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Suitability Assessment of the Properties of Agba Dam Moulding Sand for Foundry Applications

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Abstract

Understanding the attributes of moulding sands is essential for foundry efficiency and high-quality cast production, which can be achieved through adequate information on their properties. The lack of comprehensive information about indigenous natural moulding sands has led to suboptimal casting quality and stunted industry growth in Nigeria. This study employed the rigorous standards set forth by the AFS-American Foundry Men's Society to conduct a comprehensive characterization of Agba dam's natural moulding sand samples' chemical and physico-mechanical properties for sand foundry applications. The chemical analysis revealed a composition of 79.771% SiO_2 and 9.383% Al_2O_3, with trace amounts of Na_2O, K_2O, CaO, Fe_2O_3, MgO, and TiO_2, classifying this sand as Alumino-silicate. The evaluation of physico-mechanical properties showed: silt content (5%), moisture content (1.81%), grain fineness number (44.54), green compressive strength (54.54 kN/m^2), dry compressive strength (21.60 kN/m^2), specific gravity (2.65), shatter index (40.26% green and 50.89% dry), bulk density (2196.24 kg/m^3), permeability (0.05595 cm/sec), and refractoriness (>610°C). Most findings met AFS standards for non-ferrous metal casting. Enhancing the sand's performance, particularly in compressive strength, may be achievable through a suitable binder. Thus, this moulding sand is suitable for non-ferrous metal casting, and its effective use could stimulate economic growth and help address unemployment in Nigeria.

Keywords: *Agba Dam, sand, properties, foundry, application, suitability.*

1.0 Introduction

Foundry operations, constituting one of the oldest manufacturing processes, entail the melting of metals, including both ferrous and non-ferrous varieties. These molten metals are poured into precisely fabricated mould cavities crafted from moulding sand. The overarching objective is the production of durable, marketable castings characterized by favourable mechanical and physical properties, all of which contribute to the economic development of a nation [1].

Foundry is the cornerstone for various industries in developing nations, supplying raw castings and components essential to their operations. Beyond the provision of raw castings, foundries encompass a spectrum of tasks involving the production of diverse apparatus for construction, modeling, machining, and post-processing activities. Consequently, foundry technology has assumed paramount importance [2] in all fields of endervours, because of the usefulness of foundry in all applications. . Casting within foundries is an ancient technique in metal forming. It involves a sequence of steps such as mould preparation, metal melting, molten metal infusion into moulds, solidification, shake-out, and fettling. This method finds application across various castings, including investment casting, centrifugal casting, die casting, and sand casting, among others [3].

Sand casting represents a prevalent and straightforward casting approach [4], widely used for producing complex metal shapes due to its cost-effectiveness, versatility, and ability to accommodate large components. It offers economic advantages due to its cost-effectiveness, reusability, adaptability, and capacity for casting diverse shapes [5]. Silica sand's properties (including refractoriness, chemical resistance, and permeability) significantly influence the moulding process [6],[7]. The sand's resistance to high temperatures, chemical stability, and ability to allow gas passage, play a crucial role in determining how well the mould performs during the casting process.

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Global attention has been drawn to green sand mould castings due to considerations involving processing equipment, raw material availability (silica sand and bentonite), and the reclaimability of moulding materials. The properties of moulding sand are influenced by factors such as sand type (zircon or silica), particle shape and size, curing duration, the nature of binders, and incorporated additives [8].

Moulding sand constitutes a pivotal material in sand casting, with the quality of cast products hinging on the constituents, properties, and occasionally, additives employed to enhance the sand characteristics [9],[10],[11],[12],[13]. Core constituents of moulding sand encompass silica sand, binders (including clay), and moisture. The size and proximity of silica sand grains significantly impact properties like permeability and bonding [14]. Binders, which can be organic or inorganic, including clays like kaolinite, limonite, ball clay, and bentonite, serve to confer strength and cohesion upon moulding sand when combined with moisture [15].

Several studies have revealed that Nigeria is well blessed with numerous resources of sand, of which Ilorin metropolis is inclusive [1],[7],[10]. This can benefit the economy of the nation as an alternative to overdependence on importation [3],[9],[10],[11],[12],[13],[16],[18],[19],[20]. The properties of various available natural moulding sands in Nigeria have yet to be thoroughly investigated for foundry applications [9],[10].

The river beds and banks are known to be a good source of moulding sand [9],[10],[21],[22],[23],[24],[25],[26],[27],[28],[29]. Agba Dam is one of the rivers located in the Ilorin metropolis that covers approximately 326,000 m^2 and has two springs as its source [30]. Interestingly, one of the most popular trades in the Ilorin metropolis is aluminium pot casting, which involves the application of moulding sands [15],[31]. Foundry Operators (Technicians) frequently utilise sand without considering its properties [15]. This practice usually leads to poor quality casting or failure and eventually leads to the wastage of materials. Thus, the availability of river sand in Ilorin encourages investigation, which is the motivation for this study to unfold their properties for foundry applications. Better understanding of the moulding sands' behaviour through its properties will assist in its effective usage for foundry applications, which would guarantee good quality castings and high return on investment.

2.0 Materials and Methods

2.1 Materials

The sand samples used as the major material for this study, were collected from Agba Dam river bank by manual digging up to a depth of about 3.00 cm to collect pure silica sand with even distribution.

The Agba Dam area is located in Ilorin, Kwara State, Nigeria, bounded by longitudinal E 0040 35' 0.72" – E 0040 35' 40.6" and latitude N 080 28' 23.3" – N 080 28' 40.1" [30].

2.2 Determination of chemical composition

X-ray fluorescence Analysis was used to analyze the elemental chemical compositions of the sand from the Agba dam river bank, following AFS 5222-13-S standard [33] conducted at the National Geoscience Research Laboratories Centre in Kaduna, Nigeria. This was accomplished by precisely weighing the prepared sand sample and setting it in a metal sample container. This sample holder was placed into the X-ray apparatus for two minutes. Following this time frame, the analysis's findings were shown on the X-ray fluorescence spectrometer equipment monitor.

2.3 Physico-Mechanical properties tests

The removal of larger silica grains guarantees uniform grain size, and silica sand was put through a typical sieve with a 1.80 mm aperture. The prepared sand samples were then compacted using a sand compactor machine that delivered 60 blows, shaped into cylindrical standard test specimens measuring 50 mm by 100 mm, and removed from the mould following American Foundrymen's Society (AFS) 5222-13-S standards [33] and BS 1377 [34] and narrated by Head [35][36]. Some physical properties of the blended naturally moulding sands were conducted using standard procedures specified by the American Foundry Society (AFS) and British Standards. Physical tests conducted were grain fineness number and size, moisture content, clay content, permeability, refractoriness, specific gravity, green compressive strength, dry compressive strength, and Shatter Index.

2.3.1 Grain Fineness Number

The evaluation of the grain fineness number for the prepared silica sand was conducted utilizing a British Standard Mechanical Shaker (serial no. 890221010007). This assessment employed a set of British sieves with mesh sizes of 8, 10, 16, 22, 60, 100, 150, and 200 (microns) in conjunction with an electronic weighing balance. The freshly prepared AFS samples comprised 1000 g of silica sand, having undergone prior cleaning and sun-drying for twenty one days (504 hours) to eliminate moisture content and weighed. Subsequently, the set of pan sieves was arranged in descending order of aperture size. The initially weighed 1000 g of silica sand was gently poured from the uppermost sieve into this stack of sieves. The complete assembly of British sieves,

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housing the pre-weighed silica sand, was then placed onto the mechanical shaker, which was subsequently activated to induce vibration for 15 minutes. The quantity of silica sand retained in each sieve was weighed, and their respective weights were meticulously recorded employing the electronic weighing balance. This methodology was executed following the standards outlined in AFS 1105–12–S [37] and AFS 1106–12–S [38], as per the guidelines delineated in AFS [39] and ISO/R.565 series [33]. Utilizing these parameters, the AFS Grain Fineness Index (AFS GFI) was calculated using Equation (1),

$$\text{AFS GFN} = \frac{W_T}{\sum S_R} \tag{1}$$

where W_T = the total weight of the product, and $\sum S_R$ = total sum of percentage of sand retained by different sieves.

2.3.2 Moisture Content

Samples of the moulding sand were meticulously weighed and subsequently transferred into pristine aluminum containers of identical specifications. To ascertain their weight, the empty aluminum containers were individually weighed and recorded as W_1, employing an electronic balance. Following this, the aluminum containers housing the pre-weighed sand samples were placed on the electronic balance, and the collective weight was ascertained and documented as W_2. Subsequently, these containers, along with the sand samples enclosed within them, were exposed to a controlled temperature of 110°C inside an oven for an approximate duration of 24 hrs. Sequel to the drying process, the sand samples were extracted from the oven, and their weight was meticulously recorded as W_3. This systematic procedure adhered to the established protocols delineated in AFS 2218 – 00 Standard [40]. The moisture content was subsequently computed employing the formulas stipulated in equations (2a & b),

$$Moisture\ content = \frac{Loss\ in\ weight\ of\ sand\ sample\ (g)}{Weight\ of\ the\ sand\ sample\ taken\ (g)} \tag{2a}$$

$$\frac{W_2 - W_3}{W_2 - W_1} \tag{2b}$$

where, W_1 = Aluminum Can weight, W_2 = Aluminum Can weight and sand sample before drying, W_3 = Aluminum Can weight and sand sample after drying.

2.3.3 Clay Content

The quantification of clay content was conducted by assessing the weight reduction of the sample following a washing procedure. In a controlled experimental setup, a 50 g aliquot of pre-dried sand was introduced into a mixing apparatus, where it was subjected to treatment with a solution containing a 100 concentration of normal sodium chloride salt (NaCl) dissolved in water. Subsequently, a measuring cylinder was utilized, initially filled with the sodium chloride solution. The sun-dried silica sand, devoid of any moisture, was then introduced into the measuring cylinder until it reached a volume of 200 ml. Following this step, the measuring cylinder, now containing 200 ml of silica sand together with the salt solution, underwent vigorous agitation via manual shaking for an approximate duration of three minutes. This process led to the stratification of the contents into four distinct layers, each delineated by water, silt, clay constituents, and silica sand layers. Each of these stratified layers possessed a volume commensurate with the calibrated markings on the measuring cylinder, denoted as V(water), V(silt), V(clay), and V(silica) respectively. Subsequently, the determination of the clay content within the molding sand was executed following the prescribed formula detailed in Equation (3), adhering to the standards articulated in AFS 2110 – 04 [35],[36],[41].

$$Clay\ content, CC = \frac{V_{silt} - V_{clay}}{V_{clay} - V_{silica}} \tag{3}$$

2.3.4 Permeability

The constant-head permeability meter was employed, and a cylindrical mass of the sand sample with predefined dimensions was prepared, following the guidelines outlined by the American Foundry Society (AFS). Subsequently, the prepared molding sand specimen was positioned within the permeability apparatus, and 2000 cm^3 of air, under a standard pressure of 9.8 x 102 N/m^2, was passed through the specimen. The time taken for this 2000 cm^3 of air to pass through was recorded using a stopwatch. The permeability value for each specimen was then calculated using Equation (4). This was carried out using AFS 5224 – 13 Standard as presented in AFS [39].

$$Permeability\ Number, PN = \frac{V.H}{P.A.t} \tag{4}$$

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PN = Permeability Number of the specimen, V = Volume of the air passing through the specimen in cm^3, H = Height of the specimen in cm, P = Pressure of the air passing through the specimen in N/cm^2, A = Cross-sectional area of the specimen in cm^2 and t = The time required for the air to pass through the specimen in minutes.

2.3.5 Refractoriness

This test was conducted in line with the guidelines in the British standards. To determine the refractoriness of the moulding sand, the sand sample placed in an electric oven was observed for any changes during heating up to 1200 ^{o}C.

2.3.6 Specific Gravity

The specific gravity of natural moulding sand was determined using a density bottle, vacuum desiccators, and a weighing balance. The bottles were cleaned, dried, and weighed before filling with silica sand. The sand was then filled with air-free water, vacuum desiccated, and filled with water. The specific gravity was calculated using Equation (5), following the standard procedure BS: Part 2: 7.2 Standard [34], as detailed in Head [35][36].

$$Specific\ Gravity, SG = \frac{M_2 - M_1}{(M_2 - M_1)\ (M_3 - M_4)}\ [42] \quad (5)$$

Where M_1 = mass of the empty density bottle, M_2 = mass of the density bottle containing the prepared moulding sand, M_3 = mass of the density bottle containing both the prepared moulding sand and water, and M_4 = mass of the density bottle containing only water

2.3.7 Bulk Density

The AFS established protocol was used to perform a bulk density assessment for samples A and B. The process involved transferring natural moulding sand specimens into measuring cylinders. The weights of the samples were determined using an electronic balance, and the weight was recorded after sun-drying and cleaning. The specimens' volume was measured using a calibrated cylinder. Following the prescribed methodology, the bulk density for each sample was calculated using established parameters, following the BS: Part 2: 1990 Standard [34] as stipulated in Equation (6).

$$Bulk\ Density, BD = \frac{Ws1 - Ws2}{Vs} \quad (6)$$

W_{s1} = weight of the specimen before drying, W_{s2} = weight of the specimen after drying, and V_s = Volume of the specimen.

2.3.8 Green and Dry strength Test

The green compressive test was used to characterize natural moulding sands, which are prepared with ideal moisture content. The tests were conducted while the samples were in both wet and dry states, known as the green strength and dry strength of the natural moulding sands, respectively. The samples were then placed in a Tri-Axial Testing Machine (California Bearing Calibration (Model No.: 212060257; ELE (Engineering Lab. Equipment Ltd; Volts: 240.Amps:3, HZ.50Ph) at the Civil Engineering Soil Laboratory of the Federal Polytechnic, Ado-Ekiti, Nigeria, both wet and dried, and a load is applied to compress the specimen until it fails. The maximum strength that the specimen can withstand before rupturing is recorded on the machine scale, corresponding to the green compressive strength in the wet state and dry compressive strength in the dried state [35][36]. This approach was applied following the AFS 5202 – 09 Standard in AFS [39] for characterizing moulding sand.

2.3.9 Shatter Index Test

The Shatter Index was determined for the natural moulding sand as presented in AFS 5102-13 [43]. The purpose was to assess the impact of the shatter index of the moulding sand samples. To conduct the test, a standard test specimen was compacted by subjecting it to 60 blows using a sand ramming machine or sand compacting machine. Subsequently, the specimen was dried in an oven for 24 hours. After this preparation, the test specimens were dropped freely from a height of 1.83 meters onto a steel anvil. The portion of the sand samples that remained on a 12.5 mm mesh British Standard Sieve was weighed and recorded as W_s. The shatter index was expressed as a fraction percentage of the total weight of the specimen, denoted as W. The Shatter Index was then calculated using the Equation (7).

$$Shatter\ Index, SI = \frac{W_s}{W} \quad (7)$$

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W_s = Weight of the sand portion retained and W= Weight of the test specimen.

Some satisfactory moulding sands' properties for various types of casting obtained from the literature [3],[35],[36],[44],[45], [15] are presented in Table 1.

Table 1: Mould sand properties for various types of different metal castings [15]

Metal	Clay content (%)	Moisture content (%)	Green compressive strength (kN/m^2)	Dry compressive strength (kN/m^2)	Permeability No
Heavy Steel	10 – 12	4 – 5	70 – 85	1000 -2000	130-300
Light Steel	7 – 12	6 – 8	70 – 85	400 – 1000	125-200
Heavy Grey Steel	10 – 19	6 – 8	70 – 105	50 – 800	70-120
Aluminium	8 – 10	4.5 – 5.5	50 – 70	200 – 550	10-30
Brass and Bronze	10 – 15	5 – 7.5	55 – 85	200 – 800	15-40
Light Grey Iron	8 – 13	4 – 6	50 – 85	200 – 550	20-50
Malleable Iron	8 – 14	5 – 7	45 – 55	210 – 550	20-60
Medium Grey Iron	11 – 15	5 – 8	70 – 105	350 – 800	40-80

3.0 Results and Discussion

3.1 Chemical composition of Agba Dam moulding sand deposit

The results of the chemical composition analysis for the selected Agba dam moulding sands are shown in Figure 1. The X-ray Fluorescence (XRF) Analysis findings, as detailed in Table 2, have established that silica (SiO_2) is the predominant constituent in Agba dam sand samples, comprising a substantial 79.771 wt% of the sand samples. In Table 2, the notable compounds identified in the sand include alumina (Al_2O_3), iron (III) oxide (Fe_2O_3), potassium oxide (K_2O), and calcium oxide (CaO). An excessive presence of iron oxide, alkali oxides, and lime can lower the fusion point considerably; a characteristic found undesirable in casting processes [1]. In the moulding sand, trace amounts of other alkali oxides like Ta_2O_5, MnO, WO_3, BaO, PbO, CuO, and similar impurities can also be detected [7],[14]. Magnesium Oxide (MgO) was conspicuously absent in Agba Dam sand despite its customary presence in the clay content of such sands [9]. However, the negligible impact of this absence on sand strength is attributed to clay's role as a binding agent that facilitates cohesion among sand grains [9]. The Agba Dam sand is classified as an alumina silicate because of its high silica (SiO_2) and alumina (Al_2O_3) contents. Most foundry sands utilised for metal casting are characterised by high-quality silica, and by specific physical attributes [9]. Despite the low melting points associated with CaO, K_2O, TiO_2, and similar compounds, their presence within moulding sand is deemed impurities due to their potential to lower the sand's fusion point; thereby diminishing its refractoriness and chemical inertness [9]. Even slight temperature fluctuations above ambient conditions can precipitate reactions between these impurities and surrounding gases, resulting in casting defects when such moulding sand is employed in foundry applications. The reddish hue of Agba Dam sand (Table 3) can be attributed to its iron (III) oxide content (4.090 wt.%), which acquires a red colouration upon exposure to heat [46][47],[48],[49]. It is crucial to note that an excess of iron (III) oxide can significantly reduce the fusion point, a characteristic that is considered undesirable [9],[10].

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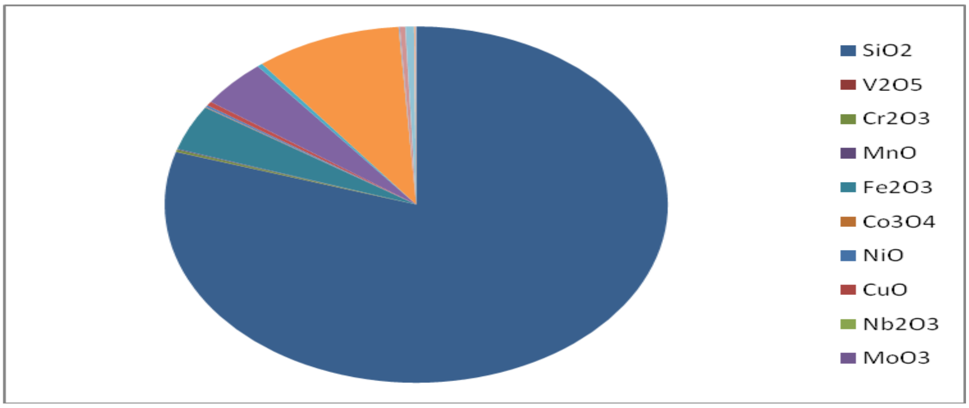

Figure 1: Chemical constituents of Agba dam sand deposit

In terms of suitability for casting Non-Ferrous metals, the Agba Dam natural moulding sands conform to acceptable standards without necessitating the inclusion of additives, as outlined in established guidelines [9],10],[33].

3.2 Physio-Mechanical properties of Agba Dam sand

The physico-mechanical properties of Agba dam sand from various experimental procedures are presented in this section.

3.2.1 Grain Fineness Number

As presented in Table 2, the Grain Fineness Number (GFN) represents a quantitative metric for characterizing the distribution of grain sizes within a given sand sample, as ascertained through a comprehensive sand sieve analysis. This distribution exerts a discernible influence on an array of sand properties, encompassing refractoriness, green strength, dry strength, hot strength, permeability, and compatibility, as outlined by Padmini *et al.* [50]. Sand featuring a wide spectrum of particle sizes typically exhibits reduced permeability in comparison to sand composed of grains possessing a standard fineness [50].

Table 2: Grain Fineness Distribution of Agba Dam Sand

BS Sieve No	Sieve size (mm)	Weight Retained (g)	% Retained (X)	% Passed	Multiplier (Y)	Product (XY)
8	9.5	0	0	100	0.375	0
10	4.75	0	0	100	4	0
16	2.36	07.88	0.788	99.21	8	6.304
22	1.18	173.32	17.332	81.88	16	277.312
60	.6	359.98	35.998	45.88	22	791.956
100	0.3	318	31.8	14.08	60	1908
150	0.15	110.26	11.026	3.06	100	1102.6
200	0.075	22	2.2	0.86	150	330
Total		**991.44**	**99.144**			**4416.172**
GFN = 44.54						

The importance of using the right grain fineness in sand for casting is highlighted by Shuaib-Babata and Olumodeji [15]. Different types of sands have varying Grain Fineness Number (GFN) values, tailored for specific casting needs. According to ASTM standards, GFN values ranging from 35 to 90 are suitable for medium and heavy metal casting [9],[50]. Sands falling within this GFN range are considered well-suited for moulding applications [9],[10],[50]. The Agba Dam natural moulding sand has a GFN of 44.54, making it suitable for casting of non-ferrous metals within the prescribed standard values (35 – 90) [51]. This indicates that the sand has a finer average grain size of approximately 210 µm, an important factor in sand selection based on particle size distribution [51]. Additionally, the average GFN of the Agba Dam natural molding sand is 45, categorising it as coarse in terms of grain fineness [51]. Coarse sand can lead to rough surface finishes on castings due to potential penetration defects; while fine sand can produce superior surface finishes but with reduced permeability, potentially causing gas-related defects. The size distribution of sand significantly affects the quality of castings produced [51]. Grain size distribution influences sand properties such as refractoriness, green strength, dry strength, hot strength, permeability, and compatibility [50].

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3.2.2 Moisture Content

Moisture content plays a crucial role in the quality of casting and moulding sand, as the porosity of moulding sand increases with its moisture level [9],[10]. A moisture test of the moulding sand sample showed moisture content of 1.81%, which was below the standard due to the sand losing most of its moisture content during prolonged drying before the experiment. Increasing the water content of moulding sand can raise the moisture content, with the acceptable range being between 4–8%, suitable for casting suitable for casting light steel (6 - 8%), heavy grey steel (6 – 8%), and medium grey iron 4 – 8%), aluminium (4.5 – 5.5%), among other materials [10],[11],[12],[15].

3.2.3 Clay Content

The Agba sand contained no clay but silt with a value of 5% because the sand was sharp. According to Shuaib-Babata *et al.* [10],[12], the recommended clay percentage for moulding sand typically ranges from 10% to 12%. However, for castings involving brass, bronze, iron, and steel, the American Foundrymen Society typically stipulated that the clay contents are between 12% and 18% [8],[9],[10],[11],[12],[15]. To meet the minimum clay content requirements necessary for metal casting, an additive (binder) can be introduced [15].

3.2.4 Specific Gravity

The result of the Agba sand sample's specific gravity is 2.65. The ASTM D854-23 standards stipulate the suitable 2.5 – 2.8 as the specific gravity values for sands for casting [52]. The moulding sand with an average value of 2.65 falls within the range obtained in literature [53],[54] and the 2.5–2.8 acceptable ASTM standard, indicating that the sand has a high specific gravity and hence has relatively few impurities, which means it won't melt with the cast at higher temperatures. It has been revealed that moulding sand with lower specific gravity contains higher impurities and inorganic materials that might melt during the casting process and cause a casting error [9].

3.2.5 Permeability

The permeability of moulding sand is contingent upon both the degree of fineness of the sand and its moisture content, as delineated by Shuaib-Babata and Olumodeji [15]. Inadequate permeability in the sand can lead to undesirable consequences such as explosions and other detrimental casting issues since it is the moulding sand's gas evolution capability. The outcome of the permeability test conducted on the Agba Dam moulding sand sample yielded a value of 0.05595 cm/sec. Several factors including the size and shape of sand particles, mold compaction, and the quantity of binder employed in the mold exert influence on the overall permeability of the mold. Smaller particles tend to result in narrower inter-particle gaps, and it is anticipated that an excess of binder can also constrain mold permeability. Excessively low and high permeability can lead to casting defects, including porosity, blowholes, and poor surface finishes. Consequently, in pursuit of successful casting outcomes, a judicious selection of moderate permeability is imperative [9].

3.2.6 Refractoriness

The average refractoriness of the sand was measured using an electric oven, and it was discovered to be higher than 610°C. The physical characteristics or measurements of the moulding sand samples did not change during this procedure, and there were no visible indications of fusion on the metal surface. According to these findings, the sand is suitable for casting non-ferrous alloys with melting temperatures of 510°C or higher. It's important to remember that a furnace may still raise the temperature to 1200°C. Additionally, some ferrous alloys that melt below 1200°C can also be used with the sand [9].

3.2.7 Green Compressive Strength

For Agba dam sand, the green compressive strength is measured at 54.54 KN/m^2. This result demonstrated that the moulding sand's green compressive strength falls within the specified range for casting aluminum (50–70 KN/m^2), light grey iron (50–85 KN/m^2), malleable iron (45–55 KN/m^2), and very close to that of brass & bronze (55–85 KN/m^2) (Table 3). It is important to note that research suggests that adding a binder can increase the moulding sand's green strength [9],[29].

Table 3: The Agba Dam natural moulding sand's green compressive strength in comparison with other satisfactory properties for various types of casting [15]

Properties	**Agba moulding sand**	**Heavy Steel**	**Aluminium**	**Heavy Grey steel**	**Light Grey Iron**	**Brass and Bronze**	**Malleable Iron**

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Dry Compressive Strength (KN/m^2)	54.54	70-85	50 – 70	70 – 105	50 - 85	55 – 85	45- 55

3.2.8 Dry Compressive Strength

The Dry compression strength value is 21.60 KN/m^2 with respect to the reference range (200-550 KN/m^2) [15]. The result in Table 4 did not meet the standard requirement for non-ferrous metal. To further increase the moulding dry strength, there will be a need to add an additive to the sand.

Table 4: The Agba natural sand's dry compressive strength in comparison with other satisfactory properties for various types of casting [15]

Properties	**Agba moulding sand**	**Heavy Steel**	**Aluminium**	**Heavy Grey steel**	**Light Grey Iron**	**Brass and Bronze**	**Malleable Iron**
Dry Compressive Strength (KN/m^2)	21.6	1000 - 2000	200 – 550	50 – 800	200 - 550	200 – 800	350 – 800

3.2.9 Bulk Density

The moisture content of moulding sand directly impacts its bulk density, and optimal bulk density can be achieved by appropriately compacting the sand to release any trapped air within the mold. The Bulk Density value is 2196.24 kg/m^3. It is worth noting that these values fall within the recommended range of 1700 to 2400 kg/cm^3 for refractory bricks, as indicated in a similar investigation [10].

3.2.10 Shatter Index

The shatter index is a quantitative measure of the mold's resilience, as discussed by Shuaib-Babata *et al.* [9]. In the case of the molding sand sample, the average shatter index value for both the wet and dry samples stood at 45.58%. This shatter index value falls within the moderate range, signifying that excessively high or low values of the shatter index are generally unfavorable for casting applications. Analysis of the shatter index value suggests that the sand possesses a relatively low collapsibility characteristic, a highly desirable attribute in molding sand. This is advantageous because moulding sands with low collapsibility values tend to impede the unrestricted contraction of the casting, thereby minimizing the occurrence of tears and cracks [7],[10]. Conversely, excessively high shatter index readings indicate poor moulding quality, often stemming from an excess of clay or water content in the sand, rendering it unsuitable for use in foundry applications [15].

4.0 Conclusion

The study on the suitability of Agba Dam natural moulding sand for foundry applications revealed significant insights into its properties and potential industrial use. Through a series of tests, it was noted that the natural sand from Agba Dam possesses several qualities that make it suitable for various foundry applications, particularly in metal casting. The key findings from the results obtained are as follows:

- Chemical analysis showed that Agba dam sand falls within the classification of Alumino-silicate sand, exhibiting chemical compositions that align with the acceptable range values stipulated by AFS for moulding sands. Thus, Agba dam sand is well-suited for the casting of metals, particularly those characterized by low melting temperatures. The analysis revealed the presence of certain oxides such as CaO, Fe_2O_3, MgO, and TiO_2 alongside the primary constituents.
- The GFN value of 44.54 indicates that the sand satisfies the physical requirement of moulding sand. This makes it suitable for moulding medium and heavy metal casting.
- The results of most physico-mechanical tests are consistent with and fall within the recommended values established by the AFS for casting certain metals, particularly non-ferrous metals. It is noteworthy that the properties assessed render the sand suitable for metal casting. Further studies could focus on improving the green and dry compressive strength properties and examining long-term performance in industrial settings to fully harness its potential for casting operations.

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