DETERMINATION OF THE OPTIMAL MOISTURE CONTENT FOR EXPENDABLE FOUNDRY SAND CORES BONDED WITH NIGERIAN ACACIA SPECIES

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ABSTRACT

The optimum moisture content of oven baked sand cores bonded with Nigerian acacia species was determined for best casting result in this study. Each of the four grades of acacia species exudates produced in Nigeria was used to bind foundry sand cores with moisture varied from 1% to 8%. The specimens were oven baked at 200^{0}C for 1-3 hours, cooled and tested for gas permeability and tensile strength using standard permeability and universal strength machines to measure the effects of differing amounts of moisture in expendable foundry sand cores. It was observed that baked tensile strength increased from 1%-3% added water and thereafter decreased continuously to the lowest value at 8% of added water. The effect was most serious with grade 2 acacia bonded cores followed by the grade 3, grade 1 and grade 4 cores in that order. The result showed that 2-3% moisture content was optimum for cores. For best results it is thus advised that water added to sand cores bonded with Nigerian acacia be 3-4% to achieve this composition. The permeability of tested specimens is sufficient for this optimum range of moisture for sand casting different alloys.

SIGNIFICANCE: The significance of the study is that the result will guide foundries that use the material on the optimal moisture needed by acacia bonded core and mixes.

KEY WORDS: Moisture, Expendable, Cores, Acacia species, Foundry.

1. INTRODUCTION

An expendable foundry sand core used for casting is usually made from a mix of refractory sand grain, binder and moisture that provides proper bond reaction environment (Tipper, 1958). These are the essential components of good cores. The synthetic sand constituent is well selected and controlled to give the desired properties within limit. Amount of moisture is directly related to type and nature of binder used for core production (Dietert, 1966). This makes it mandatory that its optimum content be investigated for sand to ascertain best compositional synthetic mix.

The use of acacia exudates in core production include addition of 5% unspecified gum Arabic to 10% sugar and protein in gelatinous mix derived from amino acid for binding expendable core for casting (Siak *et al.,* 1994). In the United Kingdom, it is used in the hot box core process. It is combined with sugar, urea formaldehyde resin and boric acid to sand bind cores (Eric, 1965). Ademoh and Abdullahi (2009[1]) used grade 1 Nigerian acacia exudates as core binder. They found it suitable at different compositions for sand casting non-ferrous and grey iron. Grade 2 acacia exudates was worked with and proved suitable for non-ferrous alloy casting cores baked at defined temperatures (Ademoh and Abdullahi, 2009[2]). Each of the grades 3 and 4 acacia exudates was separately used as sand core binder aimed at finding optimal application of the material for foundry cores (Ademoh and Abdullahi, 2008; 2009[3]). The studies showed that each was a good binder at different acacia binder compositions but with the moisture contents and baking conditions of cores acting as determinant factors in their suitability.

These previous studies strongly indicate that the material will perform satisfactorily when used as sole core sand binders when used with appropriate water content and treatment conditions. Therefore, it is very important to investigate the optimal moisture need as a critical constituent in the mix to obtain a good blend with acacia binder and sand for the best casting result. This is the main aim of this study. The objectives are to produce sand cores having different moisture contents bonded with each of four commercial grades of Nigerian acacia and to test them for tensile strength and permeability to ascertain the optimal moisture contents for best results.

2. MATERIALS AND METHODS

The most important property of a sand core is its ability to withstand the thermal stresses imposed on it in the form of tensile expansion by hot molten metal during casting. Easy escape of evolved gas from sand cores is also critical for good castings (Titov and Stepanov, 1982). These vital properties were measured on cores made of silica sand, varied moisture and each of the four grades of Nigerian acacia species as binder. The experimental tests were carried out with standard foundry test equipment in workshop and foundry laboratory of Ajaokuta Steel Company Ltd.

The silica sand used had 0.3% clay content, of BS standard grain size 40-72 mesh and was oven dried at 110^{0}C to remove free water. The acacia exudates were milled to BS standard grain size of 30 mesh for even particle distribution in the mix. The sand grains and measured quantities of each acacia grade were milled in a roller for 10 minutes and then moulded into test specimen. Green permeability test specimens were cylindrically shaped, measured 50mm diameter by 50mm height and weighed 130g after compacting in a standard rammer with three blows of 6.5kg from a height of 50mm (AFS, 1989). The tensile strength specimens were shaped like number eight as shown in Figure 1, moulded in split core box and rammed with three blows each of 6.5kg from 50mm height.

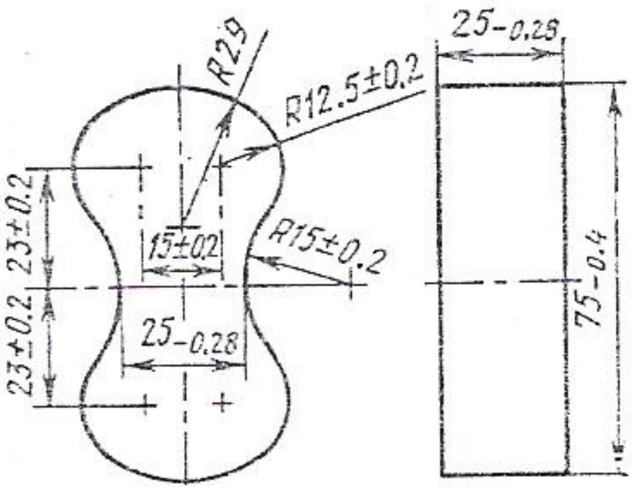

Figure 1: Shape of tensile strength core specimen (dimensions are in millimetres) (Titov and Stepanov 1982).

Tensile strength specimens were oven baked at 200^{0}C for 1-3 hours, oven cooled and then tested with a universal strength machine equipped with attachment for gripping specimens as shaped and a meter that read instantaneous strength (AFS, 1989). Steadily increasing tensile force was applied to specimen by machine until fracture failure occurred and the strength was read. For permeability test, standard air pressure of 9.8x10^{2}N/m^2 was passed through specimen in sample tube placed in meter and after 2000cm^3 of air had passed through it, the permeability was instantaneously read.

3. RESULTS AND DISCUSSION

3.1 Results: The results of the research experiments are presented in Figures 2 - 6. Figure 2 presents the results of permeability test. Figure 3 presents result of tensile strength for grade 1 acacia bonded cores baked at 200^{0}C; Figure 4 - results for grade 2 acacia cores; Figure 5 - results for grade 3 acacia bonded cores and Figure 6 presents the results for grade 4 acacia bonded cores baked at 200^{0}C for 1-3 hours. Green permeability measured ease of escape of evolved gasses from the core. Tensile strength measured ability of cores to withstand rupture stresses imposed by thermal expansion during casting.

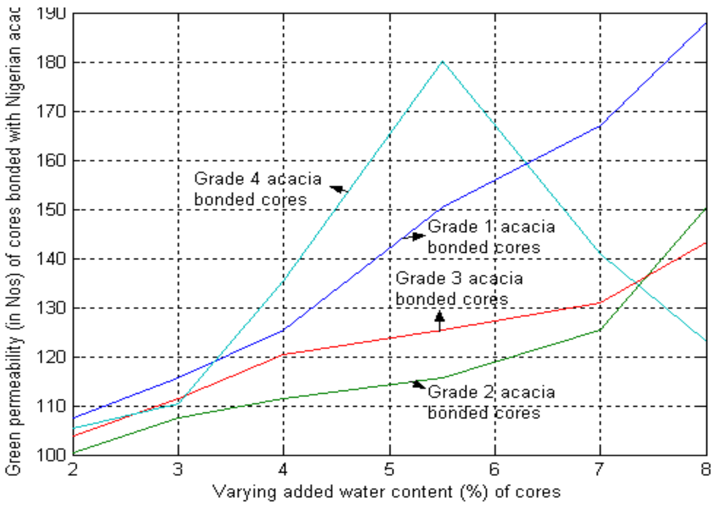

Figure 2: Green permeability (in No) of cores bonded with Nigerian acacia species with varying moisture content.

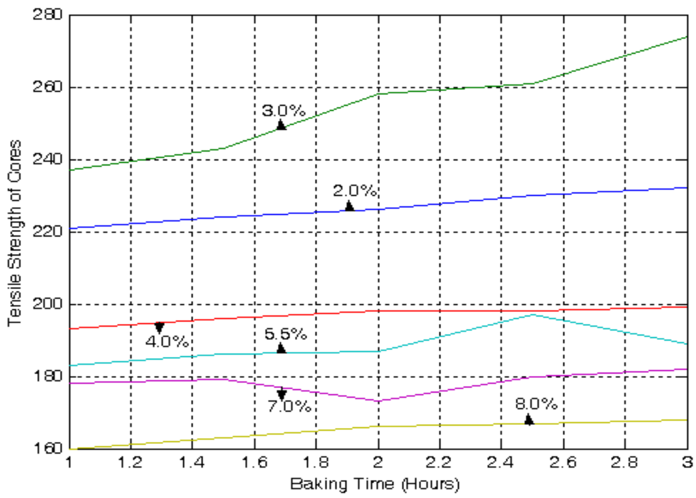

Figure 3: Tensile strength (in kN/m^2) of cores bonded with 3% grade 1 Nigerian acacia species and varied moisture content baked at 200^{0}C for varying periods in hours.

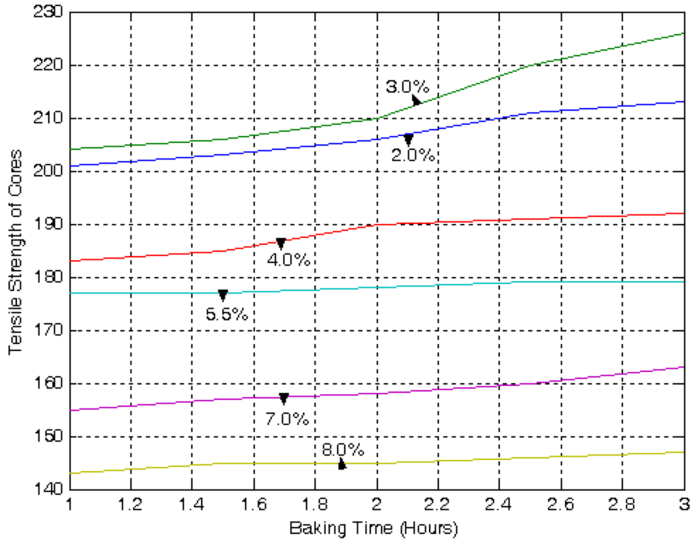

Figure 4: Tensile strength (in kN/m^2) of cores bonded with 3% grade 2 Nigerian acacia species and varied moisture content baked at 200^{0}C for varying periods in hours.

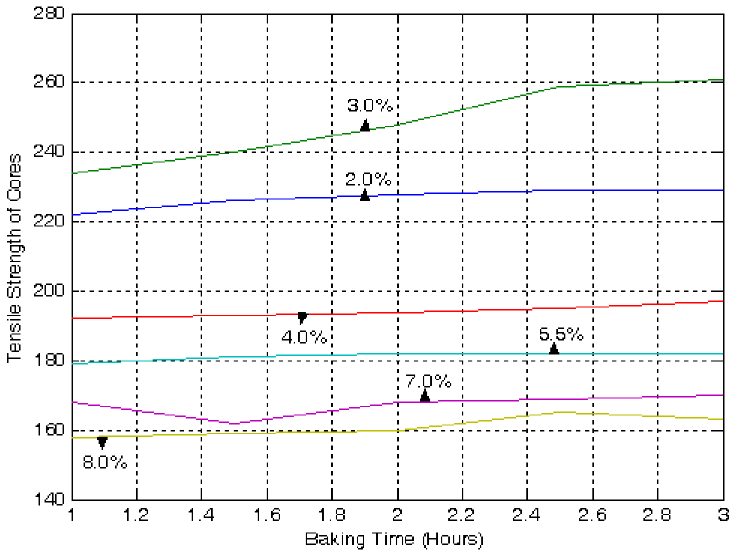

Fig. 5: Tensile strength (in kN/m^2) of cores bonded with 3% grade 3 Nigerian acacia species and varied moisture content baked at 200^0C for varying periods in hours.

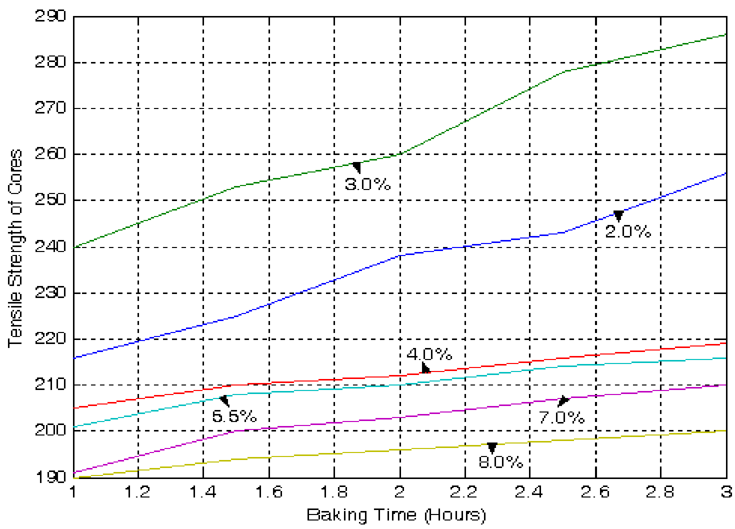

Fig. 6 Tensile strength (in kN/m^2) of cores bonded with 3% grade 4 Nigerian acacia species and varied moisture content baked at 200^0C for varying periods in hours.

3.2 Discussion of results: From Figure 2, green permeability varied from 107.4.0 No at 2% acacia to 188.0No at 8% acacia. The continuous increase of permeability with moisture for grades 1, 2 and 3 acacia bonded cores is because additional moisture caused more looseness and less compaction of sand particles in cores that resulted into increased porosity and hence easier escape route for gas. Permeability for grade 4 acacia bonded cores increased with increasing added water up to 5.5% moisture content. From here it slopped down showing reduced air passage with addition of water. It shows effect of increasing moisture on green permeability is most with grade 1 acacia cores followed by grade 2, grade 3 and then grade 4 cores. In comparison with previous studies by Ademoh and Abdullahi (2008; 2009[1]; 2009[2]; 2009[3]), permeability of core specimens with less than 4% moisture contents are sufficient for sand moulds of different alloys.

Figures 3-6 presented baked tensile strength of grades 1, 2, 3 and 4 acacia bonded cores baked at 200^0C for 1-3 hours. In Figure 3, result for grade 1 bonded core baked shows that tensile strength increased with increased baking period. This is because prolonged hold of specimen at baking temperature of free and excess moisture in cores that could weaken strength was increasingly evaporated to give stronger bonds. However, a critical study of the result shows the highest tensile strength occurred with cores with 3% moisture; followed by those with 2% moisture, followed by cores with 4%, 5.5%, 7% and 8% moistures in that order. This trend of increased strength implies that 3% moisture is optimum for this category of sand cores for best casting result and economics.

The result in Figures 4, 5 and 6 for grades 2, 3 and 4 acacia bonded cores baked at 200^0C show similar trend in characteristics as the result in Figure 3 for grade 1 acacia bonded cores because the solubility of each grade of material in water is not too dissimilar to the other grades as shown in a previous work by Ademoh and Abdullahi (2009[4]). Thus effect of moisture on tensile strength cannot be too divergent from grade to grade since their physical and chemical properties are closely related. A cross comparison of results in Figure 3-6 for cores bonded with each of the four different commercial grades of Nigerian acacia species shows that grade 4 acacia bonded cores gave the highest baked tensile strengths, followed by grade 3, then grade 1 and lastly grade 2. This is due to the fact that acacia species exudates as a class 3 type of binder that melts at elevated temperature to bind sand and form strong bonds when it cools down. As shown by Ademoh and Abdullahi (2009[4]), grade 4 acacia is most water soluble with the lowest melting point (178-182^0C) in group. Thus by baking at 200^0C all the acacia molecules became fluidized and had enough time of 1-3 hours to soak through sand mass to hold the grains together more than the other grades. Grade 3 acacia (that melts at 184-188^0C) produced cores next in tensile strength to grade 1 acacia due to same reason. Grade 2 acacia (melting point, 190-194^0C) didn't follow this trend as other factors like water solubility, active constituent e. t. c., favoured grade 1 acacia (of higher melting point of 200-210^0C) with stronger cores, thus its cores had the least baked strength.

4. CONCLUSION

The research findings showed that excess moisture content in acacia bonded sand cores resulted into reduced baked tensile strength. Optimum moisture content for each grade of Nigerian acacia bonded expendable sand cores baked at 200^0C for 1-3 hours was found to be 2-3%. This is obtainable from 4-5% raw water addition to sand mix. Thus core moisture shouldn't be excessive.

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