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Characterisation of Wushishi Sand for Foundry Application

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Abstract
A detailed experimental investigation is being reported on the characterization of Wushishi sand for foundry application. The properties of the sand samples collected were evaluated. The experimental results were analysed as per the American Foundry Society (AFS) standard such as clay content, moisture content, grain size distribution and the foundry properties among which include refractoriness, permeability, shear strength, green and dry compression strength shatter index, flowability, compactibility, and hardness. Also, the physiochemical property of the sand was conducted using X – ray fluorescence (XRF) and X – ray diffraction (XRD) machines. The analyses show that Wushishi sand could be used effectively in the foundry.
Keywords: **Characterisation, Clay, Content, Foundry, Grain, Moisture and Size**

INTRODUCTION

Casting is a fabrication technique that is achieved in a foundry workshop. Over 70 % of metal castings are produced through sand casting because of its refractoriness, permeability, and above all its availability and cheapness (Jain, 2004). The sand is mixed with binder (mostly clay) and moisture to achieve plasticity and strength (Dodo, *et al*., 2016). The quality of castings in green sand mould is influenced by its properties such as green compression strength, green shear strength, permeability etc. The relations of the casting's properties with the input parameters like sand grains size, shape, binder and clay is complex in nature. Binders play a vital role on green sand mould to enhance specific mould properties (Dhruval, *et al*., 2015). There has been various research by Nigerian researchers in the area of developing local foundry material that will be suitable for the production of sand castings. Among the various materials employed in foundry, sand is the dominant variable as it occurs in nature with sizeable range of compositions (NMDC Jos Data Bank, 2008). For this reason, sand for foundry applications need to be studied to ensure that they are put into informed use.
Binder (clay) is the second major constituent of foundry sand as it constitutes about 5 to 11% of mould sand (AFS, 2017). Clay (bentonite) was added to give cohesion and strength to moulding sand and to enables it retains its shape after forming the mould cavity. Bentonite is a form of clay that is widely used in not only foundry but also find its application in Petro – chemical industries as a seal (Ibhadode, 2001). Binders are added to based sand to bond or glue the sand particle together in other to make it easily mouldable, which also gives it sufficient strength and plasticity when mixed with the right quantity of water (Akintunde, & Omole, 2008). Other types of clay materials in use include kaolinites and special clays (illites, hallosites, and atalpugites). Bentonites and kaolinites are the one commonly in used in foundry practice.

Nuhu, (2008) carried out investigation on properties of river Niger sand behind Ajaokuta steel company. In the study, bentonite and kaolin were used as binders. His experimental techniques include mechanical sieve analysis, determination of clay content, and refractoriness, green/dry compressive, green hardness, permeability and shatter index tests to measure the foundry properties of the sand. He also conducted a physiochemical property of the sand by using X – ray fluorescence, and X – ray diffraction. The result showed that the sand contained alumino – silicate with low fusion temperature of 1380 °C, made up of about 15 % fine and 62 % medium sand by AFS standard; and found suitable for casting nonferrous alloys. The sand gave good mechanical properties when bonded with kaolin or bentonite clay, with kaolin giving better bond properties.

Tokan, Adelemoni, & Datau (2004) study the moulding characteristics of Azare foundry sand using bentonite as binder. The experimental methods they employed are moisture content, bulk density, flowability, permeability, shatter index, green strengths, dry strengths, hot strengths thermal expansion and refractoriness. Based on the experimental results as compared with AFS standard, Azare foundry sand was found essentially to be very good for non-ferrous foundries.

Karunakaran & Jegadheesan (2012) investigated the properties of moulding sand with waste powder from steel industry. Here the focus was on disposal of iron ore waste powder produced in steel industry. Number of samples in different compositions of silica sand, waste powder and bentonite were prepared and tested. The permeability, green and dry compression strengths properties were measured. The moulds prepared with various compositions of waste powder with silica sand were filled with molten aluminium. The castings obtained were inspected and the results shows that the addition of waste powder with silica sand increases the surface quality of the mould sand and reduces the cost of production of the mould sand.

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Aramide, Aribo & Folaranso (2011) also investigated the effect of binders (bentonite and dextrin) and water on the properties of recycled foundry sand made from silica sand obtained from Ilaro deposit of Ogun State Nigeria., The research discovered that with minimum additives of binders recycled, Ilaro sand can be reused.

Mbimda & Audu (2017) conducted an investigation into the suitability of Lere River Bank sand for use in green sand casting process. The samples of sand were tested for refractoriness, sieve analysis, clay content, moisture content, shatter index, dry and green strength as well as chemical analysis. The sand was divided into four specimens and tested with different percentages of bentonite clay as a binder which responded well. The result of the mechanical properties analysis was compared to the existing foundry standard and the sand was found to an alumina silicate with physio – chemical properties that are suitable for all types of nonferrous alloy casting because of its low refractories.

Mshelia, Abolarin & Abubakre (2016) characterized natural moulding sands from selected deposits in Maiduguri – Nigeria for casting applications. In this research, the physiochemical compositions of the sand samples were determined using the XRF Analyzer and, the American Foundrymen's Society (AFS) standard laboratory tests were used to determine the physio-mechanical properties. The results of the characterization revealed the following ranges of values; clay content from 21.8 % to 47.2 % corresponding to Pompomari and Gwange/Fori, and grain fineness number from 50.94 AFS to 95.02 AFS corresponding to Pompomari and Gwange/Fori deposits. Other physio-mechanical properties determined included green and dry compressive strengths, permeability, loss on ignition, and refractoriness. Results of chemical composition analysis show SiO_2 having dominance in all the samples (90.10 % to 66.77 %) with trace elements of CaO, Fe_2O_3, Al_2O_3, MgO, TiO_2, K_2O, and NaO_2 also present within acceptable limits. The overall results show that all the deposits have potential for use in sand casting applications for the casting of nonferrous metals, and malleable and ductile iron. However, the clay content range is a major problem compared with the standards recommended by the American Foundry Society. This did not only limit their uses to low melting point alloys because of relatively lower refractoriness values but also possesses danger to their life expectancy.

Materials and Method

The materials used for this research work include wushishi sand, water and bentonite. The equipment used include XRF machine, XRD machine, flowability meter, speedy moisture tester, anvil, strength testing machine, rotary furnace, hand rammer, shovel, pan and sand rammer. The following properties were evaluated according to American Foundrymen's Society AFS standard: grain shape, grain size distribution, moisture content, refractoriness, clay content, chemical composition, strength tests, and flowability.

Results and Discussion

Clay Content Result

The result of the clay content from the characterization of wushishi sand reveals that out of the 25 g of sand used for the analysis, only 24.9 g was obtained and 0.1g was lost, which gives 0.4 % clay.

Moisture Content Result

The result of the moisture content is given in Table 1.

TABLE 1: MOISTURE CONTENT OF SAND SAMPLE

S/n	Items Measured	Weight (g)
1	Container + Wet Soil (W1)	237.3
2	Container + Dry Soi (W2)	234.5
3	Container (W3)	171.1
4	Dry Soil (W4)	63.4
5	Moisture (W5)	2.8

From Table 1, the water/moisture content in percentage, W (%) was obtained using the following expression;

$$W\ (\%) = \frac{w_1 - w_2}{w_2 - w_3} x\ 100\ \% \text{ - } 1$$

$$W\ (\%) = \frac{237.3 - 234.5}{234.5 - 171.1} x\ 100\ \% = 4.4\ \%$$

The result of the moisture content shows that Wushishi sand has low moisture of 4.4 % which is within the required range of moisture (2 – 8 %) in a sand mould (AFS, 2005). The result for refractoriness of Wushishi sand sample is 1685 ºC, conforming to the American Foundrymen's Society range of fusion temperatures needed for casting ferrous and nonferrous metals (Bala & Khan, 2013).

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Grain Size Distribution

The sieve size distribution of Wushishi sand result is presented in Table 2.

***TABLE 2*: SIEVE SIZE DISTRIBUTION OF WUSHISHI SAND**

Sieve No	Sieve Size (mm)	Weight Retained (g)	Weight Retained (%)	Weight Passing (%)
10	2.000	6.5	6.5	93.5
16	1.180	12.3	12.3	81.1
30	0.600	33.4	33.4	47.5
40	0.425	19.0	19.0	28.4
50	0.300	13.2	13.2	15.1
60	0.212	08.8	8.8	6.3
100	0.150	04.9	4.9	1.4
200	0.075	01.4	1.4	0.0
Receiver Product	< 0.075	0.04	0.0	0.0
Total			**99.5**	**100**

The summary of the grain size analysis is as; Coarse Sand (52.5 %), Medium Sand (41.2 %), Fine Sand (6.3 %), and Fines - Clay and Silts (0.0 %). The size distribution in Table 2 shows that the sand sample consists of Course, Medium and Fine particles. The coarse and medium sizes fall within sand that is acceptable by American Foundrymen's Society, 1989 (sand sizes of 40 – 60 %) and are suitable for sand moulding in foundries. Coarse sand has the tendency to produce rough surface finish on castings due to penetration defects while fine sand produces good surface finishes but with the possibility of having lower permeability which can lead to gas defects.

Chemical Properties

The XRF Analysis of Wushishi Sand is presented in Table 3 and the AFS standard composition in a moulding material is in Table 4.

TABLE 3: XRF ANALYSIS OF WUSHISHI SAND

Oxides	**SiO2**	**Al_2O_3**	**K_2O**	**Na_2O**	**CaO**	**MgO**	**TiO_2**
Sand (%)	83.7	6.62	1.99	0.58	0.77	ND	3.34
Oxides	**V_2O_5**	**Cr_2O_3**	**MnO**	**Fe_2O_3**	**CuO**	**BaO**	**LOI**
Sand (%)	0.009	0.025	0.045	1.41	ND	0.15	1.36

TABLE 4: AFS STANDARD COMPOSITION IN A MOULDING MATRIAL

Oxides	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**Na_2O**	**MgO**
AFS Standard (%)	81.4 - 92.4	3.94 - 8.84	0.50 - 2.91	1.70 - 4.37	1.70 - 4.37
Oxides	**TiO_2**	**K_2O**	**CaO**	**LOI**	
AFS Standard (%)	0.12-0.43	1.7-4.37	0.12-2.82	0.9-5.0	

Source: AFS (1989)
Key: ND = Not Detected and LOI = Lost on Ignition

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From the XRF analysis of Wushishi sand result shown in Table 3, silica oxides has the highest percentage of 83.7 %. It can also be seen from Table 3 that the percentages of SiO_2, Al_2O_3 and Fe_2O_3 in the sand sample are within the range of AFS Standard (Table 4). According to Ihom & Offiong (2014), silica grains are very important in moulding as they impact refractoriness, chemical resistivity and permeability to the sand. Thus the high percentage of silica in the sand sample indicates better refractoriness of the sand.

Table 5 gives the bulk parameter test result of wushishi sand sample with 6 % clay, and 4 % moisture and some property ranges for sand casting is presented in Table 6.

***TABLE 5*: BULK PARAMETER TEST RESULT OF WUSHISHI SAND**

S/n	Bulk properties	Values
1	Green compression strength	61 KN/m^2
2	Green shear strength	0.7 KN/m^2
3	Dry compression strength	238 KN/m^2
4	Permeability	240
5	Shatter index	19.07 %
6	Compactibility	43.5
7	Flowability	95.8
8	Hardness	82

***TABLE 6*: SOME PROPERTY RANGES FPR SAND CASTING**

Metal	Green Compression(KNm^2)	Permeability (No)	Dry Compresion Strenght (KNm^2)
Heavy Steel	70 – 85	130 – 300	1000 – 2000
Light Steel	70 – 85	125 – 200	400 – 1000
Heavy Grey Iron	70 – 100	70 – 120	350 – 800
Aluminium	50 – 70	10 – 30	200 – 550
Brass and Bronze	55 – 85	15 – 40	200 – 860
Light Grey Iron	50 – 85	20 – 50	200 – 550
Melleable Iron	45 – 55	20 – 60	210 – 550
Medium Grey Iron	70 – 105	40 – 80	350 – 800

Source*:* Ademoh (2009)

From Tables 5 and 6 it can be seen that green compressive strength and dry compressive strength for the sand fell within the recommended range of values for casting nonferrous alloys as given by (Mshelia, Abolarin & Abubakre, 2016). This means that as far as the strength property requirements of the moulding sands is concern, wushishi sand is suitable for casting nonferrous alloys. The permeability value is within the accepted standard and in agreement with the recommended values given by Ihom, (2012).

The experimental results of the green permeability (Table 5) indicate that the sand sample had good green permeability for casting a good number of ferrous and non-ferrous metals (Burns, 1989). The high flowability of Wushishi sand mould (95.8) as shown might be because of rounded grains nature of the sand, which is sub angular and enhances the ease of compaction of the sand. This result is in line with that of Shuaib – Babata, Abegunde & Ambali (2017).

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Conclusion

The results of the investigation show that the Wushishi Sand with 4 % moisture and 6 % bentonite exhibit good properties for casting of non – ferrous metals. There is a close agreement in the values of green and dry compression strengths, shatter index, compactibility and permeability obtained as compared with the established values. The high permeability, flowability and hardness exhibited by the sand make it suitable trial of all ferrous castings for foundry application.

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