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Hybrid Effect of Selected Local Binders on the Moulding Properties of River Niger Silica Sand for Industrial Application

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Abstract

This work investigated the effects of bentonite, cassava starch, and yam starch binders on foundry moulding sand. The three binders were applied separately to River Niger bank silica sand in different proportions. The effects of these various additions on foundry moulding sand were investigated by conducting out various tests as permeability, moisture content, green compressive strength, dry compressive strength, mouldability, shatter index as well as the AFS of the sand. The results showed that bentonite had better binding characteristics as compared to cassava starch and yam starch. The green and dry compressive strength of the three binder's increases as the percentage binder addition increased. Mouldability of the three binders on the sand equally increases as the percentage binder additions increases. Permeability and shatter index for the three binders decreased as the quantity of binder increased. The sieves analysis results with AFS number 45 shows that the grain fineness index falls within the acceptable range which is suitable for foundry application.

Keywords: Bentonite, Cassava starch, Yam starch, Moulding properties, Silica sand.

Introduction

Sand is the major moulding material used for all types of castings, irrespective of whether the cast metal is ferrous or non–ferrous. This is because it possesses good properties such as refractoriness, mouldability, permeability, collapsibility, chemical resistivity, etc. that are important to foundry applications [1-3].

Foundry sand consist of primarily clean, uniformly sized high quality silica sand that is bounded to form moulds for ferrous (iron and steel)and non-ferrous (copper, alumimum, brass) metal casting. The major ingredients of moulding sands are: silica sand grains, clay and moisture. The silica sand grains are of paramount importance in moulding sand because they impart refractoriness, chemical resistivity, and permeability to sand. The finer the grains of the sand, the more intimate will be the contact and the lower the permeability [3-5].

Moulding sand is classified as either natural or synthetic sand. The natural moulding sand, also called green sand. Virtually all sand mould for ferrous casting is of the green sand type. Green sand is taken from river bed or dug out from pits, and it contains binder which is used in the as – received condition with water added [5]. It contains from 5 – 20% binder and about 5 – 8% water may be added. Green sand moulding is the least expensive, fastest, and most common of all the currently available moulding methods [6-7].

Bentonite Clay is a type of clay generated from the alteration of volcanic ash, predominantly consisting of montmorillonite. Bentonite is composed of plate-silicate minerals, and belongs to the group of minerals known as alumino–silicates. The mixture of sand and binder can be used immediately after the mixing process that coats the sand grains. Typically, about 1 ton of foundry sand is required for each ton of iron or steel casting produced [3,8].

High cost of imported binders has generated great interest in characterizing the locally available materials, therefore necessitating the need to look into available binders that will meet the criteria for manufacturing, i.e. reliability, cost, toxicity and availability [7,8].The local binders are materials not imported unlike bentonite for the purpose of being added to moulding sand in order to impart sand with sufficient strength and cohesiveness. This enables it to maintain the shape after the mould has been rammed and the pattern withdrawn easily [9].

However, research based series of work has been done on moulding binders which has being validated to impact to high casting performance. Among other is yam flour (starch) as binder for sand mould production in Nigeria by Shehu and Bhatti (2012), Fayomi et al 2011 worked on the effect of palm oil on the core. Critical comparison of bentonite and cassava starch as moulding sand binders was investigated byAlonge et al, (2012). Hence, this work studies the effect of some selected local binder; cassava starch and yam starch on the moulding properties of River Niger silica sand and their mechanical performance on castings.

Experimental Procedure

Materials

The silica sand used for this work was collected from River Niger bank at Felele in Lokoja, Kogi State of Nigeria, the cassava and yam starch were collected from a starch manufacturer, in Kogi State, Nigeria, while the Na- based bentonite was imported from Baroda, India. The work was carried out at the foundry Laboratory of Ajaokuta Steel Company Limited, Nigeria. The sand was thoroughly dried under the sun for about 3 to 4 Days. The sand was later crushed to remove lumps of sand and was made ready for sieve analysis.

Methods

Sieve Analysis: The dried known quantity 100gm of River Niger silica sand grains free of clay was used to determine the fineness number, using a set of standard testing sieves. The stacks of sieves were arranged in descending order of magnitude on a shaking table that is responsible for the vibration of the sieve that aids in sieving. The sieves sizes used are as follows:≥ 710 microns, 500 microns, 355 microns, 250 microns, 180 microns, 150 microns, 125 microns, 90 microns, 75 microns, 63 microns and ≤ 63 microns respectively and their arrangement was in descending order of magnitude to allow lower sizes of the silica proceeds through easily. The arranged sieves were then placed on a sieve shaker whose function is to cause vibration of the stack of sieves and aid in allowing respective sizes of the sand to pass through the sieves. The vibration was allowed to go on for about 15 minutes the timing being done with the aid of a stop –watch. After the shaking period, the grains retained on each sieve and the bottom pan was removed, weighed and their percentages determined as shown in Tables.

Moulding Sand Preparation: Moulding sand mixtures for the various tests, permeability, green compressive strength, dry compressive strength, mouldability, moisture content test and shatter index test are prepared as shown in Table 1 to 4.

Table 1: Composition of the green moulding sand used with 5% binders

S/n	Silica Sand (89 %)	Binder (5 %)	Moisture (6 %)
1.	Silica sand	Bentonite	water
2.	Silica sand	Cassava Starch	water
3.	Silica sand	Yam Starch	water

Table 2: Composition of the green moulding sand used with 10% binders

S/n	Silica Sand (84%)	Binder (10%)	Moisture (6 %)
1.	Silica sand	Bentonite	water
2.	Silica sand	Cassava Starch	water
3.	Silica sand	Yam Starch	water

Table 3: Composition of the green moulding sand used with 15% binders

S/n	Silica Sand (79%)	Binder (15 %)	Moisture (6 %)
1.	Silica sand	Bentonite	Water
2..	Silica sand	Cassava Starch	Water
3.	Silica sand	Yam Starch	Water

Table 4: Composition of the green molding sand used with 20% binders

S/n	Silica Sand (74%)	Binder (20 %)	Moisture (6 %)
1.	Silica sand	Bentonite	water
2.	Silica sand	Cassava Starch	water
3.	Silica sand	Yam Starch	water

Green and Dry Compression Strength Test: The green compressive strength test was carried out to assess bond strength of the green sand. Additives such as water, bentonite, cassava starch and yam starch were added in varying proportions to 200gm of sand. The mixture was thoroughly mixed. A universal sand strength machine was used to determine the green compressive strength of the various sand mixtures. 150gm of the sand mixture was weighed and rammed properly and was placed between the clamps on the pendulum and the clamp placed on the magnetic rider in front of the pendulum weight of the green sand strength machine.The wheel of the apparatus was turned until the test piece broke. The value of the green compressive strength was then read off the magnetic rider and recorded.The dry strength of the sand was similarly measured, but only after heating and drying each specimen of the prepared sample in an oven at a standard temperature of 105°C and cooling it to room temperature.

Moisture Content Test: A prepared mixture of 10gm was placed into a beaker and weighed with a weighing balance. The weighed mixture was then placed inside a moisture meter. The drying of the weighed sample took place at a temperature of 105 – 110°C to a constant mass and weighed again.

The moisture content was determined with formula:

Determine the difference by mass = $\frac{M_1 - M_2}{M_3} \times 100\%$

Where M_1 .... Weight of sample before drying in the moisture meter

M_2 .... Weight of sample after drying in the moisture meter

M_3 .... Weight of sample

Mouldability Test: The mouldability index test was carried out in such a way that 200gm of prepared core mixture was weighed out of the prepared sample.The perforated drum of the instrument for test was fastened on the shaft of the electric motor.A pan was placed under the perforated drum to collect the mixtures particles that fell out from the perforated drum.200gm of the prepared core mixture sample was placed into the perforated drum and was closed with the cover.The perforated drum was allowed to rotate for 60seconds.The mass of the remaining particles from the perforated drum was determined.The mouldability index was calculated with below equation

Ma= $\frac{G}{200} \times 100\%$

The mass G of the mixture that fell through the perforated drum into the pan was determined with accuracy of $\pm$ 0.5gm.

Shatter Index Test: A Standard specimen instrument used to determine the mouldability index was also used to determine the shatter index. The weight core mixture of 200gm was placed into the perforated drum.The drum was allowed to rotate for 15 seconds after which the specimen was reweighed. The shatter index was determined as the difference in the mass of specimen before and after the drum test related to the initial mass and multiplied by 100%.

$$\text{Shatter index}=\frac{M_0 - M_1}{M_0} \times 100\%$$

M_0 .... Initial mass of sample

M_1 .... Mass of sand in the receiver

$$\text{Shatter index} = \frac{\text{initial weight- final weight}}{\text{Initial weight}} \times 100\%$$

Permeability Test: Permeability was determined by measuring the rate of how air passed through a standard rammed test- piece. The standard air pressure of 98 x 10n/m was passed through the specimen tube that contained green sand placed in parameter of the permeability meter. Direct-reading instrument was used in determining the permeability by reading percentage of the sand and binder content.With a specimen retained in the table the tube was allowed to seat on the permeability forced through the specimen for a period of time. The permeability valve was read form the scale on the instrument.

Resultsand Discussion

Particle Size Analysis of Moulding S and

The AFS fineness number which is the standard for reporting the grain size and distribution of sand was used to assess the particles size. This is to determine the distribution of grain sizes within the sand. Sands used in foundry have a wide range (40 – 200) of fineness number. This was applied to the sieve result as in Table 5 to obtain the AFS number. From the table, grain fineness = total product\% sand substance = 4433\98.52=45. The sieves analysis results show that the grain fineness index falls within the acceptable range.

Table 5: Calculation for AFS grain fineness number for sand

Mesh	Amount of sample	Sand retained (%)	Multiplier	Product
6	0.00	0.00	-	-
12	0.10	0.10	10	1.00
20	1.00	2.00	12	24.00
30	6.15	12.30	20	246.00
40	8.12	16.24	30	487.20
50	20.32	40.64	40	1625.60
70	5.12	10.24	50	512.00
100	4.30	8.60	70	602.00
140	3.00	6.00	70	600.00
200	1.20	2.40	140336.00	
270	0.00	0.00	200	0.00
Pan	0.00	0.00	-	0.00
	49.31	98.52	-	4433.8

According to the AFS standard 40 to 330 average fineness is suitable for foundry application (Fayomi et al 2011). Higher numbers represent fine sands generally used for light castings, coarse grained sands with lower fineness numbers are used in steel castings. Although, the fineness number of the sand proves it suitability for steel casting but mechanical properties obtained with the mixtures did not agree with the standard.Moulding experiments using bentonite, cassava starch and yam starch separately as binder of varying composition were carried out to measure basic mechanical properties, with the discussions as follows:

The results of AFS grain fineness analysis is presented in Table 5.

Hence, the Average grain fineness of the sand = Total product / % retained $= \frac{4433.8}{98.52} = 45$

Characterization of the properties of the moulding sand

Figure 1 shows the green/dry compressive (bond strength) properties which measure the ability of the sand mould to withstand the pressure of molten metal during casting in green or dry state. The green compressive strength ranged from 38kN\m^{2}for 5% to 60kN\m^2 for 20% bentonite clay content. It ranged from 35kN\m^2 - 53kN\m^2 for cassava starch and for yam starch from 32kN\m^2 – 48kN\m^2. It was observed that as the percentage binders increases for each binder, the green compressive strength increases in bentonite and other local binders content in the moulding sand.From Figure 2, the dry strength ranged from 222kN\m^2 for 5% to 285kN\m^2 for 20% bentonite clay content. It ranged from 218kN\m^2 – 270 kN\m^2 for cassava starch and for yam starch from 212 kN\m^2–256 kN\m^2. It was also observed that as percentage binder's increases, dry compressive strength also increases. Dry compressive strength was observed to be greater than green compressive strength for all the used binders. Although such difference are expected among the binder reason being that the rate at which the bonding forces involved in holding binders together are function of individual binding constituent Seidu et al. 2016 [4].

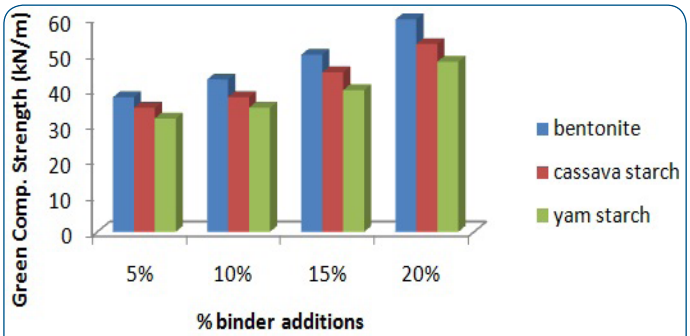

Figure 1: Green Compressive strengths (kN\m^2) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

The moisture content value for the moulding sand with each binder grade is presented in Figure 3. The moisture content test determines amount of dampness of mould specimen. The moisture content ranged from 5 for 5 % to 9 for 20 % bentonite clay content. It ranged from 3 - 7 for cassava starch and for yam starch from 2 – 5. It was observed that as percentage binder increases, moisture content increases.

However, mouldability ranged from 15 % for 5% to 60 % for 20 % bentonite clay content. It ranged from 11 % - 55% for cassava starch and yam starch from 9 % - 45 %. Mouldability was observed to increase as the percentage binder's addition increases as indicated in Figure 4.

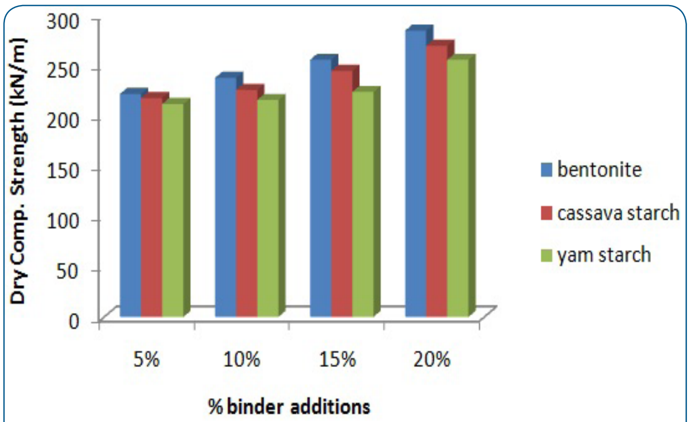

Figure 2: Dry Compressive strengths (kN\m^2) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

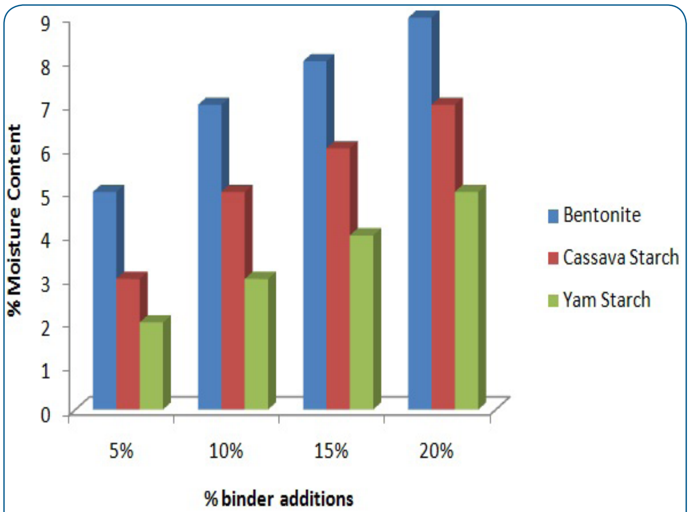

Figure 3: Moisture content (%) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

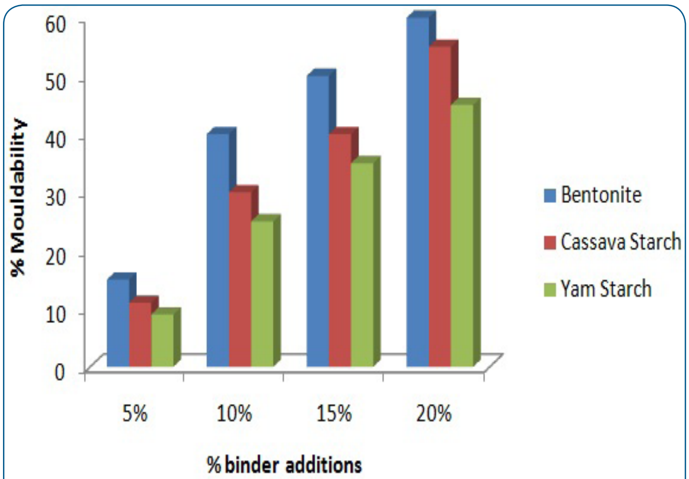

Figure 4: Mouldability (%) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

In the shatter index measurement test, the collapsibility of sand mould after casting for easy shakeout was checked. The shatter index ranged from 56 for 5 % to 40 for 20 % bentonite clay content.It ranged from 48 – 36 for cassava starch and yam starch from 42 – 32. It was observed that as percentage binder increases, shatter index decreases (see Figure 5). With decreasing shatter index, less pores are caused in the mould which will allow gas to pass through during casting.

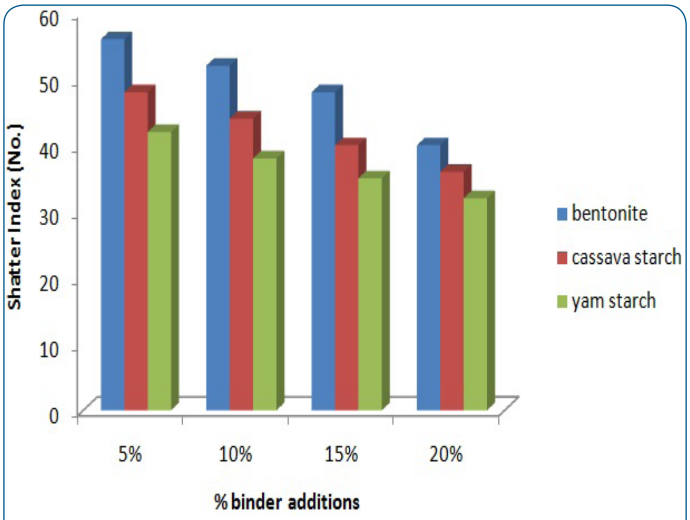

Figure 5: Shatter Index (No.) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

From Figure 6, the permeability ranged from 125 for 5 % to 105 for 20 % bentonite clay content. It ranged from 132 – 111 for cassava starch and yam starch from 137 – 116. It was noted that as percentage binder increases, permeability decreases. The results of the property analysis when compared with foundry standard [8] showed it is suitable for all categories of non-ferrous alloy castings in green or dry sand moulds from 1.5% bentonite clay and 1.0% kaolin with about 2% moisture. The limitation to application of the sand is due mainly to low refractoriness of the sand caused by presence of low melting point oxide like sodium oxide that fluxes out as sodium hydroxide at high temperature.

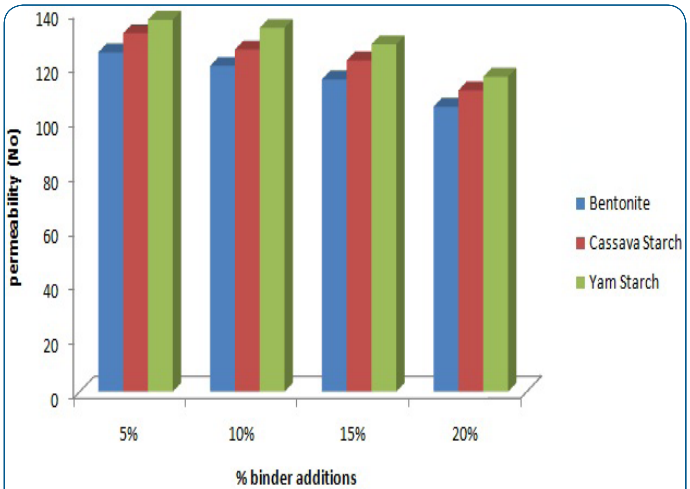

Figure 6: Permeability (No.) of Foundry sand bonded with varying percentages of bentonite, cassava starch and yam starch with 6% water content

Conclusion

The River Niger silica sand has grain finess number GFN of 45 which shows good properties for casting non–ferrous metals, malleable iron and light grey iron. Bentonite had the best green/dry compressive strength, followed by cassava starch and yam starch. River Niger bank silica sand at Felele in Lokoja with the addition of binder will give good surface finish and low cost which might be of help to the foundry men involve in sand mould production in Nigeria and other developing countries of the world.

References

1. Alonge K, Atanda PO, Olorunniwo OE, Oluwole OO. Comparison of Bentonite and Cassava Starch on the Moulding Properties of Silica Sand. International Journal of Materials and Chemistry. 2012; 2(4):132-136.
2. Ugwu FM, Odo MO. Effect of Cassava Variety on the Quality and Shelf Stability of Soy-Garri. Pakistan Journal of Nutrition. 2008; 7(2):381-384.
3. Fayomi OSI, Ajayi OO, Popoola API. Suitability of local binder compositional variation on silica sand for foundry core making. International Journal of Physical Sciences. 2011; 6(8):1940–1946.
4. Seidu SO, Joshua TO, Fayomi OSI. In-situ Behaviour of Selected Local Sand Binders on Microstructure and Mechanical Properties of Grey Cast Iron. J. Mater. Environ. Sci. 2016; 7(4):1135-1144.
5. Scaffer E, James P. The Science and Design of Engineering Materials. 1st ed. London: Longman. 1995.
6. Shehu T, Bhatti RS. The use of Yam flour (starch) as binder for sand mould production in Nigeria. World Applied Sciences Journal. 2012; 16(6):858-862.
7. Fayomi OSI, Ojo OI, Popoola API. Investigating ochadamu silica sand, clay and local oils for foundry core. International Journal of Physical Science. 2011; 6(8):1894 – 1904.
8. Popoola API, Fayomi OSI. Accessing the Performance of Binders on Core strength in Metal Casting. International Journal of Physical Sciences. 2011; 6(34):7805-7810.
9. Seidu SO, Joshua TO, Fayomi OSI. Efficacy of Graded Carbon (Cow Bones and Coal Dust) As Mould Additives on Microstructure and Mechanical Properties of Grey Cast Iron. Journal of Basic and Applied Research International. 2016; 16(1):57-65.