Characterisation of Green Properties of Use Offot Sand Deposit for Foundry Purpose and Application

Joy N. Ogbodo and David Dania
Scientific Equipment Development Institute, Enugu, Enugu State-Nigeria.
Corresponding author's email: joyogbodo429@yahoo.com

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Abstract

Characterization of green properties of Use Offot sand deposit for foundry purpose and application has been carried out. Sand samples for the characterization were obtained from Use Offot sand deposit, and the sand samples were dried in the oven at a temperature of 120^{O}C. Some samples were removed for clay content determination, particle size distribution analysis, and grain fineness number calculation. Measured quantities of the sand were also mixed with 4% bentonite, and various percentages of water to prepare different moulding mixtures for green shear strength, green compression strength, and green permeability tests. The result of the analysis show that at constant bentonite content of 4% the green strengths were affected by the increase in moisture content of the moulding mixtures. The green strengths increase to maximum at 6% moisture, after which further increase in moisture leads to decrease in the green strengths of the moulding mixture. The study showed that the 6% moisture content was a threshold value that affected all the green properties of the sand, even the green permeability dropped drastically at 6% moisture content. The result also confirmed that the sand is a synthetic sand with 1.8% clay content. It has a grain fineness number of 94.3 AFS making it suitable for foundry application and it is also a three-sieve sand with good strength and other properties commonly associated with three-sieve sands. During casting because of the sand's high grain fineness number of 94.3 it will provide good surface finish for the castings.

Keywords: *Characterization; green properties; casting; foundry sands; application; Use Offot.*

1. INTRODUCTION

Foundry technology is one of the oldest method of shaping metals in the world. The history of metal casting dates back as far as 4000 BC, when various items of silver, bronze and gold were cast in Egypt. Castings, the products of the metal founding industry, are manufactured in a single step from liquid metal without intermediate operations of mechanical working such as rolling or forging. Shaped castings are thus distinguished from ingots and other cast forms which are only at an intermediate stage of their metallurgical life. Foundry is the most direct of all metallurgical processes and has provided the foundation for the growth of a vast industry with a wide diversity of products (Ihom *et al.*, 2015; Ihom, 2022).

According to Asuquo, (2015), foundries are work establishments where ferrous and non-ferrous metals are first of all caused to be liquid or molten by application of heat and then cooled rapidly in a mould to yield a solid mass. This solidified metal takes the shape of the pattern cavity made in a mould. The pattern itself is a replica of the object which the foundry man wants to produce just as a seamstress uses paper patterns to make ladies dresses in a material of choice (Asuquo, 2015).

There are different casting techniques used in foundry, and the commonest technique is the sand casting technique. The technique is common because of its versatility and its ability to handle large, heavy and complex castings. This was the technique used during the colonial era in Nigeria at Defence Industry Corporation of Nigeria (DICON) and Nigerian Railways Corporation (NRC). The main raw materials for mould preparation was foundry sand, binder, water, and surfactants. It was the believe in those days that these materials were not available in Nigeria until some foundry workers at the Nigerian Railways Corporation, Enugu started experimenting with local raw materials for mould making, and discovered that the Enugu sand and other raw materials were equally as good as the imported sand and materials (Ihom, 2012).

This work is a continuation of their effort at developing local raw materials for sand casting. Foundry sand must meet certain characteristics which include, refractoriness, grain fineness number, four graded sieve, chemical resistivity, permeability, green strength, dry strength, flowability, collapsibility, thermal stability, and others. The green strengths aid in the mouldability of the sand and pattern withdrawal, while the dry strengths are needed during molten metal pouring. Permeability is needed for gas escape during metal pouring and solidification (Ihom, 2012; Ihom, 2022)

The objective of this work is to characterize the green properties of Use Offot sand deposit for foundry purpose and application. The shape of sand grains, their grading on the sieve; for which a four-sieve sand is the best, and sand with angular shape has the highest strength during moulding explains the importance of sand characteristics in foundry (Ihom, *et al.*, 2015).

2. MATERIALS AND METHOD

2.1 Materials

Natural and untreated water was used to reduce the effect of chlorides on the strength property of the moulding mixture. The Use Offot sand deposit used was obtained directly from Use Offot site of the deposit in Uyo Local Government area, Akwa ibom state-Nigeria. The equipment used were those in the sand testing laboratory of the National Metallurgical Development Centre, Jos-Nigeria. These include: nest of sieves and sieve shaker, electronic digital balance, speedy moisture tester, universal strength testing machine, sand rammer, electric permmeter, and others.

2.2 Method

2.2.1 Sieve Analysis

300g of Use Offot sand was weighed and dried to a constant weight using a pickstone oven produced by Ridsdale and co. Ltd. Middlesbrough-England. 100g of the Use Offot sand was weighed and introduced into the top–most sieve of the nest of sieves arranged from the largest aperture to the smallest. The nest of sieve was mounted on a sieve shaker and vibrated for 15 minutes. The sieves had the largest sieve with an aperture of 1400 microns and the smallest with an aperture of 63 microns. The result was tabulated and used in calculating the grain fineness number of the Use Offot sand deposit.

2.2.2 Determination of the Clay Content of the Use Offot sand

50g of the sand, which was dried to a constant weight was weighed, introduced into the beaker of the clay washer apparatus. This was then washed with a solution of 475ml of distilled water, and 25ml of 3% sodium hydroxide solution for five minutes with the aid of a mechanical stirrer in the washing machine. A little water was used to wash into the beaker the sand particles that stuck to the stirrer. It was allowed to settle for 10 minutes, and then the suspension formed as a result of clay was siphoned-off. Fresh water was added, allowed to stand for 5 minutes, and again the water on top was siphoned off. This continued at 5 minutes interval until the water was clear. The sand that remained was then drained of water and dried in the oven at $120^{O}C$ and reweighed. The difference in weight was multiplied by 2 and that gave the AFS clay content percentage of Use Offot sand deposit.

2.2.3 Moulding mixture preparation and standard test specimen

The moulding of the sand mixture was done using a laboratory size muller (mixer) made by Ridsdale and Co.Ltd. with serial No. 845. The mixing was done for 5 minutes, and then discharged. For each batch, 1kg of the Use Offot sand was mixed with water. The water content was varied from 2 to 10%. The sand mixture prepared was used to prepare standard test specimen (50mm x 50mm) using a digital weighing balance, specimen test tube, hopper, and sand rammer.

2.2.4 Green Compression Strength

The standard test specimen which were prepared as stated above were quickly transferred to the universal strength testing machine made by Ridsdale and Co. Ltd with serial No. M8415, using the compression head accessory, the specimens for green compression were failed and the result registered on the green compression scale of the machine.

2.2.5 Green Shear Strength

The standard test specimen which were prepared as stated above were quickly transferred to the universal strength testing machine made by Ridsdale and Co. Ltd with serial No. M8415, using the shear strength head accessory, the specimens for green shear strength were failed and the result registered on the green shear strength scale of the machine.

2.2.6 Green Permeability

The standard test specimens for green permeability were transferred immediately to the electric permmeter made by Ridsdale and Co. Ltd with serial No.872 for the determination of the green permeability of the Use Offot sand in green condition. The specimens were mounted on the device, while still inside the specimen tube. The machine was switched on and the test lever adjusted to test. The result was displayed on the dial of the machine in AFS perm units.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution of Use Offot Sand

Table 1 shows the sieve analysis of Use Offot sand as determined with the calculated grain fineness number.

Table 1 Sieve Analysis of Use Offot Sand Deposit

S/N	Sieve Aperture (mm)	BSS NO.	Weight Retained	Product
1	2.06	8	-	-
2	1.40	12	10.60	84.80
3	1.00	16	10.66	127.92
4	0.71	22	9.40	150.40
5	0.50	30	7.50	165.00
6	0.355	44	6.06	181.80
7.	0.250	60	4.64	204.16
8.	0.180	85	2.58	154.80
9.	0.125	120	2.63	223.55
10.	0.090	170	15.20	1824
11.	0.063	240	14.90	2533
12.	-0.063	300	15.70	3768
	Total		99.87	9417.43
	Clay content 1.8%	Colour: light brown	Grain shape : angular	

GFN (Grain Fineness Number) = Product/Weight retained = 9417.43/99.87 = 94.30 AFS

Table 1 shows the particle size distribution of the Use Offot sand. Microscopic examination shows that the sand has light brown colour and angular grain shape. The sand is a three-screen sand with the particle sizes reasonably distributed in all the screens. The shape of the sand and the particle size distribution of the sand could give rise to good permeability and strength (ihom and Anbua, 2006; Ihom, 2012). Table 1 gives the grain fineness number of the Use Offot sand as 94.30 AFS. This value falls within the common foundry range of 150 to 400 microns (Rundman, 2000; Ihom *et al.* 2015). While average grain size and AFS grain fineness number are useful parameters, choices of sand should be based on particle size distribution. The size distribution of the sand affects the quality of the castings. Coarse-grained sands allow metal penetration into moulds and cores giving poor surface finish to the castings (Ihom 2022). Rundman (2000), agrees also that the properties of moulding sand depend strongly upon the size distribution of the sand that is used, whether it is silica, olivine, chromites, or other aggregates (Rundman, 2000).

3.2 Clay content determination

The result of the clay content of the Use Offot sand shows that it has a clay content of 1.8%. This means that it is a synthetic sand and not a natural sand. During moulding using Use Offot sand clay binder needs to be added for the sand to be mouldable for foundry purpose (Ihom 2022).

3.3 Moisture content variation with green shear strength

Figure 1 shows that as the moisture content increases from 2% to 10% the shear strength increased from 10.5kPa to 11.2kPa peaking at 14kPa and 6% moisture and then gradually decreased to 11.2kPa at 10% moisture content. This trend is typical of most moulding mixtures where the binder or clay content remains constant with changes in moisture content. The shear strength increases as the moisture content increases reaching an optimium level where further increase in moisture weakens the sand-clay bonds, this is confirmed by the gradual decrease in the shear strength after 6% moisture content (Ihom *et al.,* 2011; Ihom, 2012; Ihom *et al.*, 2015; Ihom 2022).

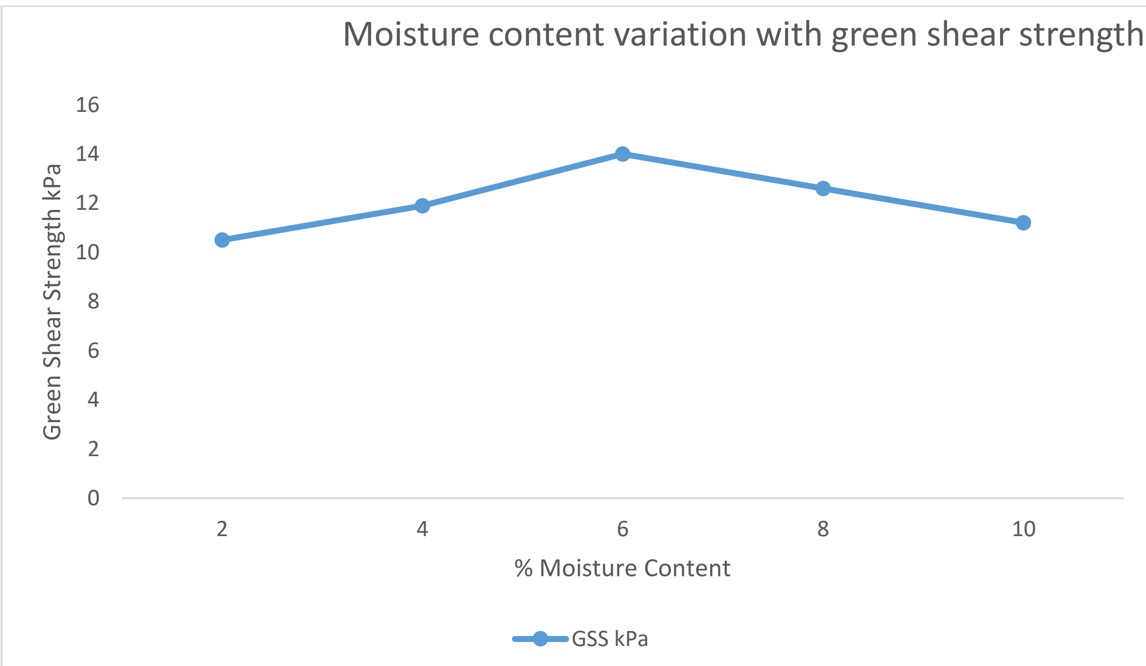

Figure 1: Moisture Content Variation with Green Shear Strength

3.4 Moisture content variation with green compression strength

Figure 2 illustrates the variation of the moisture content of the sand with the green compression strength of the Use Offot sand. As the moisture content increases the green compression strength also increases until optimum value was reached, after which the green compression strength decreased, as the moisture content increased. At the moisture content of 2% the green compression strength of the Use Offot sand was 14kPa; the green compression strength of the sand increased with the moisture content up to 31.5kPa at 6% moisture content after which further increase in moisture content led to gradual decrease in the green compression strength. This phenomenon has being explained in terms of the weakening of the clay-sand bond as the moisture content increases with constant clay content of 4%. Clay binder has a limit to the moisture it can contain; excess moisture results in weakening of the sand-clay bond that gives strength to the moulding mixture (Ihom *et al*., 2011).

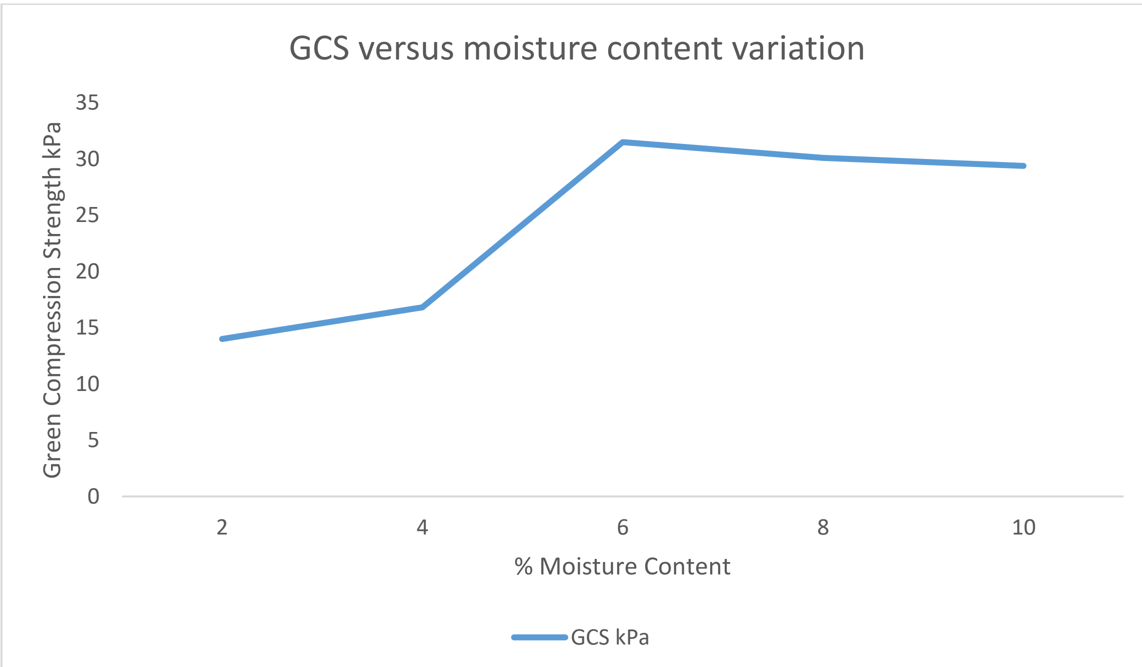

Figure 2: Moisture content variation with Green Compression Strength of Use Offot Sand

3.5 Moisture Content Variation with Green Permeability

Figure 3 shows the graph of green permeability of Use Offot sand against moisture content. At 2% moisture the green permeability was 340 perm units, as the moisture was increased the permeability was decreasing gradually until it dropped greatly at 6% moisture to 300 perm units. 6% moisture content is therefore an optimum moisture content for this moulding moisture which has a constant value of 4% clay content, after 6% moisture the permeability again rose, before dropping again to 300 perm units at 10% moisture content. This trend is seen in most of the works reviewed with moulding mixtures with constant clay value (Armond, 1982; Brown, 1994; Ihom *et al.*, 2009). According to Rundman, (2000), permeability increases in a nearly linear manner due to the swelling action of the clay particles, thereby pushing the sand particles further apart and making more room for air passages. Beyond the point where the clay becomes saturated with moisture, the water merely fills space in the void volume, resulting in an increase in density and decrease in permeability. The curve in Fig. 3 did not agree with Rundman explanation it however, clearly show the point of moisture saturation after which the permeability increased again as a result of the swelling effect of the clay (Ihom *et al.*, 2009b; Ihom *et al.*, 2011).

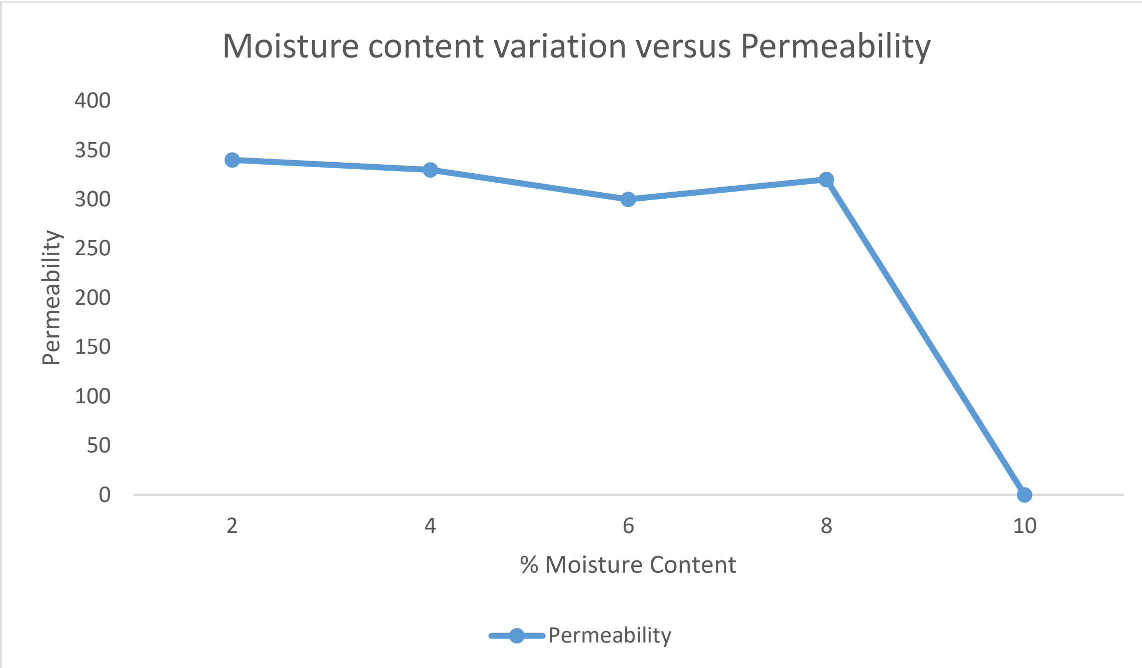

Figure 3: Moisture variation with Green Permeability of Use Offot Sand

3.6 Moisture Content Variation with Green Foundry Properties

Figure 4 shows the effects of moisture content variation on the green foundry properties of Use Offot sand. The figure shows the curve of green permeability on top, followed by the curve of green compression strength, and then that of the green shear strength. Green strengths are needed for moulding mixtures to be mouldable; experience has shown that for a moulding mixture to be mouldable the green shear strength has to be 10.5 kPa and above (Ihom and Olubajo, 2002; Ihom *et al.*, 2006; Jain, 2009). Less than that value can be moulded, but with difficulty. Green strengths are needed for easy withdrawal of patterns which are very important in quality moulding and casting. Most foundry green sands are synthetic sands just as Use Offot sand is synthetic. The recommended green permeability for green sands is 80-110, the Use Offot sand has a higher permeability which is still in order because with this high permeability gas entrapment in the mould during casting will not occur (Brown 1994; Jain, 2009). The gases and produced steam in the moulds will easily escape. The recommended green strength is 70-100 kN/m^2; the green compression strength is less than the recommended green compression strength for casting, the highest green compression strength was 31.5kPa which is lower than recommended value. Green foundry properties are very important because they are responsible for quality casting (Ihom and Olubajo, 2002; Ihom *et al.*, 2006; Jain 2009)

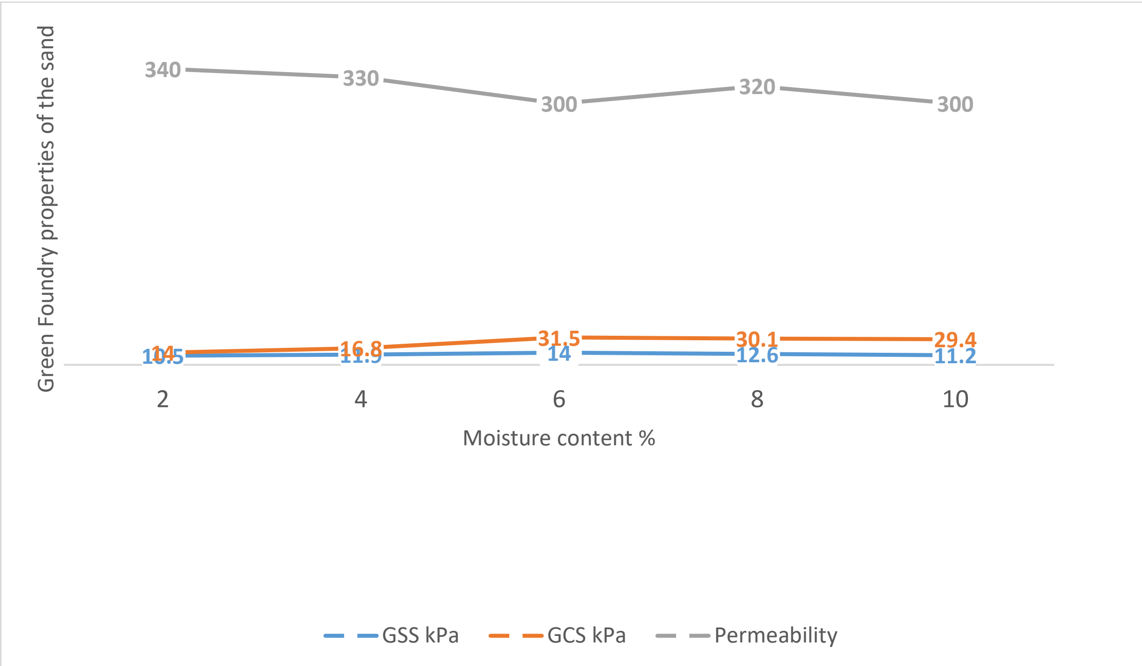

Figure 4: Moisture Content Variation with Green Foundry Properties of Use Offot sand

4. CONCLUSION

The study titled the ‘’Characterisation of Green Properties of Use Offot Sand Deposit for Foundry Purpose and Application’’ has been carried out. The green sand properties of the sand has been X-rayed and the following conclusions drawn from the study:

1. The sand is a synthetic sand with a clay content of 1.8%
2. The sand has a grain fineness number of 94.3 AFS and falls within the common casting range for foundry sand.
3. The sand is a three-sieve sand and bulk of the sand is contained in just three sieves
4. The sand is angular in shape and can contribute to good strength and permeability
5. The shear and compression strengths of the Use Offot sand increases with increase in moisture content up to 6% moisture where the optimum moisture is attained and the green strengths decreases with any further increase in moisture content.
6. The permeability was seen decreasing with increase in moisture content, there was however a drastic drop at 6% moisture which indicated the saturation point of the moulding mixture. The permeability however increased before dropping again, this was explained in terms of the swelling nature of the binder clay and the tendency of the swelling to create spaces within the moulding mixture.

REFERENCES

Armond V.J. HP Sand: Further Developments Extend the Range of Semi-Synthetic Moulding Sands, The British Foundryman, 1982, Pxxii-xxiii.

Asuquo, L.O. (2015) Foundry Technology, 2nd Edition, Uyo: published by Jesloc Intl Agencies, Ibom e-Library Complex, P1-10

Brown, J.R. (1994) Foseco Foundryman's Handbook, Tenth Edition, butterworth Heineman Publishers Oxford, p16-17

Ihom, A.P. (2012) Foundry Raw Materials for sand Casting and Testing Procedures, 1st Edition, Jos: A2P2 Transcedent Publishers, P1-25

Ihom, A.P (2022) Modern Foundry Principles and practice, 1st Edition, Uyo: PAI Memorial Centre for Innovation and Research, P20-35

Ihom, A.P, Agunsoye, J. Anbua, E.E. and Bam, A, The use of Statistical Approach for Modeling and studying the effects of ramming on the mould parameters of Yola Natural Sand, Nigeria Journal of Engineering, 2009a, 16(1), 161-165.

Ihom, A.P., Anbua, E.E., Bam, A., Onche, E. Effects of Ramming on the mould properties of yola Natural Sand, Continental journal of Engineering Sciences, 2009b, 4. 20-25

Ihom, A.P., Agunsoye, J, Anbua, E.E. and Ogbodo, J., Effects of Moisture Content on the Foundry Properties of Yola Natural Sand, Leonardo Electronic Journal of Practices and Technologies, 2011 19(1) 85-96

Ihom, A.P., Ocheri, C., and Offiong, A. (2015) Fundamentals of Foundry Technology, 1st Edition, Jos: La asuk Publications, p1-30

Ihom, A.P. and Olubajo, O.O., Investigation of Bende Ameki Clay Foundry Properties and its suitability as a binder for sand casting, NMS Proceedings, 19th AGM, 2002, 18-19

Ihom, A.P., Yaro, S.A., and Aigbodion, V.S. Application of Multiple regression model to the study of Foundry clay bonded sand mixtures JICCOTECH, 2006, Issues 2, 161-164

Jain, R.K.(2009) Production Technology, 11th Edition, New Delhi: Khanna Publishers, p148-170

Rundman, K.B. (2000) Metal Casting, Reference Book for MY4130 P11-16