

Full Length Research Paper

Assessment of foundry properties of steel casting sand moulds bonded with the grade 4 Nigerian acacia species (gum arabic)

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Gum Arabic is a plant gum exuded from bark of some species of trees called acacia species. Nigeria produces four different grades of material. Nigeria, the second largest producer in the world has no registered commercial uses for it. This research investigated the viability of casting steel in sand moulds bonded with grade 4 Nigerian gum Arabic. Sand specimens bonded with the material were subjected to standard foundry property analyses that included green and dry compressive strength, hardness and permeability, shatter index and moisture content tests. The result when compared to standard showed that 4.5 - 8.0% binder content in powdered form is suitable for casting non-ferrous alloys, malleable and grey iron while 8 - 13% is suitable for light steel. In solution form it is suitable for non-ferrous alloy.

Key words: Steel casting, foundry properties, gum Arabic exudates.

INTRODUCTION

Nigeria produces four different grades of gum Arabic in commercial quantities that include grade 1 (acacia Senegal), grade 2 (acacia Seyal), grade 3 (combretum) and grade 4 (neutral) (Osagie, 2002). This paper is one of the series aimed at finding suitability of Nigerian acacia species (gum Arabic) for binding casting sands. The first paper in the series by Ademoh and Abdullahi (2008¹) showed it possessed the required physio-chemical properties for foundry application. Ademoh and Abdullahi (2008²) researched with grade 1 Nigerian gum Arabic exudates as foundry sand binders and found the material in powdered form with 2 - 3% moisture is suitable for non-ferrous, malleable, grey iron but unsuitable for steel casting. Grade 2 acacia was suitable for non-ferrous alloys at a composition of 4.5 - 13% exudates and 3% water (Ademoh and Abdullahi, 2008³). The grade 3 acacia was found suitable for non-ferrous and grey iron sand mould at 6 - 9% content (Ademoh and Abdullahi, 2008⁴).

Acacia species exudates is a natural resin exuded from the bark of plant trees called acacia species Ency-

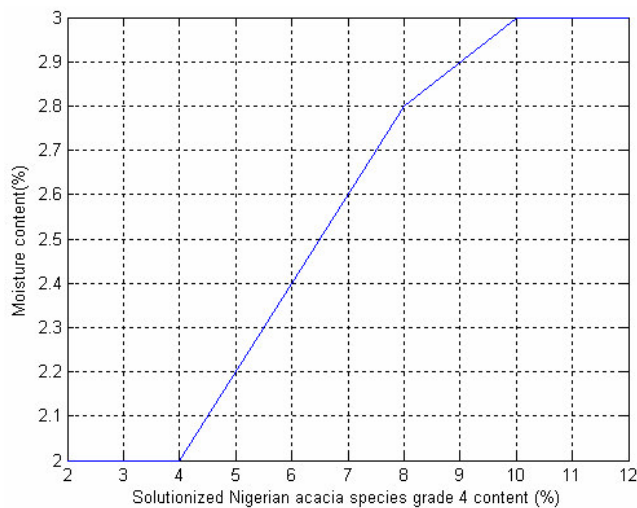
(Encyclopedia Britannica, 1989). It is gummy exudates obtained by tapping bark of acacia species trees. Nigeria is second world producer after Sudan (<http://www.nigeriaembassychina.com>, 2007). It is used as weapon in the fight against land desertification and soil degradation in the sahelian belt of the country without any industrial use. Foundries in Nigeria use local sand bonded with imported material (RMRDC, 1990). This import dependence made a very negative impact on growth of this important Industrial sector, thereby requiring urgent research to discover local materials for its use to enable it play expected leader role as witnessed in fast developed economies (Abaoba, 1995). Moreover, the preferred acacia are grades 1 and 2 exudates used in pharmaceutical, confectionary, lithographical, food, textile and beverages Industries (Rahim et. al., 2007).

As there is no registered foundry use of the material in Nigeria coupled with the fact that grade 4 regarded as cheapest is not desired by importer countries this research is aimed at finding expanded usages for the material in foundry as sand binders for steel casting. The main objective is to analyze mechanical properties like compressive strength, permeability, hardness, shatter index and moisture content of green/dry sand mould spe-

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Table 1. Sand properties for casting (Dietert, 1966).

Metal	Green Compressive Strengths (KN/m ²)	Permeability No	Dry Strengths (KN/m ²)
Heavy Steel	70-85	130-300	1000-2000
Light Steel	70-85	125-200	400-1000
Heavy Grey iron	70-105	70-120	350-800
Aluminum	50-70	10-30	200-550
Brass & Bronze	55-85	15-40	200-860
Light Grey iron	50-85	20-50	200-550
Malleable Iron	45-55	20-60	210-550
Medium Grey Iron	70-105	40-80	350-800

**Figure 1.** Moisture content (%) of Foundry sand moulds bonded with varying percentages of grade 4 Nigerian acacia species pre-dissolved in water solution.

cimens bonded with gum Arabic grade 4 and compare result with foundry standard in Table 1 to ascertain its suitability for steel castings. The significance lies on the fact that Nigerian foundries would be able to source their moulding sand binders from the exudates produced in abundance at lower prices than imported binders being used now. It would advance the fight against global warming by the increased planting of acacia trees and reduction in environmental degradation caused by mining of earth mineral like kaolin clay used as sand binders. According to Dietert (1966) the properties in Table 1 are the most commonly used in the industry to determine foundry suitability of sand and binder which is why they are investigated in the research.

EXPERIMENTAL PROCEDURES

The research measured properties such as moisture, green and dry compressive strength, hardness, permeability and shatter index of sand bonded with grade 4 Nigerian acacia species. The silica sand sourced from a river bed was used to produce the specimens. A

quantity of the sand was washed, oven dried at 110°C and sieved with BS mesh to obtain required grain sizes (AFS, 1989). The gum Arabic was milled to small particle size to enable even distribution. The sand and gum Arabic mix was thoroughly mixed in a roller for 10 min and moulded into specimens.

Each specimen measured 2 inches diameter by 2 inches height with average weight of 130 g. It was rammed with three dropping blows weighing 6.5 Kg from a height of 2 inches (AFS, 1989). Two schedules of specimen were prepared and tested. The first specimen schedule was bonded with the grade 4 exudates was pre-dissolved in solution in a ratio of 30:70% exudates to water. Binder content varied from 2 - 12%. The second schedule tested specimens bonded with 3.0 - 13% powdered acacia exudates. Green/dry compressive strength; permeability and harness; shatter index and moisture test were carried out on specimens using standard foundry test equipment. Speedy moisture teller was used and the instantaneous values of moisture were made from instrument gauge (AFS, 1989). Standard air pressure of 9.8×10^2 N/m² was passed through the specimen tube that contained mould green sand placed in parameter of the permeability meter and time for 2000 cm³ of air to pass through was read to determine permeability in numbers. The green and dry compressive strengths were tested with a universal strength machine. Steadily increasing compressive force was applied on the specimen until failure occurred and the strength in KN/m² was read instantaneously. Dry compressive specimens were initially dried at 110°C for 1 h, cooled down before test. A shatter test apparatus was used to measure shatter index (AFS, 1989).

PRESENTATION OF RESULT

Figures 1 - 3 present results of tests for specimens bonded with exudates of grade 4 Nigerian acacia species pre-dissolved in solution form and Figures 4 - 6 present those bonded with powdered exudates of grade 4 Nigerian acacia species before moulding.

Moisture test determined level of dampness of mould specimen, green and dry compressive strength measured ability of sand mould to withstand the pressure of molten metal during casting in the green or dry state. Hardness measured resistance against abrasion. Green permeability measured ease of escape of evolved gas to forestall defects. Shatter index measured ease of collapsibility of sand after casting.

DISCUSSION OF RESULT

From the result in figure 1, it was observed that moisture increased with the binder content that was varied from 2.0 - 12.0. This is due to the fact that the binder added in

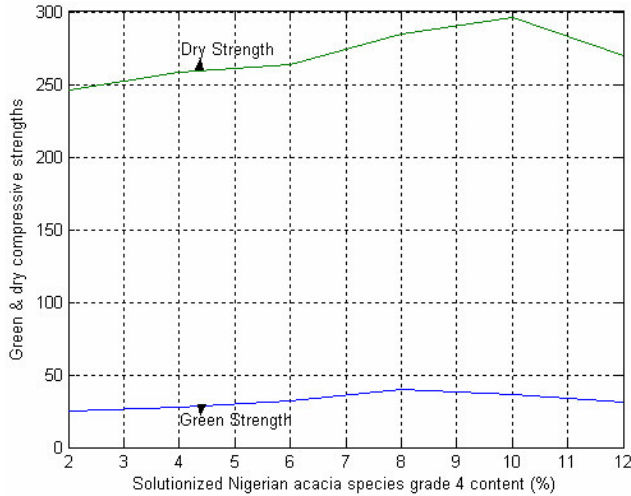


Figure 2. Green and Dry Compressive strengths (KN/m²) of Foundry sand moulds bonded with varying percentages of Gum Arabic grade 4 pre-dissolved in water solution.

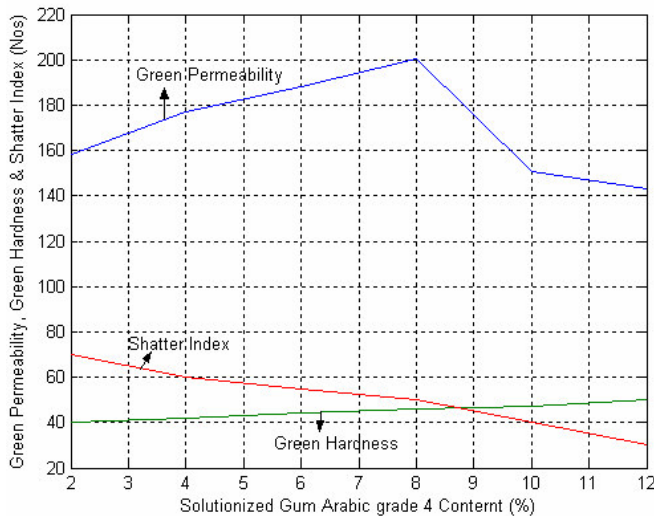


Figure 3. Green Permeability No, Green Hardness No and Shatter index No of Foundry sand moulds bonded with varying percentages of Gum Arabic grade 4 pre-dissolved in water solution.

solutionized form introduced more water to mixture. Green compressive strength of the specimens in Figure 2 increased with the binder from 2% to a maximum of 40 KN/m² at 8% after which it decreased to 31 KN/m² at 12% binder while the dry strength increased from 2% binder content to a maximum of 296 KN/m² at 10% binder and then dropped to 270 KN/m² at 12% binder. The excess moisture brought in by the increased binder must have caused the weakening of compressive strength at 10% and 12% binder for the green and dry strength respectively. Therefore 8 - 10% binder content is the optimum mix for 30/70 water/acacia species solution for

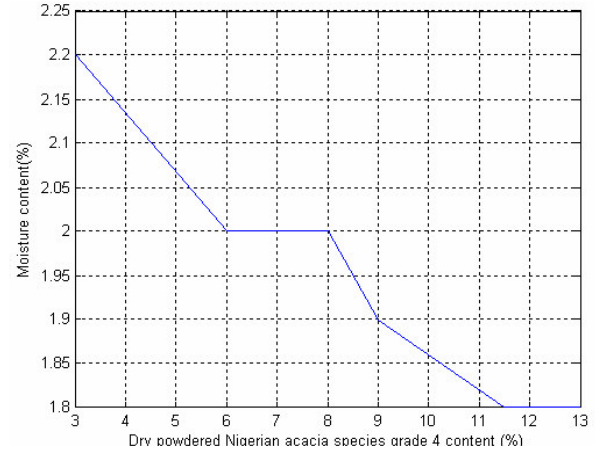


Figure 4. Moisture content (%) of Foundry sand moulds bonded with varying percentages of Dry Powdered grade 4 Nigerian acacia species exudates and 3% water content.

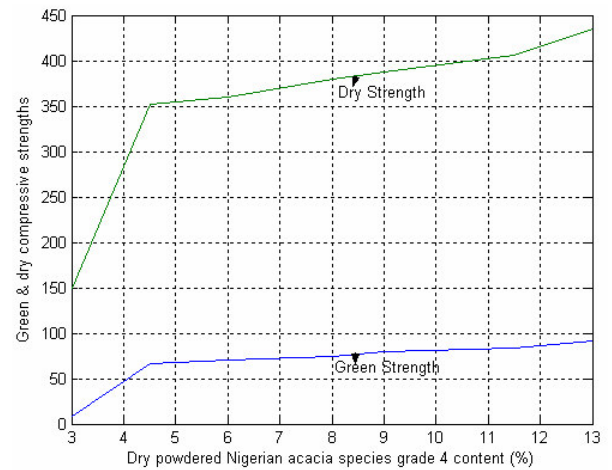


Figure 5. Green and Dry Compressive strengths (KN/m²) of Foundry sand moulds bonded with varying percentages of Dry Powdered Gum Arabic grade 4 and 3% water content.

green and dry moulding.

The green and dry compressive strength when compared with standard in Table 1 showed that the binder in solution form is unsuitable for green mould casting but suitable for dry mould casting of non-ferrous alloys, malleable and light grey iron at 2 - 12% composition. The results of the green permeability, hardness and shatter index are as presented in Figure 3. Green permeability decreased from 189 No at 2% to 143 No at 12% binder. Green mould hardness number increased with binder from 40 at 2% to 50 at 12% binder. Shatter index number decreased with increased binder content from 90 at 2% to 65. The permeability, hardness and shatter index numbers when compared with Table 1 agree with the range of suitability for sand casting (that is, non-ferrous alloy, malleable/light grey iron) as dictated by the dry compressive strength result.

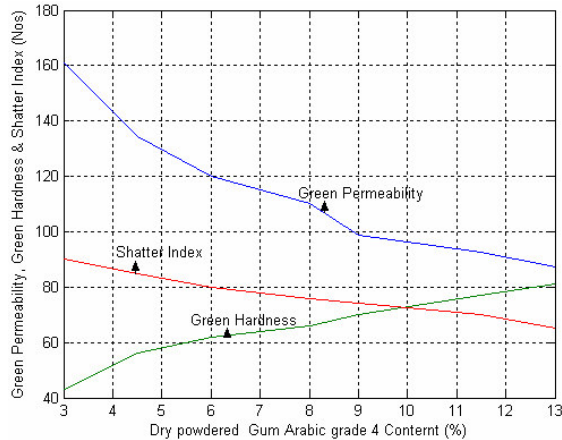


Figure 6. Green Permeability No, Green Hardness No and Shatter index No of Foundry sand moulds bonded with varying percentages of Dry Powdered Gum Arabic grade 4 and 3% water content.

Figures 4 - 6 presented result of specimen moulded with powdered acacia species. Binder varied from 3 - 13% with 3% added water. Moisture content as in Figure 4 decreased gradually from 2.2 at 2% binder to 1.8 at 13% binder. This is explained by the fact that the powdered binder and sand absorbed water and as binder content increased more water was needed to partially dissolve it and to also wet sand surface for bonding reaction in mixture. Green and dry compressive strength of the specimen as in Figure 5 increased from 9.0/150 KN/m² at 3% binder to 92/435 KN/m² at 13% binder. A comparison of this to the standard in Table 1 showed the mix with 4.5 - 8.0% binder is suitable for green/dry casting mould for non-ferrous alloy, malleable, grey iron. 11.5 - 13% powdered binder content is suitable for casting light steel in green/dry moulds and for heavy steel in wet mould. Permeability, hardness and shatter index are as presented in Figure 6. Green permeability number decreased with increased binder from 160 at 3% to 87 at 13%. The values when compared to Table 1 shows that at the 11.5 - 13% binder composition that is suitable for steel casting permeability is not sufficient except if sand grain size is increased coupled with the provision of adequate vents in sand mould. Hardness increased from 43 No at 3% to 81 No at 13% binder content. This is adequate for above application. Shatter index decreased with increased binder from 90 at 3% to 65 at 13%. The values are suitable for above application.

The results when cross compared with one another respectively show that binding foundry mould sand with grade 4 Nigerian acacia species added in powder form before wetting the mix imparted better bond properties on than binding with material pre-dissolved in solution form by about 40%. The high moisture in mould bonded with the latter must have caused reduction in bond properties. The result gave better economics in binder consumption as compared to work of Umar and Bashir (2007) that used 20% clay to bind Kano River and Challawa sand. In com-

parison with result of works of Gough M. J (1997 and 1999); USA patent no 5632326 and European patent no EP0934785 showed that gum Arabic can be used as a main binder for sand and not only for support.

Conclusions

The research revealed that exudates of grade 4 Nigerian acacia species are suitable for both green and dry moulding sand. The mechanical properties of moulded sand specimen showed that the material added in solutionized form gave weaker bonds than when it is applied in the dried powdered form. Sand Mould bonded with 4.5-8% of the powdered material is suitable for green and dry casting of non-ferrous alloys, malleable and heavy grey iron. However for steel casting bond strength, hardness and shatter index are adequate but green permeability is below standard.

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