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THE POTENTIAL OF RUMBA AND KAFI SANDS AS MOULDING MATERIALS

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Abstract

This research work was conducted to investigate the potential of two moulding sands in Bauchi state. The natural Sand samples were collected from Rumba and Kafi deposit site in Warji and Ganjuwa local Government of Bauchi state. The Chemical compositions were determined using X-ray fluorescence spectrometer. The results showed SiO_2

Keywords: *Dry compressive strength, Green Compressive strength, green fineness number, moisture content, clay content.*

INTRODUCTION

Metal casting is a shape-forming process whereby molten metal is poured into a prepared mould and allowed to solidify such that the shape of the solidified object is determined by the shape of the prepared mould cavity. The most primary metal casting include iron and steel from ferrous family and aluminium, copper, brass, and bronze from the nonferrous family. Sand is used in sand casting as a manufacturing process to produce a mould that is made with cavity having the shape and size of the products in which molten metal is poured (Shuaib-babata *et al.*, 2017). This is due to the fact that the sand particle size is packed finely together in such a way to provide excellent

having dominance in all the sand samples of 65.23% and 59.90% for Rumba and Kafi sand samples respectively. American Foundry men's Society (AFS) standard laboratory tests were used to determine the physico-mechanical properties. The result of Rumba and Kafi sand samples were found to be dark brown, sub-angular in shape with the following values; Clay content 14% and 20%, Grain fineness number 35.59 and 39.73GFN respectively, other physico-mechanical properties were determined at varying percentages of water which include; green compressive strength, dry compressive strength, permeability. thermal shock resistance and refractoriness. The results of physico-mechanical tests obtained indicated that both Rumba and Kafi natural sands are suitable for mould application in foundry for casting non-ferrous alloy; However, Kafi sand sample should be used with caution because of clay content above the recommended range for metal casting.

Surface for mould. Sand Casting process is employed in manufacturing parts, equipment, device and tools which are very difficult to produce using other means of manufacturing processes such as engine blocks, machine tool bases, cylinder heads, pump housings, valves, plies, and spanner (Tokan and Mohammad, 2007). Moulds are made of metal, plaster, ceramics or other refractory materials; this work is focusing on sand moulds and cores. Inappropriate sand conditions can easily result in the production of poor castings. It is for that reason that most foundries today operate costly for the regular monitoring and control of foundry sands and for testing new sand to discover their foundry potentiality.

This will greatly assist to determine the sand potentiality for foundry use in the foundry. The strength of the foundry rests on the fundamental behavior of sand, which is basically used in mould or core making. The properties of good moulding sand are refractoriness, green compressive strength, thermal shock resistance, shatter index, permeability, followability, dry compressive strength and cohesiveness (i.e grain size, shape, clay content and moisture content) Ayoola *et al*. (2010).

Nigeria is one of the countries that are blessed with mineral resources and silica sand is one of them, with large deposit of over 150 million tons being discovered in Kogi, Niger, Delta, Lagos, Kano, Katsina, Imo, Abia, Benue, Ondo, Borno, cross-river state etc. (Mahmoud *et* al., 2016). Research had shown that most Nigerian moulding sands, such as Azare, Alkaleri, barikin-ladi foundry sands are suitable for foundry application, this material is also used in manufacturing of glass, fused silica filler in automobile tires, rubbers and in footwear soles (Duvuna and Ayuba, 2015; Oyetunji *et al*., 2015).

MATERIALS AND METHODS

Materials

The materials that were used are Rumba and Kafi sand samples, Distill Water and Sodium hydroxide (NaOH)

Equipment

The equipment that was used in this research work includes: X-ray fluorescence spectrometer (XRF), Resistance furnace, Wash beakers, Permeability meter, Universal sand compression testing machine, Specimen tube, Mechanical sieve shaker, Laboratory rammer, Moisture teller, weighing balance.

METHOD

Moulding sand is one of the most crucial factors in casting process. Nigeria is a country that is blessed with such mineral resources at different location suitable for casting all categories of metals. Unfortunately due to lack of information they are not used appropriately. This research work employed the used of standard laboratory equipment to test the chemical and physico-mechanical properties and the result of the tests were compared with American Foundry Men's Society standard to ascertain whether the sands can be used for mould making in the foundry. With regard to the issue of unemployment and Government over dependent on crude oil, such research work will contribute greatly in job creation, business and economic development of the country as other developing countries take advantage of their mineral resources.

Collection and Preparation of Samples

The sand samples were collected from Rumba and Kafi deposit sites at the depth of 3m, 4m and 5m, mixed thoroughly for better representative and finally kept in the Discators for further test to be conducted. The sand was sieved through 2mm British standard sieve to obtain the required grain size; foundry rammer was used in breaking the grain pebbles and then re-sieved. The standard test specimens of 5cm in diameter by 5cm height in a smooth surface tube were moulded using sand compacting machine which delivered a blow of 6.5 Kg from a height of 45mm. the specimens were used in determining some physico-mechanical properties in line with the AFS standard guideline shuib-babata (2014) as shown in plate 1.

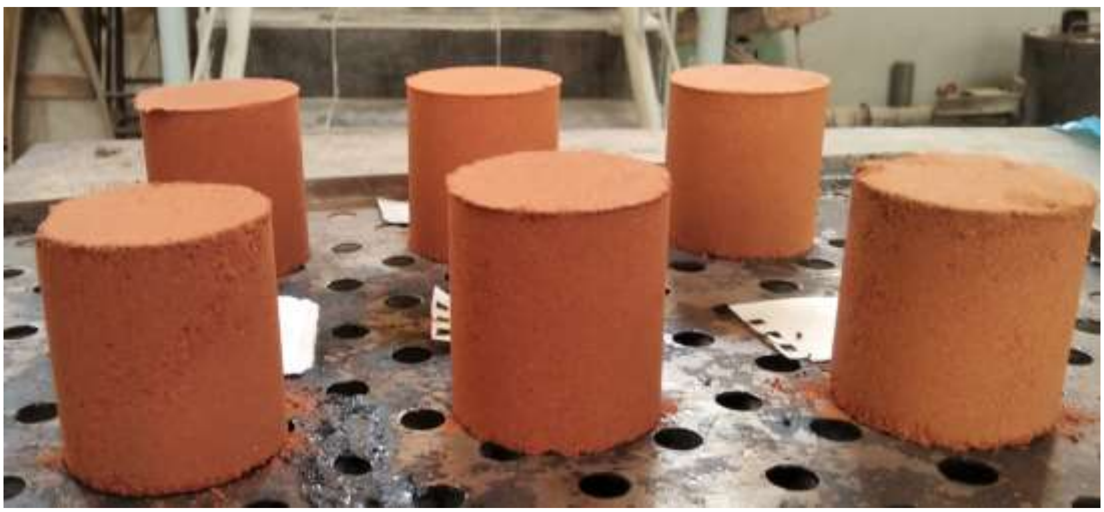

Plate I: Standard cylindrical sand samples for physicio-mechanical testing

Determination of the Chemical Composition of the Sands

The samples of Kafi and Rumba sands were prepared and tested in the laboratory to know their chemical constituents using X-ray fluorescence spectrometer (XRF) technique. 400g of sand samples were dried in an oven at 60^{o}C for 30mins and mill into powder sample of particle size 100 mesh (0.15 micro), recommended for XRF analysis. After the sample was place into the machine. It was then allowed to run for 5hours with the voltage and current around 45 volts and 40A respectively. However this preparation enables the standards and other mechanical parts to stabilize for XRF test to take place. The result of this test were obtained and compared with the foundry men's society (AFS) standard as shown in *Figure 2*.

Determination of Physico-mechanical Properties.

Determination of the grain color and shape.

100g of sand samples was measured out, washed with 1000 cm^3 of distilled water in a beaker and sun-dry for 3 - 4 hours after which it was examined on a dark board with the aid of microscope of magnification 50x (Model NS 200). The result is presented in Table 2.

Determination of grain fineness

The grain fineness number is one of the most important properties in terms of passage of gasses that will be generated when introducing the molten metal into the cavity. For the purpose of this test a 150g of Rumba and Kafi dry sand samples was taken onto a set of electrical sieve shaker of sieves of different sizes. The shaker was allowed to operate or vibrate for 15 minutes in which the retained particles were removed and weight. The grain (AFN) fineness number was determined using equation 1 (Njoku and Ocheri, 2020).

$$\text{(GFN) Grain fineness number} = \frac{Total\ product}{Total\ \%\ retained\ by\ different\ seives} \quad - - - (1)$$

Moisture content

50g of the sand sample was measured using weighing balance and dried at a temperature of 105°C-110°C for 2 hours to evaporate all the moisture in the sand. The sample was then weighted. The weight difference between the initial and new weight was expressed in percentage to give the moisture content of the sand (Ihmo *let al.,* 2009).

$$\text{Moisture } \% = \frac{A}{B} \times 100 \quad - \quad - \quad - (2)$$

A= loss of weight of the sand sample in (g) on heating

B= Initial weight of sand samples in (g)

Clay content

A dry sand sample of 50g was placed in the wash bottle. 20cm^3 of sodium hydroxide ($NaOH$) and 475cm^3 of distilled water as recommended by AFS standard were added. The mixture was stirred for 5minutes in a rapid sand washer and was allowed to rest for 10minutes. The suspended clay particles in the solution were decanted by means of siphon. This procedure was repeated three times for Rumba and four times for Kafi sand at which cleared water free from suspended clay particles was observed. The water was then removed completely and sand dried in an oven at temperature 110^{0}C. The clay percentage was calculated using equation 3 (Onche *et al*., 2007; Tokan and Mohammad, 2007).

$$\text{Clay content} = \frac{w1 - w2}{w1} \times 100 \qquad - \quad - \quad - (3)$$

Where, W_1=weight in (g) of the dried sand.

W_2= weight in (g) of the dried sand portion, free from clay

Determination of permeability number

The standard size of 5cm diameter X 5cm height green sand sample containing in the specimen tube, placed on parameter of the permeability equipment and Standard air pressure of 9.8 x 10^2 N/m^2 was applied through the Cylindrical specimen tube, at a point where 2000cm^3 volume of air penetrate through the specimen, the permeability No. of each samples was recorded and taking from the meter (mmWs) (Mahmoud *et al*., 2016).

Determination of green compressive strength

The Rumba and Kafi sand sample of the green sand were made to the standard (5cm height and 5cm in diameter) and fixed to the Universal sand strength machine in the compression head (holding device), uniform load was applied gradually until the specimen crushed. The point on the scale at which the standard specimen crushed was taken as the ultimate compression strength of the sample, and then the record was read in kN/m^2 (Yekinni *et al*., 2015; Tokan *et al*., 2004).

Determination of dry compressive strength

The Rumba and Kafi sand samples were prepared to the standard of 5cm height x 5cm diameter, dried in an oven at a temperature of 110^{0}C for 20 minutes and finally removed the sample so as to cool in air to ambient temperature. The sample was fixed into the Universal sand testing machine with the head in place. Uniform load was applied gradually until the sample reached the ultimate compressive strength and then crushed. Then the point at which the failure occurred was recorded in (kN/m^2) (Agbo *et al*., 2018).

Determination of refractoriness

A sand samples were mixed with the desired quantities of binder and water. The mixtures were molded into cone shapes and dry in an oven at $110^{o}C$, followed by sintering the cone shape samples in a furnace to a temperature of $1000^{o}C$. The prepared samples were arranged in a furnace to test for refractoriness. The cones were heated gradually until softening of the cones was observed. The softening point of the pyrometric cone was corresponded with the time of softening of the test sample which was recorded as the refractoriness of the sand (Agbo *et al*., 2018; Nuhu, 2008).

Thermal shock resistance

This is the ability of sand to resist/withstand heating and cooling cycles before failure This experiment was conducted according to (Garba *et al.,* 2018) and whereby dry specimen was heated to $1200^{0}C$ and then removed from the furnace for ten minutes continuously until failure occur (Umar *et al*., 2019).

Casting process

The following block diagram represents the steps in the casting process.

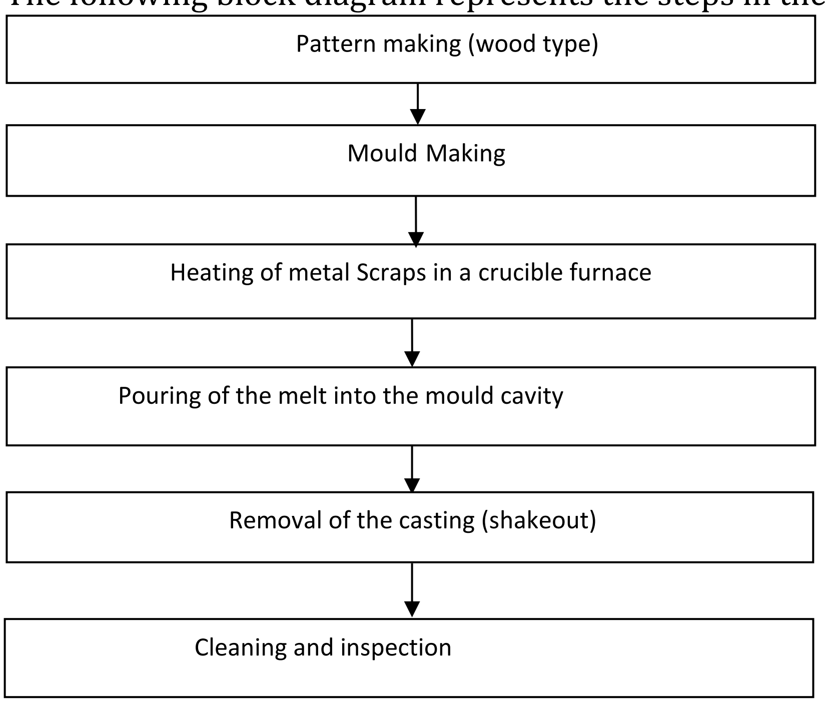

Figure 1: Block Diagram of a Casting Process

RESULTS AND DISCUSSION.

In this chapter, the sample preparation, experimental and the computed results were presented in the following tables and figures.

Result of the Chemical Composition of the Moulding Sands

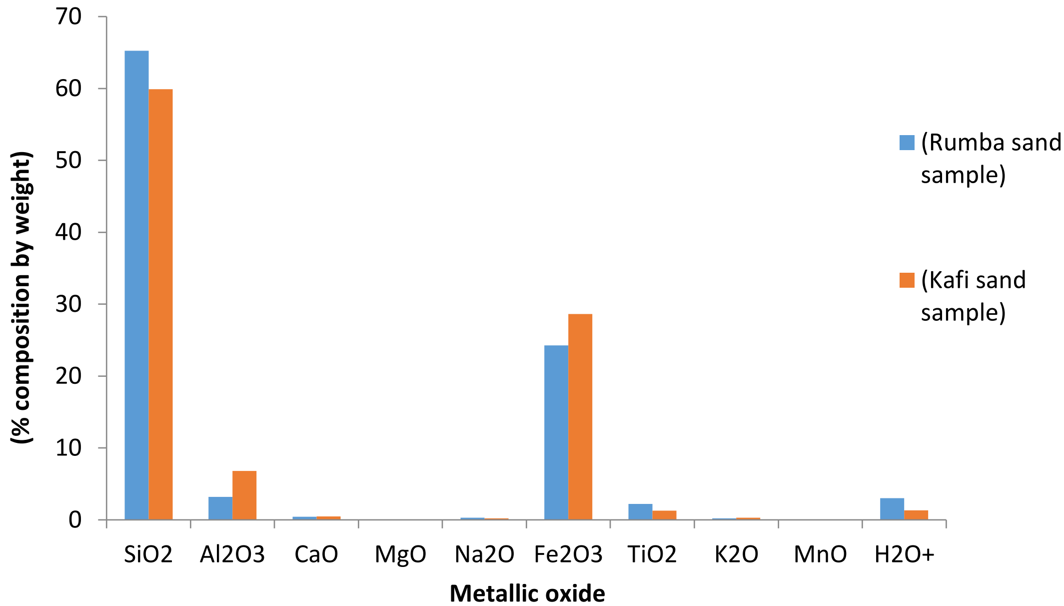

Figure 2: Represents the chemical composition of the sand samples

The results of the chemical composition analysis of Rumba and Kafi sands from Bauchi state were presented in *Figure 2*. It revealed that SiO_2 and Al_2O_3 are the main constituents of the moulding sands with values of (65.23% and 59.90%) and (3.20% and 6.82%) respectively. Thus, Rumba and Kafi natural moulding sands were found to be silica sands because of the large quantity of silica presences in the sand which are within the American Foundry men's Society (AFS) standard. The present of the excessive amount of Fe_2O_3, CO and TiO_2 lower the fusion point of the moulding sand. Mbimda and Samuel (2017) reported that any chemical composition of the sand with silica content below 80% should be limited for non-ferrours alloys. It concluded that, the result of the chemical composition tests of Rumba and Kafi sands are safe for casting of metals with low melting temperature.

Physico-mechanical Properties of Rumba and Kafi Sands

Result of the grain color and shape

S/N	Sand Samples	Color	Grain Shape
1	(R)	Dark-Brown	Sub-Angular
2	(K)	Dark-Browns	Sub-Angular

Table 1: Showed the result of grain color and shape of sand samples

The Rumba and Kafi sands were found to be dark-brown in color and sub-angular in shape. This showed that the samples have good interlocking properties which will give adequate strength and moderate permeability.

Grain fineness number

Figure 5: represents the Grain fineness number (sieve analysis) of Rumba and Kafi sand samples. The result indicated that the sands are of fine-medium grains size of 35.59 and 39.73AFS. The grain fineness number has a significant role in terms of passage of gasses generated by the melt when poured into the mould cavity. The result revealed that mould made from these sands would be used for casing low temperature metals and produced casting with good surface finish, good dimensional accuracy and low permeability of the mould; Its lower permeability may lead to a defect such as blow holes, porosity etc.

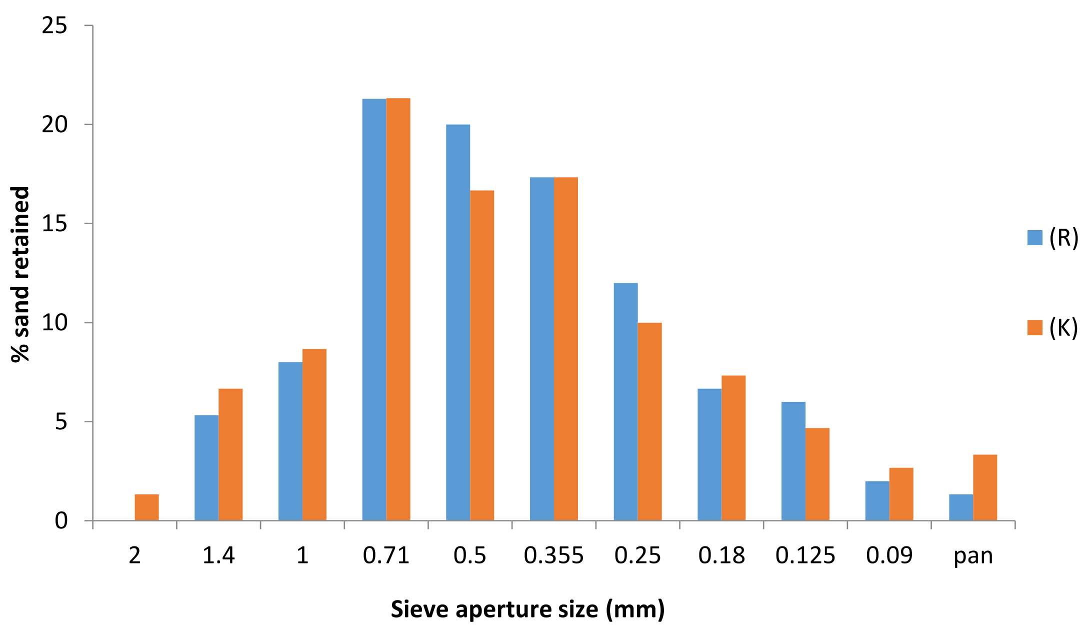

Figure 3: Result of the sieve analysis of Rumba (R) and Kafi (K) sand samples

Clay content of the moulding sands

Rumba sand have 14% clay content which is within the range recommended by AFS standard for casting brass, bronze, malleable, medium grey iron and light grey iron while Kafi sand sample has 20% clay content; this values is above the recommended standard ranged of 10-12% for ferrous metal casting and 8-15% for non-ferrous casting. Hence the natural moulding sand from this deposit site is unsuitable for ferrous alloy castings (Mshelia *et al.,* 2016). The sand can however be used for nonferrous casting with close sand control in order to minimize the production of defective castings because permeability decreases with increase in clay content which lead to casting defects like blow holes, porosity etc. (Shuaib-babata *et al,.* 2019).

Natural moisture content of the moulding sands

The natural moisture content of Rumba and Kafi sands were found to be 2.4% and 3% respectively. The results were below the recommended range as suggested by (AFS) standard. It follows that the moulding sands required addition of water so as to activate the effect of clay in the moulding sand for adequate strength. Minimum of 1.0 % to 2.66n% and maximum of 2.33 % to 4.26 % of moisture considering the lower and upper limits of the recommended ranges to make them suitable for mould making in casting processes (Mshelia 2016).

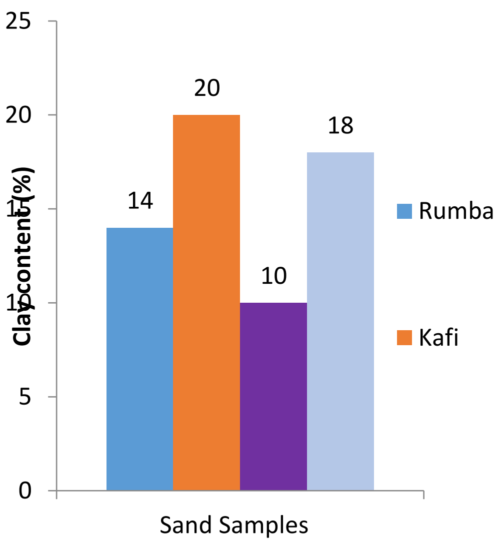

Figure 4: Represents the results of the clay content

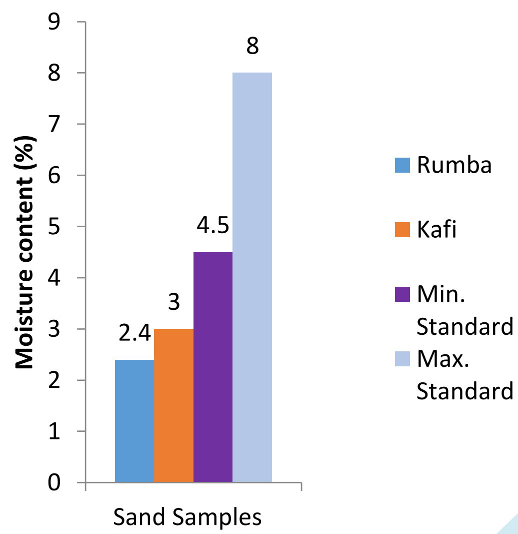

Figure 5: Represents the results of the moisture content

Green compressive strength of the moulding sands

The green compressive strength of Rumba and Kafi sand samples showed higher values of 80 kN/m^2 and 85 kN/m^2 at 2.8% moisture content and the low values of GCS of 50 kN/m^2 and 30 kN/m^2 at the lowest moisture content of 1.9% respectively. On the other hand, the GCS of Rumba and Kafi sand sample increased with increased in moisture content, it attained the maximum value at 2.8% moisture content, thereafter decreased in green compressive strength at 3.6% water content decides the presence of excess moisture in the moulding sand as shown in *Figure 6*: These values were within the AFS specified strengths values for category of metals casting (Shuaib-babata *et al*., 2017). From the result obtained, Rumba and Kafi sand samples at 2.8% moisture content are suitable for casting metals, such as aluminium, brass, bronze, malleable iron, medium grey iron, light grey iron, etc. but only Kafi sand sample at 1.9% and 2.2% moisture content, the GCS was found to be lower below the recommended range for casting metals. The result indicated that the sand can be moulded to a various shapes and able to retain its strength at wet stage without addition of binder materials. The good strength quality of the sand is as result of its GFN and moisture content (Sani *et al.,* 2013).

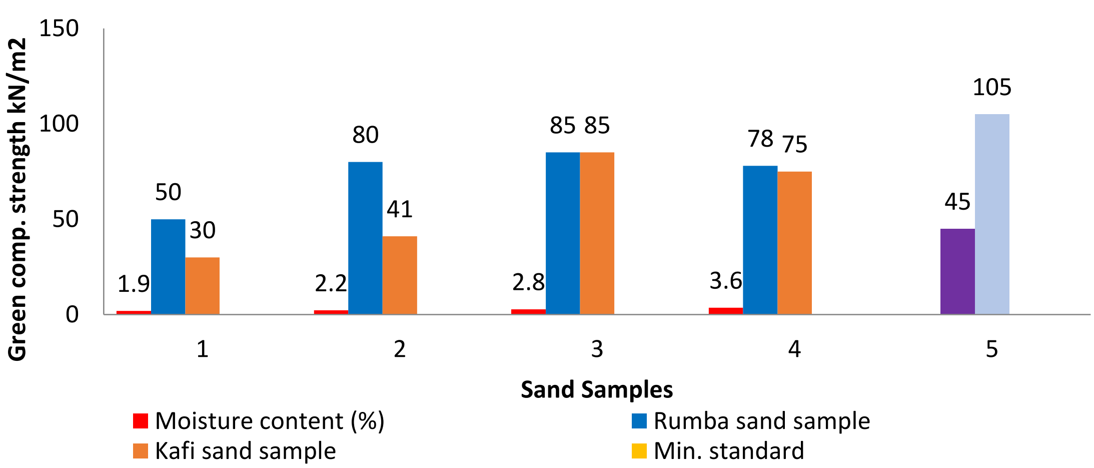

Figure 6: Represents the green compressive strength of (R) Rumba and Kafi (K) sand

Dry compressive strength of the moulding sands

Figure 7: Showed the result of the dry compressive strength of Rumba and Kafi sand samples using varying percentage of water as suggested by (Mahamoud *et al.,* 2019). The result of dry compressive strength of Rumba

and Kafi sand samples showed a high value of DCS of 200 kN/m^2 and 76 kN/m^2 at 2.8% and 3.6% moisture content respectively. Rumba sand sample at 2.8% moisture content has a DCS of 200 kN/m^2 which is within the recommended range for casting Aluminium, Brass, Bronze, and Maleable iron. The Kafi sand sample showed a higher value of 76 kN/m^2 at 3.6% moisture content. This result indicated that the sand has poor dry compressive strength and therefore cannot be used as dry mould.

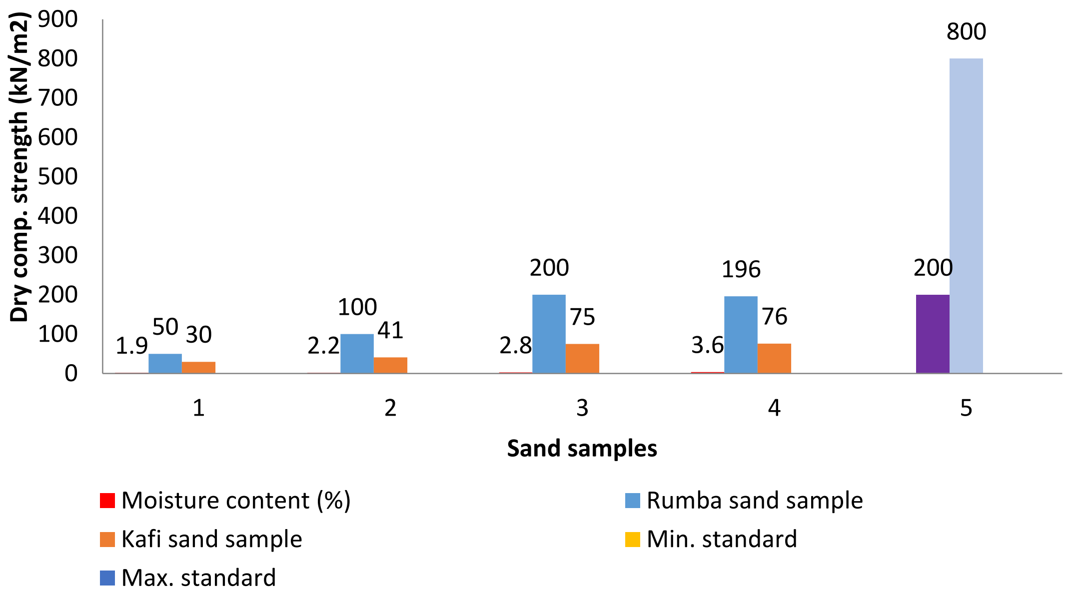

Figure 7: Represents the dry compressive strength of Rumba (R) and Kafi (K) sand samples

Permeability of the moulding sands

This is the ability of the sand to allow the passage of gases. *Figure 8*: presented the permeability of the moulding sands at different moisture content. The result of the permeability test shows a decreased in permeability number with increase in moisture content. The samples showed higher permeability number of 145 mmWs and 117 mmWs for Rumba and Kafi sand samples respectively at 1.9% moisture content while low values of 75 mmWs and 67 mmWs at 3.6 moisture content. It revealed that at 1.9%, 2.2%, and 2.8% moisture content, the moulding sand when used for casting, the cast component(s) will be free from minor and major defect, such as blown holes, porosity, scars.

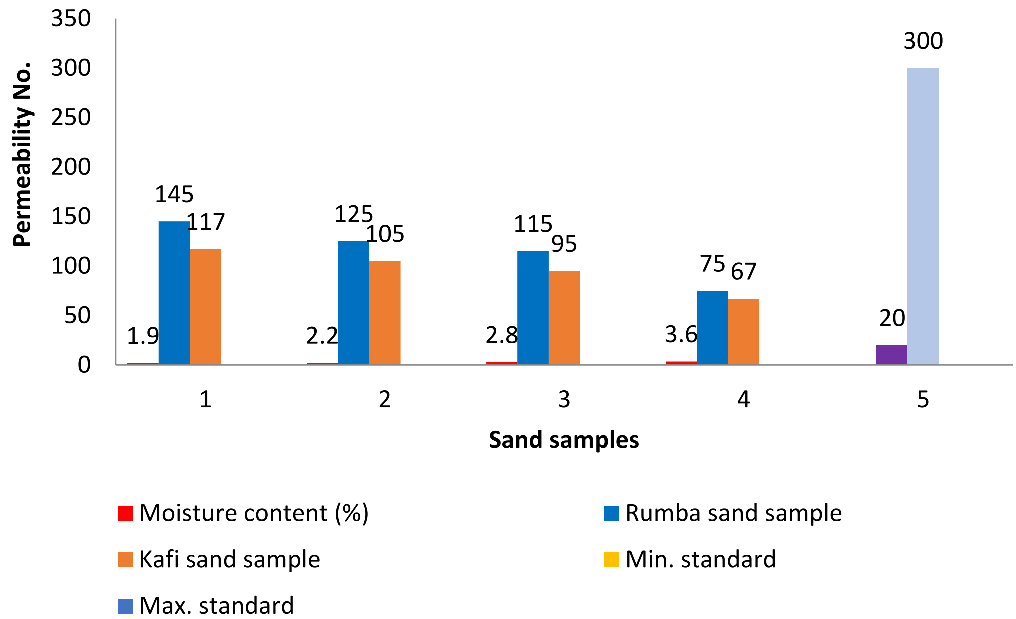

Figure 8: Represent the permeability of the sand samples

Refractoriness of the moulding sands

The refractoriness of Rumba and Kafi natural moulding sand were found to be 1350^{0}C and 1260^{0}C respectively. The results showed that the refractoriness values were found to be within the recommended standard range for casting aluminium, brass, bronze, malleable cast iron and light grey cast iron products in line with the finding of (Shuaib-Babata, et al., 2019). Refractoriness is the ability of the mould to resist high temperatures without breaking down or fusion, thus facilitate sound casting (Shuaib-babata, 2019). Moulding sand with poor refractoriness may burn on to the casting surface and no smooth surface of casting can be obtained. The degree of refractoriness depended on the SiO_2 content present in the mould Mshelia *et al.* (2016).

Thermal shock resistance of the moulding sand

The thermal shock resistance of Rumba and Kafi sands is presented in *Figure 10*. The results of Rumba and Kafi sand samples were short of the acceptable of 20–30 cycles which is in line with the finding of (Umar *et al.,* 2019). The practical indication of this is that their used is restricted to 5 and 4 number of cycles in mould making for casting using Rumba and Kafi sands respectively.

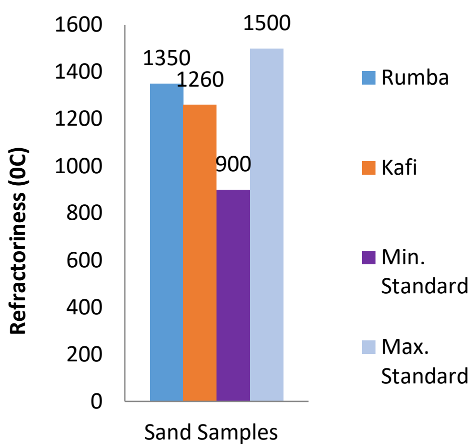

Figure 9: Refractoriness of the sand samples

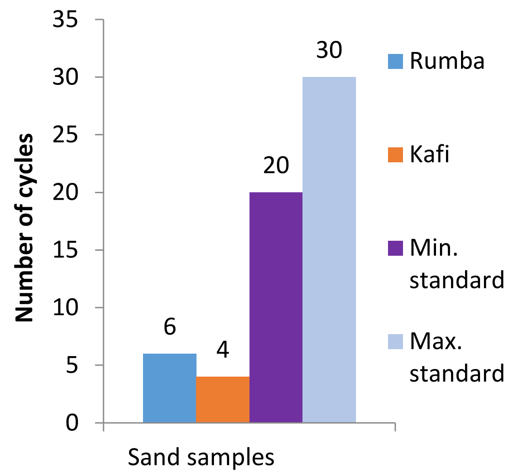

Figure 10: Thermal shock resistance of the sand samples

Conclusion

Rumba and Kafi sands are considered to be silica sand because of their higher percentage of SO_2 obtained as 65.23% and 59.90% respectively. The result of physico-mechanical properties such as grain fineness number, green compressive strength, moisture content and permeality at 2.8% moisture content are consistence for non-ferrous alloy casting.

The circular cast components were produced using the mould made from Rumba and Kafi sand samples at 2.8% moisture content and the results of the castings were observed to have good dimensional accuracy and good surface finished.

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