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Nigerian acacia species exudates and groundnut oil as mixed foundry sand core binder

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Abstract

This paper assesses the beneficial effects of addition of groundnut oil on tensile strength of foundry sand cores bonded with Nigerian acacia species exudates. Each of four known commercial grades of Nigerian acacia species was combined with groundnut (peanut) oil and used as mixed binder for sand cores. Tensile strength, the most critical of all foundry properties that make cores suitable for mould implants was investigated on sand core specimens bonded with combinations of peanut oil and acacia species to determine the property enhancement of peanut oil on such cores bonded with plain Nigerian acacia species. A standard universal strength testing machine was used to measure the tensile strength of specimens after oven baking at 200^{0}C for 1-3 hours and oven cooling them to room temperature. Specimens were shaped like figure number eight and were made with silica base sand obtained from bed of a river in Nigeria. Comparatively the result showed that mixed binder of groundnut oil and acacia species produced the highest tensile strength with grade 4 acacia followed by grade 1 acacia, grade 3 acacia and then grade 2 acacia in that order. The oil was only beneficial to cores bonded with less than 4% acacia species but depressed tensile strength of cores with higher acacia content. Groundnut oil addition generally depressed strength of acacia bonded core by 3-5%.

Key words: Groundnut oil, foundry cores, tensile strength

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1. Introduction

Plain Nigerian acacia species exudates were investigated as foundry sand core binders in a research series by Ademoh and Abdullahi [1-4]. The effects of vegetable oil including neem and linseed oil on cores bonded with acacia species investigated in other series of studies showed varied results on foundry properties of test core specimens [5-6]. This paper is aimed at investigating benefit of addition of groundnut (peanut) oil on tensile strength of acacia species bonded sand core. The objectives are to bind core specimens with each commercial grade of Nigerian acacia species admixed with peanut oil, test the oven baked specimens for tensile strength and compare result with past work to ascertain if peanut oil makes better combination with Nigerian acacia exudates than other vegetable oil used for cores. The significance of this study is that foundries would be provided with additional source of high quality core binder obtainable from combination of good attributes of two vegetable materials sourced cheaply from local markets. Moreover it will produce cores using simpler and less hazardous process of oven baking than the more complex use of corrosive organic binders mostly based around phenol formaldehyde resins [7].

Groundnut oil is one of the traditional drying oils used for core binding application [8]. Peanut oil (or groundnut oil) is an organic material oil derived from peanuts, noted to have the aroma and taste of its parent legume. Peanut oil has high smoke point relative to many other cooking oils. Its major component fatty acids are oleic acid (46.8% as olein), linoleic acid (33.4% as linolein), and palmitic acid (10.0% as palmitin). It contains some stearic acid, arachidic acid, arachidonic acid, behenic acid, lignoceric acid and other fatty acids [9]. None of these constituents of peanut oil and those of acacia exudates contain corrosive acids and volatile organic compounds whose thermal breakdown products give very foul, pungent odours and waste streams that are hazardous to human health. The none-baking type core binders provide exceptional performance with respect to process robustness, instantaneous hardening techniques like fast curing using gaseous and catalytic agents coupled with easy breakdown and removal of core sand after casting. They are however very toxic to humans and environmentally unfriendly unlike the clean mixed binder proposed in this research. The combined cost of materials and its baking is very insignificant when compared with high risks of sophisticated binders for developing foundries that do not even possess the required technologies to handle them. Tensile strength was considered as the determinant variable because it is the most critical of all core properties. Suitable cores (especially those bonded with organic resins) always possess adequate permeability and shatter index values as the high temperature baking before use drives off volatile matters from them and provide the needed porosity and collapsibility during and after casting.

2. Materials and methods

The baked tensile strength of standard core specimens was analysed using standard equipment in a foundry laboratory/workshop under normal environmental conditions in Nigeria. Tensile strength measured ability of cores to withstand thermal stresses generated within core cavity during casting. It is the most critical and vital of all desirable properties of foundry cores as it gives information on suitability of other salient properties of such a sand core and its binder [10].

***2.1. Experimental raw materials and equipment**:* The raw materials included domestic water; silica sand with 3% clay, 2 litres of groundnut oil and 5kg of each of grades 1, 2, 3 and 4 Nigerian acacia species pre-sorted and powdered to a BS sieve of size 30-50 mesh [11]. These were obtained from markets within Nigeria. Test equipment included standard sand mixer, rammer, electric baking oven and universal strength machine; all sourced from foundry workshop of a steel plant in Nigeria.

2.2. Test specimen preparation: Silica base sand collected from a river bed was washed, oven dried at 110^0C, classified with BS sieve and grain within particle size of 40-72 mesh was separated out for use. Varied quantities of grades 1, 2, 3 and 4 Nigerian acacia species, groundnut oil, treated silica sand and water were measured with digital scale and mixed thoroughly using roller mill for 10 minutes. The mixture was moulded into test specimens using set of split core box and classified for test. Each core specimen weighed 130g after compaction with three blows of 6.5Kg delivered by the sand rammer from a height of 50mm. Specimens were shaped like figure number eight as shown and dimensioned in figure 1. They were grouped, oven baked at 180^0C and 200^0C for 1-3 hours and oven cooled and stored in desiccators before the tests. The procedures were in accordance with the American Foundry Society standard [11] as adopted by Ademoh [6].

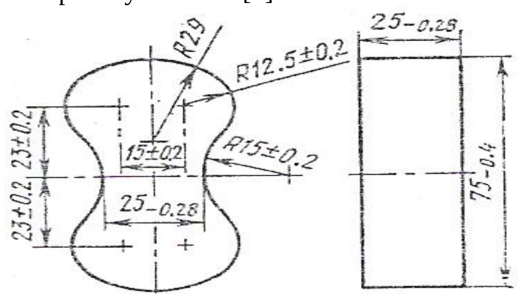

Fig. 1. Shape of core tensile strength test specimen (dimensions are in millimetres)

***2.3. Specimen Test*:** A standard universal strength machine with a meter to instantaneously read strength (in KN/m^2) with proper specimen gripping attachments was used to conduct baked tensile strength test [10]. During the test, each core specimen was gripped with attachments of the machine and a steadily increasing tensile force was applied on it by tension handle until failure just occurred and tensile strength was instantaneously read from the instrument gauge.

3. Results and Discussion

The experimental results are presented in figure 2 - 6. Figure 2 presents result of cores bonded with 3% grade 1 acacia species with 0.5 - 3% groundnut oil and baked at 180^0C for 1 - 3 hours. Figure 3 presents result of cores bonded with 3% grade 1 acacia species and 0.5 - 3% groundnut oil baked at 200^0C for 1 - 3hours. Figure 4 is that of cores bonded with 3% grade 2 acacia species and 0.5-3% groundnut oil baked at 200^0C for 1 - 3hours. Figure 5 is that for 3% grade 3 acacia species and 0.5-3% groundnut oil bonded core baked at 200^0C for 1 - 3hours. Figure 6 shows result of cores bonded with 3% grade 4 acacia species and 0.5-3% groundnut oil baked at 200^0C for 1 - 3hours. Figure 2 showed that tensile strength increased with increase in groundnut oil and baking period of 1-3 hours at 180^0C. Longer duration of baking enabled more sand and binder molecules to acquire higher reaction energy needed for stronger core bond. As groundnut oil content was increased from 0.5-3% more binder molecules became available to react with more sand for better binding. Tensile strength continuously increased without dropping as baking temperature was below melting point of acacia species grade 1 (about 210^0C) above which burning of molecules and weakening of strength could occur. Presence of silica sand and acacia exudates didn't allow direct heating of groundnut oil to vaporization point/flame point that could reduce its content and weakening of bond. The multiple chain hydrocarbons of acacia exudates didn't interact with or dissolve in fatty acids of groundnut oil to form chemical core binder as usual with vegetable oil [5]. Rather, the rich oxygen of silica sand separately reacted with diradicals of fatty acids in oil and multiple bonds of acacia exudates to bind the core mixture. The increased bond was possible from the multiple chemical reactions.

The result presented in figure 2 when compared with those of previous related work with neem oil [6] shows that 3% grade 1 acacia species mixed with 0.5% groundnut oil bonded cores baked at 180^0C for 1 hour though with lower (about 12%) tensile strength, is suitable for casting magnesium and class IV-V iron and steel alloy. Cores bonded with 3% grade 1 acacia exudates mixed with 2-3% groundnut oil baked at 180^0C for 1-3 hours are suitable for casting copper bronze, non-intricate aluminium, class III iron and steel alloys. Comparatively, addition of groundnut oil didn't cause any noticeable improvement in tensile strength over cores bonded with plain acacia exudates [1, 2, 3, and 4]. Non-reactivity of acacia exudates with vegetable oil caused this as each constituent of mixed binder displayed

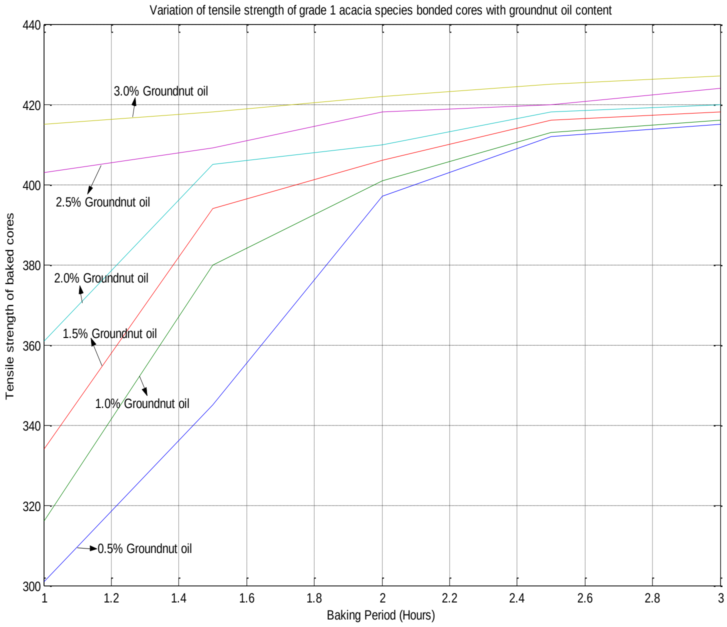

Fig. 2. Tensile strength (KN/m^2) of cores bonded with 3% grade 1 acacia species and varying groundnut oil content baked at 180^{o}C for varying periods (in hours)

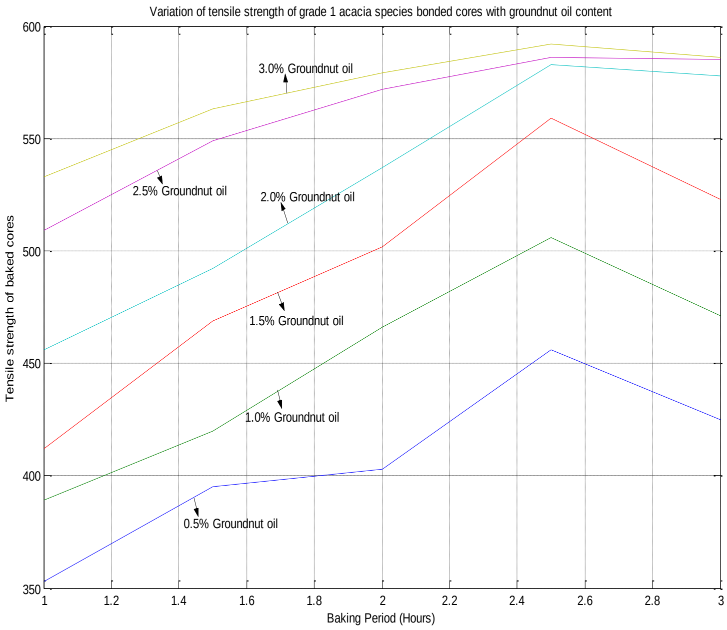

Fig. 3. Tensile strength (KN/m^2) of cores bonded with 3% grade 1 acacia species and varying groundnut oil content baked at 200^{o}C for varying periods (in hours)

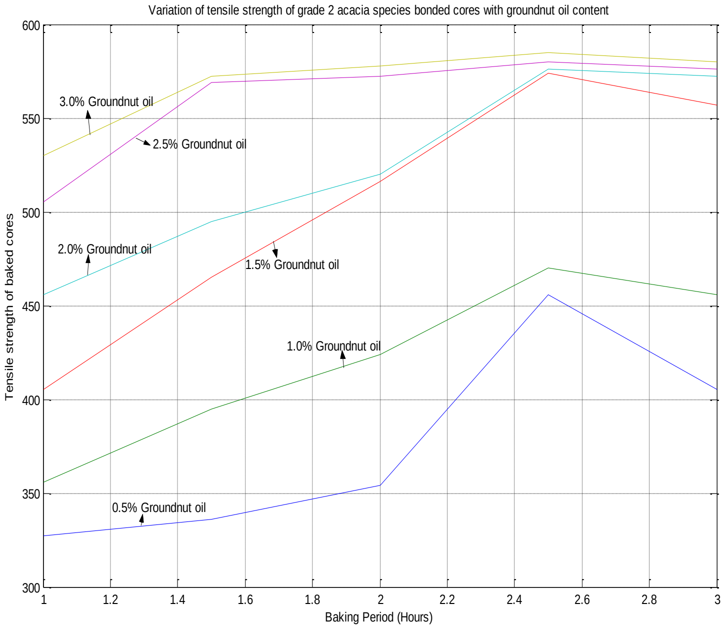

Fig. 4. Tensile strength (KN/m^2) of cores bonded with 3% grade 2 acacia species and varying groundnut oil content baked at 200^{o}C for varying periods (in hours)

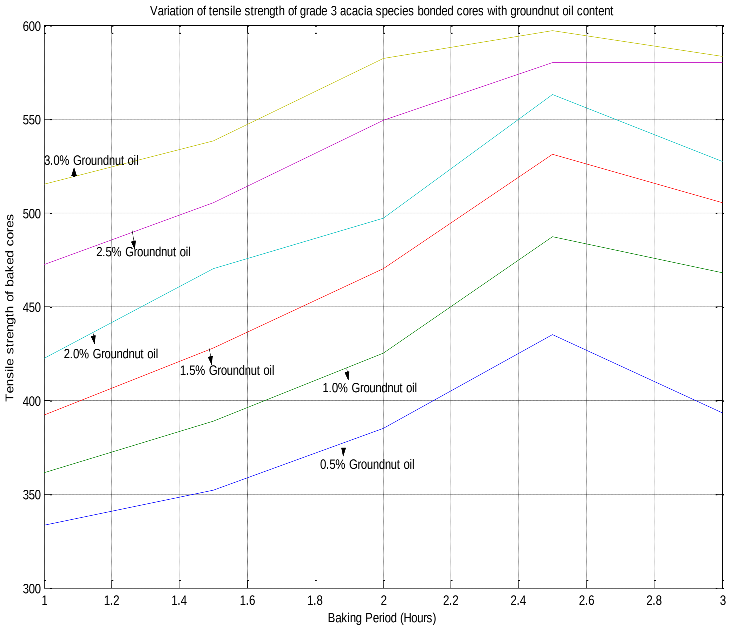

Fig. 5. Tensile strength (KN/m^2) of cores bonded with 3% grade 3 acacia species and varying groundnut oil content baked at 200^{o}C for varying periods (in hours)

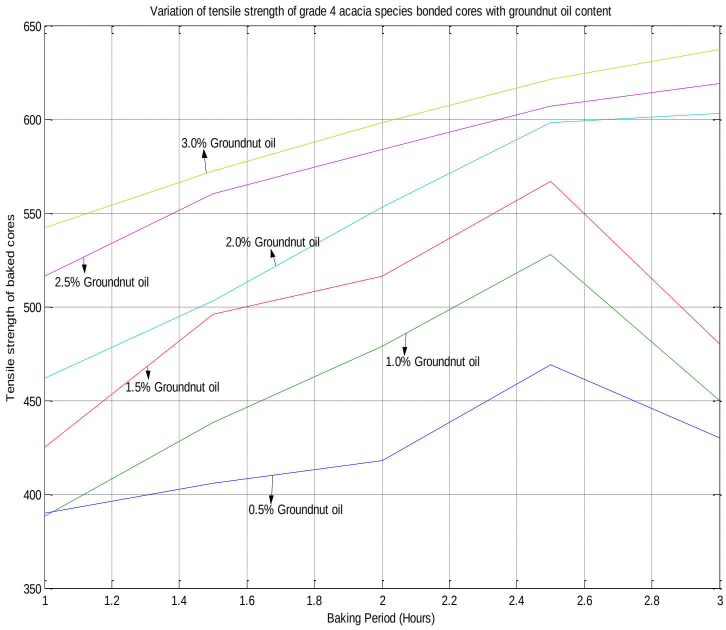

Fig. 6. Tensile strength (KN/m^2) of cores bonded with 3% grade 4 acacia species and varying groundnut oil content baked at 200°C for varying periods (in hours)

its individual bond reaction ability rather than form homogeneous chemical binder that could result to improved tensile strength. Moreover the acacia exudates were not molten at the baking temperature of 180°C to have provided the required fluidity for total bonding reaction. In figure 3 the cores baked at 200°C tensile strength increased with increasing groundnut oil content and baking period due to similar reasons as explained above. When the results are compared with those of cores bonded with composites of Nigeria acacia exudates with linseed and neem oils [5, 6]; sand bonded with 3% grade 1 acacia species and 0.5 - 1.0% groundnut oil baked at 200°C for 1hour is suitable for magnesium and class III-V iron and steel; those with 3% grade 1 acacia species and 1.0-1.5% groundnut oil baked for 1 hour are suitable for copper bronze and non-intricate aluminium casting. Cores bonded with mixture of 2.0-3.0% groundnut oil and 3% grade 1 acacia species baked at 200°C for 1-1½ hours is suitable for class II iron and steel. About 3-5% improvement over plain acacia species bonded cores was observed on cores with 1.0- 0.5% groundnut oil. Cores with higher groundnut oil showed no significant improvement in tensile strength as double bonded diradicals of fatty acids of oil reacted with sand to form peroxide, polyperoxides and hydroperoxides at lower oil content for stronger bond was overwhelmed by the multiple bonded dense polyscharides of acacia species at higher binder content. Figure 2 shows higher tensile strength than result presented in figure 3 due to the higher baking temperature that gave higher fluidity, reaction energy and faster kinetics.

Tensile strength increased with groundnut oil and baking time as shown in figure 4. Grade 2 acacia exudates melted at about 200°C. As class 3 binder it became fluid, very reactive and held sand into strongly bonded cores. However, holding core mix at 200°C for 2½ hours some of the molten acacia exudates began to deteriorate and tensile strength dropped thereafter. Preliminary vaporization of some groundnut oil also occurred due to excess heat. Drop in tensile strength was steeper in cores with lower groundnut oil content as observed in the figure because, loss of binder quickly led to sharp weakening of bond strength. The result showed lower tensile strength (4-6%) when compared with a previous work with neem oil [6]. It was observed that sand bonded with 3% grade 2 acacia species and 1% groundnut oil baked for 1-1½ hours is suitable for suitable for casting magnesium, class IV-V iron and steel alloys; that bonded 3% grade 2 acacia exudates and 1.5-2% groundnut oil baked for 1-1½ hours is suitable for casting copper bronzes, non-intricate aluminium, class III iron and steel alloy; and that bonded with 3% grade 2 acacia and 2.0-3.0% groundnut oil baked for 1-2 hours is suitable for casting of brass, intricate aluminium, class II iron and steel alloy. It showed no tangible improvement of tensile strength over plain the acacia species grade 2 bonded cores [2].

Tensile strength increased with increasing groundnut oil content and baking time in figures 5 and 6 for cores bonded with groundnut oil and grades 3 and 4 acacia species respectively. In both figures tensile strength of cores with 0.5-1.5% groundnut oil displayed sharp drop at 2½ hours of baking due to thermal deterioration of acacia exudates. This was caused by excess heat; as the core baking temperature (200°C) was about 100°C and 200°C above the melting point of the grades 3 and 4 acacia species respectively [12]. Vaporization of some groundnut oil in the mixed binder also contributed to the sharp drop in tensile strength. The effect was less in sand cores with 2-3% groundnut oil as the unsaturated fatty acids of the oil acquired heat energy that enabled the oxygen of sand to attack the double bonded diradicals to form more stable and strongly bonded polymerised molecules.

Results in figures 5 and 6 when compared with past work with cores bonded with Nigerian acacia species mixed with linseed and neem oils [5, 6] show that groundnut oil wasn't an effective additive binder with Nigerian acacia species as these two vegetable oils. Tensile strength was 3-

5% less than cores bonded with neem and linseed oil admixtures. Despite lower tensile strength, figure 5 shows that cores bonded with mixed binders made up of 3% grade 3 acacia species and 0.5% groundnut oil baked at 200°C for 1 hour are suitable for magnesium, class IV-V iron and steel castings; those with 3% grade 3 acacia species and 2-2.5% groundnut oil baked at 200°C for 1-2 hours are suitable for copper bronzes, non-intricate aluminium, class III iron and steel; and those bonded with 3% grade 3 acacia species and 3.5% groundnut oil baked for 1-3 hours are suitable for casting class II iron and steel; copper brass and intricate aluminium alloys. Figure 6 shows that a mixed binder of 3% acacia species grade 4 and 0.5% groundnut oil baked at 200°C for 1hour is suitable for magnesium, class III-V iron and steel; that with 3% Nigerian acacia species grade 4 and 1½-2% groundnut oil baked for 1hour is suitable for copper bronzes and non-intricate aluminium cores; and cores bonded with 3% acacia species exudates and 2½-3% groundnut oil are suitable for casting copper brass, intricate aluminium, class II iron and steel alloys. Comparatively, mixed binder of groundnut oil and acacia species produced the highest tensile strength with grade 4 acacia followed by grade 1 acacia, grade 3 acacia and then grade 2 acacia in that order. The groundnut oil addition generally depressed the tensile strength of acacia bonded cores by 3-5%. Thus it is less effective as additive than linseed and neem oil admixtures that increased bond strength by 7% and 12% respectively [5, 6].

4. Conclusions

Admixing groundnut oil with Nigerian acacia species exudates for core binding applications is only beneficial at low acacia species concentration of not more than 4%. Above this stated concentration a depression of tensile strength is caused due to interactions between sand and dense polysacharides of acacia exudates. Increase in tensile strength observed at low acacia species content of the mixed binder is dependent on baking temperature and time of cores. Holding cores at above melting point of acacia exudates for over two hours caused deterioration of the material and drastically reduced tensile strength. This phenomenon is a desirable property for easy core collapsibility after casting.

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