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Suitability of Using Cassava (Manihot Esculenta) Starch as Binder for the Production of Core in Foundry Application

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ABSTRACT: Sand cores were produced using silica sand from River Niger Bank in Lokoja, Kogi State, Nigeria with bentonite and cassava starch as a binder. To determine the suitability of making a core with those materials various compositions of cassava starch bonded sand cores were made and compared with bentonite bonded sand cores. The results show that cassava starch competes favourably with bentonite and is suitable for producing sand core. The following results were obtained: for hardness values; Bentonite 55-60kg/cm^2 and cassava starch 50-58kg/cm^2. The compatibility value; Bentonite 90-83% and cassava starch 88.4-76.1% while the permeability value; Bentonite 42-20MMH$_2$O and cassava starch 59-50MMH$_2$O. The aforementioned properties were found to be adequate for the production of the sand core using cassava starch as a binder. Therefore, cassava starch is a good, low-cost substitute for imported bentonite. This suitability was verified by the successful production of the cassava bonded sand cores.

KEYWORDS: Sand core, Binder, and Sand properties.

I. INTRODUCTION

A core is a mixture of particles that are synthesized, possessing some degree of porosity and a controlled mechanical strength good enough to permit the fragmented particles to be mixed without breakage; to produce internal and external sections of a mould. They are used in most cases to create hollow sections or cavities in a casting [1]. The use of locally sourced core binders has in recent times helped in boosting the ailing economy of some developing countries [2-3].

The demand for core making in the foundry industry has greatly improved since they enhance the rigidity of casting and ensure casting dimensional accuracy [3-4]. Silica sand, binders, and additives are the primary constituent of a foundry sand core, the additives are added to improve the strength of the core, while silica sand is the most acceptable based material for a core due to combinations of properties such as high melting point and boiling point [5-6]. The following are the characteristics of a good core: possession of good strength and hardness to be handled and to resist aggressive action of the liquid metal, uniform density, and wide range of sand with varying purity, enough permeability is also required for the escape of gases developed in the course of casting [7].

A binder is the second most important constituent of moulding sand [8]. Binders are mixed with foundry sand to bond the sand particles together. When added to moulding sand, they tend to impart it with strength and cohesiveness. Binders help at ensuring that the shape of a mold is maintained after the ramming and withdrawer of the pattern [9]. The uniqueness of bentonite is that it enhances green sand mould's thermal stability, compatibility, and flowability leading to good castings [9]. Bentonite clay is the most widely used foundry sand binder and two types are available: swelling bentonite (sodium bentonite) and non-swelling bentonite (calcium bentonite) and calcium type is the most occurring type [10-11]. The ability of the binder to collapse on cooling is known as breakdown and this property is very important in cored holes that are inaccessible to fettling [12].

Binders suitable for foundry core must not only hold sand grain together but must have sufficient resistance to high temperature for it to

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collapse and allow sand to be easily removed from the casting leaving its surface smooth. The ability of a binder to collapse on cooling is known as breakdown and this property is very important to the core hole, which is inaccessible to operations that turned the crude casting into a cost-effective quality component that meets human needs [13].

Sand constitutes the major moulding material applied for all casting processes, either for ferrous or non-ferrous castings. Good foundry sand must possess good refractoriness, moldability, permeability, collapsibility, chemical resistivity, which are very key to foundry applications [9].

The mechanical properties and the dimensional stability of the sand cores are highly dependent on the characteristics of the base sand and the applied binder, as well as the parameters of the moulding/core-making procedures [14-15].

A large number of binders are employed annually for the fabrication of metal casting, in recent times; many developing countries of the world have developed rapidly in the use of core binders [16]. Core binders serve to hold the sand grains together, impact strength, resistance to erosion, and the breakage and degree of collapsibility. They are divided into two classes, organic and inorganic binders. Cereals resins, proteins pitch oils, and molasses are organic binders. Cement, silicates, and some esters are inorganic binders [12, 13]. Casting is produced in foundry by pouring the molten metal into a mold made to shape the component required. The flexibility of casting production techniques enable practically, all shape to be produced [17].

The need for a possibility of using local binders as a natural source of foundry core to mitigate against foundry defects, improve core and reduce cost, necessitate this investigation. It is anticipated that the study will contribute to the present research interest of this area of study. Economic and technological benefit in envisaged from a positive result in this work.

II. RESEARCH METHODOLGY

MATERIALS

The materials used for this study include the following silica sand collected from the River Niger bank in Lokoja, Kogi State, Binders such as benthonic and cassava starch, distil water.

EQUIPMENT

Equipment used for this research work are mixer or muller, measuring cylinder, sieve analyser, mechanical rammer, core box, universal strength testing machine, permeability meter, electronic weigh balance, moisture tester, core hardness tester, and shatter index tester.

EXPERIMENTAL PROCEDURE

Collection of Raw Materials

Silica sands used for this research work are obtained from River Niger Bank in Lokoja, Kogi State. The binder used in this work is bentonite and cassava starch. The cassava starch was sourced locally from the market in Lokoja, Kogi State. The bentonite clay was imported from Baroda India. The work was carried out in the quality control laboratory of Nigeria Foundry Limited (NFL), Sango Ota, Ogun State, Nigeria.

Method Used

This silica sand used for this experiment was weighed properly until the water at the surface of the sand is cleaned and later dry under the sun. the silica sand was sieved using 0.5mm grade of a set of the standard sieved analyser to obtain a fine grade of particle sand suitable for core making.

Sand Grain Size:

The grain size, distribution, grain fitness are determined with the help of the fitness testing of moulding sands. A sand sample that is free of moisture and clay is used. The dried clay-free sand grains are placed on the top of a sieve shaker which contains a series of sieves one upon the other with gradually decreasing mesh sizes. The sieves are shaken continuously for 15 minutes. After this shaken operation, the sieves are taken apart, each size fraction was separated from one another on a different sieve having an aperture that is smaller than the diameter of the sand particles, and the sand leftover in each of the sieves was carefully weighed. The top sieve is coarsest and the bottom-most sieve is the finest of all the sieves. In between sieve placed in order of fineness from top to bottom. The GFN number is a qualitative indication of the grain distribution. GFN values are in the range of 40 - 220 for those sands used by most of the foundries. Though the sand properties depend on both the grain size and the grain size distribution, GFN is a convenient way of finding sand properties. GFN 41: Steel castings 50kg and more, GFN 67: Small steel castings, GFN 105: Light cast iron and copper castings, GFN 150: Aluminium alloy castings.

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Table 3.1: Sieve analysis of River Niger Bank silica sand in Lokoja, Kogi State

MESH DIAMETER (mm)	WEIGHT OF THE SAND ON MESH (g)	MULTIPLIER	RESULT OBTAINED
1.40	1	6	6
1.00	5	9	45
0.71	9	15	135
0.50	11	25	275
0.355	13	35	455
0.25	32	45	1440
0.18	12	60	720
0.125	14	81	1134
0.09	2	118	236
0.063	-	164	-
SIEVE PAN	-	275	-
TOTAL	**99**	**SUM**	**4446**

Mesh diameter (mm) is the opening diameter of the sieves; the weight of the sand on mesh represents the amount of sand retained on each sieve, while the multiplier is the multiplying factor for each sieve.

3.3.4 Weighing and mixing of the sample.

The silica sand, bentonite, cassava starch, and water were measured separately using an electric weighing balance. The procedure was by adding bentonite and cassava starch to the sand and then mixing each constituent thoroughly before adding water. Three sets of samples were prepared from each binder mixture, their percentage was increased in the step of 10% from 10 to 30% for every mixture. Each operation took about 5minute as mixing was done manually due to the small quantity of the materials involved, these were done to achieve the following:

1. Uniform dispersion of water (moisture)
2. To develop the binding properties of the starch.
3. For homogeneous mixing of sand and other additives.

The cores were produced by ramming the mix using the Nigeria Foundry Limited (NFL) standard rammer.

This was achieved by lowering the plunger gently into the sand in the core box and rammed with three bellows to compact the mixture. The hardness of the core, the moisture content, compatibility test, and permeability test were carried out.

Table 3.2: Composition of the green moulding sand used with 10% binder and 6% moisture

S/n	Silica sand 84%	Binders 10%	Moisture 6%
1	Silica sand	Bentonite	Water
2	Silica sand	Cassava starch	Water

Table 3.3 Composition of the green core mixture sand used with 20% binder and 6% moisture

S/n	Silica sand 74%	Binders 20%	Moisture 6%
1	Silica sand	Bentonite	Water
2	Silica sand	Cassava starch	Water

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Table 3.4 Composition of the green mixture sand used with 30% binder and 6% moisture.

S/n	Silica sand 64 %	Binders 30%	Moisture 6%
1	Silica sand	Bentonite	Water
2	Silica sand	Cassava starch	Water

Figure 3.1: Sieve analysis test of River Niger bank molding sand

Permeability Test

The permeability number of sand is the rate of flow of air passing through a standard pressure. It is determined by measuring the rate at which air passed through a standard rammed specimen. In this test, the specimens were analyzed by a permeability meter. 150g of the mixed sample was measured into the specimen tube and rammed three (3) times with a mechanical rammer, after which the specimen tube that contained green sand was placed in the permeability meter and then the machine is powered on. The permeability value was read from the scales on the instrument.

Figure 3. 2: Permeability Testing machine and operation

Hardness Test

The core hardness was measured with the mold hardness tester which is calibrated from 0-90. This was carried out by placing the mold hardness tester on the sample of a core prepared vertically with force. The hardness of the core was taken from the scale of the equipment.

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Figure 3.3: Hardness Test of a core

Moisture Content Test

A prepared mixture of 50g was placed into a beaker and weighed with a weighing balance. The weighed mixture or specimen was then placed inside an oven for 2 hours so as to ensure the proper drying of the weighed sample mass which took place at a temperature of about 105 ^{0}C to 110 ^{0}C. At the end of the drying operation, each sample was measured again to determine the weight loss. The moisture content was determined with the formula.

Moisture content = M_0 -M_1 /M_0 X100 that is to determine the differences by mass where m0 = weight of the sample before dry where M_0 = weight of the sample before drying the moisture (initial weight)

M_1 = weight of the sample after drying the moisture.

Compactibility test

Compactibility relates to the reduction in the volume of sand bonded with clay and water after undergoing compression applied by squeezing or compaction. Compatibility test was carried out by filling the standard specimen tube with the core sand mixture then the tube was placed in a mechanical rammer for ramming and the sand was rammed three times by the mechanical rammer. The distance as the percentage compatibility is obtained by dividing the decrease in height by the initial height multiplied by 100%.

Mathematically

Compatibility = h_0 -h_1 / h_0 X 100

where ,

h_0 =standard height of the equipment

h_1 = decrease in height of the equipment.

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Figure 3.5: Compatibility Testing machine and operation

Shatter Test

The shatter index was carried out by using 150g of the core which was then rammed four times in the shatter machine. The rammed sand was fixed in the shatter index machine where it was dropped from a height. The sample was then weighed after dropping from the height. The measured weight is then divided by the original weight of 150g.


Figure 3.6: Shatter Index Testing machine and operation

III. RESULTS AND DISCUSSIONS

RESULTS OF THE EXPERIMENT

From the experiment carried out earlier on River Niger Bank in Lokoja silica sand as shown in Table 3.1 to ascertain the foundry properties of the sand, the result revealed that the sand contains 8.25% moisture content, 3.32% clay content, and the sieve analysis of 45.00

To calculate for the grain fitness number = GFN

$$GFN = \frac{\text{Total product}}{\text{Weight of the sand in mesh}}$$

$$GFN = \frac{4446}{99} = 44.90$$

GFN = 45.00

Table 4.1: Shows the compactibility value of River Niger Bank Lokoja silica sand with varying binders percentage of Bentonite, Cassava starch with 6% water.

Types of binder addition	Compactibility at 10% binder addition	Compactibility at 20% binder addition	Compactibility at 30% binder addition
Bentonite Cassava starch	90 88.4	86.1 83.1	83.1 76.1

Table 4.2: Show the hardness value of River Niger Bank Lokoja silica sand with varying binders percentage of Bentonite, cassava starch with 6% water.

Types of binder addition	Hardness result at 10% binder addition	Hardness result at 20% binder addition	Hardness result at 30% binder addition
Bentonite Cassava starch	55 50	58 54	60 58

Table 4.3: Show the permeability value of core sand with varying binders percentage of Bentonite, cassava starch with 6% water.

Types of binder addition	permeability result at 10% binder addition	Permeability result at 20% binder addition	permeability result at 30% binder addition
Bentonite Cassava starch	42 59	34 57	20 55

Table 4.4: Show the moisture content value of the core sand with varying binders percentage of Bentonite, cassava starch with 6% water.

Types of binder addition	moisture content result at 10% binder addition	moisture content result at 20% binder addition	moisture content result at 30% binder addition
Bentonite Cassava starch	6.2 8.1	4.1 4.3	4.0 4.1

Table 4.5: Show the shatter index value of the core with varying binders percentage of Bentonite, cassava starch with 6% water.

Types of binder addition	Shatter index value at 10% binder addition	Shatter index value at 20% binder addition	Shatter index value at 30% binder addition
Bentonite Cassava starch	28.7 33.3	70 41.3	65.3 20.2

IV. DISCUSSION OF RESULTS

Particles size analysis of moulding sand

In order to obtain a smoother surface finish of casting through core processing, standard sieve analyses were performed. The grain fineness number which is the standard for reporting the grain size and distribution of sand was used to assess the particles; this is to determine the distribution of grain sizes within the sand. Sand used in foundry has a wide range (40 - 200) of fineness numbers; this was applied to the sieve result in table 4.1 to obtain the GFN number. From the table, grain fineness number GFN of sand that was worked on = total product divided by % sand substance (4446/99 = 44.90 = 45.00). The sieve analysis result shows that the grains fineness index falls within the acceptable range. Average fineness is suitable for foundry application and the analysis shows that this sample with GFN 41 can be used for steel castings 50kg and more.

Permeability

Figure 4.1 show the permeability of the core which measure the rate of escape of evolved gases during casting to prevent casting defect such as blowhole, etc.

The permeability of the core range from 42 for 10% to 20 for 30% bentonite clay. It ranges from 59 for 10% to 55 for 30% cassava starch. It was observed that as the percentage binder

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increase, permeability decrease, this is as a result of the fact that increased binders caused less porosity in the mould that will allow the escape of the gas during casting. It was also noted that the greater the permeability of the core, the easier it is to produce the core. In this research, cassava starch has the highest permeability.

Hardness

Figure 4.2 show the hardness of the core which measure or determine how a core will withstand shock and handling. The hardness of a core ranged from 55 for 10% to 60 for 30% bentonite clay. It ranged from 50 for 10% to 58 for 30% cassava starch. It was noticed that as the percentage binder increases in each sample, the hardness value also increases; this is evident in both the bentonite and cassava starch core sand mixtures. If the core hardness is too high, the core breaks easily even before the actual application.

Compactibility

Figure 4.3 shows how compact the core can be. Compactibility test measures the decrease in height of a riddled mass of sand under the influence of standard compacting force. The compactibility ranged from 90 for 10% to 83.1 for 30% bentonite clay. It ranges from 88.4 for 10% to 76.1 for 30% cassava starch. It was observed that as the percentage binder increase, compatibility decreases, which will, in turn, reduce the suitability of the core sand for foundry operations.

Moisture content

Figure 4.4 shows the moisture content of a core, which determines the amount of dampness of the mold sample. The moisture content range from 6.2 for 10% to 4 for 30% bentonite. It ranges from 8.1 for 10% to 4 for 30% cassava starch. It was observed that as the percentage binder increases, moisture content decreases.

Shatter index

Figure 4.5 shows the shatter index of a core. This measures the collapsibility of a core for an easy shake-out or knock-out after casting.

The shatter index range from 28.7 for 10% to 65.3 for 30% bentonite clay. It ranges from 33.3 for 10% to 20.2 for 30% cassava starch. It was observed that as the percentage binder increase for bentonite, the shatter index increase initially before decreasing which causes many pores in the core which will allow gas to pass through. And it was also observed that as the percentage binder increase for cassava starch, the shatter index increase before decreasing which causes less pore in the core which will allow gas to pass through. This might be associated with the fact that as the percentage binder increases; the grains of the sand get closer to each other, hence making the core more difficult to collapse for an easy shake-out.

Graphical Plots Of The Core Sand Analysis With Varying Binders Type Addition

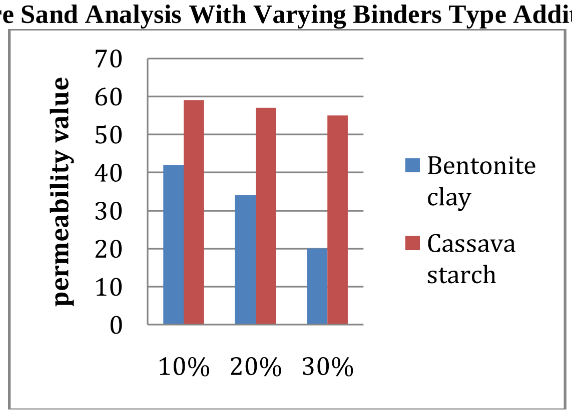

Figure 4.1: Permeability property of foundry core sand with varying percentage of bentonite, cassava starch with 6% water content.

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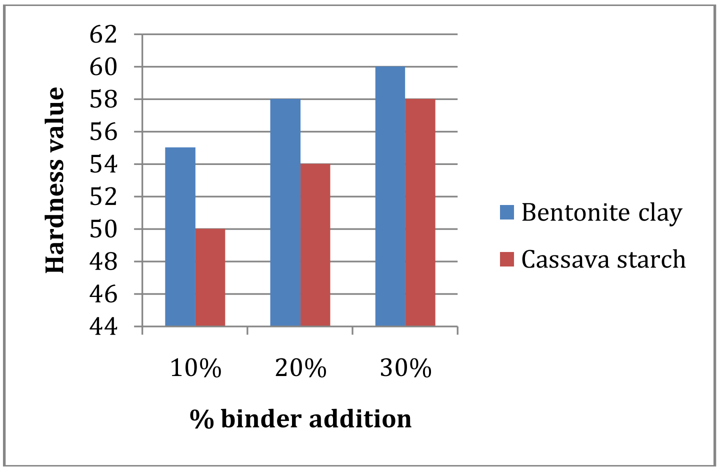

Figure 4.2: Hardness property of foundry core sand with varying percentage of bentonite, cassava starch with 6% water content.

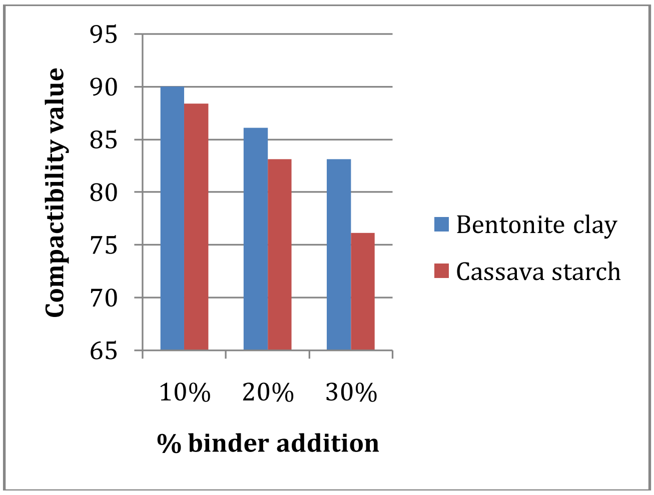

Figure 4.3: Compactibility value of foundry core sand with varying percentage of bentonite, cassava starch with 6% water content.

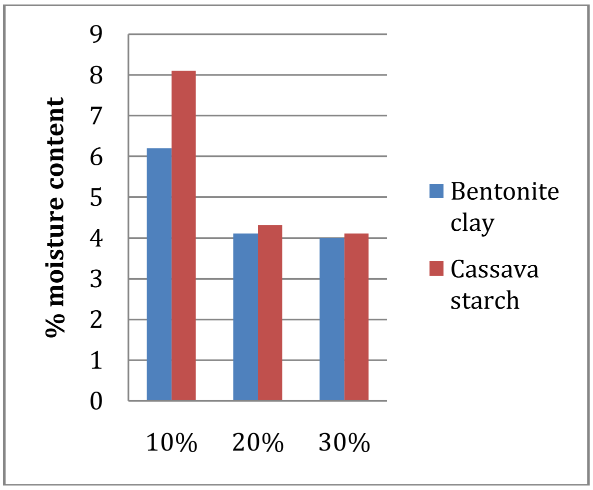

Figure 4.4: Percentage moisture content of foundry core sand with varying percentage of bentonite, cassava starch with 6% water content.

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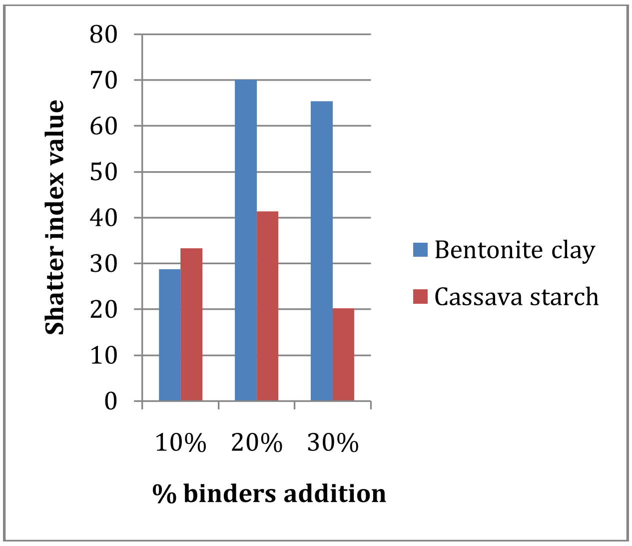

Figure 4.5: Shatter index value of foundry core sand with varying percentage of bentonite, cassava starch with 6% water content.

V. CONCLUSION

The suitability of using cassava (Manihot esculenta) starch as a binder for the production of core in foundry application was evaluated, and the following results were obtained:

a. The research has clearly shown that using the appropriate foundry sand good quality core can be successfully produced using cassava starch alone.

b. With the closeness of cassava starch to bentonite in varying proportions, cassava starch can be used as a replacement for bentonite.

c. From the result obtain from this research work, it was also concluded that the properties of these cores made them suitable for the application in the production of nonferrous casting.

d. Cassava starch bounded sand core produced from 10 - 30% starch and 6% water resulted in core with the necessary minimum properties.

e. Cassava starch bounded cores with optimum properties were produced from a mixture containing 10% starch and 6% water content.

f. From the result obtained, it was concluded that cassava starch is suitable for making foundry core.

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