

Effect of Cassava and Guinea Corn Starch on Atserem Stream Foundry Sand

¹Injor, Oryina Mbaadega, ²Edeoja, Alex Okibe, ³Tiza Aondohemba

^{1, 2, 3}Department of Mechanical Engineering, University of Agriculture, Makurdi, Nigeria
aoedeoja@gmail.com

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ABSTRACT

The effect of cassava and guinea-corn on Atserem stream foundry sand has been studied in this research. The sieve and chemical oxide analysis of the sand as well as chemical composition of the binder (cassava and guinea-corn) were carried out. The representative sample of the sand was then sieved with 1.18 mm sieve. The binders were varied at 4, 8, 12, 16, 20, 24, 28, 32, 36 and 40% level with the sand at 86, 82, 78, 74, 70, 66, 62, 58, 54 and 50%, while water was kept at 10% constant weight in the mixture. 210 test samples were produced using a cylindrical mold of 50 x 50 mm dimension. Moisture content, crushing strength, surface hardness, shrinkages, shatter index, permeability and refractoriness tests were carried out on the samples. The addition of both binders increased the moisture content, surface hardness, crushing strength and shrinkage which represent an improvement in foundry properties of the sand. On the other hand, the addition of both binders decreased the shatter index, permeability and refractoriness. In comparison, the results showed that cassava optimally improved the foundry properties than guinea-corn starch. Decrease in refractoriness with increased binders limit the use of the sand for metal casting types such as aluminum, braze malleable iron and grey iron.

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Introduction

The new policy to re-invest in Nigeria locally available industries by the present administration has given rise to urgent need to develop foundry industries in Nigeria to meet the current need of technological advancement of the country. This in turn has, led to so much interest in locally available foundry sand and materials that would be used to improve foundry sand properties. Foundry sand also known as moulding sand is high-quality uniform silica sand that is used to make moulds and cores in ferrous and non-ferrous metal casting. Foundry sands typically comprise of up to 80% high quality silica sand, 5 to 10% bentonite clay, 2 to 5% water and less than 5% seal [1]. A typical chemical analysis of foundry sand is shown in Table 1.

The most commonly used sand in the foundry industry is silica and is produced by the decomposition of granite. It is required that foundry sand mixtures for moulding purposes should possess sufficient level of certain properties such as compatibility, permeability, green strength, moisture content, grain size, shatter index and crushing strength. The desired level of these properties vary depending on the type of mould, metal cast, the shape and size of the cast [2]. The success of casting process depends to a large extent on the making of good mould. For this reason, the moulding properties of sand have to be controlled. These properties are influenced not only by the chemical composition, but also by the amount of binders in the sand, by its moisture content and by the shape and size of the

silica sand grains. The various variables are divided so as to get optimum moulding properties of the sand for a given situation [3].

Table 1: Chemical Analysis of Foundry Sand

Constituents	Value (%)
SiO ₂	87.91
Al ₂ O ₃	4.70
Fe ₂ O ₃	0.94
CaO	0.14
MgO	0.30
SO ₃	0.09
N ₂ O	0.19
K ₂ O	0.25
TiO ₂	0.15
P ₂ O ₅	0.00
Mn ₂ O ₃	0.02
SrO	0.03
LOI	0.45-9.47(5.15)
Total	99.87

Source: [4]

For naturally bounded sand, those in which the refractory grain is associated in its deposits with the need for moulding, the properties depend chiefly on the type and amount of their ingredients/constituents [5]. It becomes obvious that certain sand would be rejected for foundry application because of the absence



or insignificant level of the aforementioned properties while others that have the desired properties will be competed for. Therefore this study becomes so imperative so that alternative foundry sand can be produced.

Reference [6] studied the study of suitability of rice husk and cassava starch blended with silica sand for foundry applications. The results obtained indicated that, the blend combination of cassava starch and rice increased dry/green compression strength, contributing to green toughness as measured by the plasticity index of 138 N/mm². Thus the effect of cassava starch and rice husk on shatter index falls within (50 – 85%) representing the mouldable range [5].

Similarly, effect of cassava and maize flour as additives for improvement of foundry sand (River Benue) was investigated by [7]. The results confirmed a fair improvement in the foundry properties of River Benue sand such as crushing strength, moisture content, shatter index and surface hardness. Despite the improvement of certain properties by the increase in cassava and maize flour, properties such as permeability, refractoriness, shatter index and shrinkage decreased. The decrease in shrinkage may however be seen as improvement, because high shrinkage values are considered detrimental [7].

Furthermore, the use of yam flour (starch) as binder for sand mould production was examined. The role played by yam flour (starch) as binder to *Dukku* silica sand in Kebbi State, Nigeria showed that *Dukku* silica sand bonded with the material gave strong bonds that can be used in the foundry industry when compared with standard properties of sand casting. Green/dry compressive strengths, shatter index, collapsibility and permeability of the binder indicated good properties for casting non-ferrous metals, malleable iron and light grey iron if correct amounts are used [8]. Due to the good binder properties noted for yam flour (starch), an opportunity exists to replace some imported binders such as bentonite with the material and may be of interest to foundry men in the field of sand casting [9].

Reference [10] carried in the same vein, the use of local oils, namely groundnut oil, cotton seed oil and palm oil with local clay and silica sand for the production of foundry cores has been investigated in varying composition. These oils were tested and it was found that the three could be used to produce foundry cores.

Reference [11] investigated the effect of varying corn cob and rice husk ashes on properties of moulding sand. The results indicated that the additives improved dry strength of the moulding sand, and generally a decrease in the green strength with increase additives. Reference [12] studied the improvement and comparative analysis of River Benue foundry sand using guinea corn, cassava, maize as binders in casting. The results showed that cassava, guinea corn and maize additives improved

the properties such as the dry compressive strength, shatter index and plasticity of the sand.

This work focuses on improving the foundry properties of sand from *Atserem* stream located in Kwande LGA of Benue State Nigeria, through the use of cheaply and locally available binders, mainly cassava and corn starch. These binders are readily available in the country, particularly in Benue State, Nigeria. One may argue that the application of cassava and corn flour on a large scale for this purpose may shoot their market prices thereby affecting consumers of their commodities who use them for food stuffs. However, it will be of great benefit for commercial agriculturists. Besides, the position of foundry technology in technical advancement of any nation cannot be over emphasized.

The raw materials used for this research include silica sand, cassava starch, guinea-corn starch and distilled water. The sand was collected from *Atserem* stream, which flows from *Ngokur* Hill in Kwande Local Government Area of Benue State, Nigeria. The cassava and guinea-corn flour starch were obtained from North bank market in Makurdi Local government Area also of Benue State, Nigeria. The list of equipment used are shown in 500 g of the oven dried sand sample was weighed. Nest of sieves were mounted starting with the pan, followed by sieves of aperture numbers 75, 150, 300, 425, 600, and 850 μ m, 1.18, 1.70, 2.36, 3.5, and 5.0 mm. The soil sample was sieve through the nest of sieves arranged in descending order of magnitude to allow lower sizes of sand to percolate through easily. Quantities of silica sand, cassava starch, guinea-corn starch and water were weighed using digital balance with a sensitivity of ± 0.01 and a constant volume of water (10%) was used throughout. Samples of the mixture shown in Table 3 were thoroughly mixed in the laboratory using hand trowel for 5 minutes in order to allow the samples mix properly according to ASTM sand specimen specification. For each level of mixture, three samples were produced and the average value of the test for the three samples was taken.

To get the moisture content of the specimens, samples were carefully prepared without stripping, weighed and put inside the hot box oven maintained at a temperature of 110 °C for 2 hours to allow the escape of moisture. After which they were taken out of the oven and immediately re-weighed. The percentage of moisture was calculated from the difference in weight of the original sample (moist) and dried sample.

For surface hardness, the samples were prepared and air dried for 6 hours in the laboratory. A metal ball of 10 mm diameter was pressed into the surface of the sample for about 10 second using 1 kg of load and the diameter of the resulting depression on the surface of the mould sample was measured. This was used to indicate the surface hardness.

For crushing strength, standard cylindrical samples, 50 mm in diameter, were prepared and air dried for 12 hours in the laboratory. These were later baked at 120 °C for 12 hours in the oven. They were then allowed to cool in the oven for 4 hours and their dry compression strengths were determined using the universal strength Testing Machine. The load was gradually applied in compression at a rate of 28 kN/mm² until the cylindrical sample sheared.

For shrinkage, the cylindrical moulds of 130 mm and 15 mm in height and diameter respectively were divided into two equal halves along their height for easy removal of sample after baking. The samples were prepared, and still in the metal moulds baked at 120 °C for 12 hours. They were then immediately taken out and the final height of the samples measured.

For permeability measurement, the standard sample specimens of 5.08 cm in diameter and 5.0 cm in height were prepared by ramming the required quantity of the sample in the core mould and placed in the core tube of the permeability testing

machine. The air drum was raised to take 2000 cm³ of air into the air drum which was indicated by the graduation on it. The whole air was then allowed to escape through the sand specimen with a standard air pressure of about 10 g/cm² and the time was recorded.

For refractoriness, the samples were prepared and air dried for 12 hours in the laboratory to gain more green strength. Each sample was then put into the electric furnace. The furnace was then set to its maximum temperature of 1200 °C. The temperature was gradually increasing itself at 1 °C. The temperature at which the sample began to fuse down was recorded as the refractory temperature of the samples.

For shatter index, the cylindrical samples were prepared carefully without stripping. The samples were oven dried for 110°C for 12 hours and cooled in the oven for four hours. The initial weight after drying was noted and the samples were allowed to fall on an anvil from a height of 6 ft (1.83 m). The weight retained on an 850 µm sieve after shatter was noted.

Table 2. Equipment used

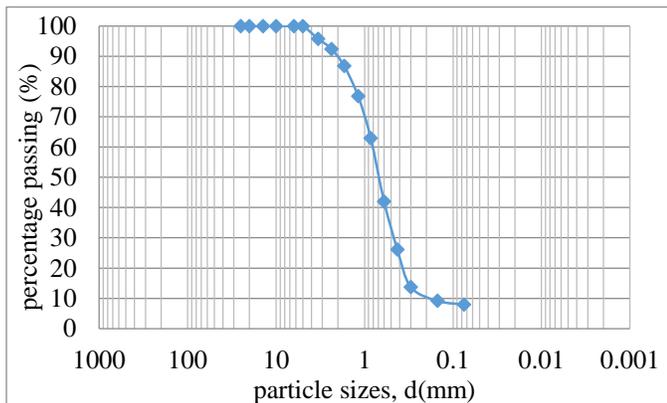
S/N	Equipment/Materials	Model	Location
1.	Set of sieve and basins		Civil Lab, UAM
2.	Weight balance	Chai-can balance, max capacity = 25 kg Type: ELE 22-500; Sensitivity : + 1	Civil Lab, UAM
3.	Standard metal cylindrical mould	50 mm diameter	Metallurgical Lab, UAM
4.	Ridsdale-dietart universal strength machine	California Bearing Ratio (CBR), England, Sensitivity = 28 kN Machine factor = 0.122	Civil Lab, UAM
5.	Beaker		
6.	Hand trowel		
7.	Hot box oven	Gallen Kamp size 2 Max Temp: 200°C Sensitivity: + 25°C	Civil Lab, UAM
8.	Digital vernier caliper	Sensitivity: ± 0.01	Metallurgical Lab.
9.	Electric furnace	Carbolite-Bamford, sheffied, England, Max Temp: 1200°C Type: GPC 12/18	Physic Lab.
10.	Atomic Absorption Spectrum (AAS)	Buck Model, Scientific 210 VGP	Soil Science lab. UAM
11.	X – ray fluorescence spectrometer (XRF)	Mini Pad model 4 version PW 430.	Soil science Lab. UAM
12.	Permeability meter	Ridale-Dieter	Soil Science Lab
13.	Digital Weighing Balance	Sensitivity ± 0.01	Metallurgical Lab

Table 3. Sample Mixtures used for the study

Mixture	Samples (%)									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Sand	86	82	78	74	70	66	62	58	54	50
Guinea-Corn	4	8	12	16	20	234	28	32	36	40
Cassava	4	8	12	16	20	24	28	32	36	40

Results and Discussions

The result of sieve analysis, moisture content, surface hardness, crushing strength, shrinkage, permeability, refractoriness, shatter index, chemical oxide analysis and chemical composition of cassava and guinea-corn are presented. Figure 1 showed a plot of percentage passage against particle size of Atserem sand. The result showed that that sand is coarse with 4 as the coefficient of uniformity. Since the value of the coefficient of uniformity is less than 5, it is considered as a poorly graded soil which is difficult to compact [13]. The result is similar to that of [14](Gbeleges, 2013) whose value was 2 and hence, binders were added to increase the compatibility of the sand.



16% to 32% binder falls within the AFN accepted standard and can be used for casting types such as aluminum, brass and bronze,

light grey iron and medium grey iron. This trend is similar to that of [16] and [18] Abdullahi et al, 2009.

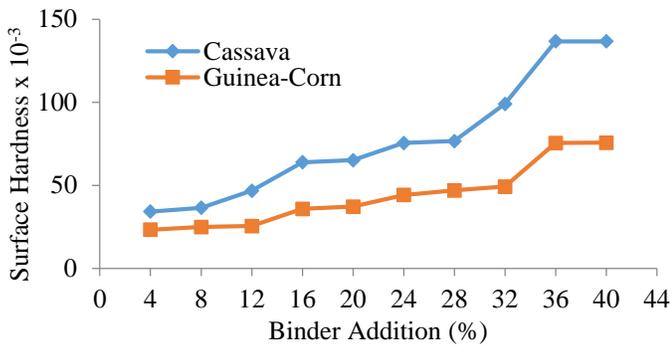


Figure 3. Variation of Surface Hardness with quantity of Binder

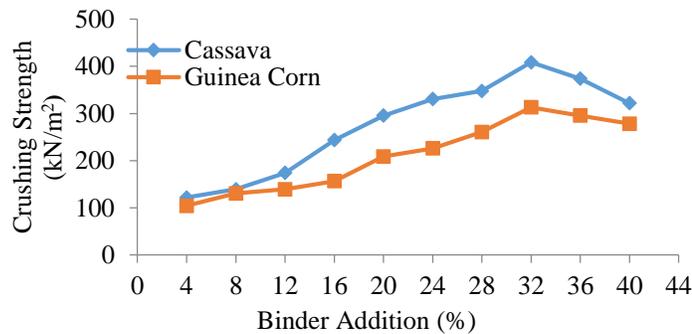


Figure 4. Variation of Crushing Strength with quantity of Binder

The shrinkage of cassava and guinea-corn starch at varying binder addition (%) is shown in figure 5. The result showed that shrinkage increase with increase in binder addition. The result indicated that at 4% binder addition, both cassava and guinea-corn starch have a minimum of 0.12 and 0.05 respectively. Similarly, at 32% binder addition (%), cassava and guinea-corn starch have a maximum value 2.15 and 1.70 respectively. This showed that cassava starch has higher shrinkage ability than guinea-corn starch [6]. It is good to note that small and negligible drying shrinkage values are good particularly in poetry. The higher dry shrinkage observed at 32% binder addition could be due to fire plates – like particulate of sand. Excessive shrinkage is considered dangerous process especially in ceramics [3].

content, both cassava and guinea-corn have a maximum value of 27 and 29 permeability AFN respectively. This showed similar trend to that of [12]. This result falls within the AFN standards for metal casting types. Cassava is good for metal casting types such as aluminum and bronze where as guinea-corn is as well good for aluminum and bronze from 4% to 14% binder addition.

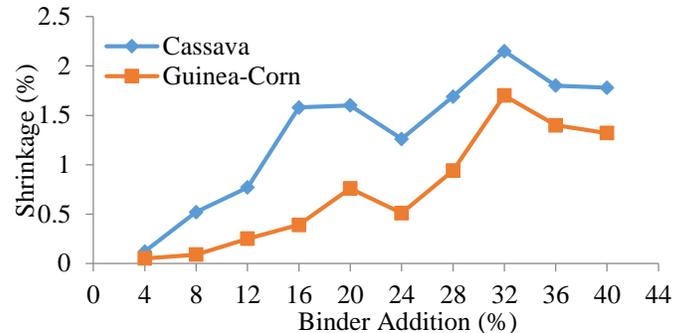


Figure 5. Variation of Shrinkage with quantity of Binder

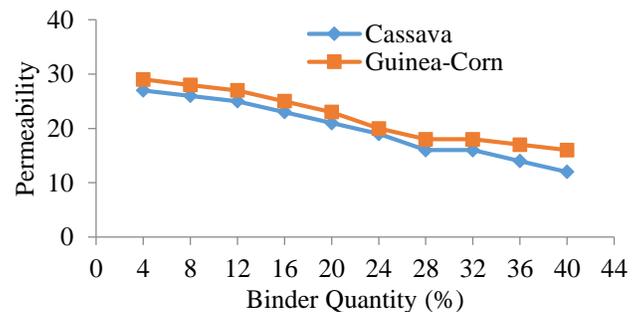


Figure 6. Variation of Permeability with quantity of Binder

The permeability of cassava and guinea-corn starch at varying binder addition (%) is shown figure 6. The result showed that permeability decreases with increase in binder addition. Though both cassava and guinea – corn showed decrease, cassava showed more decrease than guinea-corn starch. At 50% binders content both cassava and guinea-corn has a minimum value of 12 and 16 permeability AFN respectively. Similarly at 4% binder

The refractoriness of cassava and guinea-corn starch at varying binder addition (%) is shown in figure 7. The result showed that the refractoriness decrease with increase in binder content (%). Though, both refractoriness of cassava and guinea-corn starch decreases with increase in binder content (%), guinea-corn show a more decrease.

At 40% binder content, both cassava and guinea-corn have a minimum refractoriness temperature of 931°C and 818°C respectively. Similarly, at 4% binder content, both cassava and guinea-corn have a maximum value of 1100°C and 1000°C respectively, which is similar to that of [12]. The effect of both cassava and guinea-corn starch on *Asterem* silica sand limit it use for metal casting types such as Aluminum, bronze, braze malleable iron and medium grey iron due to decrease of refractoriness.

The shatter index of cassava and guinea-corn at varying binder addition is shown in fig. 8. The result showed that the shatter index decrease with increase in binder content addition (%). However, guinea-corn shows a minimum value of 11.19 than cassava starch (19.94) both at 40% binder addition. Similarly, both cassava and guinea-corn attained a maximum value of 52.66 and 59.31 at 4% binder content respectively. The result is similar to that of [19].

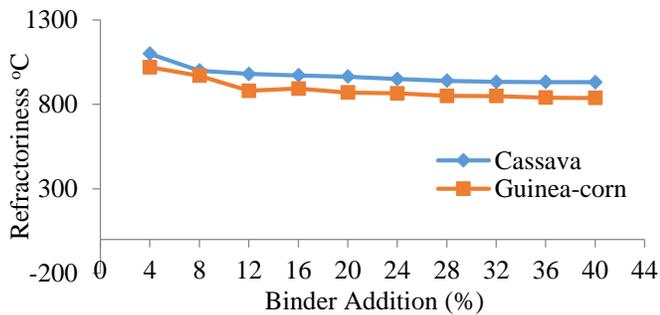


Figure 7. Variation of Refractoriness with quantity of Binder

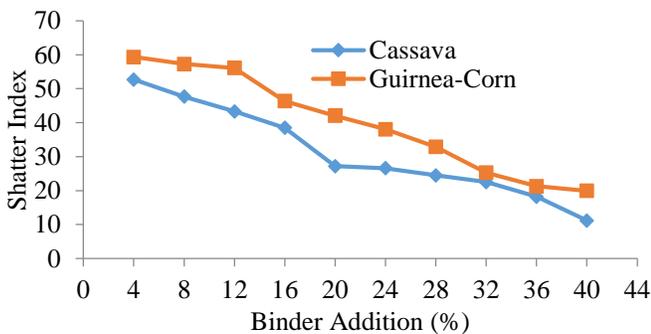


Figure 8. Variation of Shatter Index with quantity of Binder

Conclusion

The result of obtained from the particle size distribution and chemical oxide analysis test showed that *Atserem* stream sand is a silica sand because of its high content of silica 95.76%. The effect of cassava and guinea-corn starch on *Atserem* foundry sand showed that increase in both binders increased the moisture content, surface hardness, crushing strength and shrinkage. However, the shatter index for both cassava and guinea-corn decreased with increasing binder content. Similarly, the permeability and refractoriness of the samples gave the same pattern of result. The effect of both cassava and guinea-corn starch on *Asterem* silica sand limit its use for metal casting types such as Aluminum, bronze, braze malleable iron and medium grey iron due to decrease of refractoriness.

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