Effect of Moisture Content on the Moulding Properties of River Niger Sand Using Tudun-Wada Clay as a Binder

Matthew Sunday Abolarin, Sunday Albert Lawal and AbdulRahman Asipita Salawu

Department of Mechanical Engineering, Federal University of Technology Minna, Nigeria
E-mail: <abolarinmatthew@yahoo.com; lawalbert2003@yahoo.com; asipita68@yahoo.com>

Abstract

This work was conducted in order to investigate the moisture content of the moulding properties of River Niger sand using Tudun-Wada clay as a binder. All the result obtained show that the sand properties were affected by the quantity of moisture content and other factor such as clay. The moisture content has the effect on the sand properties at varying quantity of moisture, sand and fixed amount of clay. The higher value of green strength show that the mould produced would have more resistance to wear and eternal pressure. Increase in permeability number show that Tudun-Wada clay moulds are better venting out evolved gas, therefore, when hot molten metal are poured into the mould such defect as blow and holes would be eliminated. River Niger sand is found to be suitable for use as foundry moulding sand. Tudun-Wada clay could serve as a satisfactory alternative to bentonite for use as binding clay in foundry and mould. The moulding mixture of Tudun-Wada clay and River Niger sand with appropriate water content is suitable for ferrous and non-ferrous alloy casting of component parts.

Keywords: *Binder, casting, moisture, moulding, permeability number.*

Introduction

Sand is the principal moulding material in the foundry shop where it is used for all types of casting, irrespective of whether the cast material is ferrous or non-ferrous. This is because it possesses the properties vital for foundry purposes. It's most important properties include its refractory nature, which enable it to easily withstand the high temperature of the molten metal and it will not get fused. It's chemical resistivity, which help it not to chemically react or combine with molten metal and therefore can be used repeatedly and it's high degree of permeability, which allows gas and air to escape from the mould when molten metal is poured without interfering with the rigidity and strength of the mould. Foundry sand consist primarily of clean, uniformly sized high proportion of quality silica and its bonding quality will depend on the presence of some kind of clay material or lake sand that is bonded to form moulds for ferrous (iron and steel) and non-ferrous (copper, aluminum, brass etc) metal casting. Finally they must not contain impurities which might cause scabbing of the casting surfaces (Brown 1994).

Clays (binders) are added to give cohesion to moulding sands and it provide strength to the moulding sand and enable it to retain its shape as moulding cavity. The principal mineral constituent of clays is kaolinite it is relatively plentiful as the major constituent of china and ball clays and when fired, clay has high alumina content that makes those clay reasonably refractory. Water exists in many forms in clay (as combined, absorbed, free or hydrated). When clay is dissolved in free water, it forms a suspension called colloidal solution. But the clay particles flocculate (clump) and settle quickly in saline water. Clays are easily moulded into a form that they retain water when dry, and they become hard and lose their plasticity when subjected to heat.

Materials and Methods

All the materials required for this research work were sourced locally. The silica sand was sourced from River Niger at Lokoja under Murtala Mohammed bridge. The binding clay was sourced from Tudun-Wada Dankadai near Rafin Magami in Tudun-Wada Local Government Council, Kano State. Each of the test specimens from the various mixture were subjected to the relevant sand mould test such as Green Compression Strength, Green Shear Strength, Dry Compression Strength, Dry Shear Strength and permeability test and wee sieve analysis. All the tests were carried out with the sand testing equipment at the National Metallurgical Development Centre, Jos, Plateau State of Nigeria. The test sample were prepared in accordance with the standard specification for the preparation of moulding sand test samples using Ridsolate standard sand rammer conforming to imperial (2”diameter x 2” Height) or DIN (SCM diameter by 5cm height). Test sample specimens were prepared for laboratory experiment from various moulding sand mixtures as shown in Table 1.

Sample Preparation

The required quantity of the sand, clay and water for each of the samples A-F were measured in accordance with the varying proportion and put into the laboratory mixer and then mixed for about five minutes. When thoroughly mixed, the mixture was discharged from the mixer through the discharge opening at the bottom of the mixer. The quantity that gives the required size of 5cm diameter x 5cm height was weighed on the weigh-balance and then poured into the specimen tube. This weight differs for different mixtures of sand component. The tube with the sand sample inside it was positioned in the specimen rammer and then rammed with three drop of the standard weight of 6.6kg. After ramming, the specimen was ejected from the specimen tube. After ramming, the specimen was ejected from the tube with the aid of specimen extractor. This procedure was repeated for the preparation of the standard test specimens for the various compositions of the moulding mixtures.

Determination of Grain Size Distribution

The stocks of sieve were arranged according to the sieve aperture with the largest aperture on top of the stock and then smallest aperture at the bottom (on top of pan). Some quantity of sand were dried in the air and 100g of the sand sample was taken on to the top of sieve stock and stocks were placed on a sieve shaker and then switched on, the time was set to allow for vibration for a period of fifteen (15) minutes and after vibrating for a period of 15minutes, the vibration stopped automatically. The sieves were removed one after the other beginning with one on top. The quantity of sand remaining on each sieve was weighed. The weight was recorded accordingly on each sieve in the column corresponding to the sieve mesh number, i.e., British Standard Sieve number (BSS). Each separate sieve weight was multiplied by the preceding sieve mesh number. The sum total of the product was divided by the total sample aligned and this produced the fineness number of the sand. Table 2 shows the results obtained.

Table1. Percentage and weight composition of moulding mixture.

	Water		Clay		Sand	
	%	g	%	g	%	g
A	1	6	12	72	87	522
B	2	12	12	72	86	516
C	4	24	12	72	84	504
D	6	36	12	72	82	492
E	8	48	12	72	80	480
F	10	60	12	72	78	468

Table 2. Grain size analysis.

Sieve Aperture (mm)	BSS No.	Wt Retained	% wt Retained	Cumulative % wt Retained	Product
1.4	10	0.15	0.15	0.15	-
1.00	16	3.26	3.26	3.14	32.6
0.71	22	6.61	6.61	10/02	105.76
0.50	30	9.21	9.21	19.23	202.62
0.355	44	23.98	23.98	43.21	719.40
0.250	60	38.76	38.76	81.97	1705.44
0.180	100	12.73	12.73	94.97	763.0
0.125	150	3.36	3.36	98.06	336
0.090	200	0.86	0.86	98.92	129
0.063	300	0.41	0.41	99.33	82
-0.063	350	0.14	0.14	99.47	42
					4118.62

Determination of 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 which was already fixed into the machine. The sample was loaded gradually, while the magnetic rider moved along the measuring scale. As soon as the sample reached its maximum strength, the sample experienced failure and the magnetic rider remain in position of the ultimate strength, while the load was gradually released. This experiment was repeated for water content varied thus; 1%, 2%, 4%, 6%, 8% and 10%. It was discovered that the GCS reduced with increase percentage of water content in the sample as shown in Table 3.

Determination of Green Shear Strength

The Green Shear Strength (GSS) which is the measure of the shear strength of the prepared sample, when shear load is applied in its green state. The machine used for the GCS was also used for the determination of green shear strength (GSS), except that the compression head was replaced with shear head in the machine. The shear strength was recorded at the point of failures of the sample loaded. It was discovered that as the percentage of water increased, the GSS decreased as shown in Table 3.

Determination of Dry Compression Strength

The prepared standard sample of 5cm diameter x 5cm height was dried in an oven at a temperature of 110^0C for a period of 30minutes and then removed and allowed to cool in the air to ambient temperature. After cooling, the sample was fixed into the universal sand-testing machine with the compression head in place. The compressive load was applied and the samples failed at the ultimate compressive strength of the sample. The point at which the failure occurs was recorded at GCS and it is shown in Table 3.

Determination of Dry Shear Strength

The prepared standard sample of 5cm diameter x 5cm height was dried in an oven at a temperature of 110^0C for 30 minutes and then removed from the oven to cool in an air to ambient temperature. The same universal testing machine was used for dry compression strength. In this case, the shear head was replaced for the compression head. The shear strength was recorded at the point of failures of the standard test sample. The failed sample due shear load is shown in Table 3.

Determination of Permeability

Gas permeability of a moulding sand is the ability of the sand mould to allow the passage of gaseous product from the mould cavity to the atmosphere. The permeability test was carried out on the standard sample specimen of 5cm diameter x 5cm height. The specimen, while still in the tube, was mounted on permeability meter. The permeability meter is an electrical perimeter and it employed the orifice method for rapid determination of sand permeability. Air at a constant pressure is applied to the standard sample specimen, immediately after producing the sample and the drop in pressure was measured on the pressure gauge, which is calibrated directly in permeability numbers. The result was recorded as shown in Table 3.

Results and Discussion

The Green Compression Strength (GCS) of the moulding sand mixture decreased from 11.11psi (76.59KN/m^2) to 4.2 psi (28.98KN/m^2) of 1% and 10% water addition respectively. This shows that Tudun-Wada clay has good bonding characteristic at 1% water addition. Metals can be cast with 1% water addition to the moulding sand mixture, mould wall erosion could occurred during pouring of hot liquid metal as a result of friable nature of the mould.

The Green Shear Strength (GSS) of the moulding sand mixture was observed to be decreasing from 1.2psi (8.28KN/m^2) to 0.2 psi (1.38KN/m^2) of 1% and 10% water addition respectively. The Dry Compression Strength for 1% water content is 62psi (427.8KN/m^2) and this value increases with further increase in moisture content of the mixture reaching the maximum value of 467.5 psi (3225.75KN/m^2). It was discovered that the strength of the dry sample is greater than that of calibrated strength on the universal testing machine. The dry shear strength of sample of moulding mixture was observed to increase with moisture content reaching a maximum at 10% water addition as shown in Table 3.

River Niger sand is sub-angular in shape and brownish in colour. It is very fine silica sand, the free content of clay of the sand makes it suitable for use as core sand in addition to its suitability for use as a moulding sand. Tudun-Wada clay is very fine clay and has a high plastic in nature when mixed with water. This characteristic of the clay makes it suitable for foundry application as a binder. The grain fineness number of River Niger sand is 41.412 AFS fineness number. This grade of fineness number is suitable for all types of alloys steel as this belongs to the group of fineness number that has a wide range of application. The other grades of the sand are very much available within the shore of the river. The selection of the appropriate grade of grain size for a specific application largely depends on experience and the nature of the alloy production in a particular foundry industry.

River Niger sand and Tudun-Wada clay when mixed together with varying percentage of water produce a plastic mass with varying degree of strength. In the green state of the mixtures; the strength decrease with increasing moisture content, reaching its ultimate strength at 1% water addition which is friable. The level of strength reach between 2% to 6% water additions conforms to the standard specification for metal casting moulding sands. Although the strength level of 8% and 10% water addition are relatively lower enough these levels of moisture content are considerably much higher for some alloys such as ferrous alloys, under green application.

Table 3. Properties of mould sand mixtures with 12% clay.

Water (%)	1	2	4	6	8	10
Green compression strength (psi) (KN/m^2)	11.1 76.59	9.2 63.48	6.8 46.92	4.9 33.81	4.7 32.43	4.2 28.98
Green shear strength (psi) (KN/m^2)	1.2 8.28	1.1 7.59	0.6 3.6	0.5 3.45	0.3 2.07	0.2 1.38
Dry compression strength (psi) (KN/m^2)	62 427.8	73.5 507.15	465 3208.5	467.5 3225.75	>467.5 >3225.75	>467.5 >3225.75
Dry shear strength (psi) (KN/m^2)	8.5 58.65	22 151.8	110 759	140 966	205 1414.5	230 1587
Permeability (mmws)	280	360	420	350	300	260

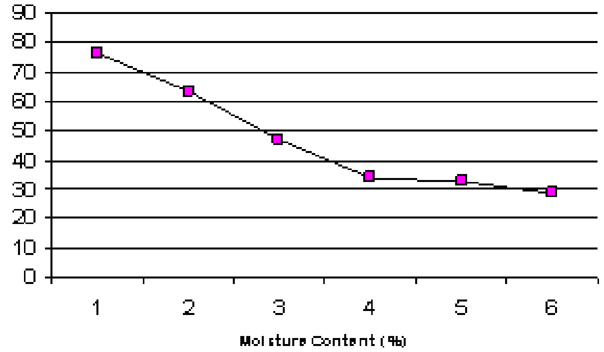

Fig.1. Effect of moisture content (%) on the green compression strength (KN/m^2).

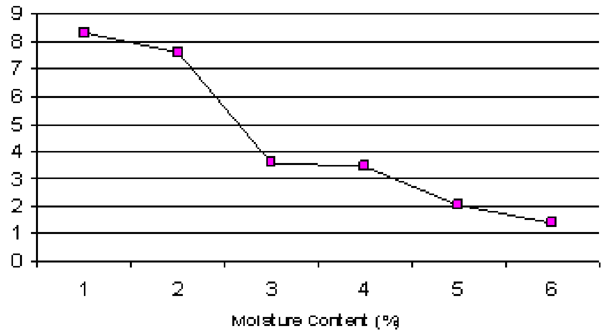

Fig.2. Effect of moisture content (%) on the green shear strength (KN/m^2).

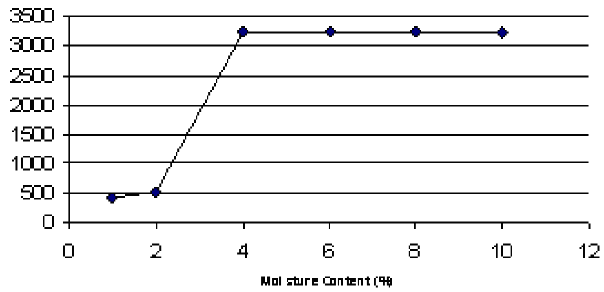

Fig.3. Effect of moisture content (%) on dry compression strength (KN/m^2).

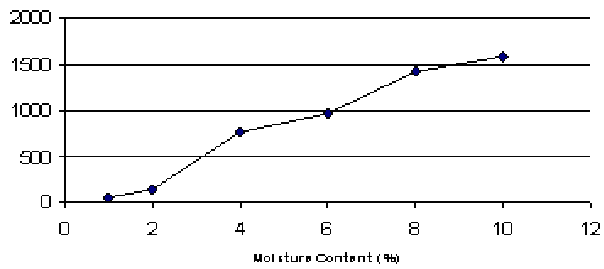

Fig.4 Effect of moisture content (%) on dry shear strength (KN/m^2).

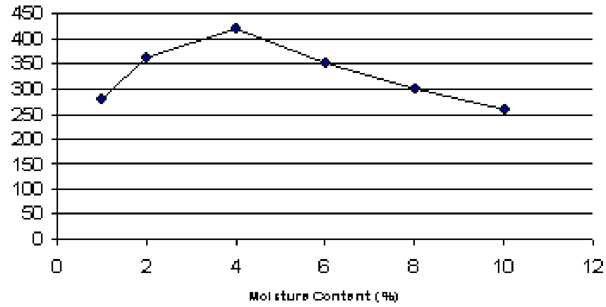

Fig.5. Effect of moisture content (%) on permeability (mmws).

When mould is applied under dry condition, high moisture content could be an advantage as shown in Figs. 1-5 and when the strength is the major factor under consideration. These important properties, such as permeability, green compression strength, and dry compression strength attain their highest value with moisture of 2% and 4% water addition. This makes 2% and 4% water addition more suitable for optimum moulding properties requirement. Water and clay are the major property variables that influence the strength of the moulding (Jain 1986; Uhvotu 2006).

References

Brown, J.R. 1994. Foseco foundry man's handbook. 10th ed., Pergamon Press PLC, Oxford, UK, pp. 28-55.

Jain, P.L. 1986. Principles of foundry technology. 2nd ed., Tala McGraw-Hill, New Delhi, India.

Uhvotu, M.S. 2006. Determination of the moulding properties of Dindima river sand using Alkaleri clay as a binder. A Postgraduate Diploma Thesis submitted to the Department of Mechanical Engineering, Abubakar Tafa Balewa University, Bauchi, Nigeria.