UNIZIK JOURNAL OF ENGINEERING AND APPLIED SCIENCES (UJEAS)

*Research Article*

# Effect of Eziadda Clay on Foundry Properties of Azumili Blue River Sand Beach

Nwanakwere D. C, Nwambu C N, Nnuka E E

**Special Issue**
*A Themed Issue in Honour of Professor Clement Uche Atuanya on His retirement.*

This themed issue pays tribute to Professor Clement Uche Atuanya in recognition of his illustrious career in Metallurgical and Materials Engineering as he retires from Nnamdi Azikiwe University, Awka. We celebrate his enduring legacy of dedication to advancing knowledge and his impact on academia and beyond through this collection of writings.

Edited by
Chinonso Hubert Achebe PhD.
Christian Emeka Okafor PhD.

UJEAS

UNIZIK JOURNAL OF ENGINEERING AND APPLIED SCIENCES

UNIZIK Journal of Engineering and Applied Sciences 3(3), September (2024), 1060-1067
Journal homepage: https://journals.unizik.edu.ng/index.php/ujeas
PRINT ISSN: 2992-4383 || ONLINE ISSN: 2992-4391

# Effect of Eziadda Clay on Foundry Properties of Azumili Blue River Sand Beach

Nwanakwere D. C[1], Nwambu C N[1*] and Nnuka E E[1]
[1]Department of Metallurgical and Materials Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Nigeria
[*]Corresponding Author's E-mail: cn.nwambu@unizik.edu.ng

**Abstract**
The study focused on the effect of Eziadda clay on Azumili Blue River Sand Beach in Aba, Abia state, Nigeria. The chemical analysis was carried out on three sand beaches using X-ray fluorescence (XRF). Azumili Blue River Sand Beach, Aba, Abia State is made up of silica $SiO_2$ (93.616%), $K_2O$ (0.15%), CaO (0.40%), $Fe_2O_3$ (1.68%), $Al_2O_3$ (3.15%), and 0.084% clay, according to the results of the chemical analysis. While the sand at Ogbo Hill River is composed of silica (89.99%), $K_2O$ (0.1563), CaO (0.075%), $Fe_2O_3$ (0.17769%), $Al_2O_3$ ($Al_2O_3$ 5.410%), and Eziedda clay contains $Fe_2O_3$ (0.3686%), $SiO_2$ (39.541 %), and $Al_2O_3$ (29.69 %), Akwuke Sand Beach in Enugu State contains silica $SiO_2$ (91.72%), $K_2O$ (0.17%), CaO (0.48%), $Fe_2O_3$ (0.84%), and $Al_2O_3$ (3.191). Because Azumili Blue River Sand Beach has a high silica concentration and 0.084% clay content, it was chosen for mechanical analysis. The following data were obtained for green strength (35.00kN/m2), dry strength (258.0kN/m2), compatibility (28.60%), permeability (5.23), and moisture content (3.25%) from the mechanical characteristics test using a 5% core sand mixture and Eziedda clay. According to the findings, a core of 3-5% Eziedda clay and 3-5% water is appropriate for casting light grey iron, malleable iron, and nonferrous alloys.

**Keywords:** Azumili Blue River Sand Beach, Foundry properties, core making, chemical analysis

## 1. Introduction

Sand is the principal molding material in the foundry industry where it is used for all types of castings ferrous or non-ferrous metals (Mathew et al., 2010). The major ingredients of core sand include silica sand grain, clay, and water. The silica sand grain is of paramount importance in core sand because it imparts refractoriness, chemical resistivity, and permeability to the core (Ayoola et al, 2010). Silica sand is one of the most abundant minerals that can be found in diverse ways such as in quartz crystals, huge forming hills, quartz sand or silica sand, sandstone, and so forth. It is quartz that over time, through the work of water and wind, has been broken down into tiny granules. Quartz is the most common mineral in the crust of the Earth comprising an estimated 35% of all rocks (Isiaka, 2013). River sands contain a high amount of silica which can be used in many sectors such as glass-making sectors, photovoltaic applications requiring high purity, construction, foundry, etc. (Rahman, 2016; Olawale Olarewaju et al., 2015; Imamudeen et al. 2024).

The strength of the foundry rests on the fundamental strength of sand, which is used in pattern making and molding or core making, as the principal raw material during the casting process (Pandey and Singh, 2003). The sand for the core mixture must exhibit the following properties: It must be capable of supporting itself after the forming operation; must not sag or distort and must be capable of holding its shape on a contoured carrier until hardened (John, 2015). This property is called 'green strength'. Green strength is aided during the forming process by the use of core irons (Nwajagu C. O., 1994; Nwoye et al. 2024). These are specially formed pieces of cast-iron or steel rod designed by the core maker to facilitate supporting the 'green' core, or lifting of the dried core during the assembly of large and complex core units (Katsina and Reyazul 2013; Agbo et al. 2017). Hardening is achieved by baking in an oven or chemically. The hardened core material must develop sufficient strength to permit handling and to resist the pressure of the molten metal. These properties are defined as ‘dry strength’ and ‘green strength the sand formulation used must not produce excessive gas upon contact with the molten metal. The degree of sensitivity to gas varies from metal to metal. To aid the removal of the gas evolved from the core binder, the base sand used in core making must have high permeability (Adesina and Adegbite, 2013; Anienye et al. 2015). There are several methods and processes of core making in the foundry and these include the hot box process, cold set process, castable sand process, Nishiyama process, oil no-bake process, and core method. Though other materials can be used for core making other than sand like ceramics, metal, and wood. Cores made from these materials are limited in size and design application but sand cores can be used in making complex big and medium castings (Dieter H. W., 1966). Core sand used for making cores known as oil sand, are highly rich in silica. Pitch or flour and water may also be used in large cores for the sake of economy (Popoola and Fayomi, 2011; Anienye et al. 2015).

The primary component of core sand is silica sand, which is granular quartz with sufficient refractoriness to give molding and core sand strength, stability, and permeability. However, there are trace levels of iron oxide, alumina, lime stone, magnesia, soda, and potash in addition to silica (Aje, 2018). The present impurities, such as lime, magnesia, alkalis, etc., can be inferred from the chemical composition of silica sand (Nwajagu C. O., 2014). By fully utilizing the sand sources closer to the foundry workshop, which are more well-known and widely publicized, considering what transpires during the coronavirus lockdown, significant cost savings on raw materials for foundry molds and cores for casting can be realized. The limitations on our movement caused a great deal of hardship, necessitating the utilization of our surroundings. This project aims to reduce the habit of incorrect sand selection for foundry sand, which greatly contributes to various casting defects. It also aims to reduce importation, which drives up inflation in the nation, by providing necessary foundry information about Eziedda clay on Azumili Blue River. The results of this study will also help maximize the use of these sands and prevent material and cost waste due to casting flaws in complex parts and other engineering products made using core through foundry operations.

## 2.0 Material and Methods

All the materials required for this research were sourced locally. The silica sand used in this research was collected from Akwuke Sand Beach in Enugu State, Ogbo Hill Sand Beach in Aba, Abia State, and Azumili Blue River Sand Beach also in Aba, Abia State, Eziedda clay (binder) in Afikpo Ebonyi State and put in a well-labeled polythene bags and kept in the laboratory before analysis. Following chemical characterization test analysis, Azumili Blue River Sand Beach was found to have the highest percentage of silica among the three sand deposits. It was then taken to the National Metallurgical Development Centre Jos for physical property examination, including compatibility, permeability, dry shear strength, green shear strength, and green compression strength tests, as well as sieve analysis and clay content tests. The following tools were used to examine the physical characteristics of the beach sand in Azumili Blue River along with the binder (Eziedda clay): a digital weighing balance, an electric oven (Gl 026), a sieve shaker, a mechanical rammer, and a universal strength testing machine (M8415). Other materials used are water, calcium carbide (speedy absorbent), NaOH, and distilled water. Following the determination of the binder's physical characteristics (Eziedda clay), the moisture content was altered while the binder's physical characteristics remained constant with the chosen sand deposit (Azumili Blue River beach sand). The sample designation is shown in Tables 1 and 2 as follows:

**Table 1: The sample designation**

| Sample | Green Comp | Green Shear | Dry Comp | Dry Shear | Permeability | Compatibility |
|---|---|---|---|---|---|---|
| Weight (g) | 150 | 150 | 150 | 150 | 150 | 150 |

**Table 2: Varying wt.% of moisture**

| Sand | | Binder | | Moisture | |
|---|---|---|---|---|---|
| 90 – 100% | 900 – 1000g | 0 – 5% | 0 – 50g | 0 – 5% | 0 – 50g |

Total weight of sample 1000g (varying the moisture content)

### 2.2 Determination of grain size distribution

The sieve analysis was done using standard ASTM C136/C136M (standard test method for sieve analysis of fine and coarse aggregates) 100g of sample was weighed out, dried, and placed on the arranged sieved. The sieve was covered tightly and the vibrator to the maximum while the time for shaking was set to 15 minutes. The equipment was allowed to shake for the set and under a thermostat. The equipment turned off on its own while successive sieves were removed and the sand retained on each which was recorded as weight retained.

**2.3 Determination of green compression strength**

The green compression was conducted using the universal sand strength testing machine. Sand samples were weighed. Sand, water, and binder (clay) total of 1kg were mixed together in a laboratory muller for 3mins, discharged and 150g of the mixed specimen was weighed out using a sensitive tabletop digital scale. The weighed sample was poured into a cylindrical ramming mold and rammed using a mechanical rammer to obtain a 50X 50mm cylindrical test specimen. The specimen was removed from the cylinder with the aid of a sample remover while it was placed onto the machine using the green compression head. The machine was turned on and the lever moved up as the sample broke, the sensor sensed it and returned the lever while the reading was taken. This was done for green compression and dry compression except for dry compression, the rammed sample was dried in an oven for 30min at 160oC

**2.4 Determination of dry shear strength**

The rammed samples were placed on the shear head of the equipment as the test was conducted the reading was multiplied by 5 which is a multiplying constant for all dry tests (dry shear and green shear) all dry test (dry compression and dry shear) were oven heated to 160oC for 30mins.

**2.5 Determination of permeability**

The test was conducted using the permeability tester. The rammed specimen inside the cylindrical drum was placed onto the tester and the knob was tightened. The machine pressure knob was opened and equipment was turned on to read the result, the principle behind this test is that the specimen was subjected to certain pressure as in metallostatic pressure to know the amount of air that can pass through the core sand. The amount of air passed through is shown on the dial reading expressed in PSI (pounds per square inch) which indicates how suitable the sand is for core. The air nozzle used for this experiment was the large orifice and reading was taken from the small orifice. Permeability tester. The black knob is the pressure knob while the outer reading gauge is for the large orifice. The top left protrusion is the air nozzle. The black handle is the pressure lever.

**2.6 Determination of moisture content**

The dried sand sample was mixed for the different moisture wt.%, weighed out on the speedy moisture content weighing balance, the sand was poured into the moisture tester, and a known quantity of special calcium carbide powder was poured as well and the knob tightened properly then shaken for 2mins and the reading on the moisture content of the dry sand was taken as expressed in percentage (this indicates the water of crystallization). The same procedure was repeated for varying binder and moisture addition.

**2.7 Determination of clay content**

A small quantity of the silica core sand was dried in an oven to remove moisture. The dry sand of 50g was weighed and transferred to a wash bottle, 475cc of distilled water + 25cc of 3% NaOH were added to the sand inside the wash bottle. The mixture was agitated for about 10 minutes with the help of a sand stirrer, then the wash bottle was filled with water up to the marker. After the sand, etc., had settled for about 10 minutes, water from the wash bottle was siphoned out.

**3.0 Results and Discussions**

**3.1 Sand Grain Fineness Number**

The average fineness number for the Azumili Blue sand beach is 71.302. This grain size falls into the medium range, which is ideal for creating cores since it permits gas movement and results in excellent permeability; if it is too fine, air will become trapped in the core and cause casting defects. (Brown, 1994). Rundman (2000) agreed also that the properties of core sand depend strongly upon the size distribution of the sand that is used, whether it is silica, olivine or other aggregates. The American Foundryman's Society (AFS) standard (1963) states that foundry applications can benefit from an average fineness of 40 to 330. Likewise, McLaws (1971) states that a grain fineness number of 70–86 AFS is essentially appropriate for medium grey iron casting.

**3.2 Chemical Properties Analysis Result (XRF)**

Azumili Blue River Sand Beach has the highest proportion of silica sand (93.616%), followed by Akwuke Sand Beach (91.717%), and Ogbo Hill Sand Beach (86.989%) according to the XRF results of the three deposit sand beaches. The Azumili Blue River Sand Beach was selected to perform the physical properties of the sand that are foundry properties because of its high richness in silica content, as evidenced by the chemical analysis of the three Sand Beaches. The fact that silica makes up the majority of the sand on the Azumili beach is advantageous since, according to Richard et al. (1983), high silica content generally improves the refractory and thermal stability of sand. However, the main elements of Eziedda clay were MgO (2.28%), $S1O_2$ (39.541%), and $Al_2O_3$ (29.69%). The minor components included fe203 (0.3686), $K_2O$ (0.1969%), and $TiO_2$ (1.23%).

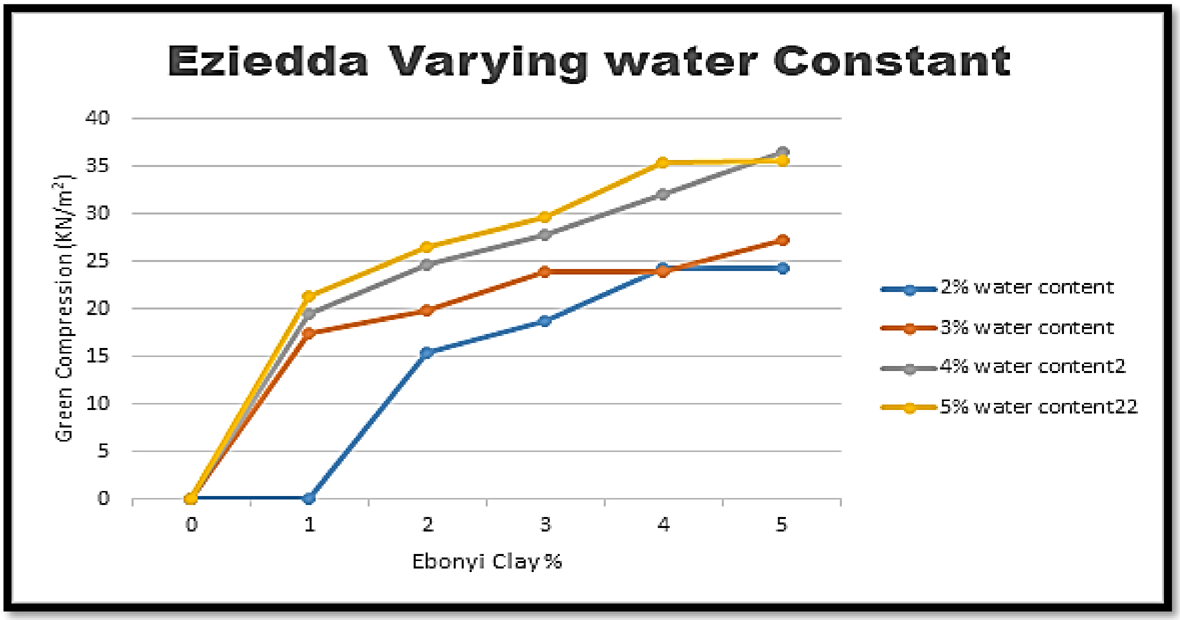


Fig. 1.0: Effect of green strength on added water content at 2%, 3%, 4%, and 5% Eziedda clay sample constant

The effect of green compressive strength at different additional water content levels, while keeping the concentrations of 2%, 3%, 4%, and 5% Eziedda clay samples unchanged, is shown in Figure 1.0. It was found that the green compressive strength of the 2% and 3% Eziedda clay samples rose with an increase in water content. On the other hand, the green compressive strength of the 2% Eziedda clay sample first climbed to 15.45 kN/m² at 2% water content addition, then decreased to 24.67 kN/m² at 4% water content addition, and finally decreased to 17.92 kN/m² at 5% water content. In a similar vein, the green compressive strength of the 5% Eziedda clay sample increased from 12.57 kN/m² at 1% water content to 36.43 kN/m² at 4% water content before declining to 35.60 kN/m² at 5% water content. The 2%, 3%, and 4% Eziedda clay samples showed a rise in green compressive strength, which could indicate that there is not any water present in the sand core, which could affect the casting's overall strength and integrity.

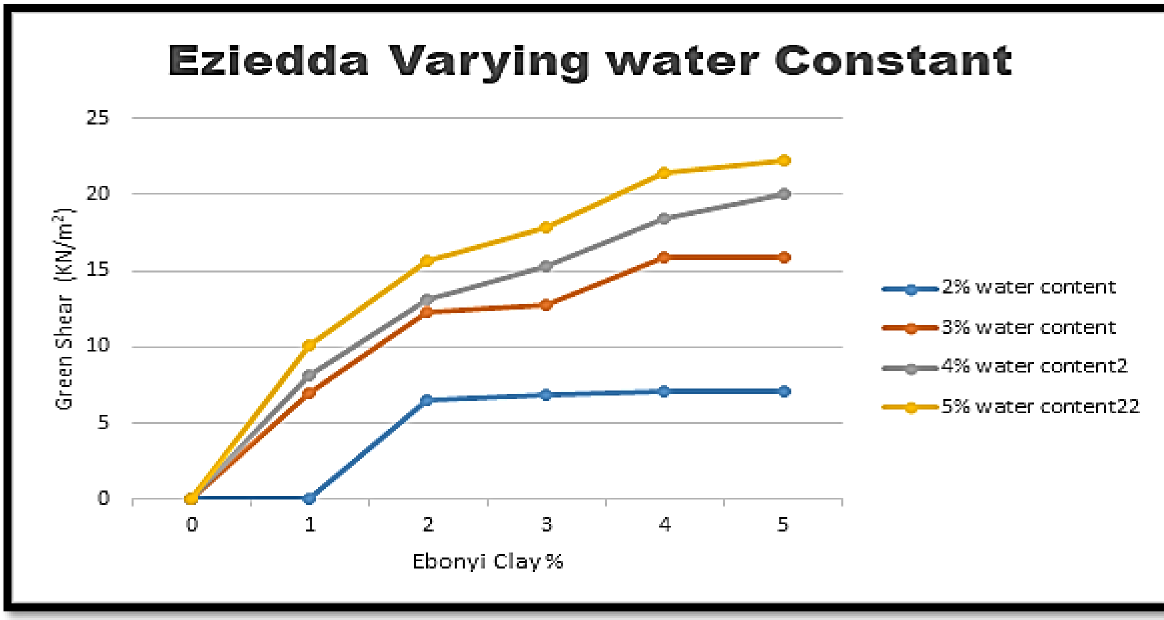


Figure 2.0: Effect of green shear strength on added water content at 2%, 3%, 4% and 5% Eziedda clay sample constant

The influence of green shear strength on different levels of added water content, with constant concentrations of 2%, 3%, 4%, and 5% Eziedda clay samples, is shown in Figure 2.0. It was found that, with the exception of the 2% Eziedda clay sample, the green shear strength increased with an increase in water content addition. That is, for the 2% Eziedda clay sample, the green shear strength increased from 6.56 kN/m² at 2% water content addition to 19.76 kN/m² at 3% water content addition, and then decreased to 11.43 kN/m² at 5% water content addition. However, for the 3%, 4%, and 5% Eziedda clay samples, the green shear strength displayed a consistent increase with the introduction of higher water content levels.

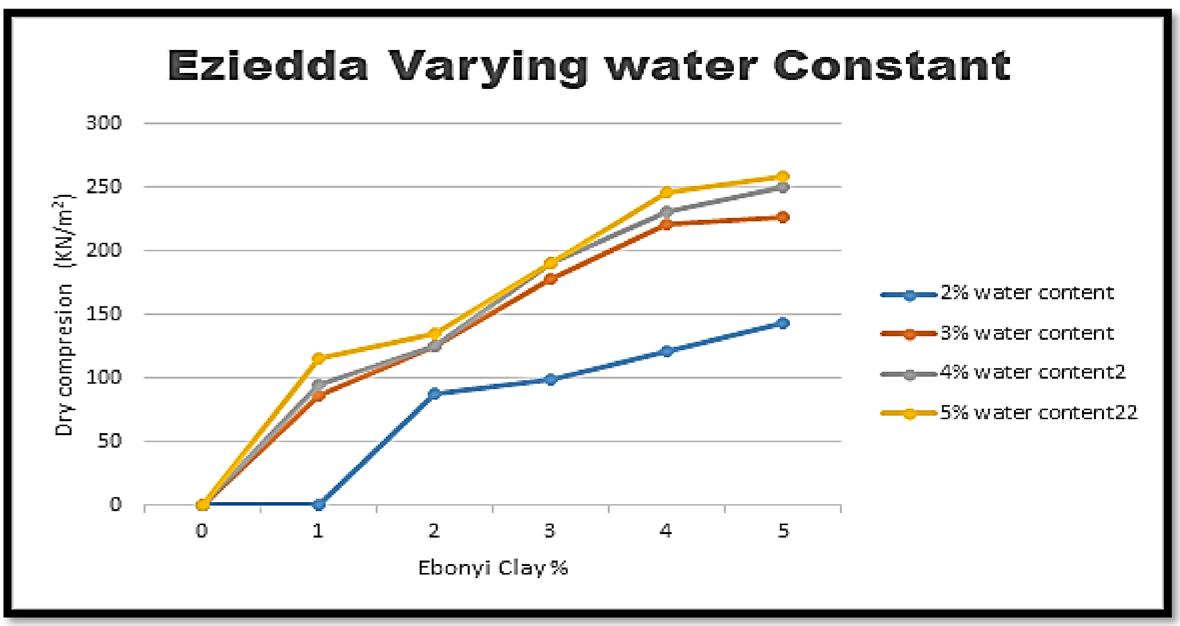


Figure 3.0: Effect of dry compression strength on added water content at 2%, 3%, 4% and 5% Eziedda clay sample constant.

The effect of dry compressive strength (measured in kN/m²) at constant concentrations of 2%, 3%, 4%, and 5% Eziedda clay samples is shown in Figure 3.0 for different added water content levels. With the exception of the 2% Eziedda clay sample, it was found that the dry compressive strength generally rose as the water content addition increased. In particular, at 2% water content, the dry strength of the Eziedda clay sample decreased to 87.67 kN/m²; at 3% water content, it increased to 12.34 kN/m², and at 5% water content, it increased to 70.01. Figure 3.0 provides a vivid illustration of these trends.

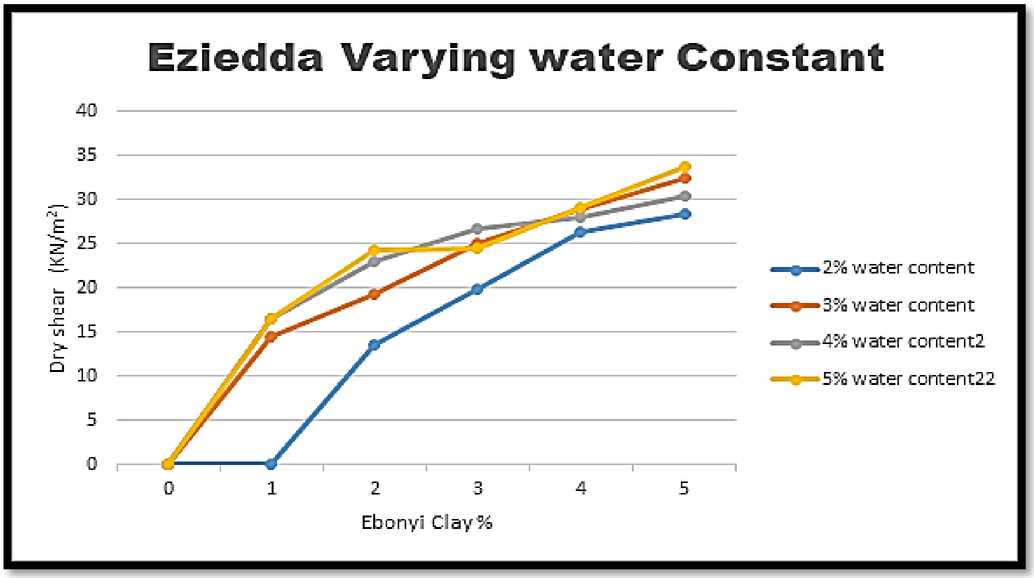


Fig. 4.0. Effect of dry shear strength on water content at 2%, 3%, 4% and 5% Eziedda clay sample constant

The effect of dry shear strength at different percentages of water content is shown in Figure 4.0, with constant concentrations of Eziedda clay at 2%, 3%, 4%, and 5%. It was observed that the dry shear strength showed a decreasing trend as the amount of added water increased. In particular, when blended with a 5% water content addition, the dry shear strength for Eziedda clay compositions of 2%, 3%, 4%, and 5% achieves values of 16.8 kN/m², 24.53 kN/m², 29.11 kN/m², and 33.65 kN/m², respectively. These results highlight the significant correlation between water content levels and dry shear strength in Eziedda clay samples.

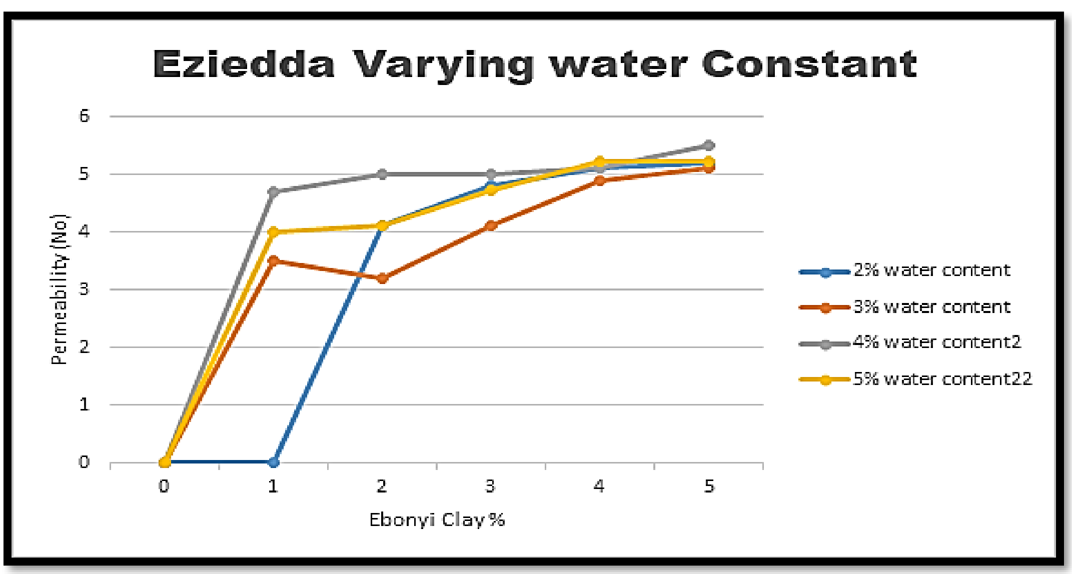


Figure 5.0: Effect of permeability on water content at 2%, 3%, 4% and 5% Eziedda clay sample

The effect of changes in water content on the permeability of Eziedda clay samples at concentrations of 2%, 3%, 4%, and 5% is explained in Figure 5.0. It was noted that the permeability showed an increasing pattern as the added water content increased, peaking at a specific point before declining further. In particular, when mixed with 5% water content, the equivalent permeability values for Eziedda clay compositions of 2%, 3%, 4%, and 5% were 4.10(No), 4.72(No), 5.22 (No), and 5.23(No), respectively. These results highlight the complex interplay between permeability and water content in Eziedda clay samples.

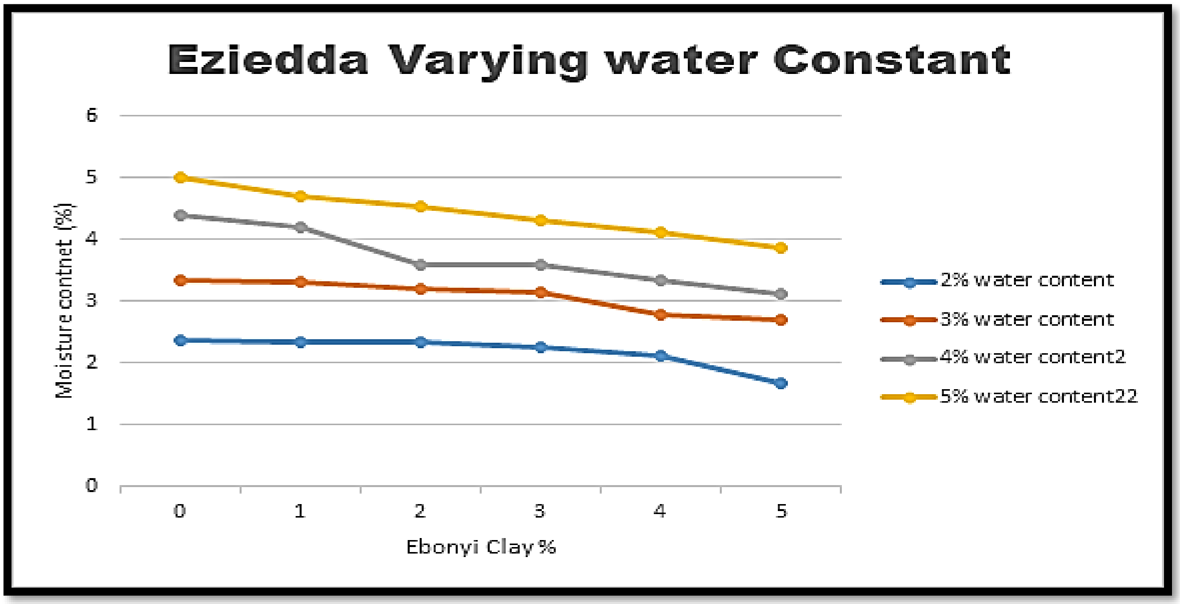


Figure 6.0: Effect of moisture content on added water content at 2%, 3%, 4% and 5% Eziedda clay sample

The impact of moisture content on the different water percentages in the constant 2%, 3%, 4%, and 5% Eziedda clay samples is shown in Figure 6.0. The findings show a clear relationship between the amount of water added and the amount of moisture that remains after it is added. In particular, for Eziedda clay samples with concentrations of 2%, 3%, 4%, and 5%, respectively, the moisture content increased to 4.67%, 4.32%, 4.10%, and 3.86% with the addition of 5% water content. This pattern is consistent with the results of Ahem and Nuhu (2008), who state that water added to a sand mixture is first absorbed by the binder and continues to do so until saturation is reached. Subsequently, any additional water is retained as free water, thereby contributing to the continuous escalation of moisture content, as depicted in Figure 6.0.

## 4.0. Conclusion

The following conclusions were reached based on the analysis's results: The results of the mechanical sieve analysis showed that the sand grain was sub-angular and had a well-defined grading, with the three neighboring sieves of 0.335 mm, 0.25 mm, and 0.18 mm retaining 70.85(%) of the sand grain concentration. The foundry properties of Azumili Blue River Sand Beach Aba, Abia State, are significantly impacted by moisture. According to the chemical analysis, silica makes up the majority of the beach sand in Azumili Blue River (93.6.16%), but not in a way that makes it suitable for use in foundries that produce steel and other heavy metals.

$Fe_2O_3$ (0.3686%), $SiO_2$ (39.541%), $Al_2O_3$ (29.69%), and other minerals are present in Eziedda clay. When the mechanical characteristics examination of the sand was compared to the current foundry standard, it was discovered that the sand, with a moisture level of between 4.32% and 3.86% for the binders, was highly acceptable for nonferrous alloy castings at a percentage of 3% to 5% of Eziedda. The ideal sand blend has a moisture level of 3.86% and 5% Eziedda clay. The characteristics were in good agreement with the percentage of core sand that is currently utilized in foundries to cast aluminum alloys. The finding is recommended for use in preparing core for casting of nonferrous alloys for possible replacement of the imported synthetic sand and binders.

**References**

Adesina S and Adegbite, 2013 “Engineering Characterization of Tsaragi River Sand for Moulding in Foundry Work”, Journal of Research and Development, 5(1):20-27

Aje, T. 2018. Investigation of Fori natural sand as foundry moulding material. International journal of engineering, 8(7):16-20

Agbo AO, Anene FA, Nnuka EE, 2017. An assessment of the binding capacity of bentonite and ukpor clay on the foundry properties of river Niger, Onitsha beach sand. International Journal of Multidisciplinary Research and Development. 4 (1) 26-30.

Ayoola W.A, Adeosun S. O., Oyetunji A and Oladoye, 2010. Suitability of Oshogbo sand deposit as moulding sand. The Kenya Journal of Mechanical Engineering Volume 6, No 1 pg. 33-41.

Imamudeen, B., Nwambu, C.N. and Nwoye, C.I., 2024. Effect of Soil Physical Properties on the Corrosion of underground API 5lx70 Steel Pipeline along Kaduna-Kano, Nigeria. *UNIZIK Journal of Engineering and Applied Sciences*, *3*(2), pp.756-763.

Nwoye, C.I., Imamudeen, B. and Nwambu, C.N., 2024. Analysis of corrosion rate of buried API 5L× 70 steel pipeline in soil by Taguchi technique. *Int. Journal of Civil Engineering and Architecture Engineering Vol. 5 (1) P28*, *33*.

Dieter H. W. 1966. Foundry core practice. American Foundrymen’s Society, 3rd Edition. Page 30-36

Isiaka O, 2013. Characterization of Unwana Beach Silica Sand and Its Industrial Applications, International Journal of Science Innovations and Discoveries, IJSID, 2013, 3(1), 93-100.

John, D. 2015. Casting in Foundry retrieved from https://link.springer.com/book/10.1007/978-1-349-01179-7 International Journal of the Physical Sciences. 7(24) :56-76.

Katsina C. B. and Reyazul H. K. 2013. Characterization of Beach River sand for foundry application. Leonardo Journal of Science. 24(1) Pp 77-83.

Mathew SA, Sunday AL, Abdul RAS. 2010. Effect of moisture content on the moulding properties of River Niger sand within Lokoja under Murtala Mohammed Bridge. Assumption University Journal Thailand. 13(3):170-174.

Mclaur I. J. 1971. Uses and Specification of Silica Sand, Edmond, Alberta. Pp 35 – 68.

Nwajagu C. O. 2014. Foundry theory and practice. ABC Publisher Ltd, Enugu Nigeria Page 35-40

Ajibola, O.O., Oloruntoba, D.T. and Adewuyi, B.O., 2015. Effects of moulding sand permeability and pouring temperatures on properties of cast 6061 aluminium alloy. *International Journal of Metals*, *2015*(1), p.632021.

Pandey, P C and Singh, C K 2003. Production Engineering Sciences, Standard Publishers Ltd. Page 150-157.

Anienye, P.N., Ijah, U.J.J. and Nnamdi, N., 2015. Assessment of the effect of kerosene spill on the physicochemical properties of soil ten years after spill at Maikunkele, Niger State Nigeria. *International Journal of Scientific and Research Publications*, *5*(8), pp.1-8.

Popoola A. P. and Fayomi O. S. 2011. Accessing the performance of binders on core strength in metal casting, International Journal of the Physical Sciences Vol. 6(34), pp. 7805 – 7810.

Rahman M.A, 2016. Valuable heavy minerals from the Brahmaputra River sands of Northern Bangladesh, Applied Earth Science, Transactions of the Institutions of Mining and Metallurgy: Section B, 125 (3):174-188.

Anienye Prince, N., Nnamdi, N., Obiorah, N.J. and Davidson, I., 2015. Assessment of the Effect of Kerosene Spill on Microbial Population of Soil Ten Years after the Spill at Maikunkele, Niger State Nigeria. *International Journal of Scientific and Research Publications*. 5 (8), 1-8.