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SYNERGISTIC EFFECTS OF STARCH AND RUBBER-LATEX AS CORE BINDERS FOR FOUNDRY SAND CORES PRODUCTION

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ABSTRACT: *Foundry technology is developing in Nigeria and other developing countries in the world; therefore, there are high demands for raw materials. New materials continue to be developed to meet special requirements which require special processing in order for their properties to be effectively utilized. High cost of imported binders has generated great interest in characterizing the locally available materials, therefore necessitating the need to look into domestically available binders that will meet the criteria for manufacturing, that is, reliability, cost, toxicity and availability; these are rationale behind this work. In this study, efforts were made to produce inexpensive and efficient binders from locally sourced materials (starch, and rubber latex) in Nigeria for the use of foundry cores. This was carried out by blending the locally sourced materials: starch-rubber latex (1:2) with silica sand, and water in different proportions while bentonite was used as control. Binders from various blend compositions were used to make core samples, and each core sample produced was subjected to the following mechanical tests: green compressive strength, dry compressive strength, collapsibility, and surface hardness. The blending caused great improvement in the mechanical properties of the core samples produced. The dry compressive strength values for all the core samples produced were greater than the corresponding green compressive strength values. The collapsibility decreased with increasing proportions of blended binders while the surface hardness values for starch-rubber latex binder cores were higher than for the core samples from bentonite binder.*

KEYWORDS: *Foundry, Cores, Binders, mechanical tests, Starch and Rubber-latex*

INTRODUCTION

Foundry is the mother of all industries for the reason that it provides components and raw materials for all other industries. This presupposes that there will be no true industrialization without a solid based foundry industry which is what Nigeria and other developing countries were experiencing.

Foundry as a manufacturing process through liquid route relies on the imported raw materials which are basically expensive. The current standard in Nigeria and other developing countries of the world have a very little advancement due to lack of affordable local sand binders, hence, the room for improvement.

Core binders in the next 5-10 years will be different from those in use now. The driving force of those changes will be environmental regulations, as binders will have to become more environment-friendly to meet the demands of lower air pollutant emission levels while maintaining or exceeding the productivity demands of a competitive global marketplace. Two major types of binders are used in core making practice: resin-based organic binder sand inorganic binders such as sodium silicate [Awopegba, 2002].

Sand cores are commonly employed, in foundry practice, to form complicated cavities in castings. Apart from being handled as separate entity in dry state during mould assembling, delicate and often complex sand cores are subjected to high stress during pouring due to hydrostatic pressure exerted by the molten metal.

Therefore, cores must be able to sustain the hydrostatic pressure of the liquid metal without breakage or change in geometric configuration. This implies that possession of sufficient strength in dry state after baking or curing is very important. In addition, cores are also expected to break easily (collapsibility) during shake out in order to release sand mass out of the inner and hidden cavities of solidified casting. Fumes and gases evolved during pouring must again be easily conveyed out via the core through the mould to avoid the formation of gas cavities in the casting. However, it is difficult to obtain natural sand that possess these properties, thus, sand cores are synthetically prepared by the combination of many ingredients such as sand grains, core binders and special additives (Olakanmi and Arome, 2009).

Meanwhile, binders were developed to strengthen the cores, which are the most fragile part **of** *a mold assembly. Clay binders are cheap, facile and convenient for core-making, but, they are rarely used because of their low bonding strength and poor permeability. Synthetic resins have high strength and good moisture resistance but their high cost, high gas forming capacity and non-recycling feature restrict their widespread applications in foundry practice. Rubber latex cores belong to the organic category (Olakanmi and Arome, 2009). Therefore, an efficient core binder, sourced locally in a developing economy such as Nigeria, represents a major advancement in obtaining sand cores of desirable performance and high strength in reducing the cost of production of castings. Core oils, synthetic resin, clays and cereal binders had been identified by Gilson (1993), Beeley (2001) and Jain (2003), as widely used core binders.*

Various researchers have worked on some of those materials. Among them are Ademoh (2009) that studied the establishment of the beneficial effects of addition of linseed oil to foundry sand cores bonded with Nigerian gum Arabic grades 2 and 4. Characterization of the core-binding properties of fatty - based oils was studied by Olakanmi and Arome (2009;) and Shehu and Bhatti (2012) investigated the use of yam flour (starch) as binder for sand mould production in Nigeria.

This research work centered primarily on the production of core binders starch and rubber latex characterized with a view to finding alternatives to the imported foundry core binders that deplete Nigeria's foreign exchanges for the production of foundry cores, from locally sourced materials, which could be used as substitutes for the imported binders such as bentonite and resin. The work mainly concentrates on two materials: starch and rubber latex, all of which are sourced locally. Starch was obtained from cassava tubers in a cassava plantation at Ikire (7.35N and 4.183E) in Irewole local Government Area of Osun State Nigeria and rubber latex from the Horticulture Department of the Federal College of Agriculture (7.25N and 5.195E), Akure, Ondo State Nigeria.

MATERIALS AND METHODS

Materials: The materials used are silica sand (which was obtained along the River band of Owena in Owode-Owena (Igbaraoke) (7° 24" 0"N and 5° 3" 0"E), Ondo State, Nigeria), Cassava tuber that produced hydrolyzed starch from Ikire in Irewole local Government, Osun State, Nigeria, standard specimen moulding box, rubber-latex, bentonite, wooden core box, water, ammonium hydroxide, rammers and distil water.

Equipment:

A standard foundry equipment –Laboratory shatter index testing machine (CCRB), weighing machine, batch type oven, pH meter, universal sand-strength testing machine, (tensiometer), cylinder core box, measuring cylinder and beakers, set of sieves, shaking tables, automatic vibrating sieve machine, and hardness tester, mechanical rammer, moisture tester, permeability machine, BSS set of sieves and shatter index tester in the foundry shop of Nigeria was employed to measure the most relevant properties (green/dry compressive strengths, shatter index, moisture content, collapsibility and permeability) of foundry sand.

Methods - Sample Preparation:

The binders were weighed and blended together in this order (starch-rubber latex) and they were mixed with quantities of silica sand, water and binders in different proportions.

Five compositions were prepared from the binders using bentonite (as control) and starch-rubber latex. The total number of prepared compositions from the binders was twenty (20). Thirty-five core samples each were made from the two different binders with varied sand, water and binder compositions as shown in Table 1.

The prepared core samples were dried by spreading in the sun for three days. Thereafter, each sample was subjected to mechanical tests. Dry compressive strength, green compressive strength, and surface hardness tests were all carried out on the samples before they were oven-dried while the other tests were carried out after oven-drying in a batch-type oven set at temperature of 120 to 150°C for 3 hours in conformity with destructive tests approach. The core samples were prepared in accordance with Onyemaobi (1998). Altogether, 210 samples were oven dried while green compressive strength test was simultaneously carried out on the remaining 35 samples being allowed to stay for 18 hours.

A total of seventy (70) samples were made altogether for this research as seven samples were obtained from every composition using two different binders.

Table 1: Types of cores using blended binders and their compositions

Types of Core	Compositions		
	%Sand	%Water	%Binder
Bentonite-Bonded Core	93.86	4.10	2.04
	92.96	4.08	2.96
	92.07	1.39	6.54
	94.45	1.22	7.33
	90.79	0.51	8.70
Types of Core	**Compositions**		
	%Sand	%Water	%Binder (Starch + Rubber) 1:2 ratio
Starch-Rubber Latex(S+R) Core	93.86	4.10	2.04
	92.96	4.08	2.96
	92.07	1.39	6.54
	94.45	1.22	7.33
	90.79	0.51	8.70

The weights of the samples from each composition were taken using a weighing machine. Six samples from each composition were carefully arranged into the oven cabinet and placed in the batch-type oven which was set at a temperature of 120 to 150°C, and heating was continued for 3 hours.

Particles Size Analysis:

The dried known quantity 50 gm of Owena river silica sand grains free of clay was used to determine the fineness number, using a set of standard testing sieves. The BSS No. of 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 were used. The sand was placed on the coarsest sieve at the top and after 20 minutes of vibration, which is the recommended shaking time to achieve complete classification of the sand, the weight of the sand retained on each sieve was obtained and converted to a percentage equivalent. Each percentage was multiplied by a factor and the fineness number was obtained by adding all the resulting products, dividing the total by the percentage of sand retained and grain fineness number (BSS) were computed according to equations [1, 2].

$$Average\_grain\_fineness = \frac{Total\_products}{\%retained} \quad (1)$$

$$Average\_grain\_fineness = \frac{4433.8}{98.52} = 45 \quad (2)$$

(Sheu & Bhaiti, 2012)

The purpose of the analysis is to determine the distribution of grain sizes within the sand. Sands used in foundry have a wide range (40-220) of fineness number. Higher numbers represent fine sands generally used for light castings, coarse-grained sands with lower fineness numbers are used in steel castings (Eze, et al, 1993) (Ayoola, 2012) .

Moisture Content Determination:

The moisture contents were determined using a speedy moisture tester. A sample of each mixture was weighed on the weighing balance of the tester and poured into the flask of the moisture tester. The flask was shaken for the recommended 3 minutes and percentage moisture content of the sample was read directly from the calibrated dial instrument at the top of the flask attached to the machine.

Green/Dry Compressive Strengths Determination:

The green compressive strength test was carried out to assess the bond strength of the green sand core. Green compressive strength test was performed immediately after the specimen was stripped from the tube to prevent any increase in green strength due to air drying with increase in exposure time (Heine, et al, 1977). The silica sand of fineness number of 45, according to the British standard, was used to produce core test specimens with different percentages of mixtures of cassava (starch) and rubber latex as the binders.

160 g sand was poured into the standard cylindrical test tube with diameter of 50 mm and length 50 mm, rammed by impact with three blows of 6.50 kg weight. By manually turning ramming device, the weight was dropped from a height of 50 mm and the test-piece was stripped from the tube. Stead increase in load was applied on the specimen under the universal sand-strength testing machine until failure occurred and the load at which the sample collapsed was recorded. Each of the five samples was subjected to gradual load on the machine in the foundry workshop of Federal Polytechnic Idah Kogi State, Nigeria. Same procedure was used (that is, as in green compressive strength test) in preparing test samples for dry compressive strength, but in this case samples were sun-dried for two days before the tests (Sheu and Bhaitti, 2012).

Shatter Index Determination:

The shatter index test was performed with the shatter index tester. The test sample was prepared without stripping. The sand test-piece was positioned at the top of a tower 1.83 m high and ejected from a specimen tube by gently pulling down the handle onto a steel anvil head 75 mm in diameter. On impact, the test-piece shatters, some of the sand from the sand core remaining on the anvil and the rest was been projected on to 12.5 μm mesh B.S.sieve. The sand which passes through the sieve into the sieve pan was weighed and the shatter index was computed. Shatter index values ware used to determine the collapsibility of the moulding sand core (Loto, 1990).

Permeability Determination:

Permeability was determined by measuring the rate of flow of air through a standard rammed test-piece. Standard air pressure of 9.8×10^2 N/m^2 was passed through the specimen tube that contained green sand placed in parameter of the permeability meter and time for 2000cm^3 of air was recorded to determine permeability in numbers (Schey, 1997). Direct-reading instrument was used in determining the permeability by increasing percentages of cassava (starch) and rubber-latex content.

RESULTS AND DISCUSSION

The results for the five tests carried out on the entire core samples from the locally sourced blended binders and the imported binder (bentonite) used as control are shown in Figures 1, 2, 3 and 4.

Green Compressive Strength:

The green compressive strength result obtained for each of the samples is shown in Figure 1. The green compressive strength value increased as the quantity of binder in the core mixture increased. Starch-rubber latex cores were observed to have the highest green compressive strength. For instance, cores with starch-rubber latex 8.70 g composition have green compressive strength value of 72.0 N. This was due to the relatively large quantity of rubber latex (twice that of starch) which when exposed to the atmosphere coagulates to form a tough and sticky mass (Morrison, 1987). Cores using bentonite as binder, with the same binder composition of 8.70 g, gave a compressive strength of 38.0 N

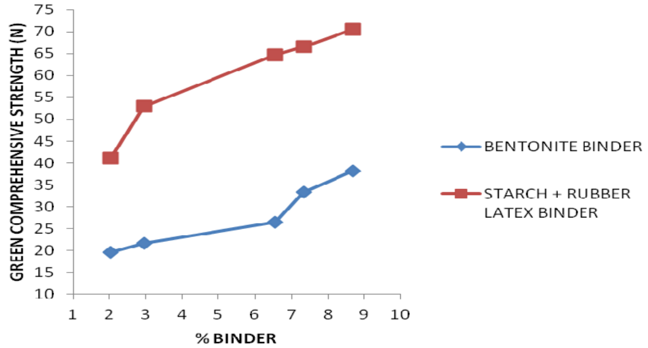

Figure 1: Variation of Green Comprehensive Strength (N) with % Binder in Produced Cores

Dry Compressive Strength Test:

The dry compressive strength for each core samples was observed to increase as the quantity of the binders in the core mixture increased (Figure 2).

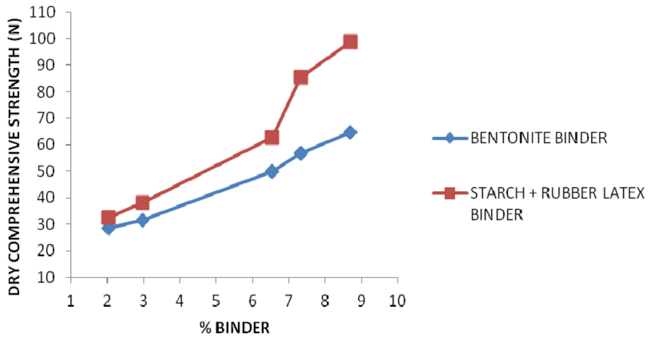

Figure 2: Variation of Dry Comprehensive Strength (N) with % Binder in Produced Cores

The starch-rubber latex cores were observed to have higher dry compressive strength at all binder compositions than all the other cores made from other binder (bentonite). Also the deviation from bentonite-bonded cores was observed to be critically high at all binder compositions. Cores from binder mixtures of composition 8.7 g (that is, 2.90 g starch and 5.80 g rubber latex) had dry compressive strength of 102N while bentonite bonded cores had dry compressive strength of 65 N. The reason for this was the fact that starch and rubber latex were extremely hardened when oven-dried (baked) coupled with the fact that rubber latex is characteristically gummy (Premamony Ghosh, 1990), which made the cores produced from it not to disintegrate easily when subjected to compressive forces.

Collapsibility Test:

The result shows that starch-rubber latex core samples have a collapsibility of 4.0x10^3 g for binders of composition 2.87 g. While higher collapsibility was obtained from cores with a composition above 2.87 g. At a relatively high binder composition for the core mixture, starch-rubber latex core samples collapsed relatively well on application of weights. This was due to the high proportion of starch present in the core samples which by its nature was syrupy and when used solely as binder for the production of cores gave crack-bonded cores that are easily collapsed on application of loads. This confirms that starch aids collapsibility (Mikhailor, 1989).

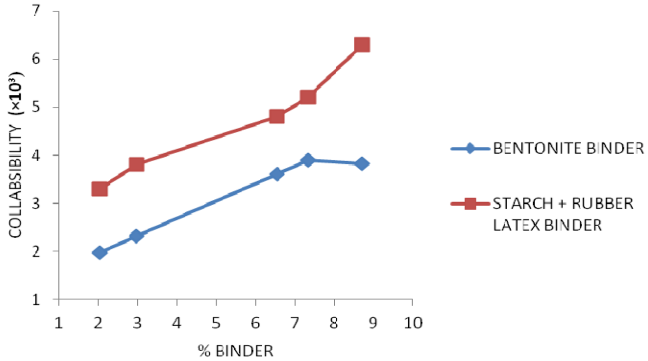

Figure 3: Variation of Dry Collapsibility with % Binder in Produced Cores

Bentonite-bonded core samples have superior collapsibility properties (Figure 3). This shows that relatively low weights were required to disintegrate a given bentonite-bonded core samples. For instance, at binder composition of 3.5 g, the bentonite-bonded core samples required 2.71 x 10^3 g load to collapse while the starch-rubber latex core samples required 4.4 x 10^3 g load to collapse. Although the deviations from the ideal were critical in all the cases considered.

Surface Hardness Test:

Starch-rubber latex-molasses core samples have the same surface hardness value (Figure 4).

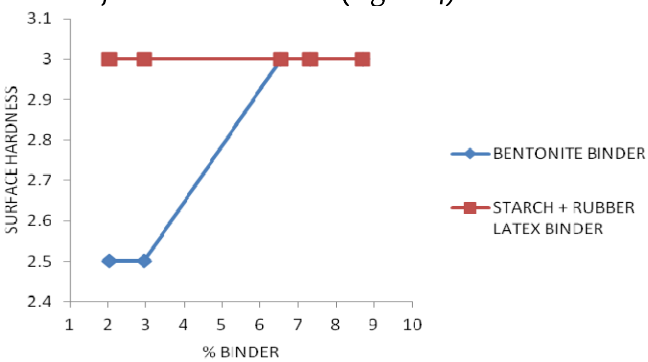

Figure 4: Variation of Surface Hardness with % Binder in Produced Cores

This result trend was due to the presence of rubber latex, in the binder composition, which is a gummy mass that gets toughened when baked (Stanley, 1987). Above this composition, the surface hardness of bentonite-bonded core samples increased up to a binder composition of 6.25g at which point it was observed that the surface was as hard as that of starch-rubber latex

CONCLUSIONS

The following conclusions were drawn from the research results:

a) Compressive Strength

Green compressive strength values for all the cores produced from all the blended blenders increased as the quality of binder in the core mixture is increased. The cores produced from starch-rubber latex binder mixture have the highest green compressive strength values. The dry compressive strength values for starch-rubber latex cores deviate far from bentonite cores.

b) Surface Hardness

Starch-rubber latex cores had greater surface hardness values than bentonite-bonded cores with composition below 6.5 g, while the surface hardness value was the same for the cores with 6.5g composition and above.

c) Collapsibility

For binders of 2.8 g composition, starch-rubber latex had collapsibility of 4.0x10^3 g. The choice of either of these binders at this composition should therefore be based on their relative availabilities and market costs.

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