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Full Length Research Paper

Foundry properties of sand cores bonded with composites of Nigerian grades 1 and 2 acacia species with bentonite clay

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The permeability, green compressive and tensile strength of foundry cores bonded with composite mixtures of bentonite clay with each of grades 1 and 2 Nigerian acacia exudates were determined. Silica sand grains were used as base for the specimens which in accordance with foundry standard were cylindrically shaped for green permeability and compressive strength but shaped like figure eight for tensile strength test. A standard permeability meter and a shatter machine were used to test air permeability and collapsibility of cores. A standard universal strength machine was used to test the compressive and tensile strength of core specimens. The tensile strength specimens were baked at 200°C for 1 - 3 h and then oven cooled before test. The result showed that bentonite clay addition to acacia bonded cores had beneficial effects on only permeability of cores. It caused an average in permeability by 62 and 8% for grades 1 and 2 acacia bonded cores respectively. Averagely it depressed green compressive strength by 10%, tensile strength by 2 - 4% and shatter index by 6%. This means that when grades 1 and 2 acacia species is used as main binders for sand cores for casting alloys that require high permeability like iron and steel casting of intricate shapes bentonite clay addition will serve without wide adversity on other important core properties.

Key words: Foundry, cores, bentonute clay, acacia exudates.

INTRODUCTION

Acacia species exudates are natural resins that contain arabin; a semi solidified sticky fluid that oozes from incisions made on the bark of acacia trees (Encyclopedia, Britannica, 1989). 5% of some acacia exudates had been added to 10% sugar and some protein derived from gelatinous mix of amino acid and used to bind foundry sand cores in United States of America (Siak et al., 1994). In United Kingdom, it is used in hot box core process. It was combined with sugar, urea formaldehyde resin and boric acid to bind cores (Eric, 1965). These core practices used multi stage processes that applied corrosive chemicals which is why this research is designed to use naturally available materials with simple processes that can easily be adopted by foundries in developing countries.

In previous research experiments with plain Nigerian grades 1 and 2 acacia species exudates the material was found suitable for binding foundry sand moulds for non-ferrous and iron casting (Ademoh and Abdullahi, 2008). The plain material was used as binder in production of expendable foundry sand cores oven baked at 180 - 220°C for 1 - 3 h (Ademoh and Abdullahi, 2008). It proved suitable for different casting. Based on these previous studies, it is believed that combining acacia species with a conventional binder like bentonite clay would give higher quality cores for better foundry production economics. The main objectives of this paper is to mix each of grades 1 and 2 Nigerian acacia species exudates with refined bentonite clay, use the composites to bind core specimens and analyse specimens for foundry mechaniccal properties including permeability, green compressive and tensile strength; the accepted standard values of which are as presented in table 1 (Titov and Stepanov, 1982). The significance of this study is that developing foundries would be availed with good core binders made from pure organic and mineral materials.

EXPERIMENTS

Silica sand with 0.3% clay was used as base to produce test specimens. The sand was oven dried at 110°C to remove free water,

Figure 1. Samples of green compressive strength and permeability test specimens.

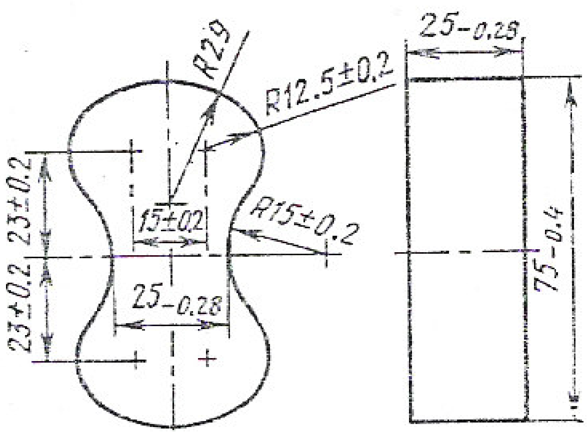

Figure 2. Configuration of the tensile strength specimens (dimensions are in millimetres).

weighed and vibrated with a mechanical sieve for 30 min for to obtain grains that corresponded with BS standard size 40 - 72 mesh (Titov and Stepanov, 1982). The acacia exudates were milled to the small particle size and added to measured bentonite clay as the composite binder for the cores. The core mix was mixed in a roller mill for about 10 min and then moulded into test specimens. The green compressive strength, shatter index and permeability test specimens were cylindrical in shape, each measured 50 mm in diameter, 50 mm in height and weighed 130 g after compacting with three blows each of 6.5 Kg from a height of 50 mm (American Foundry Men Society, 1989). Some samples of the test specimens as obtained from the standard rammer before the tests are as shown in Figure 1.

The tensile strength specimens were shaped like figure eight as in Figure 2. They were moulded in a split core box and rammed with three blows each weighing 6.5 Kg from a height of 50 mm. After oven baking specimens at 200°C for 1 - 3 h, they were oven cooled and tested with a universal strength machine equipped with attachment for gripping cores as shaped and a meter that read the instantaneous strength (American Foundry Men Society, 1989). A steadily increasing force in compression or tension was applied on either the compressive or tensile strength specimen by the universal strength machine until failure occurred and the strength was read. For permeability, a standard air pressure of 9.8×10^2 N/m^2 was passed through specimen in sample tube placed in the meter and after 2000 cm^3 of air had passed through, the permeability (in number) was read. A shatter specimen placed in the container of the shatter machine was pushed upwards over stripping post until it struck anvil, fell and shattered. The retained and over size sand was measured and used to compute shatter index.

RESULTS

Figure 3 presents result of green compressive strength test; Figure 4 presents that of permeability and shatter test. Figure 5 - 6 present the result of tensile strength test of specimens baked at 200°C for 1 - 3 h. The values are instantaneous readings obtained from meters of the test equipment.

DISCUSSION

Compressive strength varied from 44 KN/m^2 for sand cores bonded with 3% grade 1 acacia mixed with 0.5% bentonite clay to 54 KN/m^2 for those bonded with 3% grade 1 acacia mixed with 3% bentonite. The strength of the composite of grade 2 acacia species with similar bentonite content varied from 30 - 38 KN/m^2 respectively. This shows grade 1 acacia species composite with bentonite clay gave stronger bond than grade 2 acacia species composite with bentonite clay. A comparison of the result with table 1 shows that 3% grade 1 Nigerian acacia per 0.5 - 3%bentonite composite binder is suitable for cores for sand casting all metal alloys except magnesium alloys. Similar composites made with grade 2 acacia species composite with bentonite clay are suitable for the applications though at lower green compressive strengths.

In previous works, plain acacia species grade 1 gave green compressive strengths of 58 and 62 KN/m^2 while plain acacia grade 2 gave strength of 37 and 40 KN/m^2 at 4.5 and 6.0% binder content respectively (Ademoh and Abdullahi, 2008). In this study, grade 1 acacia species composite with bentonite clay gave green compressive strengths of 48 and 54 KN/m^2 while acacia grade 2 acacia species composite with bentonite clay gave strengths of 34 and 38 KN/m^2 at 4.5 and 6.0% binder content respectively. A comparison of these two results shows that the green compressive strength of grade 1 acacia bonded cores was decreased by addition of bentonite clay by about 20 and 14% while that of grade 2 acacia bonded cores was decreased by about 9 and 3% at 4.5 and 6.0% binder content respectively. Thus increase in clay reduced the depression of strength.

Permeability for grade 1 acacia species composite with bentonite clay varied from 201-215 No while that of grade 2 acacia species composite with bentonite clay varied from 176 - 189 No at 3% acacia species per 0.5% bentonite to 3% acacia species per 3% bentonite clay. It showed that the addition of bentonite clay improved the permeability of acacia species bonded cores due to the creation of additional porosities by bentonite clay particles in mix. The permeability values when compared with the standard in Table 1 show that they are 200°C are

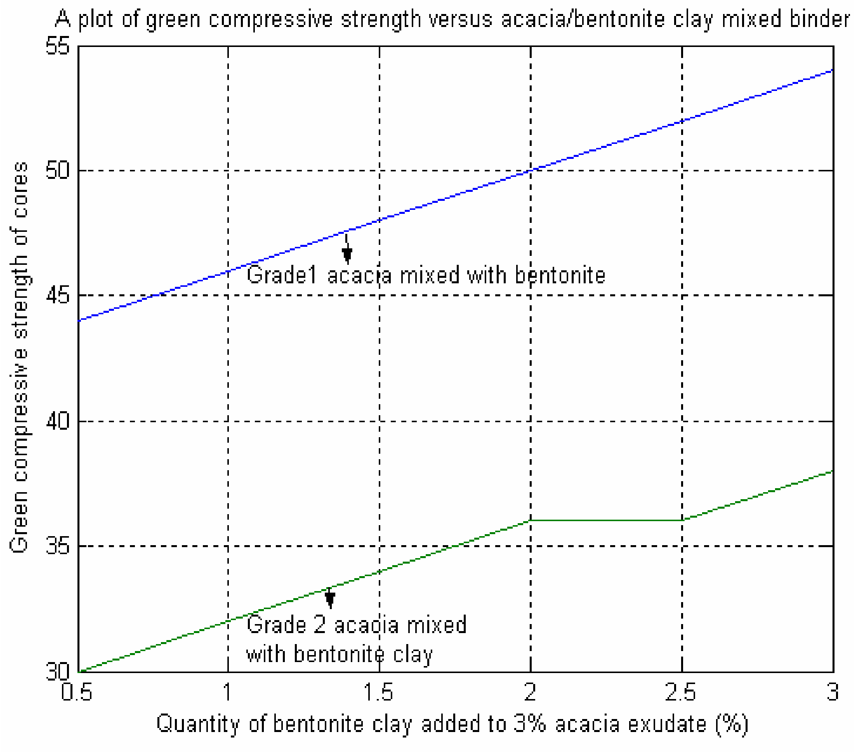

Figure 3. Compressive strength (KN/m^2) of cores bonded with composites of bentonite and acacia exudates.

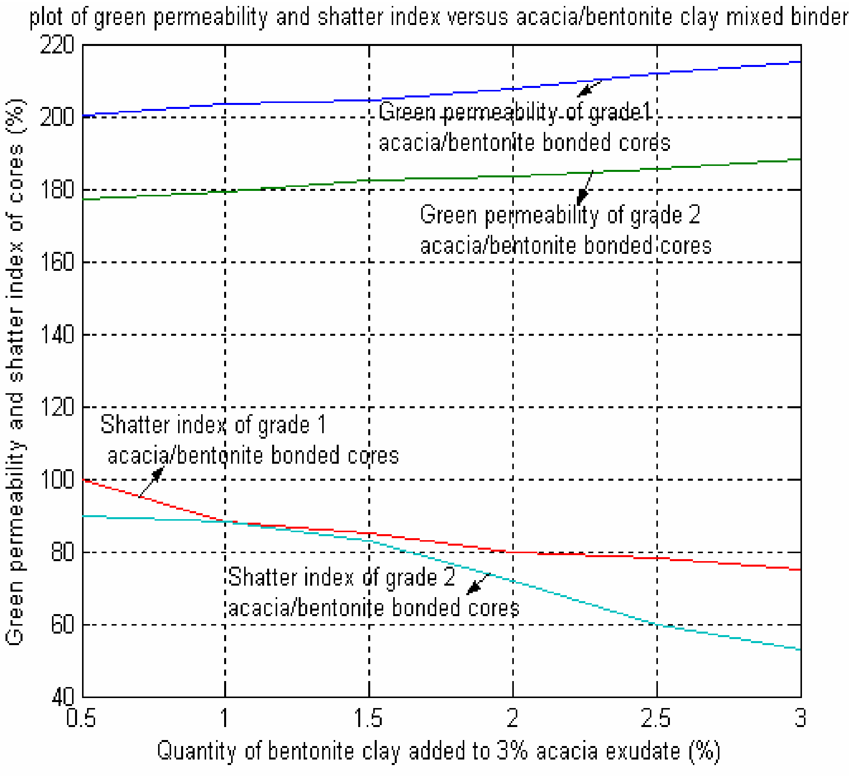

Figure 4. Green permeability and shatter index (No) of cores bonded with composite of bentonite and acacia.

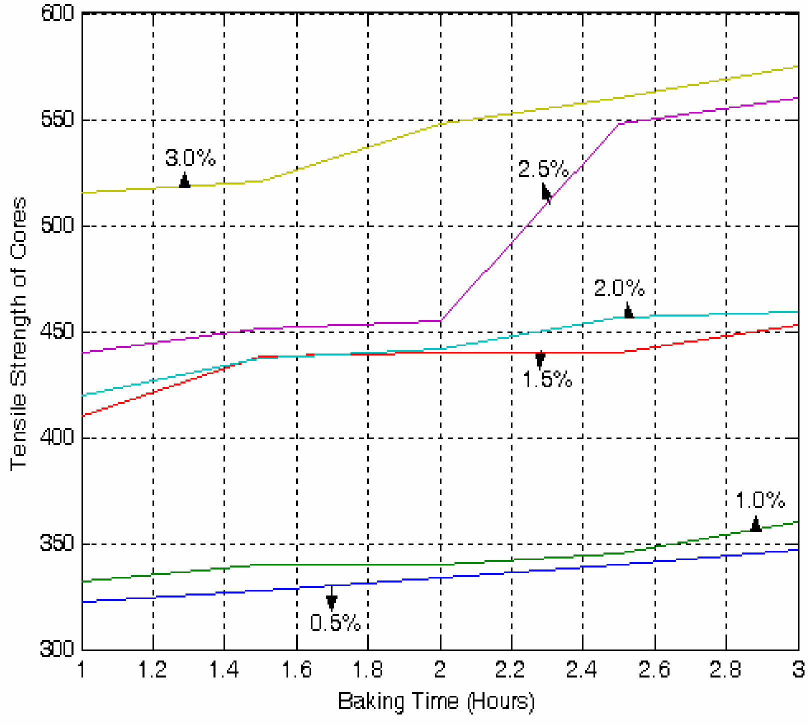

Figure 5. Tensile strength values (KN/m^2) of cores bonded with varied amounts of bentonite clay content and 3% grade 1 gum Arabic baked at 200℃ for varying periods in hours.

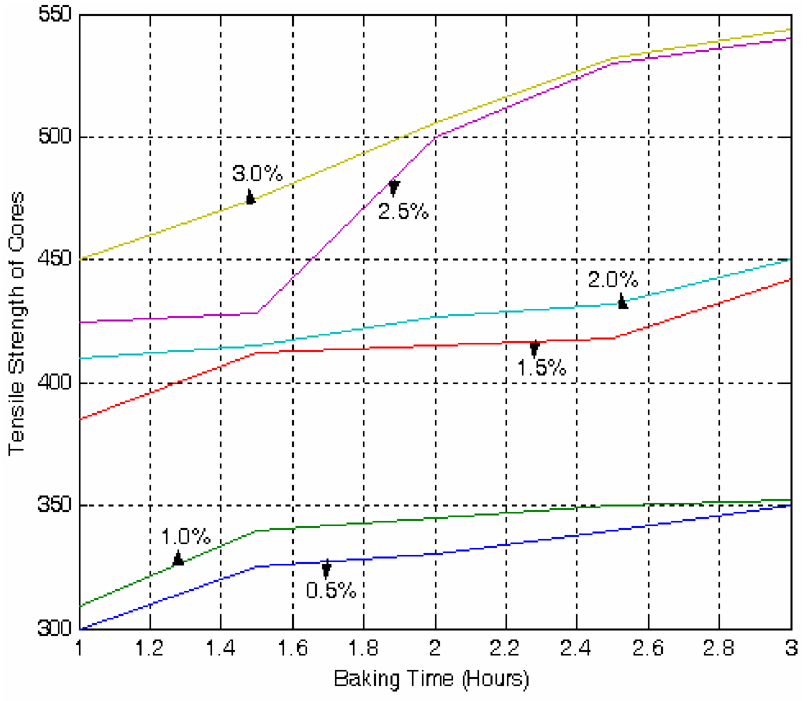

Figure 6. Tensile strength values (KN/m^2) of cores bonded with varied amounts of bentonite clay content and 3% grade 2 gum Arabic baked at 200℃ for varying periods in hours.

Table 1. Accepted mechanical property ranges of foundry sand cores.

Alloy casting	Permeability (No)	Strength (KN/m^2)	
		Green compression	Baked tensile
Class I iron/steel cores	130 - 150	3 - 6	700 - 1000
Class II iron/steel cores	100	5 - 10	500 - 700
Class III iron/steel cores	100	10 - 16	350 - 600
Class IV iron/steel cores	70	15 - 25	200 - 300
Class V iron/steel cores	70	20 - 35	80 - 150
Copper bronzes cores	90	3 - 5	400 - 600
Copper brasses cores	60	6 - 8	500 - 700
Intricate Aluminium cores	100	3 - 7	500 - 700
Non-intricate Aluminium cores	80	6 - 15	400 - 600
Magnesium cores	80	60 - 150	300 - 500

suitable for binding cores for all categories of alloy casting in sand mould. Shatter index varied from 100 - 75 No and 90 - 53 No for the grades 1 and 2 acacia species composites with bentonite clay. The values are also suitable for above castings.

Permeability for plain acacia species grade 1 bonded cores were 137 No and 125 No; that for plain acacia species grade 2 bonded cores were 176 No and 167 No at 4.5% and 6.0% binder contents respectively (Ademoh and Abdullahi, 2008). In this work permeability for cores bonded with grade 1 acacia composite with bentonite clay are 205 No and 215 No while those for cores bonded with acacia grade 2 acacia species composite with bentonite clay are 182No and 188No at 4.5% and 6.0% binder contents respectively. These show that green permeability of grade 1 acacia bonded cores was increased by addition of bentonite clay by about 50 and 75% while that of grade 2 acacia bonded cores was increased by about 3 and 13% at 4.5 and 6.0% binder content respecttively. Increase in clay correspondingly increases permeability of cores. The effect was higher with grade 1 acacia cores. Similarly, addition of bentomite clay to grades 1 and 2 Nigerian acacia species for core binding applications averagely caused reduction of shatter index by 10% and 2% respectively. The results of the tensile strength tests for the specimens baked at presented in figures 5 and 6 for cores bonded with composites of 3% of grades 1 and 2 acacia species per 0.5 - 3% bentonite clay. The result when compared with the standard in table 1 shows that foundry sand bonded with 3% grade 1 acacia/0.5% bentonite composite baked at 200℃ for 1 h is suitable for magnesium alloy, class IV - V iron and steel cores. Synthetic sands bonded with 3% grade 1 acacia species/1% bentonite clay composite baked at 200℃ for 3 h are suitable for class III iron and steel cores, that bonded with 3% grade 1 acacia species per 1.5 - 2.0% bentonite composite baked at 200℃ for 1 h is suitable for non-intricate aluminium, copper bronze and class III iron and steel cores while that bonded with 3% grade 1 acacia per 3.0% bentonite and baked at 200℃ for 1 h is suitable for aluminium, magnesium, copper alloys and class II iron/steel cores. A content of 2.5% bentonite clay seems to mark the point of the composite mix from which very strong bonds begin to form.

Similarly, sand bonded with 3% grade 2 acacia per 0.5 - 1.0% bentonite composite baked at 200℃ for 3 h is suitable for magnesium, class III, IV and V iron/steel cores, that bonded with 3% grade 2 acacia per 1.5 - 2.0% bentonite baked at 200℃ for 1.5 h are suitable for non-intricate aluminium, copper bronze and class III iron and steel cores while that bonded with 3% grade 2 acacia per 3.0% bentonite baked at 200℃ for 2 h is suitable for aluminium, magnesium, copper and class II iron/steel cores. Result for grade 1 acacia species/bentonite clay composite show better strength at shorter baking duration of about one hour than grade 2 acacia species composite with bentonite clay implying that grade 1 acacia species per bentonite clay composite is more economical in terms of heat energy cost than the grade 2 acacia per bentonite clay composite. When this result is compared with those obtained in previous works with plain grades 1 and 2 acacia species core binder under similar experimental conditions (Ademoh and Abdullahi, 2008); baked tensile strength of cores bonded with acacia species in composite with bentonite clay was decreased by 2 - 4% at 4.5 and 6.0% binder contents.

Conclusions

The research showed that bentonite clay addition to acacia bonded cores has beneficial effects on only permeability of cores. It reduced the shatter index, green compressive and tensile strength of cores bonded with plain acacia species exudates. This means that when acacia exudates are used as main binders for core sands bentonite clay addition will help to improve permeability to desired values without wide adversity on other important properties like in intricate iron and steel casting.

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