International Journal of Multidisciplinary Research and Development
www.allsubjectjournal.com
ISSN Online: 2349-4182 ISSN Print: 2349-5979
Received: 02-07-2024, Accepted: 02-08-2024, Published: 17-08-2024
Volume 11, Issue 8, 2024, Page No. 79-84

# Characterization of beach sand foundry properties in south east Nigeria

**Nwanakwere D C, Nwambu C N, Unegbu C, Nnuka E E**
Department of Material and Metallurgical Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Nigeria

**Abstract**
Characterization of Azumili Blue River Sand Beach, Ogbo Hill Sand Beach and Akwuke Sand Beach South Eastern Nigeria were conducted. The samples were sourced from their deposits. Impurities and other foreign objects were removed by washing and sorting. The chemical analysis was carried out using X-ray fluorescence (XRF) to determine the deposit with the highest silica percentage (%). The results of the chemical analysis show that the Azumili Blue River Sand Beach is composed of silica $SiO_2$ (93.616%), $K_2O$ (0.15%), CaO (0.40%), $Fe_2O_3$ (1.68%), $Al_2O_3$ (3.051%), and has 0.84% clay content. Akwuke Sand Beach and Ogbo Hill Beach are next in line, with silica $SiO_2$ (91.72%), $K_2O$ (0.17%), CaO (0.48%), $Fe_2O_3$ (0.84%), $Al_2O_3$ (3.191%), and Agu-Awka clay containing $Al_2O_3$ (26.43%), $SiO_2$ (29.84%), and $Fe_2O_3$ (1.043%). Azumili Blue River was chosen to perform the foundry properties from the result because of its highest value of silica. The result of the foundry properties test conducted with a core sand mixture of 5% Agu-Awka clay and 5% water content included: green strength (32.02kN/$m^2$), dry strength (235.65kN/$m^2$), permeability (6.3), compatibility (25.20%). The result of the particle size analysis showed that over 70.85% of the sand were retained on the following screens: 0.18mm, 0.125mm and 0.09mm respectively. The result showed that 3-5% of Agu-Akwa clay content with 3-5% water content is suitable for making cores for casting of light grey iron, malleable iron and nonferrous alloys.

**Keywords:** Characterisation, beach sand, foundry properties, south east Nigeria

## Introduction

The most important component in foundry operations is sand. Understanding this material better through an understanding of its properties is crucial. (Thiel, 2011). This will be very helpful in determining whether or not sand is suitable for use in foundries (Edoziuno, 2015) [8]. The strength of the foundry rests on the fundamental strength of sand, which is basically used in pattern making, moulding and core making, as a principal raw material during the casting process. The quality of casting produced depends largely on the pattern, mould and core boxes on its materials, design and construction (Ukachi, 2006) [14]. Mould and core sand must be readily mouldable and produce defect free castings. This can only be achieved, if the properties and behaviours of the sand are known and controlled. The properties of good moulding sand include good permeability, cohesiveness (i.e. grain size and shape, moisture content, bonding material, among others), plasticity, refractoriness and chemical resistivity (Ademulegun, 2008) [1].

The properties vary in sands and some sands tend to be defective in these properties (Adesina, 2005) [2]. Considerable economies in the cost of raw material for foundry moulds and cores for casting can be achieved by fully exploiting those sources of sand nearer to the foundry rather than better known and more strength and types of sand (Fayomi *et al* 2011) [9, 11]. Good quality sand is essential for foundry work regardless of initial cost. Silica sand in form of granular quartz is the main constituent of moulding sand because it has satisfactory refractoriness which can impart strength, stability and permeability to moulding and core sand (Popoola and Fayomi, 2011) [9, 11]. Along with small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities as the chemical composition of silica sand show (Ajao, K. S. 2019). The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point of moulds and cores to a considerable extent which is undesirable (Adesina, 2005) [2]. Silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded (Isiaka, 2013) [12]. Effect of grain shape and size of silica sand; the shape of the sand grains in the mould or core sand determines the possibility of its application in various types of foundry practice (Katsina, 2013) [13]. Silica sand, or granular quartz with enough refractoriness to offer moulding and core sand strength, stability, and permeability, is the main ingredient in core sand. In addition to silica, there are also trace amounts of iron oxide, alumina, lime stone, magnesia, soda, and potash (Aje, 2018). The chemical makeup of silica sand can be used to infer the presence of contaminants such as lime, magnesia, alkalis, etc (Nwajagu C. O., 2014). Given what happens during the coronavirus lockdown, realizing the full potential of the more well-known and publicized sand sources near the foundry workshop can result in significant cost savings on raw materials for foundry moulds and cores for casting. The restrictions on our movement were quite difficult, so we had to take advantage of our surroundings. The goal of this project is to lessen the practice of choosing the wrong sand for foundry sand, which significantly increases the likelihood of numerous casting faults.

## Materials and me0thodology

### Materials collection

Samples of sand were 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 and put in a well labelled polythene bags and kept in the laboratory prior to analysis. At the end of chemical characterization test analysis, the best among the three-sand deposit was Azumili Blue River Sand beach with the highest percentage of silica and it was taken to National Metallurgical Development Centre Jos for examination of physical properties such as: Sieve analysis test, Clay content test, Compatibility test, Permeability test, Green compression strength test, Dry compression strength test, Dry shear strength test, Green shear strength test. Materials used are: Silica (Azumili blue river beach sand) sand, clay (Agu-awka Clay), water and calcium carbide (speedy absorbent), NaOH, Distilled water.

**1.0. Materials 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)

**1.2. 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.

**1.3 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 mould 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.

**1.4. 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.

**1.5. 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 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.

**1.6. 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 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.

**1.7. 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.

## Result and discussion

**1. Sand Grain Fineness Number:** The sieve analysis result as shows that the grain fineness number fell within the acceptable range. According to the American Foundryman's Society (AFS) standard (1963), 40 to 330 average fineness is suitable for foundry application. According to McLaws (1971), 70-86 AFS grain fineness number is suitable for medium grey iron casting. The Azumili blue river beach sand has an average fineness number of 71.302.

The grain fineness number is a useful parameter that represents the sieve number through which all the sand grains would pass if they were of the same sizes. The grain fineness number though is a useful parameter but the choice of sand for the core should be based on particle size distribution. The size distribution of the sand affects the quality of casting.

Medium-grain Sand (that is not too fine and not too Coarse grain sands) is the best for making a core it will allow an easy flow of gas which means permeability will be high but if it is too fine air will be entrapped to the core and cost defeat in the casting (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.

**2. Chemical Properties Analysis Result (XRF)**

Chemical properties analysis result of Azumili, Akwuke, Ogbo hill river beach sand and Agu-Awka clay (binder) is as follows: From the XRF result of the three deposit sand beach it indicate that Azumili Blue River Sand beach have the highest percentage of silica sand 93.616% followed by Akwuke sand beach with 91.717% silica and finally Ogbo hill sand beach of with 86.989% silica. From all observations of the chemical analysis of the three-sand beach, it is clear observed that the percentage silica of the Azumili blue river is higher with the value of 93.616%. Therefore, the Azumili river sand beach is the one chosen to carry out the physical properties of the sand that is foundry properties due to its high rich in silica. It can be that the percentage of $SiO_2$ content for the Chelford, Warri and Ughelli River sand samples is very close to the Azumili sand sample. Silica being the predominant component in the Azumili beach sand is of good advantage, since high percentages of silica in sand according to Richard *et al* (1983) usually enhance its refractory and thermal stability. Agu-Awka clay has 29.34% silica, 26.87% $Al_2O_3$, 26.3% $Ce0_2$, 8.306, 1.0543 $Fe_2O_3$ and 2.44% MgO as the principal constituent.

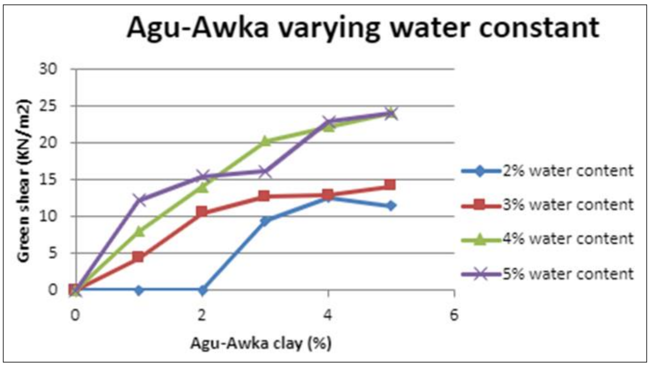


**Fig 1:** Effect of green shear strength on added Agu-Awka clay at constant 2%, 3%, 4% and 5% water content

Figure 1.0 depicts the influence of green shear strength on varying percentages of Agu-Awka clay at constant 2%, 3%, 4%, and 5% water content. The data reveals a consistent increase in green shear strength with higher levels of Agu-Awka clay content. Specifically, for 2%, 3%, 4%, and 5% water content, when mixed with 5% Agu-Awka clay content, the green shear strength values were 11.43 kN/m², 14.10 kN/m², 24.10 kN/m², and 24 kN/m² respectively. These findings suggest that the addition of Agu-Awka clay enhances the green shear strength, indicating its potential to improve the mechanical properties of the material at different water content levels.

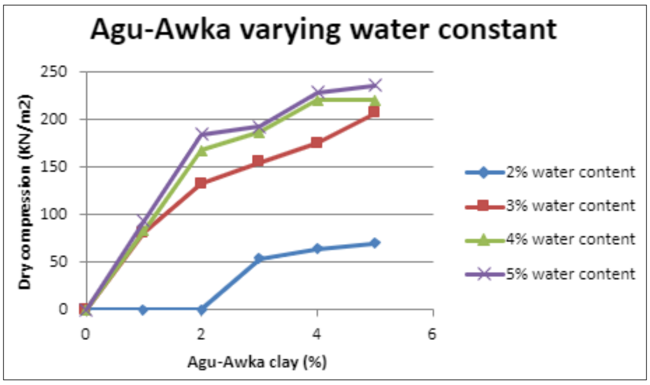


**Fig 2:** Effect of dry compressive strength on Agu-Awka clay at constant 2%, 3%, 4% and 5% water constant

Figure 2.0 illustrates the impact of dry compressive strength on varying percentages of Agu-Awka clay at constant 2%, 3%, 4%, and 5% water content. The data indicates a consistent increase in dry compressive strength with higher levels of Agu-Awka clay content. Specifically, for 2%, 3%, 4%, and 5% water content, the dry compressive strength values increased progressively from 53.86 kN/m²,155.4 kN/m², 186.6 kN/m², and 192.22 kN/m² respectively at 3% Agu-Awka clay content to 70.1 kN/m², 206.4 kN/m², 220.23 kN/m², and 235.64 kN/m² respectively at 5% Agu-Awka clay content. These findings suggest that the addition of Agu-Awka clay enhances the dry compressive strength, indicating its potential to improve the structural integrity of the material across different water content levels.

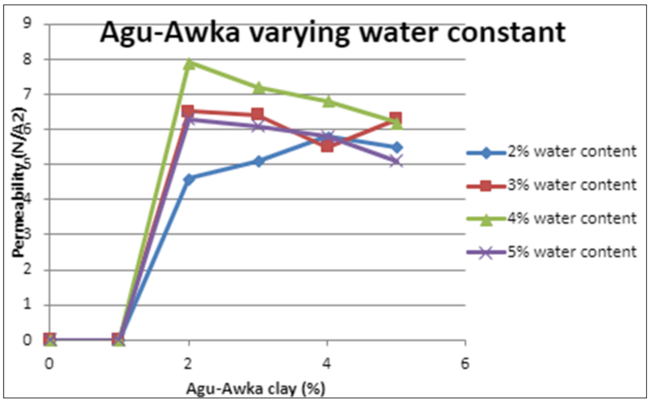


**Fig 3:** Effect of permeability on Agu-Awka clay at constant 2%, 3%, 4% and 5% water content

Figure 3.0 illustrates the impact of permeability on varying percentages of Agu-Awka clay at constant 2%, 3%, 4%, and 5% water content. The data reveals a consistent increase in permeability with increasing levels of Agu-Awka clay content. Specifically, for 2% but for 3%, 4%, and 5% water content, the permeability values declined progressively from 6.5(N/A2), 7.9 (N/A2), and 6.3 (N/A2) respectively at 3% Agu-Awka clay content to 6.3 (N/A2), 6.2 (N/A2), and 5.1 (N/A2) respectively at 5% Agu-Awka clay content. These findings indicate that the addition of Agu-Awka clay leads to a reduction in permeability, suggesting its role in enhancing the material's resistance to fluid flow, which could be beneficial in various engineering applications.

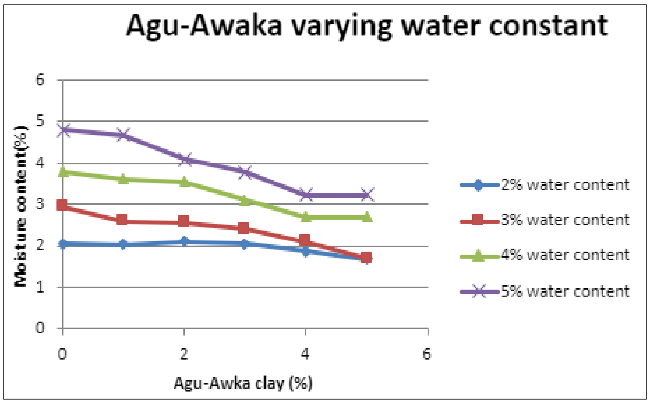


**Fig 4:** Effect of moisture content on added Agu-Awka clay at constant 2%, 3%, 4% and 5% water constant

Figure 4.0 depicts the influence of moisture content on various percentages of Agu-Awka clay content at constant 2%, 3%, 4%, and 5% water content. It is evident from the data that the moisture content exhibits a consistent decrease with increasing levels of Agu-Awka clay addition. Specifically, for 2%, 3%, 4%, and 5% water content, the moisture content progressively decreases from 2.05% to 1.67%, 2.95% to 1.70%, 3.79% to 2.70%, and 4.66% to 3.22% respectively, as the Agu-Awka clay content increases from 0% to 5%. This observation suggests that the incorporation of Agu-Awka clay into the mixture leads to a reduction in moisture content, which could have implications for the material's properties and performance in engineering applications.

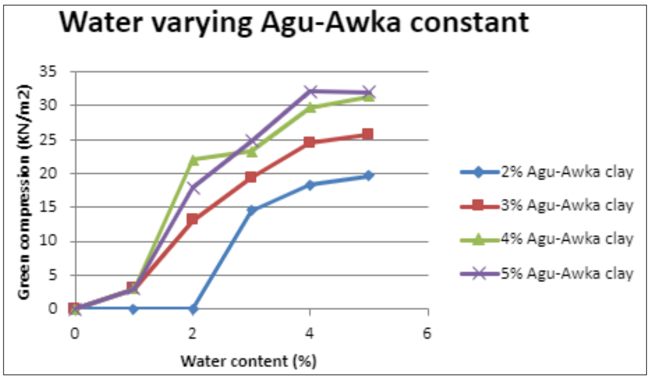


**Fig 5:** Effect of green strength on added water content at 2%, 3%, 4% and 5% Agu-Awka clay sample constant

Figure 5.0 illustrates the impact of green compressive strength on varying levels of added water content, while maintaining constant concentrations of 2%, 3%, 4%, and 5% Agu-Awka clay samples. It was observed that, for the 2%,3%,4%,5% Agu-Awka clay samples, the green compressive strength exhibited an increase as the introduced water content increased. The increase in green compressive strength observed in the samples indicates strong resistance to deformation, potentially impacting the overall strength and integrity of the casting.

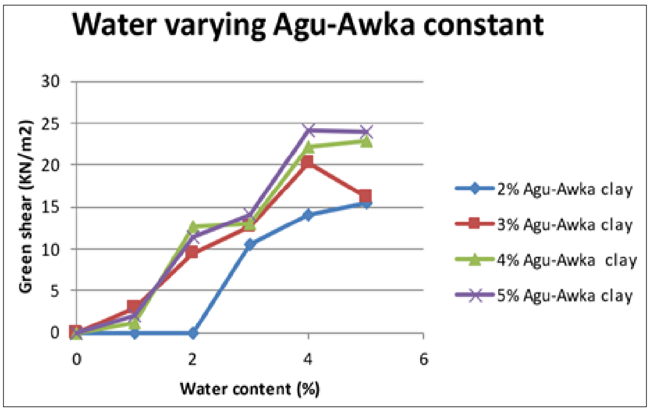


**Fig 6:** Effect of green shear strength on added water content at 2%, 3%, 4% and 5% Agu-Awka clay sample constant

Figure 6.0 depicts the influence of green shear strength on varying levels of added water content, while maintaining constant concentrations of 2%, 3%, 4%, and 5% Agu-Awka clay samples. It was observed that, the green shear strength generally increased with an increase in water content addition. Specifically, for the 2% Agu-Awka clay sample, the green shear strength exhibited an increase from 3.00kN/m² at 1% water content addition to 20.32kN/m² at 4% water content, followed by a decrease to 16.20 kN/m² at 5% water content addition. However, for the 2%, 4%, and 5% Agu-Awka clay samples, the green shear strength displayed a consistent increase with the introduction of higher water content levels.

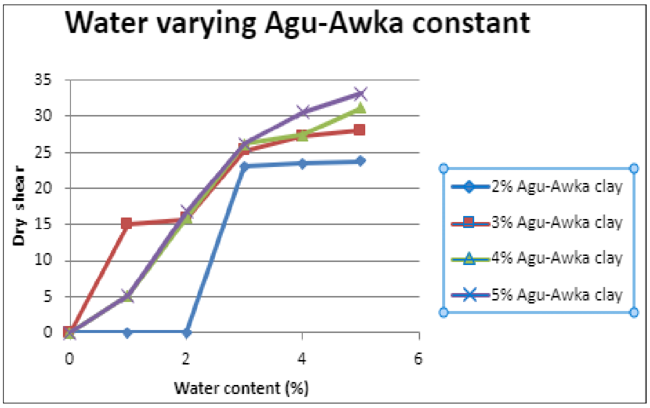


**Fig 7:** Effect of dry shea r strength on water content at 2%, 3%, 4% and 5% Agu-Awka clay sample constant

In Figure 7.0, the influence of dry shear strength on varying proportions of water content is depicted, holding constant Agu-Awka clay concentrations at 2%, 3%, 4%, and 5%. It was discerned that the dry shear strength exhibited an incremental trend in tandem with the augmentation of introduced water content. Specifically, for Agu-Awka clay compositions of 2%, 3%, 4%, and 5%, the dry shear strength attains values of 23.8 kN/m², 28 kN/m², 31.12 kN/m², and 33.11 kN/m², respectively, when blended with 5% water content addition. These observations, succinctly delineated in Figure 4.7, underscore the consequential relationship between water content levels and dry shear strength in Agu-Awka clay samples.

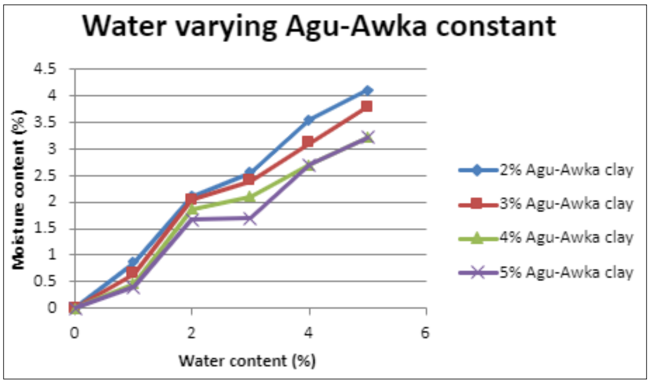


**Fig 8:** Effect of moisture content on added water content at 2%, 3%, 4% and 5% Agu-Awka clay sample

In Figure 8, the influence of moisture content on varying water percentages within constant 2%, 3%, 4%, and 5% Agu-Awka clay samples is delineated. The results indicate a direct correlation between the introduced water content and the subsequent moisture content. Specifically, upon the addition of 5% water content, the moisture content rose to 4.10%, 3.11%, 3.22%, and 3.22% for Agu-Awka clay samples with concentrations of 2%, 3%, 4%, and 5% respectively. This trend aligns with the findings of Ahem and Nuhu (2008), who assert that initially, water introduced into a sand mixture is absorbed by the binder until saturation is achieved. Subsequently, any additional water is retained as free water, thereby contributing to the continuous escalation of moisture content, as depicted in Figure 4.8. The characterization and the chemical properties analysis result of Azumili, Akwuke, Ogbo hill river beach sand and Agu-awka clay result is as follows: From the XRF result of the three deposit sand beach, it indicated that Azumili Blue River Sand beach have the highest percentage of silica sand 93.616% followed by Akwuke sand beach with 91.717% silica and finally Ogbo hill sand beach of with 86.989% silica. From all observations of the chemical analysis of the three-sand beach, it is clearly observed that the percentage silica of the Azumili blue river is higher with the value of 93.616%. The Azumili river sand beach is the one chosen to use to carry out the physical properties of the sand that is foundry properties due to its high rich in silica percentage. Agu-awka clay contain Al2O3 (26.43%), SiO2 (29.84%), Fe2O3 (1.043%). The foundry properties results showed that sand mix 3.80% moisture content produced the best core mixture is 5% Agu-awka 3.5 moisture content. The properties compared favourably with the proportion of the core sand currently used in foundries for the casting of aluminium alloys. The chemical analysis result has been proven that Azumili Blue River Sand beach is the best among other 2 sample Akwuke and Ogbo hill sand beach having the highest percentage of silica sand.

### 3.0. Conclusion

From the results of the analysis presented, the following conclusions were drawn. The mechanical sieve analysis result revealed that the grain of the sand was sub-angular and it has a well-defined grading with 70.85(%) percent concentration of the sand grains retained by the three adjacent sieves of 0.335mm, 0.25mm and 0.18mm. Moisture has a very strong influence on the foundry properties of Azumili Blue River Sand Beach Aba, Abia State. The chemical analysis showed that the Azumili blue river beach sand is composed predominantly of silica (93.6.16%), but not in the range that could be used for steel and other heavy metals production. Agu-awka clay contain Al2O3 (26.43%), SiO2 (29.84%), Fe2O3 (1.043%). The result of the mechanical properties analysis of the sand was compared to the existing foundry standard and it was found to be very suitable for nonferrous alloy castings at about 3% to 5% of Agu-awka clay and with about 3.14% to 4.60% moisture content for the binder. The sand mix with 5% Agu-awka clay with 3.22% moisture content. The properties compared favourably with the proportion of the core sand currently used in foundries for the casting of aluminium alloys. The Azumili blue river mixture with moisture content of 3.22% to 3.78%, for core making to produced a quality casting of aluminium using aluminium silicon alloy. The grain fineness number (G.F.N.) was found to be 55.6 AFS with for pure silica sand, when mixed with 5% Agu-Awka clay each with constant 5% of water for the binder**.** For effective and efficient utilization of solid minerals in Nigeria, the following recommendations are made. Further research aimed at determining mechanical properties of Akwuke river sand beach and Ogbo hill sand beach local binders like starch clay and other binders for core making can be suggested**.** This project is recommended foundry industry for use in preparing core for casting of nonferrous alloys for possible replacement of the imported synthetic sand and binders.

### References

1. Ademulegun F. Manufacturing Processes, Tess-Tech Educational Publisher. Ikeja, Nigeria, 2008, 151-159
2. Adesina A. "Foundry Properties of Bacita Sand", Compendum of Engineering Monographs (CEM). Journal of Engineering Science and Technology,2005:2(3):28-40.
3. Adesina S, Adegbite. "Engineering Characterization of Tsaragi River Sand for Moulding in Foundry Work", Journal of Research and Development,2013:5(1):20-27.
4. Agbo AO, Anene FA, Nnuka EE. 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,2017:4(1):26-30.
5. B Imamudeen, CN Nwambu, CI Nwoye. 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), 756-763.
6. CI Nwoye, B Imamudeen, CN Nwambu. Analysis of corrosion rate of buried API 5L× 70 steel pipeline in soil by Taguchi technique Int. Journal of Civil Engineering and Architecture Engineering,2024:5(1):28 33.
7. Dhairya S. A study of core and its types for casting process, International Journal of Advanced Technology in Engineering and Science,2015:3(1). ISSN (online): 2348 – 7550 1571.
8. Edoziuno FO. Effect of Ukpor clay content on the properties of synthetic moulding sand produced from River Niger sand. International Journal of Physical Science Department of Metallurgical & Materials Engineering, Nnamdi Azikiwe University, Awka,2015:9(5):64-68

9. Fayomi OSI, Ajayi OO, Popoola API. Suitability of local binder compositional variation on silica sand for foundry core making. International Journal of Physical Science,2011:6(8):1940-1946.
10. Fayomi OSI, Popoola API, Ojo OI. Investigating Nigeria Ochadamu Silica Sand, Clay and Local oils for foundry core making. International Journal of Physical Science,2011:6(8):1894-1904.
11. Nwanakwere DC, Nwambu CN, Nnuka EE. Effect of Eziadda Clay on Foundry Properties of Azumili Blue River Sand Beach. UNIZIK Journal of Engineering and Applied Sciences,2024:3(2):608-613.
12. Isiaka O. Characterization of Unwana Beach Silica Sand and Its Industrial Applications, *International Journal of Science Innovations and Discoveries*, IJSID,2013:3(1):93-100.
13. Katsina C. Characterization of Beach/River Sand for Foundry Application. The International Journal of Engineering and Science,2013:9(45):54-60
14. Ukachi P. *Essentials of Foundry Technology and Practice*, Book 2, Green Line Publishers, Ado- Ekiti, Nigeria, 2006, 12-16.
15. PN Anienye, UJJ Ijah, N Nnamdi. 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,2015:5(8):1-8.
16. N Anienye Prince, N Nnamdi, NJ Obiorah, I Davidson. 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,2015:5(8):1-8.