IJCBS, 1(2012):85-90

International Journal of Chemical and Biochemical Sciences

Journal Home page: www.iscientific.org/Journal.html

Bentonite clay as a composite mix with grades 1 and 2 Nigerian acacia species for binding foundry sand moulds

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Abstract

The potential of composite combination of each of grades 1 and 2 Nigerian acacia species exudates and bentonite clay as sand mould binder was investigated. The study involved foundry property analyses of sand mould specimens bonded with composites mixes of grades 1 and 2 acacia species exudates and bentonite clay. Standard foundry equipment that included universal strength machine, permeability meter, hardness tester, shatter index machine and quick moisture teller in the foundry workshop and laboratory of Ajaokuta Steel Company Limited, Nigeria were used as the research equipment. The foundry properties measured were the moisture content, green and dry compressive strength, permeability and shatter index of sand moulds bonded with varied combinations of the composite materials. The result was compared to existing foundry standard and past related work. It showed that composite combination of 8% grade 1 acacia species with 1% bentonite clay was a suitable binder for green and dry sand mould for casting light steel, grey iron and non-ferrous alloys. A composite of 8% grade 2 acacia species and 1% bentonite clay was a suitable binder for green and dry sand mould for casting grey iron and non-ferrous alloy. Presence of bentonite clay generally improved mould sand binding ability of grades 1 and 2 Nigerian acacia species exudates.

Key words: Acacia exudates, bentonite clay, foundry, binder.

Full length article Received: 15-10-2011 Revised: 19-12-2011 Accepted: 04-01-2012 Available online: 15-01-2012

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1. Introduction

Acacia species exudate is a natural resin that contains arabin; a semi solidified sticky fluid oozing from incision made on bark of trees called acacia species [1]. The four commercial grades of acacia species produced in Nigeria include grade 1 (acacia Senegal), grade 2 (acacia Seyal), grade 3 (combretum) and grade 4 (neutral) [2]. Nigeria is second largest of the material in the world with an average annual production output of 20,000 tonnes since 2005.

Sudan is the world biggest producer and exporter (http://www.nigeriaembassychina.com). Fennema [3] described it as a compound mixture of arabino galactan, oligosaccharide, polysaccharide and glycoprotein; less consistent than other hydrocolloids. Ademoh and Abdullahi [4] found grade 1 acacia exudates mixed with 2-3% moisture suitable mainly for non-ferrous, malleable and grey iron castings. Plain grade 2 acacia species was found suitable for non-ferrous casting at compositions that range from 4.5% to 13% [5]. Bentonite clay is of American origin and is used in moulding sand as colloidal clay binding agent [6]. Its deposits exist in most acacia species producer countries like Nigeria making it easily available [7-8]. Bentonite clay has long been an established foundry sand binder but acacia exudates are only used as additives to core binders because of its high cost [9]. This study aims at blending organic resins like acacia exudates with traditional mineral binder like bentonite clay to give high quality synthetic composite sand binder that is very suitable for selected use in the sub-sector. The objectives are to separately blend different compositions by weight of each of grades 1 and 2 Nigerian acacia species with varied quantities of bentonite clay as composite binder for sand; analyze them for properties like green and dry compressive strength; permeability and hardness; shatter index and moisture content and compare result to standard in Table 1 [10] to ascertain its efficacy. The significance of the research lies in the fact that foundries can shift from more expensive and hazardous chemical binders to these composites that of high purity, cheaper and non corrosive materials for better savings on process costs and risks.

2. Materials and methods

Properties of mould sand bonded with composites made of each of grades 1 and 2 Nigerian acacia species exudates with bentonite clay were measured using standard test specimen and equipment in laboratory of the Ajaokuta Steel Company Limited in Nigeria. The moisture content; green and dry compressive strength, hardness, permeability and shatter index which are the properties reported by as the most important in ascertaining suitability of sand and the active binder for foundry use. They were adopted in this study to evaluate the potentials of the composite binder as their values always give adequate information on other salient foundry properties [10].

Table 1: Satisfactory property ranges for sand casting

Metal	Green Compressive Strength [KN|m^2]	Permeability No	Dry Strength [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

***2.1. Materials and equipment*:** Silica sand that contained 0.03% clay content sourced from a river bed collected from base of the river along a kilometer range at five different spots after quartering down was used for the research. It was mixed thoroughly and a representative sample was taken for the experiments. About 2.0 kg of each of the grades 1 and 2 Nigerian acacia species was purchased from acacia species markets in Gombe and Bauchi States of Nigeria. The experimental equipment included laboratory sand mixer, sand rammer, universal strength test machine, permeability meter, hardness tester, drying oven, shatter machine and quick moisture teller sourced from a workshop.

***2.2. Specimen Preparation**:* The sand specimen was washed and oven dried at 110^{0}C to remove free water. The sand was classified with standard British sieve to separate the different grain sizes. Sand grains in range of BS 40-70 mesh was collected for preparation of the test moulds. The acacia species exudates was milled into powder to obtain average grain size of 20-40 mesh to enable even particle distribution within mix. The sand and quantities of each of grades 1 and 2 acacia exudates with defined quantities of bentonite clay as the composite binder were thoroughly mixed in a roller mixer for 10 minutes and then moulded into specimens using a standard sand rammer that delivered a compaction blow of 6.5 Kg from a height of 50.4 mm (2 inches). Specimens were all cylindrically shaped as shown in figure 1. Each specimen measured 50.4 mm (2 inches) in diameter by 50.4 mm (2 inches) in height [6] and of average weight of 130g.

2.3. Test Procedure: The test moulds were classified into those for green tests and those for dry tests. The dry test moulds were selected and first oven dried at 110^{0}C for about one hour and then oven cooled down to room temperature before tests [6]. Specimens were then grouped for the different property tests according to the research schedule. A speedy moisture teller was used to quickly test and read moisture content of mould specimens. Instantaneous moisture (in percentages) was read from the instrument gauge. For permeability, standard air pressure of 9.8x10^{2}N\m^2 was passed through the cylindrical specimen tube containing green sand mould placed in parameter of permeability equipment and the time taken for 2000cm^3 of air to pass through specimen was read to determine permeability. Green and dry compressive strength tests were carried out with universal strength machine. A steadily increasing compressive force was applied on a specimen until failure just occurred and strength in KN/m^2 was instantaneously read. A shatter test apparatus was used to measure shatter index of specimens. The tests were in accordance with the procedures adopted in a research by Ademoh and Abdullahi [4]. Moisture test determined dampness of mould specimen. Green and dry compressive strength measured ability of the mould to withstand pressure of molten metal during pouring into the green or dry sand mould. Green hardness measured the resistance of the sand mould against abrasion. Green permeability measured ease of escape of gasses from mould to forestall defects. Shatter index measured the collapsibility of mould sand after casting.

Figure 1. A collection of some of the cylindrical test specimens

3. Results and discussion

The results of the research are presented in figures 2 - 13. Figures 2 - 7 present result of analyses with bentonite clay content of the composite fixed at 1% and the acacia species content varied from 1%-8%. Figures 8 - 13 present the result of analyses with bentonite clay varied from 0.5-3% with the acacia species content of the composite binder fixed at 3%. Figures 2-4 presented the result for the experimental analyses of specimens bonded with 1-8% grade 1 Nigerian acacia exudates composite with 1% bentonite clay. In figures 2 and 5, moisture content decreased from 2.6% at 1% to 2% at 8% acacia species. This is because additional binder took up moisture to partially dissolve binder, wet clay and sand grain to create appropriate bond reaction. In figure 3, green and dry compressive strengths for specimens varied from 44 KN/m^2 and 336KN\m^2 at 1% acacia species with 1% bentonite clay to maximum of 72 KN/m^2 and 438KN/m^2 at 8% acacia species with 1% bentonite clay respectively. This compared with moulds bonded with plain grade 1 acacia [4], where 9%

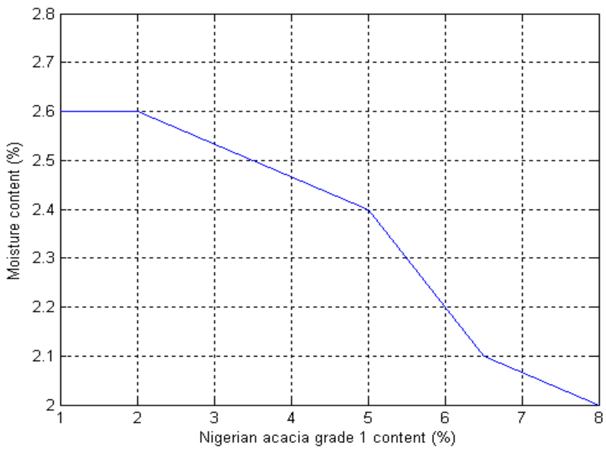

Figure 2. Moisture content (%) of foundry sand moulds bonded with varying percentages of composites of Nigerian acacia species grade 1 with 1% bentonite clay and 3% water.

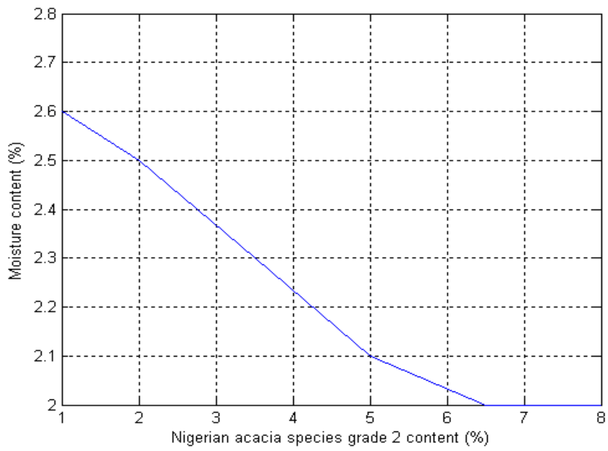

Figure 5. Moisture content (%) of foundry sand moulds bonded with varying composites of Nigerian acacia species grade 2 mixed with 1% bentonite clay and 3% water.

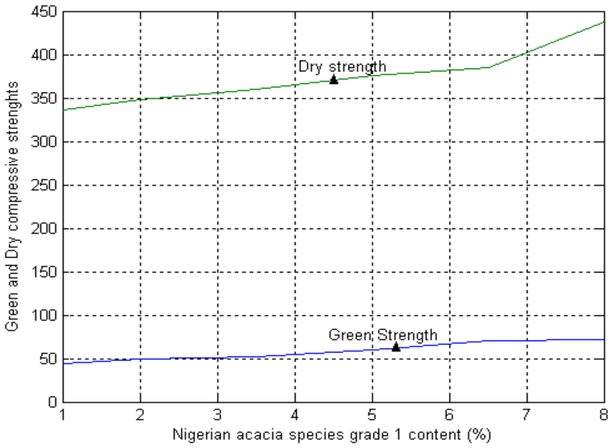

Figure 3. Green and dry compressive strengths (KN\m^2) of foundry sand moulds bonded with varying composites of Nigerian acacia species grade 1 with 1% bentonite clay and 3% water.

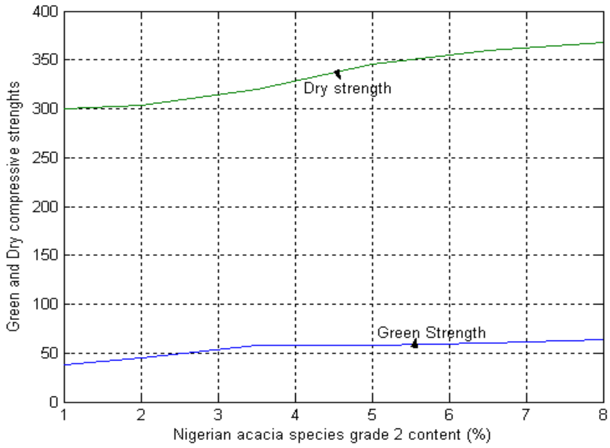

Figure 6. Green and dry compressive strengths (KN\m^2) of foundry sand moulds bonded with varying composites of Nigerian acacia species grade 2 mixed with 1% bentonite clay and 3% water.

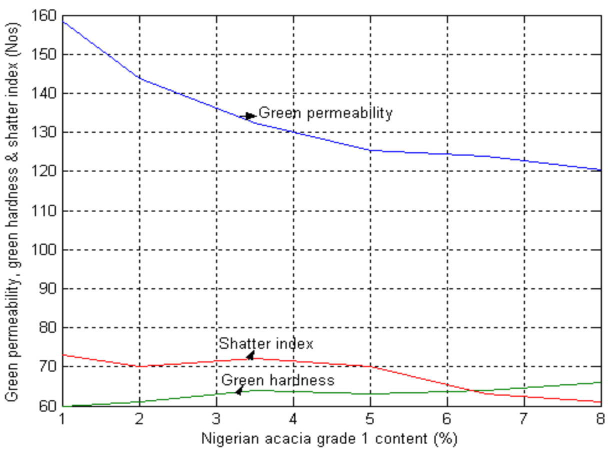

Figure 4. Green permeability, green hardness and shatter index No of foundry sand moulds bonded with varying composites of Nigerian acacia species grade 1 with 1% bentonite clay and 3% water

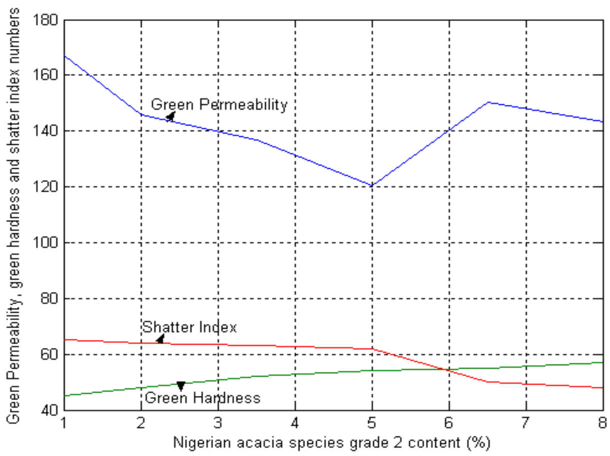

Figure 7. Green permeability, green hardness and shatter index No of foundry sand moulds bonded with varying composites of Nigerian acacia species grade 2 mixed with 1% bentonite clay and 3% water.

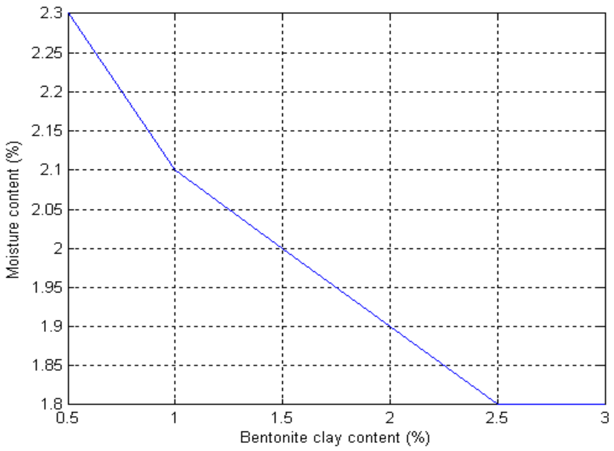

Figure 8. Effect of bentonite clay content on the moisture content (%) of foundry sand moulds bonded its composite with 3% Grade 1 Nigerian acacia species and 3% water.

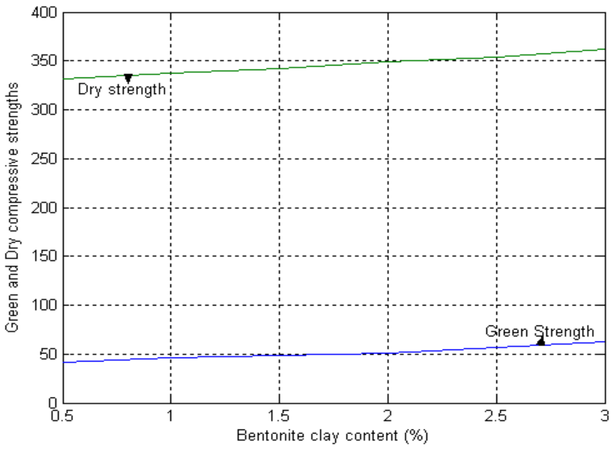

Figure 9. Effect of bentonite clay content on the green and dry compressive strengths (KN\m^2) of foundry sand moulds bonded its composite with 3% grade 1 Nigerian acacia species and 3% water.

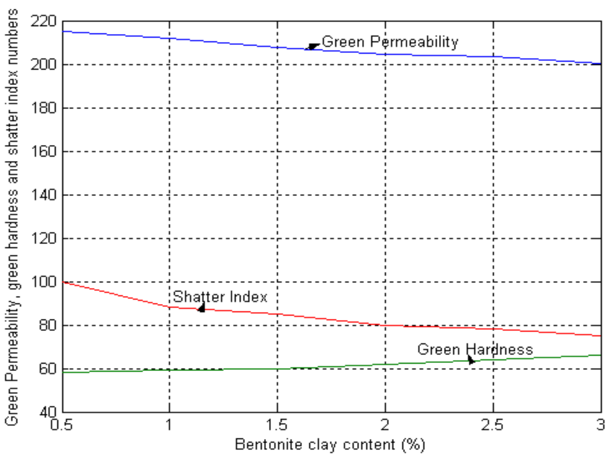

Figure 10. Effect of bentonite clay content on the green permeability, green hardness and shatter index No of foundry sand moulds bonded with its composite with 3% grade 1 Nigerian acacia species and 3% water.

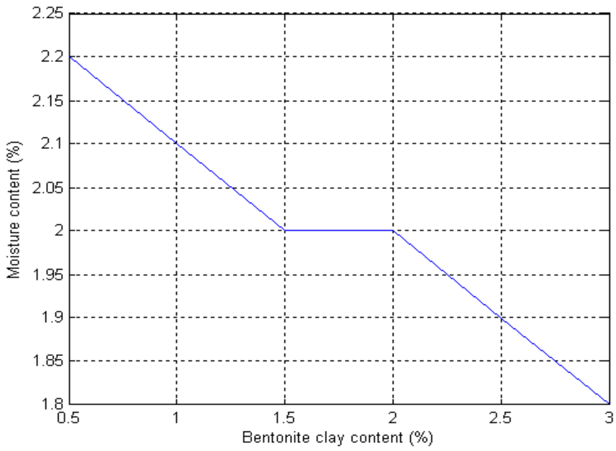

Figure 11. Effect of bentonite clay content on the moisture content (%) of foundry sand moulds bonded with its composite with 3% grade 2 Nigerian acacia species and 3% water.

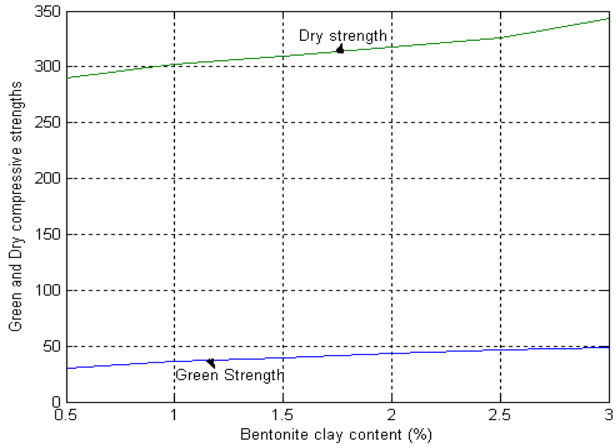

Figure 12. Effect of bentonite clay content on the green and dry compressive strengths (KN\m^2) of foundry sand moulds bonded with its composite with 3% grade 2 Nigerian acacia species and 3% water

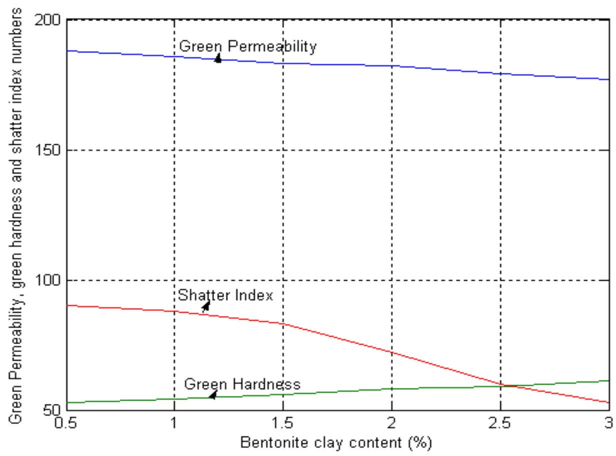

Figure 13. Effect of bentonite clay content on the green permeability, green hardness and shatter index No of foundry sand moulds bonded its composite with 3% grade 2 Nigerian acacia species and 3% water

binder gave 71KN/m^2 and 349KN/m^2 green/dry strength showed that 1% bentonite clay addition to grade 1 acacia species bonded mould marginally increased green strength and dry strength by about 35%.

In comparison with the standard in table 1 it showed that a composite binder of 1% bentonite with 2.0% grade1 acacia is suitable to bind green and dry moulds for casting aluminium and malleable iron; 1% bentonite clay with 5.0% grade 1 acacia species for brass, bronze and light grey iron; 1% bentonite clay with 8.0% grade 1 acacia species for medium/heavy grey iron and light steel moulds. Green permeability, hardness and shatter index as presented in figure 4 compared with table 1 show the values are suitable for the above range of application as based on bond strength.

In figure 6, green and dry strength varied from 38KN/m^2 and 300KN/m^2 at 1% acacia species with 1% bentonite clay to 64KN/m^2 and 368KN/m^2 at 8% grade 2 acacia species with 1% bentonite clay respectively. In comparison with work with plain grade 2 acacia species bonded mould [5, 11] in which 9% binder gave 53KN/m^2 and 298KN/m^2 green and dry strength showed that 1% bentonite clay addition to grade 2 acacia bonded mould increased green strength by about 16% and dry compressive strength by 25%. In comparison with standard in table 1 composite binders of 1% bentonite clay with 2.0% grade 2 acacia exudates is suitable for binding green and dry moulds for casting malleable iron; 1% bentonite clay mixed with 3.5% grade 2 acacia species is good for aluminium, brass, bronze and light grey iron green and dry sand mould and 1% bentonite clay with 8.0% grade 1 acacia species is good for medium and heavy grey iron dry moulds.

The green permeability, hardness and shatter index in figure 7 for same composite bonded moulds when compared with table 1 showed the values are suitable for above specified range of castings. A cross comparison of result for composite of grade 1 acacia species and bentonite with that of grade 2 acacia species and bentonite clay shows that grade 1 acacia and bentonite mix is better than grade 2 acacia/bentonite mix. The former was suitable for binding light steel moulds and the latter wasn't. Moisture content in figures 8 and 11 also decreased as that in figures 2 and 5 due to similar reason. In figure 9, green and dry strength varied from 42KN/m^2 and 331KN/m^2 at a content of 3% grade 1 acacia species with 0.5% bentonite clay to 63KN/m^2 and 362KN/m^2 at 3% acacia species with 3% bentonite respectively. This compared with plain grade 1 acacia bonded mould where 6% plain grade 1 acacia species bonded mould gave 62KN/m^2 and 320KN/m^2 green and dry strength show that green strength of composite bonded mould was marginally increased and dry strength by 13%.

In comparison with table 1 composite binders made of 1% bentonite clay and 3.0% grade 1 acacia exudates is suitable for binding green and dry sand mould for casting light grey and malleable iron; 2% bentonite clay with 3.0% grade 1 acacia species is good for sand moulds for casting aluminium; 2.5% bentonite clay composite with 3.0% grade 1 acacia species is suitable for green and dry mould for casting of brass and bronze alloys; while 3.0% bentonite clay with 3.0% grade 1 acacia species is suitable for only binding green mould for casting medium and heavy grey iron. The permeability, hardness and shatter index in figure 10 show that the values are suitable for above uses. In figure 12 green and dry strength varied from 30KN/m^2 and 290KN/m^2 at 3% acacia species composite with 0.5% bentonite clay to 49KN/m^2 and 343KN/m^2 at 3% grade 2 acacia species with 3% bentonite clay respectively. When compared with plain grade 2 acacia species bonded mould when 6% binder gave 39KN/m^2 and 272KN\m^2 green and dry strength, it shows that 3% bentonite clay added to 3% grade 2 acacia species bonded mould increased green and dry compressive strength by 25% and 24%, respectively. By the standard in table 1 composite binders made of 0.5% bentonite clay with 3.0% grade 2 acacia exudates is suitable for dry moulds for casting of aluminium, brass, bronze, light grey and malleable iron. Composites of 2.5% bentonite clay with 3.0% grade 2 acacia species is suitable for binding green and dry sand moulds for casting malleable iron. Permeability, hardness and shatter index in figure 13 are all suitable for sand moulds for the specified castings. Based on foregoing, composites of 3% grade 1 acacia species with varying bentonite clay are better binders than those of 3% grade 2 Nigerian acacia species with bentonite clay as they were suitable higher ranges green and dry sand moulds for different alloy castings.

4. Conclusions

The research revealed that combination of bentonite clay and each of the grades 1 and 2 Nigerian acacia species as composite binders for moulding sand gave better performance than when each of the materials is used separately as plain binders in a foundry. Presence of bentonite clay in grades 1 and 2 Nigerian acacia species bonded moulds generally improved permeability, hardness, shatter index and particularly, green and dry compressive strength by about 12% and 25% respectively. Though the peak values of bonding strength were not attained as shown by non sloping of the green and dry compressive strength curves, further addition of binder may cause decreases in values of some other critical foundry properties like permeability of moulds.

References

[1] Encyclopedia, Britannica (1989). Vol. 5 Encyclopedia, Britannica Inc. William Benton Publisher, London.

[2] C. Osagie (23rd July, 2002)."Gum Arabic and diversification of Nigerian economy". Thisday Publishing Co. Limited. Lagos, Nigeria.

[3] O. R. Fennema (1996). "Food Chemistry". Marcel Dekker, New York. Pp. 18 – 67.

[4] N. A. Ademoh and A.T. Abdullahi (2010). "Determination of optimal binding properties of grade 1 Nigerian acacia species for foundry mould sand". Middle East Journal of Scientific Research. http://www.indosi.org. IDOSI Publications. Vol. 5 (5) Pp. 402-406. ISSN 1818 - 6785.

[5] N. A. Ademoh and A.T. Abdullahi (2009). "Investigation of potentials of grade 2 Nigerian acacia species exudates as moulding sand binder in local non ferrous foundries in Nigeria". International Journal of Engineering Studies. http://www.ripublication.com/ijes.htm. Research India Publications. Vol. 1 (2) Pp.117 - 126. ISSN 0973 – 4562.

[6] American Foundry Men Society (AFS, 1989)."Mould and core testing Handbook". 2nd edition Procedure 113. Pp 74-78.

[7] R. Griffiths (1982)."Application of Australian bentonite clay in automobile foundry", British Foundry Men, London. Pp.93.

[8] S. Sawyerr (2008). Nigeria after oil: Preparing for sunset in the oil fields (Source FMSMN). Tell magazine, Nigeria. 18th February, 2008. Pp. 112-115.

[9] J. S. Siak, R. M. Schreck and K. Shah, USA Patent No. 5320157 (14th June, 1994)."Expendable core for casting processes".

[10] H. W. Dietert (1966)."Foundry core practice" 3rd edition American Foundry men's society, Des Plaines, Inc. Pp 2 - 154.

[11] http://www.nigeriaembassychina.com/eco/PRODUCE %200F% 20NIGERIA.htm. (2009) Retrieved 19-12-2011.