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EVALUATION OF CALABASH CHALK AS BINDER FOR PRODUCTION OF FOUNDRY CORES

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Abstract

Foundry researchers in developing countries like Nigeria are faced with the quest of finding new substitute input materials such as binding materials from locally available renewable sources to replace imported binders which are expensive. This quest has led to the finding of binding materials derived from yam, cassava, cereals and vegetable oil. However, these binders are obtained from foods and hence competing with their use for foundry work, which is of economic value to the country. This study focuses on using calabash chalk a non-edible substance as a binder for foundry practice. The study was carried out using calabash chalk as a binder together with Lamingo silica sand obtained from Lamingo dam in Plateau state, Nigeria. The sand was collected and analyzed in terms of grain size and clay content. The sand was then prepared to meet the basic requirement of a standard moulding foundry sand. By varying the binder and moisture content, cores were produced. The experimental investigation was focused on the mechanical properties of these cores. These include green compression, dry compression, and green shear strengths; dry compression, shear strength and permeability. Trial castings using aluminum alloy were made using cores made from 7% moisture content and 9% binder. The result obtained suggests that the calabash chalk material can be used as binder for non-ferrous metals.

Keywords

Foundry, casting, cores, calabash chalk, binder

INTRODUCTION

There are several foundry industries in Nigeria that source raw materials (silica sand, clay, binders and additives) used for producing effective sand cores from overseas, so there is a need to develop appropriate moulding raw materials since the foundry work in Nigeria depends exclusively on imported raw materials including the moulding sand. A binder is any material or substance that holds or draws other materials together sometimes with the use of heat to form a cohesive whole mechanically, physically with the binder or as an adhesive. Special binders are introduced into core sands to add strength. The oldest binder was vegetable oil, however now synthetic oil is used together with cereal or clay. The core is then baked in a convection oven between 200°C and 250°C. The heat causes the binder to cross-link or polymerize while this process is simple, the dimentional accuracy is low (Dhairya et al, 2015)

Metal casting industries uses large quantities of binders (Fayomi *et al,* 2011). In recent years, use of locally available core binders has increased. The variety of materials of which castings are made (types of alloys and their casting temperatures) will always make foundrymen face the requirements for obtaining moulds and cores with high

technological properties (Major *et al,* 2015). Binders suitable for foundry cores must not only hold sand grains together, but also be sufficiently resistant to high temperature so as not to collapse before the metal solidifies, but after solidification and cooling, they should completely collapse to allow sand to be easily removed from the casting leaving its surface smooth (Ademoh, 2010). Many domestic and foreign scientific centers have been trying to develop new non- toxic foundry moulding sand binders (Stachowicz *et al,* 2014). All organic binders have excellent breakdown, which makes them ideal for the casting of cores, where accessibility for fettling is difficult and the reduced fettling cost makes this binders economical. However, inorganic binders (clays, aqueous sodium silicate, bentonite, silicon flour and iron oxides are used to obtain additional green strength, retard or increase collapsibility of a core and to prevent cutting or penetration. The current direction in modern scientific research is to gradually replace binding materials produced from petrochemical stocks with biomaterials originating from renewable sources. This direction is consistent with the concept of sustainable development which is one of the priorities of the European community policy (Averous *et al,* 2012).
Binders obtained from farm produce have been in use since sand moulding was first introduced in the foundry industry. The first core oil were harvested by pressing the seeds of the flax plant (Lessiter *et al,* 2002). In a study toward establishing the beneficial effects of addition of linseed oil to foundry sand core bonded with Nigerian gum Arabic grades 2 and 4, Ademoh (2010) established that core bounded with 3% grade 2 gum Arabic and 3% linseed oil and baked at for 2.5 hours developed a baked strength of 720kN/m². Bentonite has been widely used as foundry – sand bond in iron and steel foundries. Sodium bentonite is most commonly used for large castings that use dry moulds, while calcium bentonite is commonly used for smaller castings that use green or wet moulds (Peter *et al,* 2012). According to Ian (2014) cores from linseed, petroleum, soya and vegetable oils were commercially introduced as binders during the early 1950s. Starch binders which are majorly produced from cassava in Nigeria, possess good ductility, good bind-ability, self-curing properties and hygroscopicity (Oladele *et al,* 2015).
This study aims at evaluating the mechanical properties of locally available material known as calabash chalk as a binder in sand mould casting for foundry practices.

Calabash Chalk
Calabash chalk is a naturally occurring material composed of fossilized sea shells. However it can be prepared artificially by combining clay, sand, wood ash and salt. By mixing and heating this mixture, the calabash chalk is obtained (Callahan, 2003). Most of the calabash chalk samples are clay rich soil materials that have been dried or baked in to blocky or spherical units (Abraham *et al,* 2013). Calabash chalk also known according to language/ localitys Argile (French), Calabar stone (English), China clay (Kaolinite), La Craie (French), Mabele (Lingala of Congo), Ndom (Igbo,Efik/Ibibio of Nigeria), Nzu (Igbo of Nigeria), Shilè (Ghana), and Eko (Urhobo, Nigeria) is a generic term used for naming these geophagical materials (Ijeoma *et al,* 2014). In its natural state, calabash chalk is a white soft solid block as shown in plate I and which can be ground to powder form as shown in plate II.

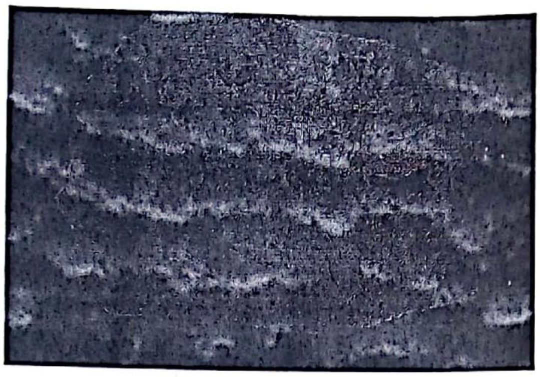

Plate I: Solid Calabash chalk

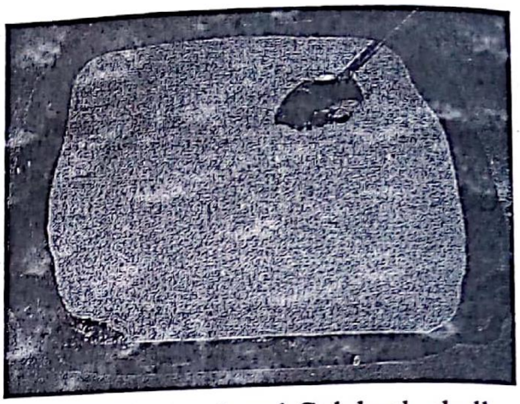

Plate II: Powdered Calabash chalk

MATERIALS AND METHOD

Materials and Equipment

The materials used for this research work were sourced locally. The silica sand was obtained from Lamingo dam in Plateau State. The calabash chalk (African kaolin clay) was sourced from Chobe market in Jos North local Government Council together with grey cast iron scraps. Table 1 shows the reference number, description and serial number of all the equipment's used for this study. All equipment's listed were manufactured by Ridsdale and Co. Ltd. Other equipment include crucible furnace, mortar and pestle mould boxes, gloves, goggles and molten metal handling equipment.

Table 1 List of Equipment Used

Item Ref. N0	Description	Serial Number
N0 44-CHT	Core Hardness Tester	-
No 14- DB	Digital Balance	LP50A
No 27- EPM	Electric Permmeter	872
No 25- LCO	Laboratory Core Baking Oven	DR-311
No 31-GCSM	Green Compression Strength Machine	8415
No.15- LSR	Laboratory Sand Rammer	7322
No 15-RB	Ramming Block for LSR	7323
No 33-USSM	Universal sand strength machine (motor driven)	LM-8415
No 8- STS	Standard Test Sieves	-
No7-BMM	Sieve Shaker (octagon 2000 Digital)	F- 1673
	X-ray Florescence spectrometer	PW 4030
	X-ray diffraction model 2000	

Source: National Metallurgical Development Center Equipment Catalog

Method
The calabash chalk was grinded to powder and finally sieved to obtain a uniform powdery texture. And the sand sample from Lamingo dam prepared to meet standard foundry specification. Sieve analysis was done to determine the grain size and finest number of the sand sample. By mixing and varying calabash chalk and water in various proportions, sand cores were produced and subjected to green compression strength test, shear strength test, permeability test and dry compression test. The results obtained from these tests were evaluated and recorded. Finally the casting of a mechanical part (connecting rod) was carried out.

Chemical ED – XRF
The calabash chalk was grounded into powder using a porcelain mortar and pestle and sieved with a 5mm hole size of sieve and oven dried at 100°C to uniform weight. The pulverized calabash chalk was collected in sampling poly bags for analysis. The mineral phases within the pulverized calabash chalk sample were identified by powered X-ray diffraction spectrometry method. The values of the various chemical elements contained in calabash chalk were recorded.

Grain Fineness Number
To determine the grain size and finest number of the sand sample, sieves were cleaned and arranged according to their sieve number from higher to lower. 100g of the freshly prepared sample sand was weighed and poured on the top of the sieve and was tightly closed. The machine was switched on and allowed to vibrate for 15 minutes. The sieves were removed one after the other starting with the topmost sieve. The weight retained on each sieve was obtained and recorded.

Test Specimen Samples
The test specimen made up of varying proportion of mixtures of sand, calabash chalk and water, were prepared using standard specification for sand test moulding. The mixture for each sample were measured introduced into a specimen tube of 50mm height by 50mm diameter. The test sample in the tube was then fed to the Ridsdale rammer which was then rammed with three blows of the standard rammer weight of 6.6kg. Using an extractor, the rammed specimen was ejected from the tube. This procedure is repeated for the various mixed samples.

Green Compression Strength
The green compression strength was carried out using the universal sand strength testing machine. A prepared standard sample was positioned in the compression head fixed to the machine. The magnetic reader on the scale was adjusted to start from the initial point on the scale. The compression testing machine was then powered. The sample was loaded gradually while the magnetic reader moves along the scale. As soon as the sample reached its maximum strength, the sample experienced failure and the magnetic reader remain in the position of the ultimate strength as the loading was gradually released. This process was repeated for samples with water content varying thus 1%,2%.3%,4% 5% 6%,7%,8%,9% and 10% and calabash chalk varying from 2%-10% respectively.

Permeability Test
Permeability test of the samples done by introducing into the test tube a standard specimen. The tube was then mounted on a permeameter and fastened. The permeameter lever was then moved and the meter powered. Air was thus passed through the sample and the reading on the meter was noted and recorded. This was repeated for the various mixed test samples.

Mould Preparation and Casting of sample piece
Using the value of the study sample with the highest shear strength, a sand mould using a connecting rod as pattern with sand sample of 30% was mixed with 3.9kg (10%) of calabash chalk and 156g (4%) of water was

produced. Aluminum was then melted in a crucible furnace at a temperature of 750°C. The molten metal was then poured into the mould and allowed to solidify. After solidification, the mould was then broken off and the casted metal piece was removed.

RESULTS AND DISCUSSION

Chemical ED – XRF Test Result

Table 2 shows the result of the chemical Energy Dispersive X-ray fluorescence test performed on the calabash chalk sample used for the investigation.

Table 2: Chemical ED-XRF Parameters (%)

Sample	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	NiO
Calabash chalk	22.70	63.20	0.41	0.04	2.83	0.37	0.09	0.03	6.33	0.008

CuO	Ga_2O_3	As_2O_3	SrO	ZrO_2	Nb_2O_5	PbO
0.02	0.01	0.003	0.03	0.18	0.02	0.03

The result shown in Table 2 shows that the calabash chalk used contains seventeen (17) different elements with ten (10) occuring as traces. From the result the sample contains more of Silicon oxide and Aluminum oxide followed by Iron (III) oxide and Titanium dioxide. Zinc, Mercury (II) oxide and Gold were not detected in the calabash chalk sample.

Mechanical Test Results

The result of green compression and green shear strength, dry compression and dry shear as well as permeability for various percentages of calabash chalk at 4%, 5%, 6%, 7%, 8%, 9% & 10%.

Figure 1 shows the variation of moulding green strength with increasing calabash chalk content in the sand and at moisture content of 4%, 5%, 6%and 7%. Here, it shows a general progressive increase in the green strength as the calabash chalk is increased. The highest green strength of 130kN/m² was achieved with 5% moisture content and 11% calabash content. 6% moisture content also gave good green strength. The figure shows a decrease in green strength obtained at 8%, 9% and 10% moisture content showing that the binding property of calabash chalk is affected by the moisture content.

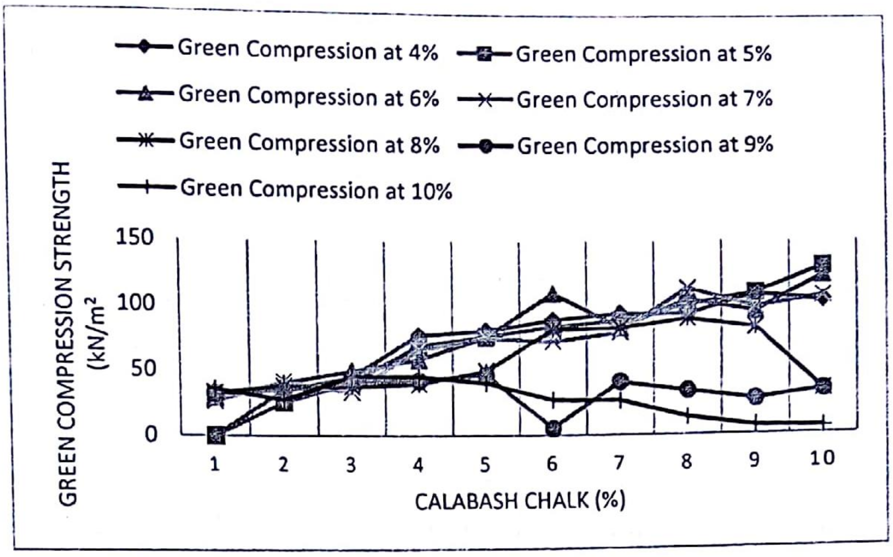

Figure 1: Variation of green compression strength with calabash chalk

Figure 2 shows the green shear strength obtained from 4% to 10% moisture content. Green shear strength at 4%, 5% and 7% was between 20kN/m² and 31kN/m². The highest green shear strength was achieved at 6% moisture content with a value of up to 44kN/m². The green shear strength at moisture content of 8%, 9% and 10 % also decreased has the case with green strength.

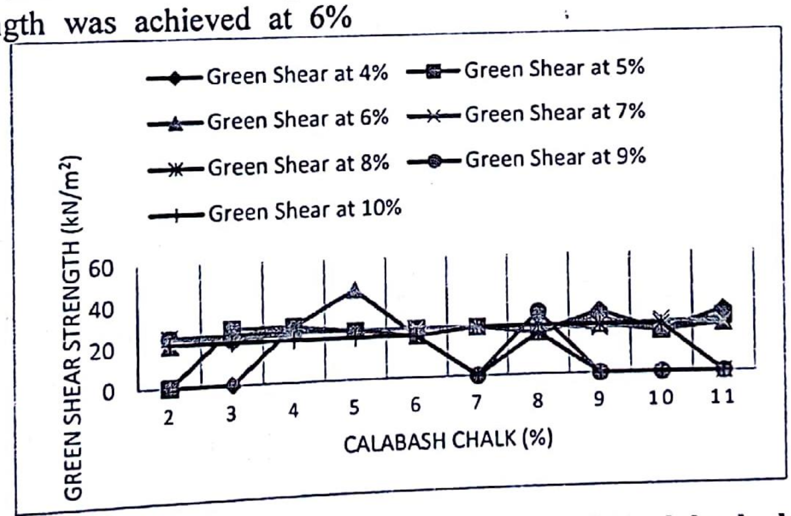

Figure 2: variation of green shear strength with calabash chalk

Figure 3 shows the dry compression strength at various moisture content. At 3% calabash chalk and 4% moisture content no strength was achieved, implying that that moisture content was too low to create a strong bond after drying. At 4% calabash chalk and moisture content of 6% and 7% it was seen that the dry compression strength was constant and stable. Lower value of dry compression strength was obtained at 4% and 5% moisture content. However, the cores produced between 8% to 10% moisture content gave a constant dry compression strength values. At 2% calabash chalk content, dry compression was below 200kN/m² and at 11% calabash chalk dry compression strength was below 50kN/m².

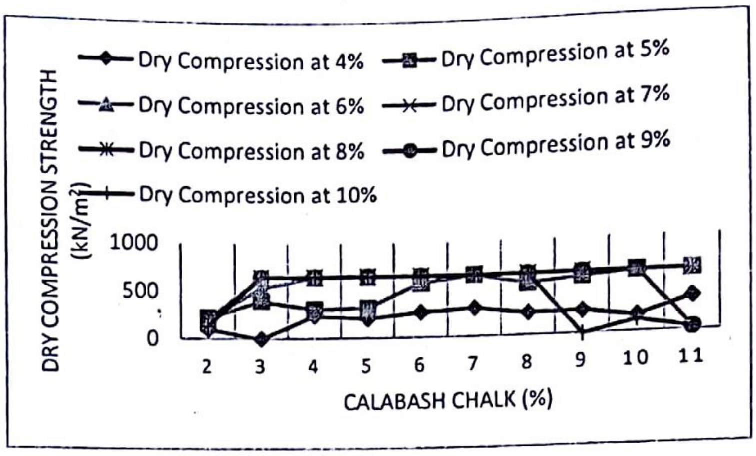

Figure 3: Variation of dry compression strength with calabash chalk

Figure 4 at 6% calabash chalk and 4%, 5%, 6% and7% moisture content dry shear strength is constant. However, the highest dry shear strength was attained at 9% calabash chalk and 6% moisture content. Highest value of dry shear was attained at 6% moisture content and lowest at 4% moisture content. The dry shear strength lies between 3% and 6% calabash chalk. Highest dry shear was attained at 4% calabash chalk at moisture of 10%. Figure 5 shows the various permeability results of the cores produced. Permeability values obtained was found to decrease generally with increase with calabash chalk.

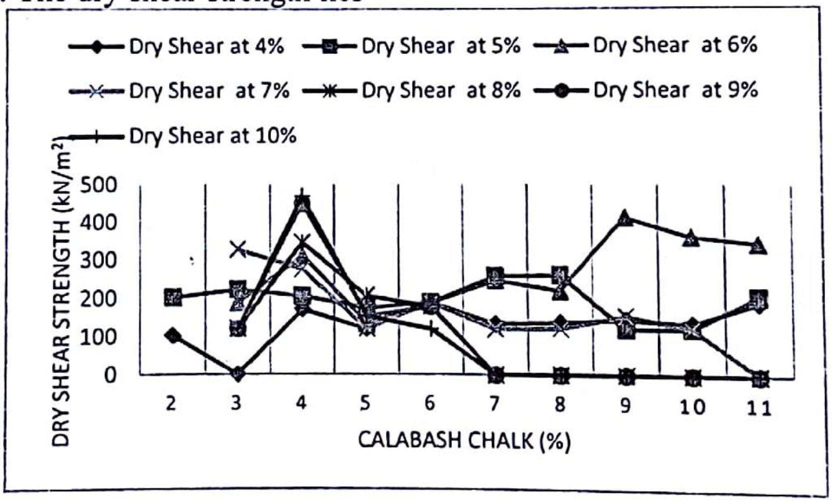

Figure 4: Variation of dry shear strength with calabash chalk

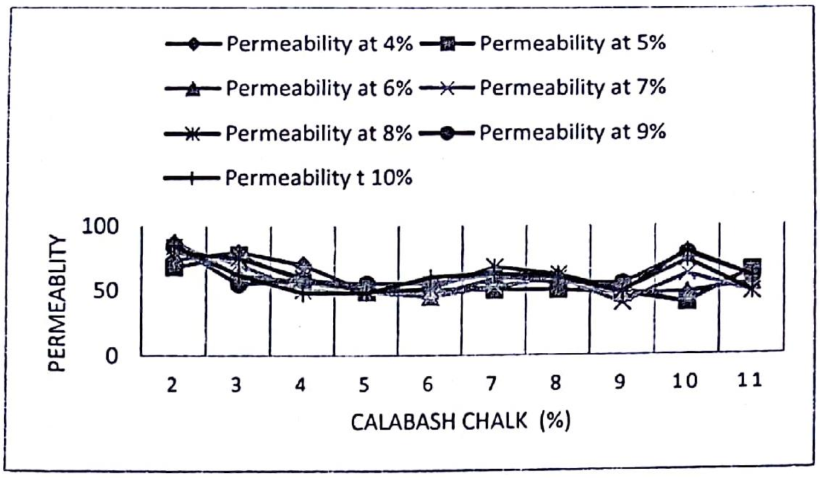

Figure 5: Variation of permeability with calabash chalk

Samples of cast pieces using calabash chalk as binder.

Plate III shows the outcome of the cast metal produced using calabash. The cast piece showed some form of erosion defect on the surface. This must have been caused as a result of the poor compaction of the binder and sand mix of the mould and thus resulting to insufficient sand cohesion.

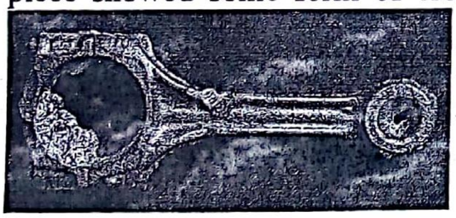
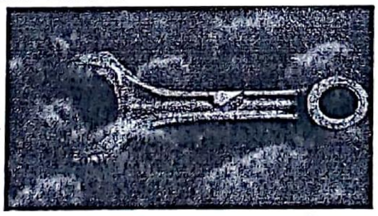
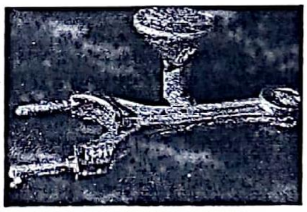

Plate III : Cast connecting rod

CONCLUSION

Using calabash chalk as a binder in sand moulding has shown that green and dry compression strength cannot be attained for moisture content of the mix less than 4%. The moisture content in which good green strength and dry compressive strength was developed was between 4 and 7%. Above 7% moisture content there is a general decrease in the green strength of the core and an irregular behavior of variation in strength is observed. Permeability numbers obtained in the study is between 40 and 88 in all the test values suggesting that the cores developed using calabash chalk as binder have fairly good foundry properties. Green compression strength between 58.6kN/m² and 122.7kN/m² was developed, which suggests that the cores could be handled in the green state without shattering. The properties of these cores made them suitable for the application in the production of ferrous and non – ferrous castings as it was successfully demonstrated in the casting of aluminium connecting rod.

REFERENCES

Abraham, P., Davis, T., Solomon, A., Trow, A., Wragg, J. Human Geophagia Calabash Chalk and Undongo: Mineral Element Nutritional Implication. Accessed 31st July 2017

Ademoh, N.A. (2010). Evaluation of The Tensile Strength of Foundry Cores Made With Hybridized Binder Composed of Neem Oil and Nigerian Gum Arabic. *International Journal of the Physical Sciences* Vol. 5(5): 557-563.

Averous, L, Pollet E. (2012). Enviromental Silicate Nano- Biocomposites. ResearchGate Springer, ISBN: 978-1447-4108-2 DOI: 10.1007

Callahan, G. (2003). Eating Dirt. Emerge infectious disease, 19(8): pp. 1016-1021.

https://dx.doi.org/10.3201/eid0908.030033.

Dhairya S.D, Gunjan B.C, Aman G.C, Shrikant U.G. (2015). A Study of Core and Its Type for Casting Process. *International Journal of Advanced Technology in Engineering and Science.* ISSN 2348-7550 pp. 1579.

Fayomi O., Abdulwahab, M., Popoola, A.P. (2014). Potentials of Elaeo Guineensis and Pinus Sylvestries as Binder on Foundry Core Strength. *Journal of Scientific & Industrial Research,* Vol (73), pp. 173 - 176.

Ian, D. (2014). The Environmental Performance of Bio-Based Resin with Phenolic- Urethane No-Bake Binders: A Feasibility study. Paper 54 http://scholarwork.uni.edu.etd

Ijeoma H., Otokpa E., Oguezi V., and Ibekwe F. (2014) Assessment of Heavy Metals in Edible Clays Sold in Onitsha Metropolis of Anambra State, Nigeria *British Journal of Applied Science & Technology* 4(14): pp. 2114-2124.

Lessiter. M.J., & Kotzin. E.L. (2002). Timeline of Casting Technology. *Engineered Casting Solutions.* Vol.4 (3), pp. 76-80.

Major, K.G., Dobosz, S.M, Drozynski, D., Jakubski, J. (2015). The Compositions: Biodegradable Material- Typical Resin, as Moulding Sand's Binders. Archive of Foundry Engineering; ISSN: 1897-3310, Vol. (15), pp. 35-40.

Oladele, I.O. & Okoro, M.A. (2015). The Effect of Cassava Starch and Natural Rubber as Binder on the Flexural and Water Absorption Properties of Recycled Paper Pulp Based Components. *International Journal of Engineering and Technology Innovation,*vol.5(4), pp.255-263.

Peter, K.M., Maranga, S. M. and Ikua, B.W. (2012). An Appraisal on the Potential Uses of Bentonite and Its Availability and Exploitation in Kenya. *Proceedings of the Mechanical Engineering Conference on Sustainable Research and Innovation,* Volume 4, pp. 200 – 205.

Stachowicz, M., Mazulis, J., Granat, K., Janus, A. (2014). Influence of Moulding Sand And Core Sand Matrix on The Effectiveness of the Micro-waves Absorption. *Metallurjiga,* vol.53 (3), pp.317-319.