

Evaluation of the Foundry Properties of Oyun River (Ilorin) Moulding Sand

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ABSTRACT

Inadequate information on available natural moulding sands in Nigeria resulted to the use of the sand for casting without recourse to their suitability. This practice resulted to poor casting quality and underdevelopment of Nigerian foundry industry. In this study, the properties of Oyun natural moulding sand were evaluated to determine its suitability for sand casting. The chemical and physico-mechanical properties of the sand samples were examined using America Foundrymen's Society (AFS) guidelines. The results of the chemical analysis showed that the sand contained SiO₂ and, Al₂O₃ from 84.49 to 84.58% and 7.17 to 7.22% respectively, with smaller proportions of other elements such as Na₂O and K₂O, CaO, Fe₂O₃, MgO and TiO₂. The physico-mechanical properties of the sand were clay content (14.96 - 15.79 %), moisture content (8.15 – 8.48%), grain fineness number (83.40 – 89.24), green compressive strength (77.31 – 79.73 KN/m²), dry compressive strength (200.24 – 214.65 KN/m²) and refractoriness (above 1300°C). These results were within the AFS standard recommendation values for non-ferrous metal casting. Hence, Oyun moulding sand was found suitable as mould sand for various types of casting of metals like grey steel, aluminum, bronze, brass and light steels. Effective utilization of this sand for foundry applications will help to improve the economy of Nigeria and subsequently aid in reducing social problems as result of unemployment.

1. INTRODUCTION

Natural moulding sands are found at the bed, bottom and bank of rivers, oceans and seas (Bala and Khan, 2013; Moulding sand, 2019), which makes the sands more abundant and readily available, especially in Nigeria. In the practice of foundry, sand is the most crucial factor (Shuaib-Babata and Olumodeji, 2014), as a major material in making mould in sand casting process. Several available moulding sands in Nigeria were inappropriately utilized by local fabricators, most especially for foundry applications due to non-availability of the required sands' properties (Shuaib-Babata *et al.*, 2017a). Production of Aluminum pots of different varieties, for instance, is a common economic activity in Ilorin, Kwara State capital in Nigeria, where available foundry sands are used (Alabi and Abdulkareem, 2011), without recourse to their properties (Shuaib-Babata *et al.*, 2017a). This act usually results to casting defects. Availability of data bank on Nigeria moulding sands' properties is essential, which could be achieved through characterization of severally available natural moulding sands. Though, several researchers (Aweda and Jimoh, 2009; Shuaib-Babata and Olumodeji, 2004; Bala and Khan, 2013; Aji *et al.*, 2015; Ajibola *et al.*, 2015; Mbishida and Audu, 2017, Shuaib-Babata *et al.* 2017a,b,c; Bukar *et al.*, 2017; among others) have investigated moulding sands from different locations across Nigeria. These sands were found suitable for different

foundry operations without or with little treatment. However, significant numbers of moulding sands in different deposits across Nigeria have not been investigated.

Studies revealed that natural moulding sands contain sufficient amount of binder, moisture and other moulding properties from their deposited locations (Rajender, 2006), which make them cost effective and encourage their applications for casting of different metals. An advantage over artificial moulding sands which are prepared to a specific desire, that is, binder are added to a predetermined level (Rajender, 2006). The basic ingredient of natural moulding sand is silica which provides the refractory properties of the sand and the distribution of these grains makes provision for the permeability of the sand (Ammen, 1979). The sand contains 80 to 90% silicon oxide (Surupa, 2019; Moulding sand, 2019), with traces of other elements in their oxide form. The binder, otherwise known as clay, is another major constituent of moulding sand (ME Mechanical Team, 2016). The moisture content is also a requirement for natural moulding sand, because it helps in filling the pores between the sand and the binder (Gutpa *et al.*, 2009). Shuaib-Babata *et al.* (2017b) were of the view that apart from chemical analysis, the following physico-mechanical properties: permeability, green compressive strength, dry compressive strength, permeability, refractoriness, flowability, among others are essential to characterizing a natural moulding sand. The determination of these properties will aid appropriate applications of the sand for foundry applications, which in turn yield quality casting (Mshelia *et al.*, 2016). The choice of the right moulding and binder for casting operation is also an important factor contributing to high productivity in foundry (Mshelia *et al.*, 2016).

Unemployment among Nigeria youths greatly contributes to the problem of social vices in the country. Jobs creation through establishment of Small and Medium Scale enterprises (such as foundry) is a means to solve the problem. This will also help to boost the nation's economy status. Thus, since moulding sand is a major material in foundry practice, proper evaluation of the available Nigerian natural moulding sands in the country is therefore essential. This is due to the fact that foundry is an important source of industrial emancipation and economic self-reliance in Nigeria (Ademulegun, 2008, Shuaib-Babata and Olumodeji, 2014). In this study the properties of *Oyun* river (Ilorin) natural moulding sand for foundry applications were evaluated in order to enhance appropriate applications of the sand in the field of foundry. Subsequently, it will reduce occurrence of various casting defects that usually occur as a result of usage inappropriate material. Thus, material and financial wastages as results of casting defects in production of intricate parts and other devices would be drastically minimized in the foundry practice. Overdependence on importation of foundry sand and its products into Nigeria will be drastically reduced, if not totally stopped.

2. METHODOLOGY

2.1 Sample Collection

Sand samples were collected from three different points (5 km apart) at *Oyun* River bed, Ilorin, Kwara State, by digging to 2.54 cm deep, so as to collect pure and even silica sand. *Oyun* river is located along Kwara State Polytechnic Road, Ilorin, Kwara State, Nigeria. Its coordinates are 8°34'60" N and 4°34'0" E (getamap.com, 2019). Figure 1 shows location of Ilorin on map, where the river is located.



Figure 1: Map showing Ilorin City, the town where Oyun River is located (Getamap.com, 2019)

2.2 Preparation of the Natural Moulding Sand.

The sample of the natural moulding sand was prepared using American Foundry-Men Society (AFS) guidelines as presented in Faluyi *et al.* (2013) and Mittal and Shukla (2003). To remove moisture from the sand, it was sun dried for five (5) days, and subsequently filtered to remove the debris and other unwanted materials from the sand.

2.3 Determination of the Chemical Composition of the Moulding Sand.

The elemental chemical constituents of the prepared natural moulding sand was determined in accordance with the practices of earlier researchers (Shuaib-Babata and Olumodeji, 2014; Aweda and Jimoh, 2009) using AFS standards guidelines. The analysis was done with Atomic Absorption Spectrophotometer (AAS) (model: Buck Scientific, ACCUSYS 211, 2 hollow cathode lamp, 58 Fort Point East Norwalk Connecticut, U.S.A.) at the University of Ilorin Central Research Laboratory in Nigeria.

2.4 Preparation of Specimens

The sand was sieved through 2 mm British standard sieve to remove coarse particles and obtain required grain size. Using foundry flat edge rammer, the grain pebbles were broken into pieces and then re-sieved. To produce standard test specimens of 50 mm by 85 mm size, the moulding sand was moulded using sand compacting machine and its mould. The sand compacting machine delivered a blow above 6 kg from a height of about 45 mm. The specimens were used for various foundry tests to determine the sand physico-mechanical properties in line with the AFS standard guidelines (AFS, 1982). Plates 1a and b respectively shows the sand compacting machine with its mould and some moulded specimens.



(a)



(b)

Plate 1: (a) compacting machine and its mould, (b) sand specimen

2.5 Determination of Some Physico-Mechanical Properties of the Moulding Sand

2.5.1 Grain Fineness Number (GFN)

The sand GFN was determined using a set of British sieve and a mechanical sieve shaker (Octagon Test Sieve Shaker; Volts: 220/240; Single phase). The British set of sieve was arranged from the sieve with the highest mesh opening to the lowest mesh opening in descending order on the mechanical sieve shaker (Plate 2). The prepared moulding sand (200 g) was poured into the top sieve. Subsequently, the mechanical sieve shaker was put on and left for 10 minutes. The percentages of the sand passed through the sieves and retained in the sieves were recorded and used in calculating the GFN using Equation 1 (Shuaib-Babata and Olumodeji, 2014).

$$GFN = \frac{\text{Total Product}}{\text{Total Percentage of Sand Retained by different sieves}} \quad (1)$$



Plate 2: Set of sieve stack on a mechanical sieve shaker used

2.5.2 Moisture Content (MC)

The sand's moisture content was determined using aluminum cans, temperature controlled oven and weighing balance. Some of the prepared mould sand was poured into an aluminum can and then weighed and recorded. The aluminum can containing moulding sand was then placed in an oven at temperature of 105 °C for 24 hours. The aluminum can containing the moulding sand was then removed from the oven, cooled at room temperature, weighed and recorded. This process was repeated thrice and the sand moisture content was calculated using Equation 2.

$$MC = \frac{\text{Weight of water}}{\text{Weight of dry soil}} = \frac{W_2 - W_1}{W_3 - W_1} \times 100 \quad (\text{Aweda \& Jimoh, 2009}) \quad (2)$$

Where W_1 is the weight of the can, W_2 is the weight of the can and wet moulding sand and W_3 is the weight of the can and dried moulding sand.

2.5.3 Clay Content

The clay content of the moulding sand was determined using a calibrated tube and solution of a salt water (NaCl) solution. A 20 g of NaCl was mixed with water to produce a salt water solution. The mixture was poured into a calibrated tube. Moulding sand was then poured to the calibrated level. The mixture of the solution and the moulding sand was shaken thoroughly and then left for 24 hours after which difference layers showed on the calibrated tube. The solution then formed four layers in the measured cylinder. These layers included: water at the

top (V1), followed by the silt (V2), then the clay (V3) and lastly, the silicate sand at the bottom (V4). The clay content was determined using Equation 3.

$$\text{Clay content} = \frac{(V2-V3)}{(V3-V4)} \quad (\text{Tasmia et al., 2013}) \quad (3)$$

2.5.4 Permeability

The permeability of the prepared moulding sand was determined using the falling head method, where a falling permeability mould was filled (well packed) with the moulding sand. The permeability mould was then deep in a water bath and left for 24 hours. A hose was fixed from the falling head equipment to the stop cock on the permeability mould. Water was then poured into the tubes on the falling head equipment and the stop cock valve was opened to allow water to flow into the permeability mould. The time at which the water level reached h_1 and h_2 were recorded using stop watch. The process was repeated four (4) times consecutively. The required permeability coefficient (K) was determined using Equation 4. Plate 3 shows the permeability constant falling head equipment and its mould.

$$K = \frac{2.3aL}{At} \log \frac{h_1}{h_2} \quad (\text{Aweda and Jimoh, 2009}) \quad (4)$$

Where: K= coefficient of permeability at T °C (cm/sec), L=length of the soil specimen (cm), h= constant hydraulic head (cm), a = cross-sectional area of stand pipe(cm²), A= cross-sectional area of the soil specimen (cm²), t = (t₁ - t₂), time interval in seconds for the head to fall from h_1 to h_2 , h_1 = initial head of time t₁ in the pipe above the outlet (cm) and h_2 = final head of water at time t₂ in the pipe above the outlet (cm).



Plate 3: The permeability constant falling head equipment and its mould.

2.5.5 Specific Gravity

This was determined using density bottles and weighing balance. Density bottle was weighed and recorded as m_1 , the bottle was then filled with prepared moulding sand, weighed and recorded as m_2 . The density bottle containing moulding sand was then filled with water to the top, vigorously shaken, weighed and recorded as m_3 . The bottle was then emptied out and filled with water, weighed and recorded as m_4 . The specific gravity was then determined using Equation 5.

$$\text{Specific gravity} = \frac{m_2 - m_1}{(m_2 - m_1) - (m_3 - m_4)} \quad (\text{Oke and Omidiji, 2016}) \quad (5)$$

2.5.6 Compressive Strength

The sand compressive strength was determined using the California Bearing Calibration (Model No.: 212060257; ELE (Engineering Lab. Equipment Ltd; Volts: 240.Amps:3, HZ.50Ph). A moulded specimen (5 x 5 cm) was placed into the calibration machine specimen (shown in Plate 4), a uniform load was applied by the weighed arm and the

point on the scale at which the specimen got crushed was recorded. The green compressive strength was determined using Equation 6.

$$\text{Compressive strength} = \frac{G_L - F_S}{A} \quad (\text{Shuaib-Babata and Olumodeji, 2014}) \quad (6)$$

Where: G_L = Gauge length, F_S = Factor of safety and A = Specimen surface area.



Plate 4: Specimen being mounted on the California Bearing Machine

2.5.7 Shatter Index

The shatter index was determined using the procedures in IS : 1918 – 1966 (Bureau of Indian Standards, 1997) by weighing and recording a sand specimen as m_1 , which was then allowed to fall freely from a height of 1.83 m on a steel anvil. Portion of the sand retained on 12 mm Indian sieve (IS) was collected and weighed and recorded as m_2 . The shatter index was calculated using Equation 7.

$$\text{Shatter index} = \frac{m_1 - m_2}{m_1} \times 100 \quad (\text{Msheli et al., 2016}) \quad (7)$$

2.5.8 Refractoriness

The refractoriness of the moulding sand was determined by placing a sand specimen into a furnace, heated to above 1300 °C. The specimen was then observed for any changes.

2.5.9 Flowability

The sample's flowability was determined using rammer machine (Plate 5), which has a dial guage attached to it in accordance to the soil laboratory testing guideline (Head, 1997a and b). A sample of the specimen in the tube was placed in position in the machine. The flowability of the moulding and core sand was determined by the rammer plunger's movement, between the fourth and fifth drops indicated in percentages on the indicator (guage) by using a rammer of 6.35 kg to give the fourth blow on the specimen and subsequently the fifth blow. The stem of the indicator that rested on top of the plunger of the rammer recorded the actual movement of the plunger between one blow and the other blows. The maximum flowability was attained from the scale value corresponding to the movement between the fourth and fifth blows (Bergaya, et al., 2011).



Plate 5: The machine used to determine the sand flowability

2.5.10 Determination of Bulk Density

The sand's bulk density was determined using American Foundry-Men Society Standards guidelines (AFS, 1982). Green sand in a cleaned cylinder with known weight was placed in oven at 105°C and dried for 24 hours till a constant weight was achieved. The cylinder was removed from oven and covered with lids and allowed to cool. Difference in the weight before oven drying and after cooling was determined. The volume of the sand was also determined using a measuring cylinder and weighed on a balance. The samples' bulk density values were then determined using Equation 8.

$$\text{Bulk density} = \frac{W_s}{V_s} (\text{g/cm}^3) \quad (\text{Hassan, 2005}) \quad (8)$$

Where: WS= Weight of sand, VS = Volume of sand

3. RESULTS AND DISCUSSION

3.1 Chemical Analysis

The results of the chemical analysis determined on the moulding sand are given in Table 1. In determining the suitability of the sand samples for foundry operations, the samples' constituent elements in their oxide forms were determined through chemical analysis, and results presented in Table 1. The results showed SiO₂ and Al₂O₃ as the main constituents of the sands with values of 84.49 – 84.58% and 7.17 – 7.21% respectively. Thus, Oyun river natural moulding sand was found to be silica sand due to large quantity of silica in the sand. Foundry sand for metal casting is highly quality silica sand with uniform physical characteristics (AFS, 2017).

Table 1: The chemical composition for moulding sand.

Element		SiO ₂	Al ₂ O ₃	K ₂ O	CaO	MnO	Fe ₂ O ₃	MgO	NaO ₂
Percentage Composition by weight (%)	A	84.58	7.22	1.45	0.21	0.02	4.06	0.20	2.06
	B	84.49	7.20	1.50	0.24	0.02	4.07	0.23	2.12
	C	84.51	7.17	1.48	0.23	0.02	4.06	0.21	2.20
	D	84.50	7.21	1.46	0.21	0.02	4.06	0.21	2.06
	E	84.52	7.17	1.48	0.22	0.02	4.07	0.21	2.08

Silica is very important in moulding sand because it determines the sand high refractoriness, and chemical inertness. The level of silica in the sand determines its refractoriness; as higher the percentage of silica, the higher the refractoriness of the sand (Brown, 2000). Hence, the samples are likely to be of good refractoriness.

The samples also contained smaller proportion of other elements such as Fe_2O_3 , Na_2O , K_2O , CaO , MgO , and TiO_2 . The Fe_2O_3 contents in the sand samples were in the range of 4.06 and 4.07%. This reflected in the samples' colour, which was fairly brownish with sub-angular shape. The levels of silica, alumina and iron oxide were within a standard moulding sand's specified values of 80 to 90%, 4 – 8% and 2 – 5% for silica, alumina and iron oxide respectively (Surupa, 2019). The presence of impurities such as CaO , K_2O , and Na_2O lowers the refractoriness (Brown, 2000), which may affect the suitability of the sand for casting of ferrous casting. Addition of Zircon sand will increase the refractoriness and make it suitable for ferrous casting (Aweda and Jimoh, 2009). The values of the chemical constituents were in line with the recommended mould sand chemical compositions in literature (Shuaib-Babata, *et al.*, 2017a; Otawanna, 2011). From the chemical analysis, the sands are likely to be suitable for sand casting for both ferrous and nonferrous metals, especially aluminum, brass, bronze, grey and light steels.

3.2 Physico-Mechanical Properties

The results of Oyun natural moulding sand's physico-mechanical properties (Table 2). These results are very important to determine the sand's suitability for foundry applications, as measures of essential sand's parameters (moisture, green strength and permeability) could be achieved through regular sand testing of the properties (Burns, 2000).

Table 2: Physico-mechanical properties of Oyun river natural moulding sand.

Samples	G.F.N	Moisture content (%)	Clay content (%)	Permeability (cm^3/sec)	Specific gravity	Green compressive strength (kN/m^2)	Dry compressive strength (kN/m^2)	Shatter Index (%)	Refractoriness ($^\circ\text{C}$)	Bulk density (g/m^3)	Flowability (%)
1	83.40	8.15	15.79	0.075	2.57	77.70	214.65	27.36	1300	13.64	64.64
2	89.24	8.48	15.17	0.072	2.56	77.31	210.41	29.90	1300	13.23	64.97
3	86.02	8.31	15.42	0.072	2.57	79.73	200.25	22.03	1300	14.06	64.49
4	86.22	8.32	14.96	0.073	2.57	77.58	208.28	26.33	1300	13.57	64.67
5	86.11	8.32	15.22	0.072	2.58	78.00	214.11	23.10	1300	13.64	64.54

3.2.1 Grain Fineness Number (GFN)

The average Grain Fineness Number of the moulding sand was between 83.40 and 89.22 (Table 2), which fell within the specified standard values (36 – 90) for non-ferrous metals (Burns, 1986). The result shows that the grains of the moulding sand were fine-medium. This is a good quality for casting, since choice of sand for casting should be based on particle size distribution (average grain size of sand) (Ihom *et al.*, 2011). An average value of GFN will result to good permeability and compressive strength, which will enhance the cast mechanical properties and give better fracture resistance (Burns, 2000). More so, Fineness is an essential on the physical properties and clay in foundry sand (Shuaib-Babata and Olumodeji, 2014). High GFN leads to reduced porosity due to the presence of organic matter, which is not suitable for foundry application (Burns, 2000). Therefore, as a results of the sand's average GFN, the sand sample tends to have good surface finish with low binders (Tuncer, 2017), since GFN serves as a guide to determine the quantity of binding materials required to produce desirable properties in a new foundry sand (Shuaib-Babata and Olumodeji, 2014).

3.2.2 Moisture Content

The average moisture content of the moulding sand was in the range of 8.15 to 8.48% (Table 2), which were within the specified standard moisture content values for various types of casting (Burns, 1989). Knowing the moisture content of a sand helps in resolving the problem of the amount of water to be added to the sand in producing a quality cast and to eliminate defect usually cause by excessive or recessive amount of moisture in a moulding sand (Mshelia *et al.*, 2016). Moisture content has high effect on the permeability, compressive strength and permeability of the moulding sand (Tasmia *et al.*, 2013). The quantity of moisture in moulding sand can also affect the sand's physical properties (Strobl, 2000), hence it is an essential factor to exhibit adequate permeability and compressive strength required of a good moulding sand. The sand samples might therefore be a suitable sand for casting of various metals as indicated by Burns (1989).

3.2.3 Clay Content

The average amount of clay content in the moulding sand was found to be in the range of 14.96 to 15.79% as presented in Table 2. The recommended clay content values for ferrous metals are between 10 and 12% (Mikell, 2010), while that of non-ferrous metals are between 8 and 15% (Burns, 1989). Though, Burns (1986) specified the clay content for light grey steel, malleable iron and medium grey iron to be between 8 and 15%. The sand's clay content is an indication of the sand suitability for casting of non-ferrous metals and light grey steel, malleable iron and medium grey iron. The sand also has the tendency of having good compressive strengths, flowability and permeability, since clay content has high effect on the compressive strengths, flowability and permeability (Tasmia *et al.*, 2013).

3.2.4 Permeability

The average permeability value of the moulding sand was between 0.072 and 0.075 cm³/sec (Table 2). Moulding made from coarse sand has low porosity, blowholes which are caused by entrapped gases in the molten metal during pouring (Gutpa *et al.*, 2009). Permeability is a function of moisture content and clay content (Tasmia *et al.*, 2013). Good permeability of the sands' samples was due to reasonably distributed of the samples' grain (Rudman, 2000).

3.2.5 Compressive strengths

The average green and dry compressive strengths of the moulding sand were in the range of 71.31 to 79.73 KN/m² and 200.25 to 214.65 KN/m² respectively as presented in Table 2. These values were within the AFS specified strengths values for various categories of castings (Burns, 1989). From the results, it shows that the moulding sand will have sufficient strengths both at the wet and dry stage when used to cast low temperature metal. This shows that the sand can be mouldable into various desired shapes and able to handle it at the wet stage. The dry strength quality exhibited will also help in resisting erosion during pouring especially for the sand adjacent to the poured molten metal (Ammen, 1979). The good strength quality of the sand is a reflection of its GFN and moisture content, since a reasonably distributed of the samples' grain resulted to their good compressive strength (Rudman, 2000). Also, grain size and moisture also have effect on the green compressive strength of moulding sands, as moisture content increases coarse grained sand mould have higher green compressive strength than fine-grained sand moulds (Gutpa *et al.*, 2009). Therefore, the potential casts from this sand are likely to possess good mechanical properties and also exhibit better fracture resistance (Burns, 2000).

3.2.6 Shatter Index

The average shatter index value of the moulding sand is 25.33 % as presented in Table 2. Shatter index will increase as clay content increases. The measure of toughness (ability to withstand rough handling when pattern is been removed) of the sand is known as shatter index (Donald, 2010).

3.2.7 Refractoriness

The average refractoriness of the moulding sand was above 1300°C (Table 2). This implies that the tested moulding sand had the ability to withstand high temperature beyond 1300°C without fusing to the surface of the cast. Thus, the sand has the tendency for casting of metals above the temperature. To produce excellent quality of casting that is

free from defects, it is required of moulding sand to possess enough refractoriness properties (Mishra, 2017). The refractoriness of a moulding sand is influenced by the shape and size of the grains and the present of impurities in the moulding sand which lowers the refractoriness of the moulding sand (Brown, 2000).

3.2.8 Flowability

The average flowability of the moulding sand was between 64.49 and 64.97% (Table 2). This is the ability of the sand to be compacted and behave like a fluid thereby allowing uniform flow to all portions of the pattern when rammed and its pressure to all directions generally. Flowability of the sand samples was approximately equal to the acceptable AFS flowability value for sand casting (Burns, 1989). The analysis of the results show that the flowability increased with decreased in green compressive strength, in line with the findings of Mikell (2010).

3.2.9 Bulk Density

The results of the sand samples' bulk density are presented in Figure 2. The results were compared with the AASHTO, ASTM and AFS specified bulk density values for a standard moulding sand (Tokan *et al.* 2004; Ihom *et al.*, 2011).

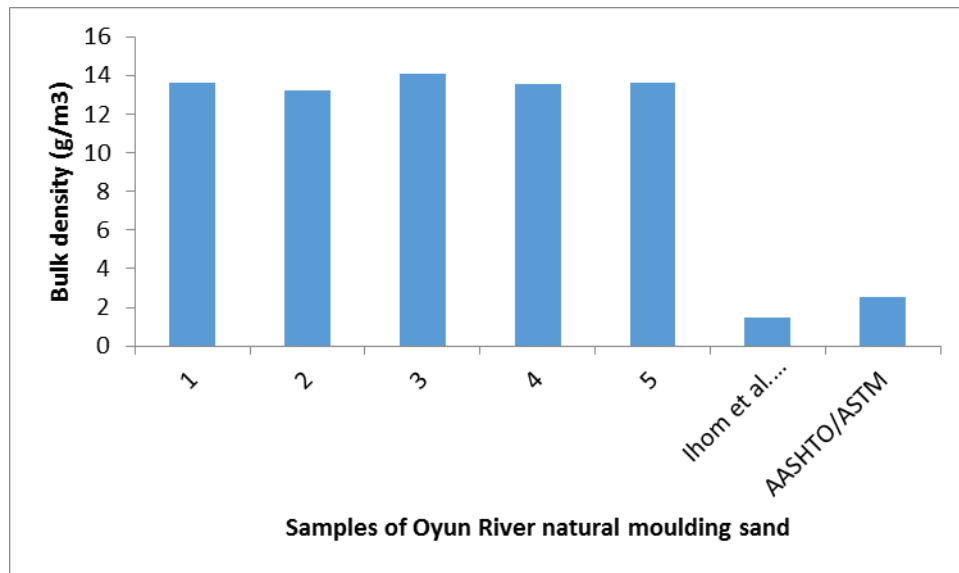


Figure 2: Oyun river natural moulding sand compared with the standards values

The samples' bulk density ranged between 13.23 and 14.06 g/cm³, which was within the AFS specification (Tokan *et al.*, 2004). The recommended bulk density for green moulding sand as given by Ihom *et al.* (2011) is 1.49 g/m³ and above. AASHTO and ASTM standards / design parameter for foundry sand performance is 2.563 g/cm³ (160 lb/ft³) (Tuncer, 2017).

4. CONCLUSION

The following conclusions were drawn from this study:

1. The chemical analysis showed that Oyun moulding sand **was silica sand** with chemical compositions within the AFS acceptable range values for moulding sands. Thus, Oyun natural moulding sand was suitable for casting of metals, most especially with low melting temperature.
2. There were presences of some elements such as CaO, Fe₂O₃, MgO, and TiO₂ apart from the main constituents which most of them serve as impurities. The present of these impurities such as CaO, K₂O, and

NaO₂ lowers the refractoriness, which may affect the suitability of the sand for casting of ferrous casting, though suitable for nonferrous casting. Though, these elements were in smaller proportion.

3. The results of the physico-mechanical tests agreed favorably with the AFS recommended values for casting some metals, most especially non-ferrous metals. Therefore, the properties make the sand suitable for metal casting.

1.1. Recommendations

It is recommended that sand should be practically tested for casting of metals, especially ones with low melting points like aluminum. Possible optimization of the sand's properties is recommended by blending the sand with other available natural moulding sand of better properties and/or by addition of additive to the moulding sand.

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