Issue 19, July-December 2011
p. 85-96

Effects of Moisture Content on the Foundry Properties of Yola Natural Sand

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Abstract

The effect of moisture content of Yola natural sand has been studied. The moisture content was varied from 1 to 9%. The effect of the moisture content on the green compression strength, green permeability and bulk density was investigated. Particle size distribution of the natural sand, the grain fineness number, average grain size, grain shape and the clay content of the natural sand were also studied. 5% moisture gave the optimum green compression strength of 118.6KN/m^2. The dry compression strength increased with moisture content, an optimum value of 4000KN/m^2 was obtained at 9% moisture. The Yola natural sand had a grain fineness number of 88.05AFS, average grain size of 335.78 microns and a clay content of 26%. A sand mixture containing 5% moisture was prepared and used to produce a test casting with aluminium scraps, the test casting was sound.

Keywords

Moisture Content; Variation; Effects; Properties; Yola Natural Sand.

Introduction

Yola natural sand deposit is found in the Northern part of Nigeria by the river Yola basin. The river forms the upper part of the River Benue, which is one of the major rivers that flow through Nigeria. Various sand systems in Nigeria have been investigated including this sand deposit. Interestingly enough to the best of the knowledge of the researchers no investigator have investigated the effects of moisture content on the foundry properties of moulding mixture of this natural sand. Studies has clearly shown that the shape and size of sand grains, the nature and content of clays, moisture and additives, efficiency of mulling the raw materials etc are very important in deciding the properties and behavior of the sand mixture [1].

However, for many years, sand control had been practice through the evaluation of the physical properties of the sand mixtures in line with the recommendations made [1]. Later, this practice came under sharp attack and it was felt that the physical properties must be supplemented by complete analysis of the sand mixture. Subsequently, new methods for testing sands and also some type of control graphs were developed which were claimed to be useful in sand control vis-à-vis analysis of the sand mixtures. Literature review has clearly shown that there is a correlation between the physical properties and the variable factors of the sand mixtures for the purpose of attaining a satisfactory level of sand control. The mulling station is the central point in deciding the properties and behaviour of clay bonded sands. It is the point at which water is introduced into a moulding mixture [1, 2].

Basically there are two types of sands the natural sand and the synthetic sands [2, 3]. Natural sand has enough clay content for moulding. During mulling of natural sands they only need moisture and other additives to improve the quality of the casting [3]. Synthetic sands require clay binders, moisture and other additives before they can be moulded. Natural sands are more economical and easy to use. They however, in most cases lack the high refractoriness that is commonly associated with synthetic sands. The properties of synthetic sands can also be adjusted with ease [3, 4].

Moisture content has been cited by many researchers as one of the variables that affect the properties of a moulding mixture in a sand mixture. The variation of moisture affects properties like bulk density, permeability, green compression strength, dry compression strength, shear strength, and other properties of the moulding mixture [3, 5].

The objective of this work was to see how moisture variation will affect the properties of moulding mixtures prepared using Yola natural Sand. The best moulding mixture with the best foundry properties was used in producing some castings for quality assessment. The investigation of the effect of moisture on this sand has become necessary, so as to provide foundry men using this sand with information on the optimum amount of moisture to be used while moulding the sand. Local foundries around the area are already using this sand for casting of aluminium and its alloys as well as cast irons. This information will go a long way in enhancing quality production in the local foundries.

Material and Method

Natural and untreated water was used to reduce the effect of chlorides on the strength property of the moulding mixture. The natural sand used was obtained directly from the source at Yola, Adamawa state North eastern Nigeria.

The equipment used was those in the Sand Testing Laboratory of the National Metallurgical Development Centre, Jos-Nigeria. These include: nest of sieves and Sieve Shaker, clay washer, electronic digital balance, speedy moisture tester, universal strength testing machine, sand rammer, electric parameter and others.

Methods

Sieve Analysis: 300g of the natural sand was weighed and dried to a constant weight using a pickstone oven produced by Ridsdale oven produced by Ridsdale and co. Ltd Middlesbrough- England. 100g of the natural 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 natural sand.

Another 100g was weighed and introduced into a nest of sieves, which had the largest sieve with an aperture of 710 microns and the smallest with an aperture of 63 microns. The nest of sieve was mounted on the sieve shaker and used in calculating the average grain size of the natural sand.

Determination of the Clay Content of the Natural 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 stick 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 1190C and reweighed. The difference in weight was multiplied by 2 and that gave the AFS clay content percentage in the natural sand.

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 natural sand was mixed with water. The water content was varied from 1 to 9%. The sand mixture prepared was used to prepare standard test specimen (50mmx50mm) using a digital weighing balance and a sand rammer.

Green Compression Strength (GCS): the standard test specimens which were prepared as stated above were quickly transferred to the universal strength testing machine made by Ridsdale and Co. Ltd with serial No. M-8415, using the compression head accessory, the specimens for green compression were failed and the result registered on the green compression scale of the machine.

Dry Compression Strength (DCS): the specimens for the dry compression were dried under natural conditions in the open foundry for 24hrs. They were then tested using the universal strength testing machine, with the compression head accessories in place for the failing of the specimens. The result was registered on the dry compression strength scale of the machine.

Green Permeability: the standard test specimens for green permeability were transferred immediately to the electric parameter made by Ridsdale and Co. Ltd with serial No. 872 for the determination of the green permeability of the natural 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.

Bulk Density: the bulk density of the sand mixture was determined using a density indicator attached to the sand rammer made by Ridsdale and Co. Ltd. Middleborough-England, with serial No.8421.

Casting: the sand mixture was used to produce aluminium alloy test casting to assess the quality. The sand mixture had 5% moisture content. It was mulled and moulded using a cylindrical wooden pattern with a core-print. Gating system was created with a spree for pouring the molten metal which was melted using an electric furnace. After pouring the molten metal was allowed to solidify before finally carrying out the shaking out and cleaning operation.

Results and Discussion

Tables 1 and 2 show the sieve analysis of Yola natural sand.

Table 1. Sieve Analysis of Yola Natural Sand

S/No	ISO Aperture (microns)	Sieve No	Weight Retained (g)	Weight Retained (%)	Cumulative Weight (%)	Product
1.	1400	14	1.80	1.80	1.80	0.00
2.	1000	18	3.00	3.00	4.80	42.00
3.	710	25	4.10	4.10	7.90	73.30
4.	500	35	4.50	4.50	11.40	112.50
5.	355	45	7.00	7.00	18.40	245.00
6.	250	60	17.00	17.00	35.40	765.00
7.	180	80	18.50	18.50	53.90	1110.00
8.	125	120	17.40	17.40	71.30	1392.00
9.	90	170	8.20	8.20	79.50	984.00
10.	63	230	2.90	2.90	82.40	493.00
11.	-63	-230	15.60	15.60	100.00	3588.00
						Σ8805.30

Grain Fineness Number (GFN) = 8805.30/100.00=88.05AFS; Colour: Dark Brown; Grain Shape: Angular

The two tables show the particle size distribution of the natural sand. Microscopic examination shows that the sand has dark brown colour and angular grain shape. The sand is 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 [2, 6,]. Table1 gives the grain fineness number of the natural sand as 88.05AFS.

Table 2 gives the average grain size of the sand as 335.75 microns. This value falls within the common foundry range of 150 to 400 microns [2, 6]. 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 [4]. Rundman [2] 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 [2].

Table 2. Average Grain Size of Yola Natural Sand from Sieve Analysis

S/NO	ISO Aperture (microns)	Weight Retained (%)	Multiplier	Product
1.	710	12.80	1180	15104.00
2.	500	4.150	600	2490.00
3.	355	6.360	425	2703.00
4.	250	17.75	300	5325.00
5.	180	15.76	212	3341.12
6.	125	17.40	150	2610.00
7	90	6.51	106	690.06
8.	63	3.58	75	268.50
9.	63(pan)	14.18	38	538.84
		Σ98.49		Σ33070.52

Average Grain Size (AGS) = 33070.52/98.49 =335.78 microns

Table 3 shows the result of green compression strength of Yola natural sand as the moisture was varied. Figure1 illustrates the variation of the moisture content of the sand with the green compression strength of the natural 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. In the case of Yola natural sand the maximum green compression strength occurred at 5% moisture content corresponding to green compression strength of 118.6 KN/m^2. After this maximum value the green compression strength decreased down to 75.2 kN/m^2 as the moisture was increased to 9%. The result agrees with work done by different researchers on green sands [1, 6-18]. The strength of green sands depends upon a number of factors, including the clay and water content, the type of clay, the sand size distribution, the temperature of the sand, the amount and type of additive, the degree of mulling or mixing, the extent of compaction (number of rams of a testing machine), the adsorbed species (Na or Ca) etc. [2].

Table 3. Foundry Properties of Yola Natural Sand as the Moisture Content was Varied from 1- 9%

Moisture %	1	2	3	4	5	6	7	8	9
Green Compression Strength kN/m^2	80.67	87.6	97.2	106.9	118.6	106.5	86.2	92.4	75.2
Dry Compression Strength, KN/m^2	172.4	413.7	1034.3	1327.3	2189.2	2568.4	3033.8	3600	4000
Green Permeability (AFS Perm units)	280	290	290	280	310	320	400	420	400
Bulk Density g/cm^3	1.65	1.63	1.61	1.63	1.64	1.66	1.68	1.73	1.78
Clay Content %	26								

Table 3 gives the result of moisture content variation of Yola natural sand with the dry compression strength of the sand. The effect of the moisture content is clearly shown in Figure 2. The figure shows that as the moisture content of the natural sand increased the dry compression strength of the sand also increased. The dry compression strength of the sand increases and got to optimum value of 4000KN/m^2 at 9% moisture content. This trend is seen in several literatures that have been reviewed [6, 7]. It should be noted that although the green compression strength was reducing after 5% moisture content, the dry compression kept increasing with increase in moisture content,(figures 1 and 2). It therefore means that if higher dry compression strengths are required with the natural sand then higher moisture content above of 5% will be needed. The drying time will however be longer to avoid defective casting as a result of water vapour from the mould. Higher dry compression strengths are required during pouring to reduce mould-collapse, cracking, and erosion to enhance quality casting [6-8].

Table 3 shows the results of green permeability of Yola natural sand as the moisture was increased. The effect of the variation of the moisture content on the green permeability is show Figure 3. As the moisture content increases the green permeability also increased to a high value of 420 AFS Perm units corresponding to 8% moisture, after which it started decreasing. This trend is seen in most of the works reviewed [1, 2, 4]. According to Rundman [2], the 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 [2, 8].

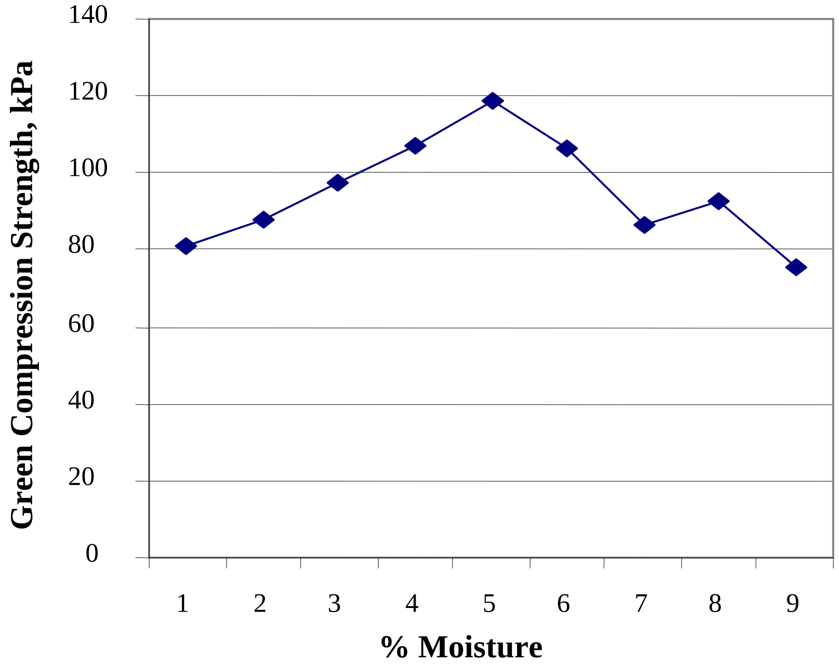

Figure 1. *Moisture Content Variation with Green Compression Strength of Yola Natural Sand*

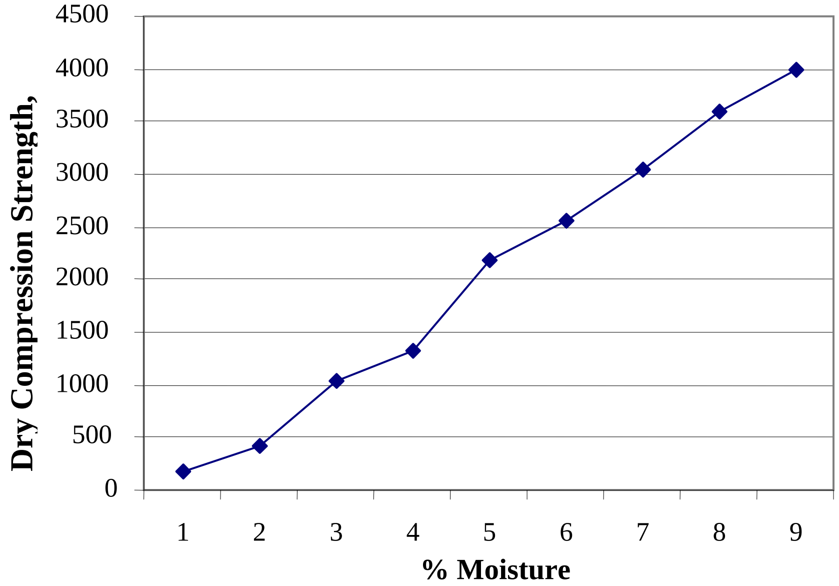

Figure 2. *Moisture Content Variation with Dry Compression Strength of Yola Natural Sand*

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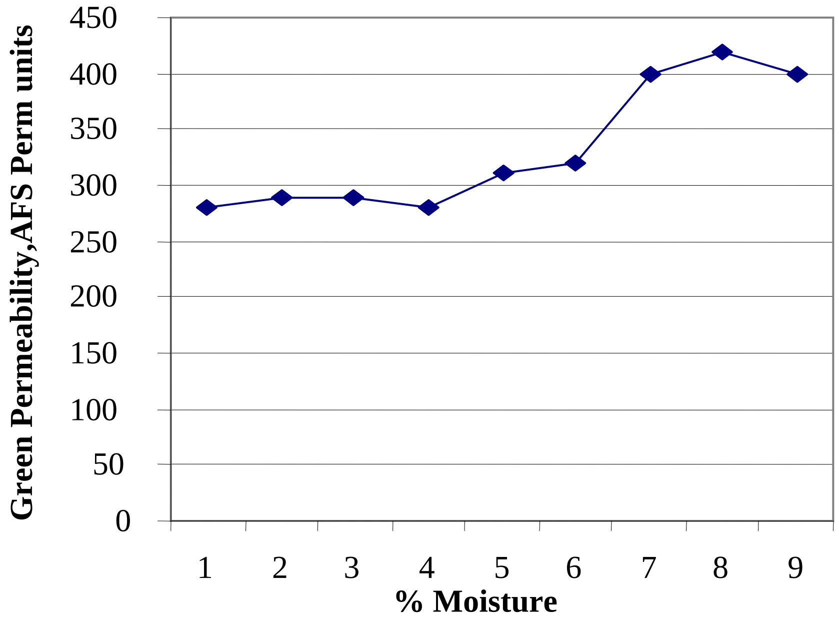

Figure 3. *Moisture Content Variation with Green Permeability of Yola Natural Sand*

Table 3, shows the results of bulk density of Yola natural sand as the moisture content was varied. Figure 4, shows the results with a curve which showed bulk density decreasing, then rising again to a high value of 1.78g/cm3 at 9% moisture content. Rundman [2] explained what happens to bulk density when moisture is increased. According to him as the moisture content is increased the clay content takes up the water, resulting in swelling of the clay particles, thereby pushing the sand particles apart, resulting in reduced bulk density and permeability. The point where the bulk density starts rising again indicate the point where the clay content becomes saturated with water, beyond this point the water merely fills space in the void volume, resulting in an increase in bulk density and decrease in green permeability. Several other researchers also agree with this explanation [7-18].

Yola natural sand has a clay content of 26% as can be seen from Table 3. The sand is natural sand. Here in Nigeria most foundries still make use of natural sand because most of the foundries are into the casting of aluminium and cast iron as against steel. According to Brown [4] natural sands are little used nowadays (except for some aluminium castings) and most foundry green sands are synthetic. This is the situation in the USA and Europe [2, 3]. The recommended green permeability for green sand is 80-110, green strength is 70-100KN/m2 and bulk density is 1.49g/cm3 and above [10-13,15].

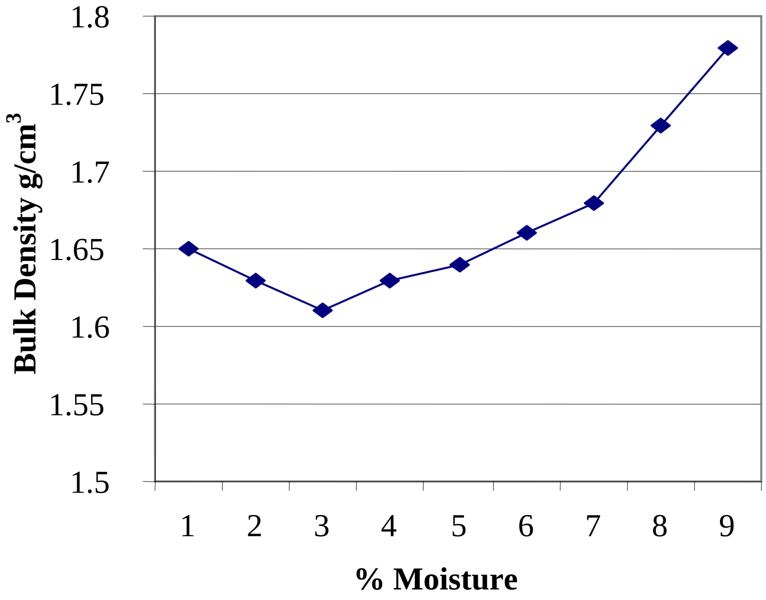

Figure 4. *Moisture Content Variations with Bulk Density of Yola Natural Sand*

A test casting was made using aluminium scrap and mould preparation using Yola natural sand. The result showed that the casting had good surface finish and was of good quality. Plate 1 shows the casting produced using Yola moulding sand mixture.

Plate 1. *Test Castings Produced from Aluminium Alloy using Yola Natural Sand*

Conclusions

From the results obtained in this study and the analysis of the results, it can be concluded that:

- Moisture has a very strong influence on the foundry properties of Yola natural sand.
- For optimum green compression strength the moisture content should be 5%
- For high dry compression strength moisture contents between 5-9% should be used. Caution should however be taken to allow the moulds to dry properly.
- The permeability of the natural sand increases with moisture content increase before finally decreasing at saturation point.
- The bulk density decreases as the moisture content increases and at saturation point the bulk density starts increasing with moisture content.
- The Yola sand mixture with moisture content of 5% produce a quality casting of aluminium using aluminium alloy scraps.

Acknowledgements

The author acknowledges the management of National Metallurgical Development Centre, Jos for allowing us to use their equipment. The authors are equally grateful to the staffs of the foundry shop, Engr. Solaogun, and Engr. Suleiman Mohammed who assisted in carrying out the various tests. The authors equally appreciate all the corpers attached to the foundry on industrial training, and research.

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