Physico-Chemical Assessment of Ijapo Clay Deposit as Binder for Moulding in Foundry.

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ABSTRACT

The use of clay finds it's way into diverse applications. Different deposits of clay are found in different states of Nigeria like Kogi, Taraba, Ondo, and Enugu among others. Ijapo clay is a deposit found in the Ijapo area of Akure, Ondo State, Nigeria. Samples of the clay were collected, dried, pulverized, and milled in a ball mill. The milled sample was sieved in a set of iso-sieve. 6.0 kg of -212 μm size was used for the experiment. The composition of the clay was determined and found to contain 47.50% silica (SiO_2), 30.99% Alumina (Al_2O_3), 4.77% Iron oxide(III) (Fe_2O_3), and 2.65% Calcium oxide (CaO). The clay was used at 5% and 6% to prepare greensand for moulding. Compressive, tensile, scatter, and permeability tests were carried out on the greensand. The results indicated that when 5% Ijapo clay was used, the following were obtained: green compressive strength of 9.81 kN/m^2, dried strength of 78.45 kN/m^2, scatter test results of 82.51%, and permeability of 108. Greensand was also prepared with 5% and 6% bentonite, having the following results when 5% bentonite was used: green compressive strength of 51 kN/m^2, dried strength of 519.8 kN/m^2, scatter test results of 50%, and permeability of 99%.

(Keywords: greensand, clay, mechanical tests, bentonite, Ijapo Clay, composition)

INTRODUCTION

Foundry or casting of metals is one of the oldest industries in the world. This is evidenced by the fact that metal castings were made by the Egyptians about the year 400 BC (Rashtravani, 1981). Metal was used for ornamental purposes because of its beauty, but as man became more familiar with metal, it was developed for use in weapons for the purpose of protecting against enemies (Rashtravani, 1981). Founding of metals, therefore, has been improved in the modern days to include the production of spare parts for any kind and machinery construction.

Sand casting involves the preparation of greensand for making a mould. Molten metal is then poured into the mould and upon solidification, a casting is made. The bindability of a moulding sand is one of the most requirements for effective performance of the sand for moulding. However, this property cannot be achieved without a good and adequate binder in the sand. Binders can be clay such as bentonite or other materials like sodium silicate, cement, starch, resin, etc. (Steve, 1996).

Bentonite has been the binder used with sands such as silica-sand, Zircon-sand and olivine-sand. When the sand is mixed with bentonite and water, an appreciable degree of plasticity is developed for moulding. Bentonites are a clay which can contain either sodium or calcium ion as the exchangeable ion (John, 1994). Sodium bentonite occurs naturally in USA in locations such as Wyoming and also in other countries, particularly in the Mediterranean area.

Greensand produced with this clay has strength from medium green strength to high strength which increases the resistance to erosion (wear or corrosion) of metals (John, 1994).

According to Rashtravani, (1981), clays are those particles under 20 microns in diameter which fail to settle a distance of 25 mm per minute when suspended in water. Average clay particles are of colloidal size. Clays are essentially aggregates of extremely minute crystalline sand, usually flake-shaped particles, which can be classified on the basis of their structure and composition into a few groups called clay minerals (Nyle, 1974). As compared with sand grains, sand binders are less refractory. Binders produce cohesion between the mould sand grains in green or dry state (Asuquo and Bobojama, 1991). They give strength to the moulding-sand so that it can retain it's shape as mould cavity. Binders to the moulding-sand should be in minimum required quantity as it reduces permeability. Increasing binder content to a limit-increases green compression strength; after which this strength remains practically unchanged with increase in binder content (Beely, 1972). In order to bind mould sands, clay binders are most commonly used.

Clays are inorganic binders. The best clay is one which imparts the optimum combination of bonding properties, moisture, mould strength, and low cost of producing a casting, and produces a thin and adhesive film around the moulding sand grains (John, 1994). Clay gets baked and hardened when heated to high temperatures during the pouring of molten metal (Asuquo and Bobojama, 1991). In order to maintain the adequate bonding strength of mould sand, clay is added to the moulding sand from time to time. The objective of this research is therefore to investigate the suitability of Ijapo clay as a binder so as to be considered an alternative to bentonite.

MATERIALS AND METHODS

Ijapo clay sample was collected at a deposit site in the Ijapo area of Akure, Ondo State of Nigeria. A pulverizer was used for the initial reduction of size. A ball mill was used for second stage grinding. The material was then sieved in a set of iso-sieves. A sand testing machine was used for compression and tensile tests. Permeability meter was used to determine the permeability of sands. A scatter test drum was used to study the scatter parameter of the green sands prepared.

The collected sample of Ijapo clay was dried thoroughly in the sun for ten days. After drying, it was pulverized in a pulveriser at the Metallurgical and Materials Engineering Department Laboratory, Federal University of Technology, Akure. Nigeria. The pulverized sample was charged in a ball mill with balls as a grinding media to further reduce the size of the clay. The product of the ball mill was later poured in a set of iso-sieves on a sieve shaker and vibrated for fifteen minutes. Six kilograms of -212 μm size was collected for the experimental work, although all was not exhausted.

Pure silica sand (100%) was used as base sand for the preparation of greensand. The greensand was prepared by mixing in a sand muller with bentonite or Ijapo clay as binder. Two samples each of greensand made from bentonite and Ijapo clay were prepared as follows:

Sample (1): 5% bentonite, 3% water and 92% silica sand;

Sample (2): 6% bentonite, 3% water and 91% silica sand. Ijapo clay was also used as binder in 5% and 6% instead of bentonite for another greensand preparation.

The specimen for evaluating the mechanical properties of the moulding sand was prepared using a standard rammer and a specimen tube. Three hundred grams of prepared greensand were put in a specimen tube and set into the standard rammer. The plunger of the rammer was raised to make three separate turns of the handle, allowing the weight of the rammer to fall freely and make three ramming blows on the sand in the specimen tube. The tube was then removed from the rammer and placed on a stripping post to remove the prepared specimen.

The specimens for tests were prepared with greensand containing bentonite as binder as well as with greensand containing Ijapo clay as binder so that comparison can be made after the tests.

A compressive test was carried out on a sand testing machine at foundry sand laboratory, Ajaokuta Steel Company, Ltd., Ajaokuta Kogi State of Nigeria. The flat face compression head was inserted with the rammed specimen was placed between the compression heads. The specimen was loaded progressively so that it could be compressed together. The compression strength was read on the scale of the machine at the point of fracture of the specimen. This process was repeated for all the greensands prepared and the results of each test were taken. Dried specimen was obtained by heating the samples to a temperature of 150 ^{0}C in an oven for 1½ hours. Compressive test was also done on the dried specimen for all the preparations (Bentonite and Ijapo clay green sand).

Tensile tests were carried out on the samples using sand testing machine. However, instead of a compression head, the specimen was fixed on a portion having a tensile grip so that the upper arm is moveable upward so as to pull the specimen. At the point of fracture, the value for the tensile strength was read. Tensile tests were also carried out on dried specimens.

A scatter test was used to determine how the green sand will scatter when not rammed. This test was carried out in a scatter test drum. The drum has a perforated body which will rotate when in operation. A 500 g sample of prepared green sand was poured into the drum, set in motion, and allowed to rotate for 30 seconds. The part of the sand that fell without sticking to the drum or remained in the drum was collected and weighed. The weight of the dropped sand was taken as a fraction of the total weight. This was done on only green sands and not dried sand because dried sand can not bind.

A permeability test was carried out on a permeability meter. It consisted of water in a tall cylindrical container in which there is another cylindrical shaped apparatus called bell. This bell can be raised so that it will lower itself down by gravity in the water. It pushes air by pressure into the specimen. The bell was raised inside the water when the specimen was placed on a permeability seat, thereby causing air to flow through the specimen. The time taken (in minutes) for the bell to be lowered down the mark 2000 on the bell was recorded. The pressure **P** reading at the moment when the bell passed the mark 1000 was also taken. A permeability number was then calculated from Equation (1). Other useful equations can be found in the works of Ijagbemi (2005) and Aye (2006). More detailed experimental set-ups can be found in the work of Omole (2008).

$$K = \frac{Vh}{Pt} \quad \textbf{(1)}$$

where,

V= volume of air in (cm^3)
h =height of the specimen in (cm)
P = pressure (gauge) reading when the bell pass the mark 1000
t = time in minute when the bell pass the mark 2000

RESULTS AND DISCUSSION

Table 1 shows the chemical composition of the clay as determined using Atomic Absorption Spectroscopy (AAS).

Table 1: Chemical Composition of Ijapo Clay.

Silica (SiO_2) %	Alumina (Al_2O_3) %	Iron oxide (Fe_2O_3) %	Calcium oxide (CaO) %	Magnesium oxide (MgO) %	Alkalis Na_2O + K_2O %
47.50	30.99	4.77	2.65	1.32	3.81

Tables 2 and 3 show the results of the mechanical tests for 5% bentonite and 5% Ijapo clay as binders, as well as 6% bentonite and 6% Ijapo clay as binders, respectively. Table 2: gives the results of the mechanical tests for 5% bentonite and 5% Ijapo clay as binders, while Table 3 shows the results of mechanical tests for 6% bentonite and 6% Ijapo clay as binders.

Table 2: Results of Mechanical Tests for 5% Bentonite and 5% Ijapo Clay as Binder.

	BINDERS USED			
	5% Bentonite		5% Ijapo clay	
	Green sand	Dried sand	Green sand	Dried sand
Compressive strength	51 kN/m^2	519.8 kN/m^2	9.81 kN/m^2	78.45 kN/m^2
Tensile strength	19.61 kN/m^2	39.23 kN/m^2	No significant result	No significant result
Scatter parameter %	50	-	82.51	-
Permeability	99	-	108	-

Table 3: Results of Mechanical Tests for 6% Bentonite and 6% Ijapo Clay as Binder.

	BINDERS USED			
	6% Bentonite		6% Ijapo clay	
	Green sand	Dried sand	Green sand	Dried sand
Compressive strength	58.84 kN/m^2	588.4 kN/m^2	14.71 kN/m^2	89.24 kN/m^2
Tensile strength	39.23 kN/m^2	49.03 kN/m^2	No significant result	No significant result
Scatter parameter %	47.10	-	80.20	-
Permeability	98	-	106	-

Comparing the results of the mechanical tests presented in Tables 2 and 3, the green compressive strength of 5% bentonite binder is 51kN/m^2, while that of 5% Ijapo clay as binder is 9.81kN/m^2. The greensand tensile strength of 5% bentonite is 19.61 kN/m while that of 5% Ijapo clay has no significant result. There is therefore a sharp variation in the values. The compressive strength of 6% bentonite is 58.84 kN/m^2 while that for 6% Ijapo clay as binder, is 14.71 kN/m^2.

The scatter test value for 5% bentonite binder is 50% while that of Ijapo clay binder of the same percentage is 82.51% which is an indication that 5% bentonite green sand binds together better than 5% Ijapo clay green sand. The permeability results for Ijapo clay green sand is 108 which is higher than that of bentonite green sand which is 99, indicating that as a result of lower binding strength of Ijapo clay binder, it is more permeable to gas than bentonite of the same quantity.

CONCLUSION

The results of the mechanical tests performed in this research shows that the two greensands (bentonite-based and Ijapo clay-based sands) have different values of compressive strength, tensile strength, scatter parameters, and permeability. It can be concluded that Ijapo clay is not suitable for use alone as a binder for sand moulding. This is because the clay's behavior shows that it cannot form enough micro-film on the flakes of the clay when water is added, which should result in the formation of a gel. The thickness of the microfilm should increase to a level called the ultimate gel formation level when water is added. The thickness of the film formed varies with different clay minerals. This was not so with Ijapo clay which resulted in low binding quality of the clay.

However, since the clay exhibits very low swelling and also resulted in non-formation of a gel, it is more of a kaoline than a montmorillonite. Kaolines exhibit the property of non-formation of gel and low swelling, but with high refractoriness. Ijapo clay would then be suitable for use as a refractory material.

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