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Comparative Study of Effects of Ado-Ekiti Moulding Sands on Some Metal Castings

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Ado-Ekiti is known for abundance of moulding sands used for building, construction and foundry works. The effects of moulding sands on some metal castings was studied in this work. Four sand samples were taken from four river locations (Oke-Ureje, Omisanjanna, Odo-Ayo, and Ogbese) at Ado-Ekiti. These samples were employed as moulding material to construct moulds for the production of aluminum alloy castings. The materials were characterized and investigated to determine the effects they would have on the mechanical properties and microstructures of the castings. Even though the samples produced close value results, they all within the range of standard values for foundry operations. Oke-Ureje sand gives the highest values of yield strength, ultimate strength and Young Modulus of 105.74 N/mm^2, 125.26 N/mm^2 and 352.47 N/mm^2 respectively.

Keywords: Sand; moulding; aluminum; mechanica; casting.

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1. INTRODUCTION

Foundry is the process of producing metal components of desired shapes by pouring the molten casting material into a prepared mould and then allowing it to cool and solidify [1]. The mould can either be sand or die in nature. Sand mould is broken and die mould is taken apart to remove the castings. Sand casting method is one of the manufacturing processes in foundry technology whereby foundry sand is used to produce a mould in which molten metal is poured to produce a cast. Foundry sand is a vital material used in the foundry industries. It often determines the quality of castings when good control of other factors is ensured [2].

Raw Material Research and Development Council (RMRDC) in 1990 delved into geological survey of Nigeria resources and found sand as one the major mineral deposits in the country. Sand covered an estimated proven reserve of billions of tones of mineral resources; out of which petroleum, gas and coal resources exploration had only received sufficient attention [3,4]. One of the best-known applications of sand in the olden days was in the manufacture of some articles such as pottery and statutes, dating back to the 'NOK' culture of eighteenth century, particularly in Benin City in Nigeria. Nwajagu [2] narrated the story of the Assyrian King Sennacherib (704 – 681 B.C) who cast massive bronzes of up to 30 tons, and claimed to have used clay moulds rather than the 'lost–wax' method. Atanda and Ibitoye [5] revealed that almost all foundry industries in Nigeria using the sand casting technique imported 60% of the sand used.

Sand nowadays is used to cast components that have useful strengths for construction. Shuaib-Babata and Olumodeji [6] submitted that the strength of castings rest on the fundamental behaviour of the foundry sand among other parameters that was basically used in casting the component. It is therefore clearly understood that foundry sand occupies a special and non-substitute position in the foundry industry which has to be properly maintained and put into consideration before being used.

It was discovered that foundry sands were abundantly available and scattered all over the towns and villages in the country which had been in use for past decades for casting of aluminum cooking utensils, decorative ornament and others without any evidence or trace of determining the mechanical properties or carrying-out any effect of sand on the casting components. This research presents the moulding sands from four rivers in Ado-Ekiti, South Western, Nigeria and influence of the sand on the mechanical properties of the components produced from the moulding sand.

2. MATERIALS AND METHODS

2.1 Study Area of the Research and Collection of the River Sands

Ado-Ekiti is the study area selected for this investigation. It is located in Ekiti State of Nigeria; situated in between longitude 5^0 11' and 5^0 25' and latitude 7^0 11'and 7^0 37' [7] as shown in Figure 1. The sand samples for the experimental work were collected from four different major locations in Ado Ekiti metropolis:

Sample A – Oke Ureje river bank's sand along The Federal Polytechnic, Ado Ekiti road
Sample B - Omisanjanna river bank's sand along 132KV area Ado Ekiti
Sample C – Odo-ayo river bank's sand at Bawa Estate along Iworoko road Ado Ekiti
Sample D - Ogbese river bank's sand along Ijan road, Ado Ekiti

2.2 Properties of the Sand Samples

The physical and mechanical properties of the sand samples had been obtained from a previous characterization study conducted by one of the authors in Abegunde et al [8]. Table 1 shows the properties of the sand obtained from the study:

2.3 Preparation of Moulds for Aluminum Casting

The sands samples used in analysis were made into moulds (Fig. 2). The sand samples were thoroughly turned and mixed to achieve homogeneity for the construction of the moulds.

2.4 Determination of Tensile Strength of Cast Aluminum

Test pieces were machined from the castings produced in this study. The work piece was machined on the lathe machine in order to produce a round test piece, with the center turned down to a reduced diameter to provide for a 2-inch gauge length. The specification is shown in Figure 3 and process of production is shown in Fig. 4.

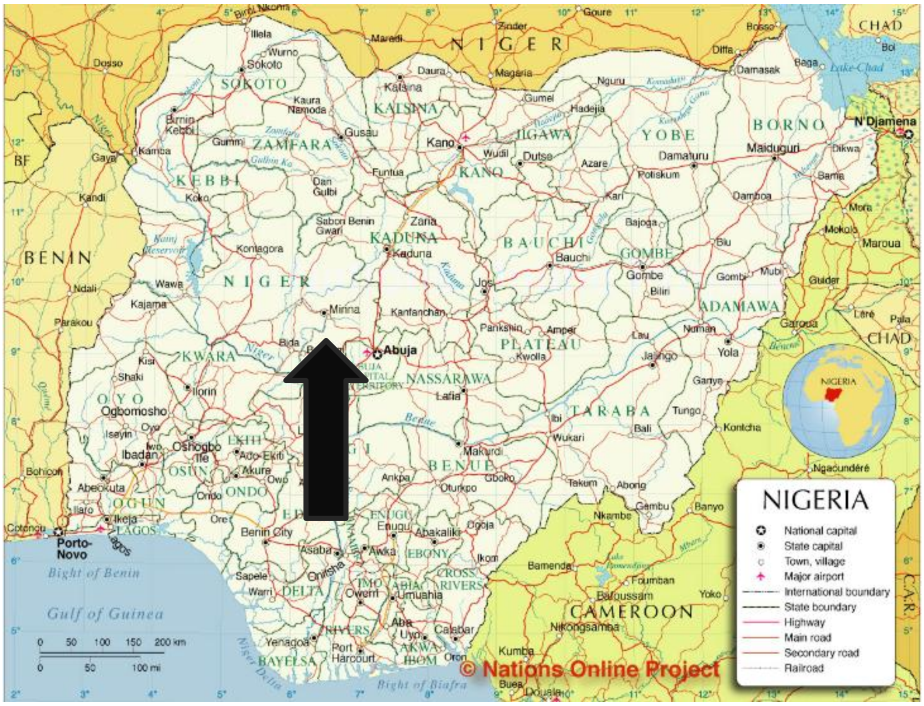


Fig. 1. Map of Nigeria showing Ado Ekiti in Ekiti State (Ayodele and Fakolade, 2014)

Table 1. Physical and Chemical Properties of the Sand Samples

Sand Samples	Bulk Density (g/cm^3)	Flowability (%)	Permeability (cm^3/min)	Dry Shatter Index	Green Shatter Index	Dry Compressive Strength (kN/m^2)	Green Compressive Strength (kN/m^2)	Clay Content
Oke-Ureje	12.25	61.25	67.52	0.66	0.84	97.6	58.8	13
Omisanjana	12.04	62.5	66.2	0.51	0.78	94.5	55.8	12
Odo-Ayo	12.23	61.87	61.87	0.61	0.73	91.8	54.1	10
Ogbese	11.9	61.25	61.25	0.59	0.89	82.9	44.4	6
Standard Value	9.7-13.4	50-68	50-68	0.46-0.68	0.69-0.89	80-100	25-60	8.5-13.4

(a) Placing of pattern **(b) Filling & ramming of mould** **(c) Top filling of the drag**

(d) Placing of cope over drag (e)Removing of runners & riser (f) Venting of the mould

(g) Opening of mould to remove the patterns (h) Dressing & gating the mould. (i) Covering of the mould & ready for casting.

Fig. 2. Mould Preparation for casting

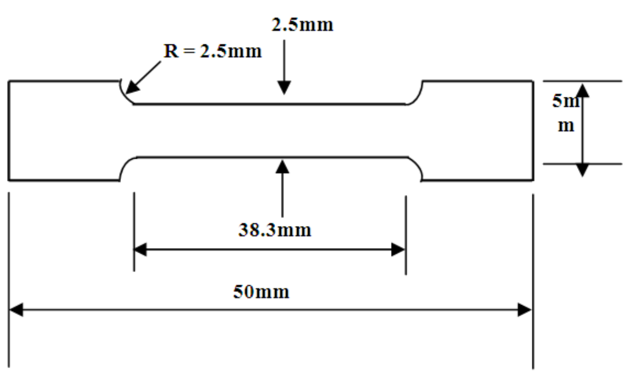


Fig. 3. Test-Piece Specification

Fig. 4. Production of Tensile Specimens on Lathe Machine

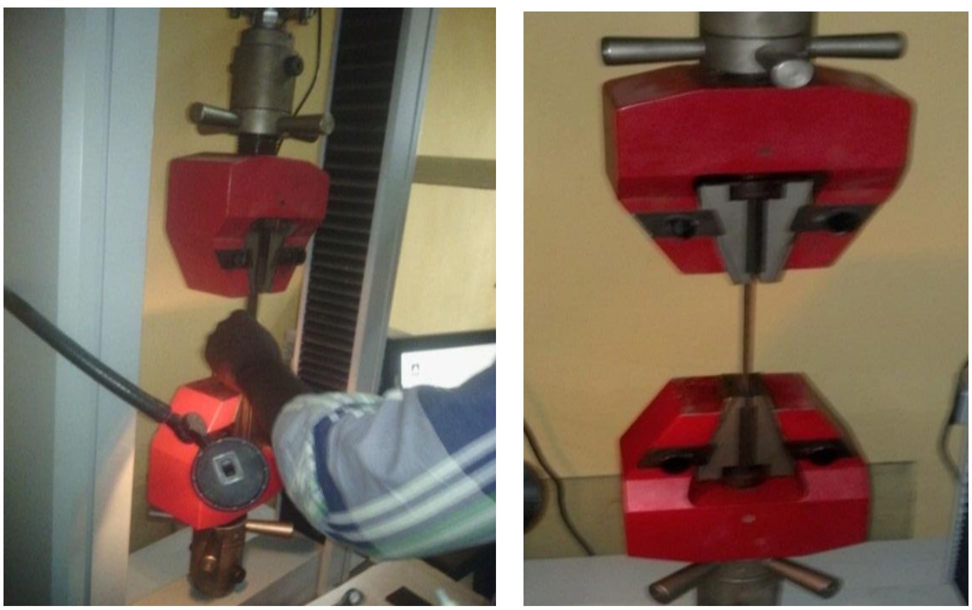


Fig. 5. Tensile Test on Tensometer

Fig. 6. Specimens for Hardness Test & Tensometer Fittings

A universal testing machine (UTM) and a tensometer (Fig. 5) were used to determine the yield strength and the engineering ultimate strength of the sample. The yield strength and ultimate strength were determined from the load-extension relationship obtained from the tensometer and the stress-strain relationship obtained from the UTS.

2.5 Determination of the Hardness of Cast Aluminum

The hardness test was done with the aid of Brinell hardness tester on each of the four.

samples. The surfaces of the machined specimens were ground to remove the skin or scale present on them. A hardened steel ball was pressed for a time of 10 to 15 seconds into the surface of the material by a standard force using tensometer machine (Fig. 6). After the load and ball have been removed, the diameter of the indentation is measured. The Brinell hardness number, signified by HB, is obtained by dividing the size of the applied force by the surface area of the spherical indentation.

2.6 Microscopic Structure of Cast Aluminum

The macro - examination was done with the naked eyes while the microstructure examination was carried out on the specimens in accordance with Dibiezue (1997) using 2% of trioxonitrate (v) acid as an etchant and viewed with metallurgical microscope of X50 magnification.

3. RESULTS AND DISCUSSION

3.1 The Chemical Composition (wt. %) of the Cast Aluminum Alloy

The chemical composition (wt. %) of the Aluminum alloy cast is as shown in the Table 2.

3.2 Tensile Test Results for Untreated Cast Aluminum Alloy

The load-extension relationship obtained from the tensile test are shown Figures 7-14. The test result from the UTM (Table 3) also showed that the castings produced from Ado-Ekiti foundry sands had the following average values of engineering properties: ultimate t ensile strength (UTS) 125.3N/mm^2, strain values 0.3, proof stress 20.7N/mm^2, fracture strength 83.35N and extension at fracture 12.66mm.

Table 2. The chemical composition (wt. %) of the Aluminum alloy cast

Constituent	Si	Cu	Fe	Zn	Mn	Mg	Ni	Ti	Pb	Al
Specimen(%)	9.83	2.99	0.98	1.11	0.19	0.04	0.064	0.052	0.19	84.6
Standard (%)	9.82	2.97	0.95	1.33	0.25	0.06	0.072	0.081	0.016	84.5

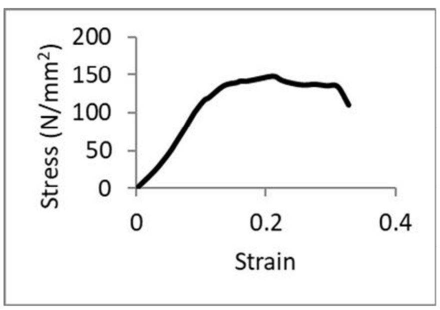


Fig. 7. Load versus Extension for Oke ureje specimen (A1)

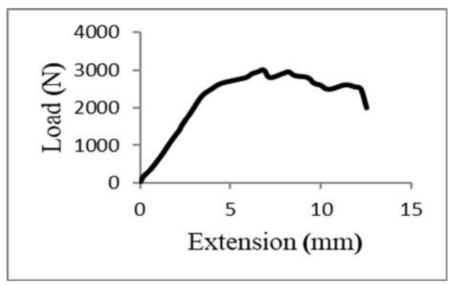


Fig. 8. Stress versus Strain for Oke ureje specimen (A1)

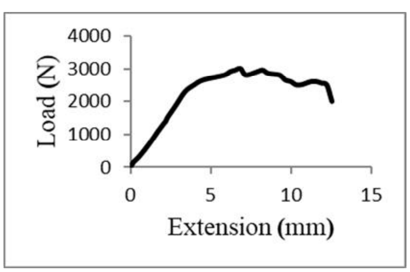


Fig. 9. Load versus extension for Omisanjanna specimen (A2)

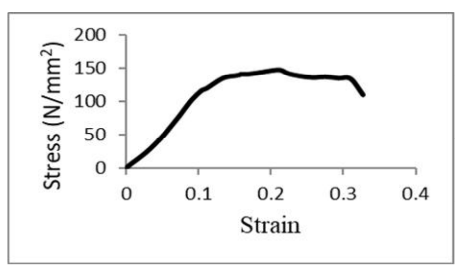


Fig. 10. Stress versus Strain for Omisanjanna specimen (A2)

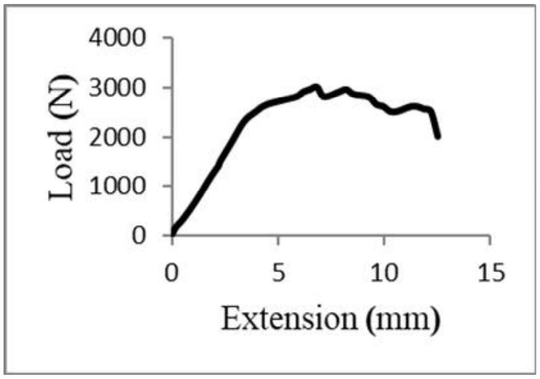


Fig. 11. Load versus extension for Odo-ayo specimen (A3)

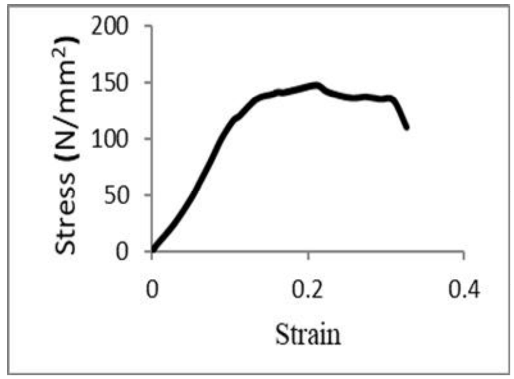


Fig. 12. Stress versus strain for Odo-ayo specimen (A3)

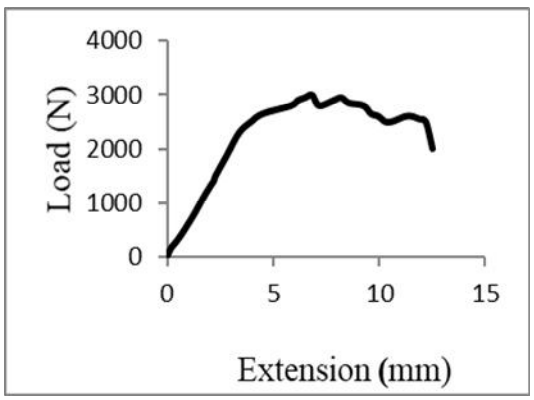


Fig. 13. Load versus extension for Ogbese (A4)

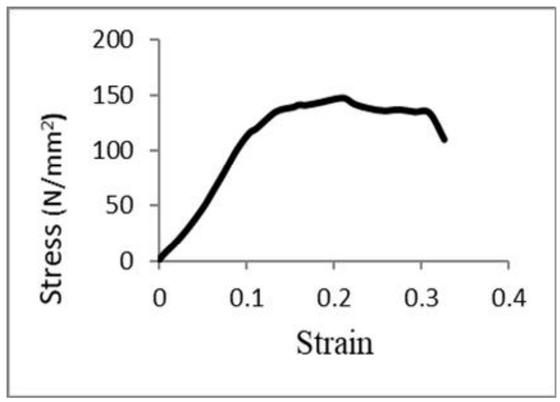


Fig. 14. Stress versus Strain for Ogbese (A4)

Table 3. The Strength value of the cast Aluminums

Moulding Sand	Yield Strength (N/mm^2)	Ultimate Tensile Strength (N/mm^2)	Fracture Stress (N/mm^2)	Fracture Strain	Young Modulus (N/mm^2)
Oke ureje	105.74	125.26	83.38	0.3	352.47
Omisanjanna	103.90	125.20	83.38	0.3	346.33
Odo-Ayo	103.69	125.20	83.38	0.3	350.90
Ogbese	103.67	125.20	83.38	0.3	345.57
Standard	100 -150	122.6	80-120	0.25-0.42	200-400

Table 4. Hardness Test Result of untreated-Cast Aluminum

Aluminum sample	READING 1 (KN/mm^2)	READING 2 (KN/mm^2)	READING 3 (KN/mm^2)	AVERAGE (KN/mm^2)	Source
Oke ureje	120.9	128.0	102.0	116.9	
Omisanjanna	91.60	100.6	113.6	101.9	
Odo-ayo	114.6	107.1	120.7	114.1	
Ogbese	119.0	121.9	127.8	122.9	
Standard value				97-135	NMDC

***DWELL TIME**: 10 sec* ***TEST LOAD**: 980.7mm*

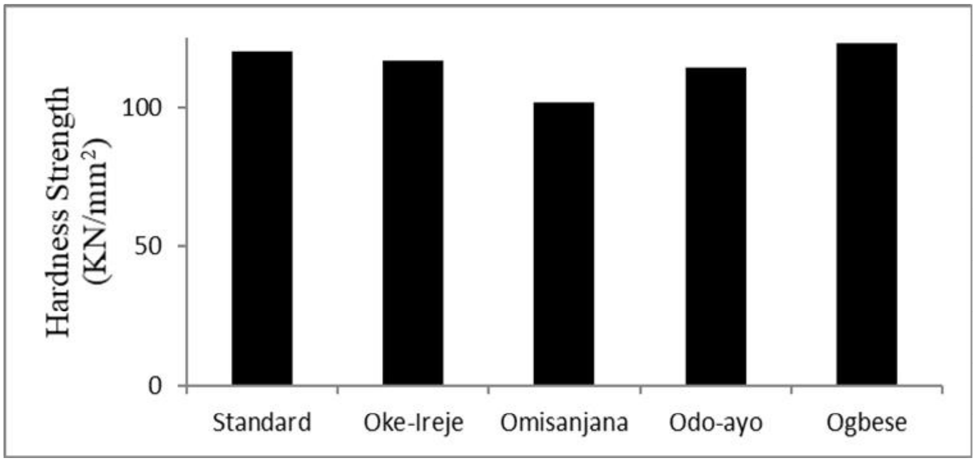


Fig. 15. Hardness Values of untreated-Cast Aluminums

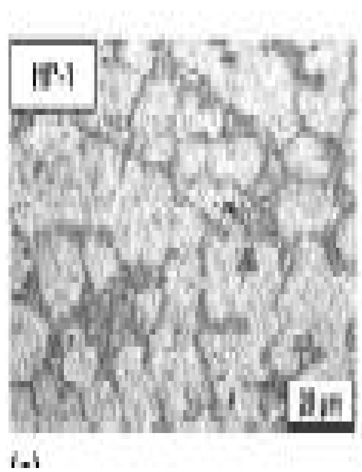
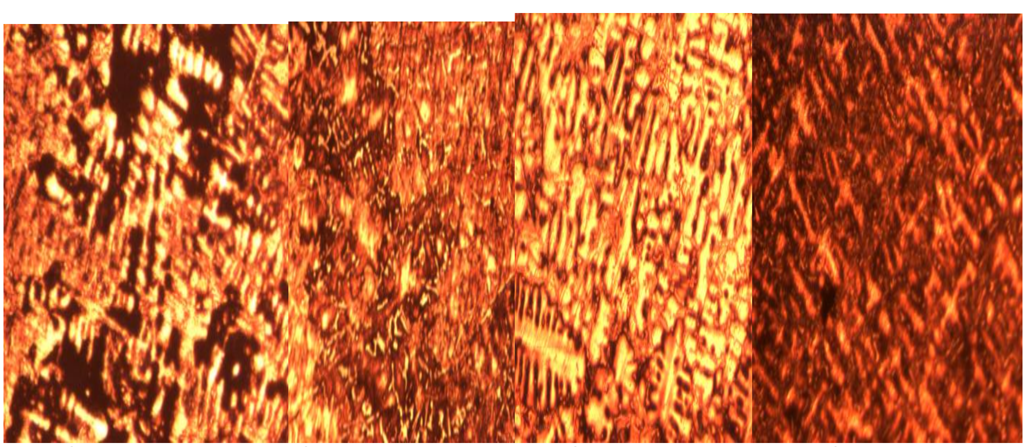


Fig. 16. Microscopic Structure of cast Aluminum (Choi et al, 2011)



Oke ureje ×*100* *Omisanjanna* ×*100* *Odo-ayo* ×*100* *Ogbese* ×*100*

Fig. 17. Microscopic structure of cast Aluminums

3.3 Hardness Test Result of Untreated-Cast Aluminum

The hardness strengths of the cast Aluminum alloys produced are 116.90KN/mm^2 for Oke ureje, 101.90 KN/mm^2 for Omisanjanna, 114.1 KN/mm^2 for Odo-ayo and 122.9 KN/mm^2 for Ogbese (Table 4). These values are found to be favorably compared with the standard value of Aluminum cast by the standard natural sand. The chat for the hardness is represented in figure 16.

3.4 Microscopic Structure of Cast Aluminums alloy from sand

The Figure 17 shows the microstructures of un-treated Al-Si alloys that consist of the constituents of cast Aluminum. It showed that large primary α-Al grains including dendrites, interdendritic networks of eutectic silicon plates and intermetallic $CuAl_2$ phase formed along the interdentric region were similar when compared with the microstructure of un-treated Al-Si alloy shown in Figure 17. (Choi et al, 2011). The main difference is that the cast being made of Ado Ekiti natural mould were not adequatelly controlled and they were made of uncalculated constituents. The structure implied that Ado Ekiti natural foundry sand is suitable for foundry activities.

3.5 Effects of the Moulding Sands on Properties of Aluminium Castings

The yield strength, ultimate strength, Young Modulus, hardness values and chemical compositions of the castings produced with the four moulding sands fall within the standard values. Oke-Ureje sand gives the highest values of yield strength, ultimate strength and Young Modulus of 105.74 N/mm^2, 125.26 N/mm^2 and 352.47 N/mm^2 respectively.

4. CONCLUSION

Four river sand samples were taken from different locations at Ado-Ekiti and used to produce Aluminum alloy castings. Mould preparations principles using the samples as mould materials were followed and the casting material which was Aluminum alloy was melted and poured into prepared moulds for solidification to take place. It was observed that the samples were good moulding materials because the values of the mechanical properties of the castings that were examined in terms of strength and hardness fall within the standard values, though Oke-Ureje sand gives the highest values of yield strength, ultimate strength and Young Modulus of 105.74 N/mm^2, 125.26 N/mm^2 and 352.47 N/mm^2 respectively. The micrographs of the microstructures of the castings were also visually inspected and they had similar structure with the standard Aluminum casting.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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