casting both ferrous and non-ferrous alloys, including aluminium, brass, bronze, lead, light grey iron, medium grey iron, and malleable cast iron. The findings demonstrate the potential of the locally available sand as a suitable alternative moulding material for foundry applications.

REFERENCES

[1] Yami, A. M (2020). Investigation of the Foundry Properties of Girei Sand Deposit in Upper Benue River Basin for Casting Purposes Nigeria Journal of Engineering Science and Technology Research Vol. 6, No. 2, pp.22-26

[2] Gana M. A., Mshelia Z. A., Isuwa S. A., Gujja A. and Kolo L. A. M. (2025), Investigation and Comparative Analysis of Natural Moulding Sands from Five Deposits in Maiduguri, Nigeria, FUDMA Journal of Engineering and Technology Vol. 1, No. 2, pp. 627-638

[3] Guma, T. N. (2012). Characteristic Foundry Properties of Kaduna River Sand, International journal of Engineering and Science, Vol. 1, No. 11, pp. 3-8.

[4] Aweda, J. O. and Jimoh, Y. A. (2009). Assessment of Properties of Natural Moulding Sand in Ilorin and Ilesha, Journal of Research Information in Civil Engineering, Vol. 6, No. 2, pp. 68-77.

[5] Oke, A. O. and Omidiji, B. V. (2016). Investigation of Some Moulding Properties of a Nigerian Clay-Bonded Sand, Archives of Foundry Engineering, Vol. 16, No. 3, pp. 71-76.

[6] Bala, K. C. and Khan, R. H. (2013), Characterization of Beach/River Sand for Foundry Application, Leonardo Journal of Sciences, No. 23, pp. 77-83.

[7] Yekinni, A. A., Bello, S. K., Animashaun, L. A. and Olaiya, K. A. (2015). Assessment of Mechanical Properties of Foundry Moulding Sands, International Journal of Engineering Innovation & Research, Vol. 4, No. 2, pp. 365 – 372.

[8] Ayoola, W. A., Adeosun, S. O., Ayetunji, A. and Oladoye, A. M., (2010). Suitability of Oshogbo Sand Deposit as Moulding Sand, The Kenya Journal of Mechanical Engineering, Vol. 6, No. 1, pp. 33-41.

[9] Aminu Z. Y., Hayatuddeeen A. I. and Abdussalam M. (2024), Moulding Properties of Kaduna River Bank Sand for Application in Foundry Workshop, Journal of Engineering Research & Technology (IJERT), Vol. 13 Issue 4,

[10] Abolarin, M. S., Lawal, S. A. and Salawu, A. A., (2010). Effect of Moisture Content on the Moulding Properties of River Niger Sand Using Tudun-Wada Clay as a Binder, Assumption University, Journal of Technology (AU J.T.), Vol. 13, No. 3, pp. 170 -174.

[11] Ihom, P. A., Agunsoye, J., Anbua, E. E. and Ogbodo, J. (2011). Effects of Moisture Content on the Foundry Properties of Yola Natural

Sand, Leonardo Electronic Journal of Practices and Technologies, No.19, pp. 85-96.

[12] Amare, D., Biruk, A. and Merkuz, A., (2014). Foundry Properties of Silica Sand Deposits at Blue Nile Gorge and Jemma River Basin in Northwestern Ethiopia, International Journal of Emerging Technology and Advanced Engineering, Vol. 4, No. 4, pp. 979-988.

[13] Nuhu, A. A. and Abdullahi, A. T. (2009). Assessment of foundry properties of steel casting sand moulds bonded with the grade 4 Nigerian acacia species (gum arabic), International Journal of Physical Sciences, Vol. 4, No. 4, pp. 238-241.

[14] Burns, T.A. (1975). The Fosses Foundry Man's Hand Book. Golden Publishers, 9th edition, pp. 218- 226.

[15] 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), Vol. 20, No. 1, pp. 148-156.