

Evaluation of the Effective Baking Conditions for Grade 3 Nigerian Acacia Species Bonded Foundry Sand Cores

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Abstract: The most effective economical baking conditions were determined for foundry cores bonded with the grade 3 Nigerian acacia species exudates. Silica sand base cores bonded with the material were oven baked at temperatures ranging from 160 to 250°C for varying periods oven cooled and then subjected to tensile strength tests to ascertain the best baking conditions for different alloy castings. The experimental core specimens were in accordance with foundry test standard, shaped like figure number eight. They were tested with standard universal strength machine equipped with attachment for gripping the cores and an instantaneous meter from which the test values were read. The result were compared with established standard foundry core property table which showed that the class V iron/steel cores are best made with 3% acacia bonded silica sand baked at 160°C for 1 h. For magnesium cores, sand bonded with 4.5% acacia baked at 160°C for 1-2 h was optimum. For class IV iron/steel cores 4.5% acacia bonded sand baked at 180°C for 1 hour was optimal. Sand bonded with 4.5% grade 3 acacia baked at 200°C for 1.0-2.0 h was optimum for copper, aluminium, classes II and III iron/steel cores. Sand bonded with 8.0-13.0% grade 3 Nigerian acacia species baked at 200°C for 1.5-2 h was found most effective for class I iron and steel cores.

Key words: Acacia grade 3, baking, cores, oven, temperature

INTRODUCTION

Acacia species is a natural resin that contains arabin; a semi-solidified sticky fluid that oozes from incision made on bark of acacia trees (Fennema, 1996). Nigeria produces four grades of acacia species exudates in commercial quantities some of which are exported for foreign exchange earnings. Grades 1 and 2 acacia are preferred by major importer countries of USA and Europe that use it in food, beverage, pharmaceutical, confectionary, textile and printing industries (Rahim *et al.*, 2007). This creates a research gap to find industrial uses for grades 3 and 4 acacia species like using it in other sectors like foundries that lack cheap sources of good binders. Ademoh and Abdullahi (2009) tried the grade 3 Nigerian acacia exudates as sole binder for sand mould and it was found suitable at 6-9% compositional content for non-ferrous and grey iron casting at content.

The use of acacia species in foundry core production include addition of 5% acacia species exudates gum to 10% sugar and protein in gelatinous a mix derived from amino acid for binding expendable cores for casting (Siak *et al.*, 1994). Acacia gum combined with sugar, urea formaldehyde resin and boric acid to bind cores (Eric, 1965). These processes involve use of acids to enhance core performance. Other processes free of acids use corrosive organic, inorganic resins and chemicals,

which are toxic to human and involve multiple process stages that imply additional costs for safety precautions. This coupled with defects like porosity, cavities and pinholes caused by evolved gases entrapment require that simpler, non-hazardous processes that generate less gas and defects are developed to assist small scale and less advanced foundries especially in the developing countries.

The aim of this paper is to determine the most effective baking temperature and time for Nigerian acacia species grade 3 bonded cores. The objectives are to measure tensile strength of cores bonded with acacia grade 3 baked at 160, 180, 200, 220 and 250°C for 1-3 h, test them for tensile strength; permeability and shatter index and compare result with the standard in Table 1 (Titov and Stepanov, 1982), to determine the optimal baking conditions for such sand cores. The significance is that foundries that use the material in oven baking process for core production would be properly guided on the most effective and economical operating conditions for best results.

MATERIALS AND METHODS

Silica sand sample with clay content of 0.3% was used to produce the core test specimens. The sand was oven dried at 110°C to remove free water, weighed and transferred to a mechanical sieve and vibrated for about

30 min for grain size distribution (AFS, 1989). A quantity of sieved sand of BS standard grain size of 40-72 meshes was taken and used to produce specimens. The grade 3 Nigerian acacia species exudates was milled to grain size corresponding to BS sieve of 30 mesh for proper particle mix and bond reaction. The sand and acacia exudates were thoroughly mixed in a roller mill for 10 min and moulded into core specimen in accordance with the research test schedule. The tensile strength specimen was in accordance with usual foundry standard moulded in split core box to shape like figure number eight (Busby and Stancliffe, 1997). They were rammed with three compacting blows each weighing 6.5 Kg dropped from a 50 mm height.

After oven baking specimens at 160, 180, 200, 220 and 250°C for periods of 1-3 h, they were oven cooled and tested with standard universal strength equipped with attachment to grip specimen and meter that read tensile strength instantaneously (AFS, 1989). Permeability and shatter index specimens were cylindrical in shape, measured 50 mm diameter by 50 mm height and weighed 130 g after ramming with three compaction blows each of 6.5 Kg dropped from 50mm height with a standard sand rammer. These are the most critical mechanical properties of cores that determine their performance in practice (Titov and Stepanov, 1982; Dietert, 1966). For tensile test, a steadily increasing tensile force was applied on core specimen by universal strength machine until failure just occurred and the strength was read instantaneously. For the green permeability test, standard air pressure of $9.8 \times 10^2 \text{ N/m}^2$ was passed through the specimen in the sample tube placed in meter and after 2000 cm^3 of air passed through it, permeability was read (Dietert, 1966). Shatter specimen placed in container of the test machine was pushed upwards over stripping post until it struck anvil, fell and shattered. Retained sand and over size were collected, measured and automatically used by machine to compute shatter index read instantaneously from the meter.

RESULTS

Figure 1-6 presents the experimental results of research in graphical plots. Figure 1 presents the result of green permeability test. Figure 2-6 present the results of the tensile strength specimen's oven baked at 160, 180, 200, 220 and 250°C for of 1-3 h, oven cooled and then tested as described above. Tensile strength is the most critical of the properties of cores and it measured their ability to withstand the rupture stresses imposed on them by thermal expansion during casting. Permeability measured the ease of escape of gas from sand cores during casting, while shatter index measured the collapsibility of core after casting for easy fettling and cleanliness.

Table 1: Desired physical properties ranges of sand cores

Alloys	Permeability (No)	Tensile strength (KN/m ²)
Class I iron/steel cores	130-150	700-1000
Class II iron/steel cores	100	500-700
Class III iron/steel cores	100	350-600
Class IV iron/steel cores	70	200-300
Class V iron/steel cores	70	80-150
Copper bronzes cores	90	400-600
Copper brasses cores	60	500-700
Aluminium cores	80-100	400-700
Magnesium cores	80	300-500

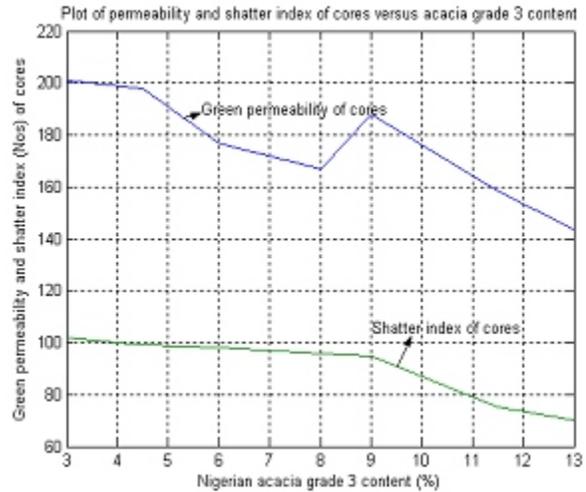


Fig. 1: Green Permeability and shatter index (No) of foundry sand cores bonded with varying percentages grade 3 Nigerian acacia species

DISCUSSION

The results of green permeability and shatter index tests are as presented in Fig. 1. Permeability was observed to decrease from 201.0No at 3% acacia binder to 143.5No at 13% acacia binder content. The trend is explained by the fact that increase in binder led to increased compaction and decreased porosity for gas escape. The permeability was compared to the standard in Table 1 showed that the material is suitable at all compositions investigated for all classes of sand cores for different alloys. Shatter index decreased with increased binder because more binder imposed higher bonding and less collapsibility of sand cores. However the values are adequate for all classes of cores.

Figure 2 presented the result for cores bonded with grade 3 acacia baked at 160°C for 1-3 h. When compared with foundry standard in Table 1, it shows that 160°C is the optimum baking temperature for classes IV and V iron and steel cores, 1 h is the optimum baking period for class V cores and 2.5-3.0 h for class IV iron and steel cores. For magnesium and class III iron and steel cores, sand bonded with 4.5% acacia baked for 1-2 h is the optimum. For bronze and aluminium cores optimum baking period at the same composition is 1.5-2.0 h. Cores bonded with 11.5-13% acacia baked at 160°C for 1.5-2.0 h is most effective for brass, class II iron and steel castings.

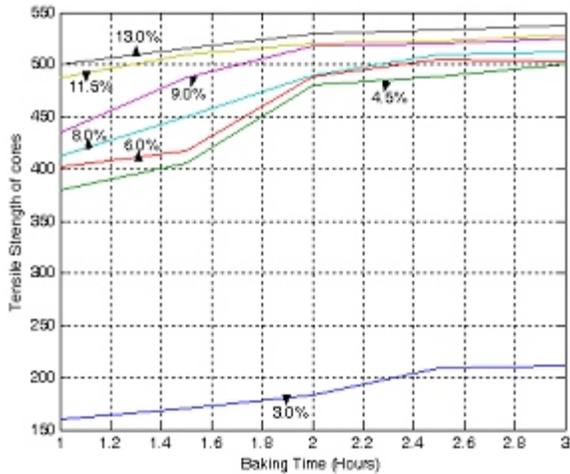


Fig. 2: Tensile Strength (KN/m²) of sand cores bonded with varying percentages grade 3 Nigerian acacia species baked at 160°C for varying periods in hours

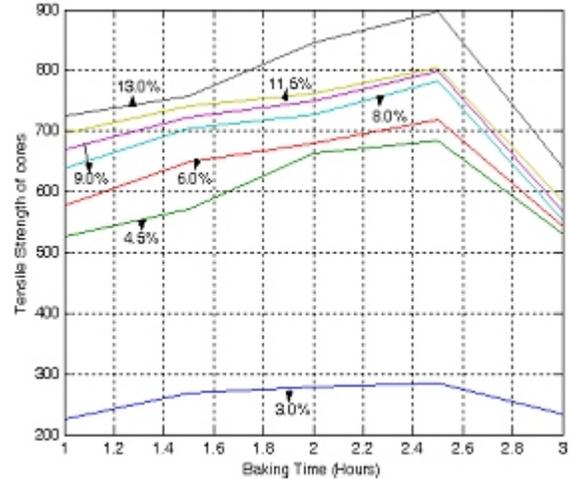


Fig. 4: Tensile Strength (KN/m²) of sand cores bonded with varying percentages grade 3 Nigerian acacia species baked at 200°C for varying periods in hours

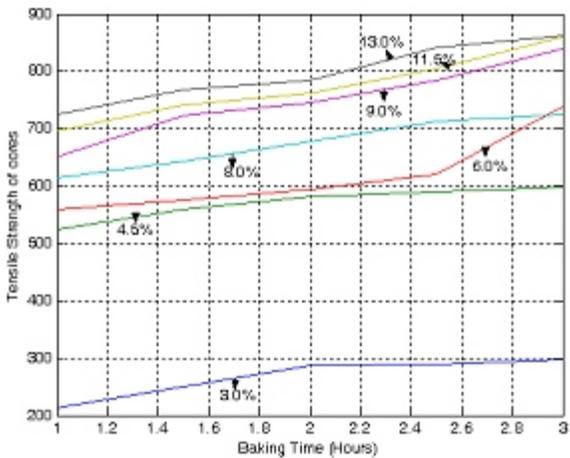


Fig. 3: Tensile Strength (KN/m²) of sand cores bonded with varying percentages grade 3 Nigerian acacia species baked at 180°C for varying periods in hours

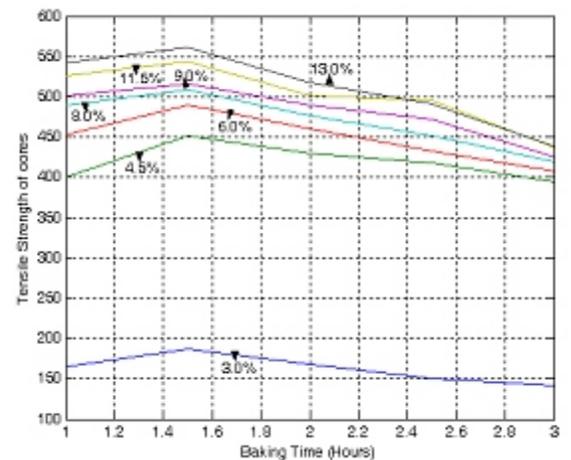


Fig. 5: Tensile Strength (KN/m²) of sand cores bonded with varying percentages grade 3 Nigerian acacia species baked at 220°C for varying periods in hours

The result for core specimens baked at 180°C is presented in Fig. 3. Just as observed in Fig. 2 tensile strength of baked cores increased with increasing binder and baking period because the two baking temperatures of 160 and 180°C are below the melting point of material above which it will begin to burn off and weaken strength. The grade 3 Nigerian acacia melts at 184-188°C (Eric, 1965). The result in Fig. 3 when compared with Table 1 show that 3.0% acacia bonded sand is optimum for class IV iron and steel core when it is baked at 180°C for 1-3 h. 4.5% acacia bonded sand baked for 1-3 h at 180°C is optimum for copper, aluminium and classes II and III iron and steel cores; while 9-13% acacia bonded cores baked at 1.5-3.0 h is optimum for class I iron and steel cores.

Figure 4 presented tensile strength test result for cores specimens bonded with grade 3 acacia baked at

200°C for 1-3 h. Cores strength increased with baking time for each acacia binder composition up to a baking time of 2.5 h from where strength decreased with baking period because above the melting point (184-188°C) prolonged holding of the material caused some acacia binder to burn off from cores resulting to weakening of strength. In comparison with Table 1, the result shows that sand bonded with 3.0% acacia baked for 1.0 hour is suitable for class IV iron and steel cores; that with 4.5% acacia binder baked for 1.0-2.0 h is effective for copper, aluminium and classes II and III iron and steel cores while 8.0-13.0% acacia bonded sand baked for 1.5-2.5 h is optimum for class I iron and steel casting cores.

Figure 5 and 6 presented tensile strength test results for cores specimens bonded with grade 3 acacia baked at

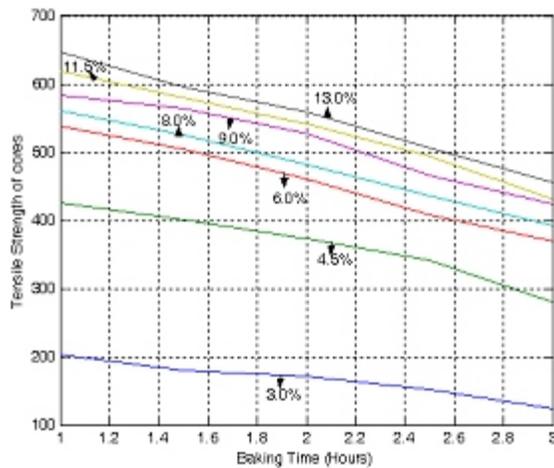


Fig. 6: Tensile Strength (KN/m²) of sand cores bonded with varying percentages grade 3 Nigerian acacia species baked at 250°C for varying periods in hours

220 and 250°C for 1-3 h, respectively. In Fig. 5 there was marginal increase in strength from baking period of 1-1.5 h followed by rapid decrease in core bond strength with increased baking duration. This trend was caused by over baking of cores at a temperature in excess of what was required. Acacia species exudates as a class 3 type of binder that melts and flows to form strong bonds with sand when cooled to low temperature would perform best at just above its melting range. Therefore, the 220°C baking temperature appears excessive for optimum performance of material. The situation in Fig. 6 is even worse than that in Fig. 5 as tensile strength followed trend of slopping continuously from 1-3 h of baking due to similar reason of over baking cores. Thus cores bonded with grade 3 acacia exudates are not to be baked at or above these two temperatures.

CONCLUSION

The grade 3 Nigerian acacia species exudates has been shown to be suitable for binding sand cores for

different alloy castings at specified compositions, baking temperatures and time for best result. The effective baking condition determined in the study is vital as it prevents unnecessary waste of time, material and energy and lowers production cost. When compared with the chemically based core processes (Rahim *et al.*, 2007; Siak *et al.*, 1994), this work produced good sand cores with simpler materials and method.

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