Optimizing the Moulding Properties of Recycled Ilaro Silica Sand

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Abstract

Effect of varying binders (bentonite and dextrin) and water on the properties of recycled foundry sand made from silica sand mined from Ilaro Silica sand deposit in Ogun State Nigeria and have been used in several cycles for production of cast iron was examined. The used sand was washed in hot water, dried and the sieved for grain distribution. Varying bentonite and dextrin contents were added together with water to portions of the silica sand and thoroughly mixed. The moulding sand properties (permeability, green strength, compatibility, shatter index and moisture content) of the recycled foundry sand were determined. It was observed that the recycled Ilaro sand (after several cycle of usage) has grain Fineness Index (GFI) of 50 and that it can still be reused by minimum addition of binders. It was concluded that the optimum green strength and permeability for the recycled sand was achieved when 12g of bentonite, 8g of dextrin and 12cm3 of water were added to 200g of recycled sand.

Keywords

Recycled; Foundry sand; Moulding sand properties; Bentonite; Dextrin.

Introduction

Foundry is one of the most ancient methods of metal forming. It includes such basic production processes as moulding, melting of metals and alloys, pouring of metal into moulds, solidification, shake-out, shot blasting and fettling of the casting. Casting processes include permanent mould casting, centrifugal casting, die-casting, investment casting, shell casting and sand casting [1]. Sand casting is the most widely used of the casting processes. It accounts for about 80% of cast product and can be employed for both ferrous and non-ferrous metals. All materials used for the manufacturing of sand mould and cores are termed moulding materials [2]. These materials are divided into the initial materials and molding mixture. The properties requirement of the materials is determined by moulding and casting condition. Hence proper choice of the composition of a moulding mixture is of prime importance.

The study of foundry sand constitutes one of the main sections of foundry technology and sand testing has become an essential part of the day-to-day control of foundry operation. Green sand moulding remains the most important method for producing casting, especially when the castings are required in a large number. In order to obtain the optimum economic production with green sand plant, it is imperative that foundry managerial and supervisory staff is familiar with the best method for control and operation of green sand plant [1].

The sand is re-used numerous times (Recycled) within the foundry, however heat and mechanical alteration eventually render the sand unsuitable for use; this is due to partial sintering of clay content of the moulding sand after the pouring or casting cycle [3]. The spent foundry sand, that is the sand that was removed is either recycled in a non-foundry application or land filled [4]. Research shows that less than 15 percent of 6 – 10 Million tons of annually produced spent foundry sand can be safely and economical recycled [4, 5]. The focus of this work is to investigate the possibility of recycling spent Ilaro foundry sand safely and economically.

Material and Method

The Recycled foundry sand used for this project was obtained from Nigerian Foundry Limited; Ilupeju, Lagos. The silica sand used in making the initial green sand before the several cycles was obtained from Ilaro sand deposit in Ogun State, Nigeria.

Particle Size Analysis

The recycled sand was washed in hot water to remove the caked binder and other undesirable materials. It was then dried and the grain size distribution of the sand was determined with the sieve analyzer. Dried 100g of the sand was weighed with a weighing balance. The sand sample was placed on top of a series of sieves of 1400µm, 100µm, 710µm, 500µm, 355µm, 250µm, 180µm, 125µm, 90µm, 63µm and mesh and was shaken for 15 minutes by electrical vibrator set at 3 Hertz. After the shaking period, the grains retained on each sieve and the bottom pan was removed, weighed and their percentages determined.

Determination of Green Sand Strength

Additives such as water, dextrin and bentonite were added in varying proportions to 200g of the recycled sand as shown in Tables 2, 3 and 4. The mixture was thoroughly mixed in a mixer. A universal sand strength machine was used to determine the green compression strength of the various sand mixtures.150 g of the sand mixture was weighed and rammed properly and was placed between the clamps on the pendulum or dead weight apparatus and the clamp placed on the magnetic rider in front of the pendulum weight of the green sand strength machine. The wheel of the apparatus was turned until the test piece broke. The value of the green compression strength was then read off the magnetic rider and recorded.

Determination of Permeability

The gas permeability was determined using a gas permeability tester Another 150 g of the recycled sand mixed with the additives was weighed on a scale and transferred to a specimen sleeve with the base already plugged in the socket. The sand was rammed three times using George Fisher Rammer. The sand sample was then removed from the sleeve and placed on an electric permmetre in an inverted form. The permmetre was switched on and the arrow was allowed to settle. Then the permmetre was adjusted to zero by the control knob. The lever was then moved to check the position. Then the value was read off.

Determination of Shatter Index

The shatter index test was carried out using shatter index tester. The standard specimen of size 50mm diameter and 50mm height was prepared and kept in the steel tube as in the case of permeability. The tube holding the specimen was fixed on the machine. The plan (receiver) was zero and fixed on the normal position at the foot of the machine directly below the specimen. The handle of the mechanism was pulled downward and the plunger entered and rejected the specimen from the steel tube. The sand fall under gravity and hit the anvil in the sieve on top of the receiver. The mass of the sand in the receiver was determined and the shatter index was determined for each mix as follows:

÷ Initial mass, m_0

÷ Mass of sand in the Receiver, m_i

÷ Shatter index, $\frac{m_0 - m_i}{m_0} \cdot 100$

Determination of the Moisture Content

To determine the moisture content, the moisture teller was set up to warm for 3 minutes by setting the time switch to 3 minutes while warming the machine, 50g of freshly prepared sand mix was weighed and spread over the pan of the moisture teller. After 3 minutes, the machine stopped itself and the pan together with the sand sample was then inserted into the lower part of the machine that holds it in position as fast as possible. The heating time was set at 2 minutes. After the 2 minutes the machines automatically stopped and the pan with dried sand was taken out and put in a cooling place. It was then allowed to cool to the room temperature. The cooled sand weighed and moisture content determined as follows

÷ Taking the initial readings to be: Y (g),

÷ The final readings at room temp to be: X (g),

÷ Then the percentage moisture content, $\frac{Y - X}{Y} \cdot 100$

Compatibility Test

Compatibility test is carried out to know the way moulding sand will withstand repeated cycles of heating and cooling during casting operations. An empty sand sleeve with the stopper plugged underneath it is placed under the funnel outlet of the compatibility tester's sieve. The sand is sieved until a heap is formed. The heap is then stickled off the sand. The sand is rammed four times and a value X is read off the calibration. The compatibility value is then calculated as X·100/67.

Results and Discussion

The sieve analysis result (Table1) shows that that the Grain fineness Index falls within the acceptable range. According to the AFS standard as stated in Foundry Sand Handbook [6], 40 to 330 average fineness is suitable for foundry application. The recycled Ilaro sand has an average fineness number of 50 and is therefore coarse in nature [7, 8].

Table 1. Sieve Analysis of Recycled Ilaro Silica Sand

MS	a	b	a·b	CRS
1.40	0.5	6	3	3
1.00	2.2	9	19.3	22.8
0.71	5.6	15	84	106.8
0.50	12.3	25	307.5	414.3
0.355	14.0	35	490	904.3
0.25	26.1	45	1174.5	2078.8
0.18	19.8	60	1188	3266.8
0.125	13.3	81	1077.3	4344.1
0.09	3.5	118	413	4757.0
0.063	0.3	164	49.2	4806.3
Sieve Pan	0.3	275	82.5	4888.8
Total	97.9			4888.8

MS: mesh size (mm); a: weight of sand on mesh (g); b: multiplier; CRS: cumulative retained sand; GFI: Grain Finest Index
GFI = 4888.8/97.9 ~ 50

From Tables 2, 3 and 4 it can be observed that permeability decreased with increasing binders.

Table 2. Effect of varying bentonite content on 200g of recycled foundry sand

	Recycled Sand (g)	Bentonite (g)	Water (cm^3)	Green sand Strength (kN/m^2)	Permeability (l/min)	Compatibility (%)	Shatter Index (%)	Moisture Content (%)
A	200	4.00	8.00	64.00	80.00	85.07	68.33	3.80
B	200	8.00	8.00	71.00	70.00	85,58	70.47	3.60
C	200	12.00	8.00	78.00	65.00	86.56	72.69	4.00
D	200	16.00	8.00	80.00	60.00	88.65	77.34	3.40
E	200	20.00	8.00	86.00	50.00	89.55	79.35	3.20
F	200	24.00	8.00	90.00	46.00	81.26	81.26	3.80

Table 3. Effect of varying tempering water content using the optimum value of bentonite content in table 2

Recycled Sand (g)		Bentonite (g)	Water (cm^3)	Green sand Strength (kN/m^2)	Permeability (l/min)	Compatibility (%)	Shatter Index (%)	Moisture Content (%)
A	200	12.00	4.00	74.00	70.00	64.07	70.40	3.80
B	200	12.00	8.00	76.00	65.00	67,58	65.34	3.40
C	200	12.00	12.00	78.00	62.20	69.56	62.04	3.80
D	200	12.00	16.00	82.00	55.00	73.65	69.33	4.00
E	200	12.00	20.00	84.00	50.00	78.55	67.33	4.20
F	200	12.00	24.00	80.00	60.00	69.26	64.70	8.01

Table 4. Effect of varying dextrin content using the optimum value of tempering water (in table 3), 200g of the recycled foundry sand and 12g of bentonite

Recycled Sand (g)		Dextrin (mm)	Water (cm^3)	Green sand Strength (kN/m^2)	Permeability (l/min)	Compatibility (%)	Shatter Index (%)	Moisture Content (%)
A	200	4.00	12.00	88.00	60.00	89.33	63.60	3.60
B	200	8.00	12.00	92.00	65.00	92.66	73.80	3.80
C	200	10.00	12.00	94.00	50.00	94.04	84.00	3.60
D	200	16.00	12.00	97.00	50.00	96.20	88.00	3.80
E	200	20.00	12.00	98.01	40.00	98.21	89.00	3.20
F	200	24.00	12.00	98.33	38.0	99.46	91.00	3.80

Dextrin and bentonite are expected to bind silica sand and other particles together in the presence of water. This is achieved by filling up the pores between the grains of the silica sand; hence the decrement observed with increase in the binder content. Thus the permeability is expected to decrease with increase in the binders [9].

It was also observed according to Tables 2, 3 and 4 that the compatibility increases as the additives introduced increased according to Jain [10], compatibility test measure the percentage decrease in the height from the original content level of loose sand under the influence of a fixed compacting force. It can be seen from Table 2, 3 and 4 that as the bentonite increases, compatibility increases as a result of the strong bond forming between the sand particles as a result of the increase in bentonite content and compaction under pressure [11].

The green strength increases with increase in bentonite and dextrin content in the moulding sand as shown in Figures 1 and 2; this agrees with the findings of Ademoh [12]. It is also observed that the green strength increases with increase in tempering water up to a particular point (Figure 3). But on the other hand the permeability of the moulding sand decreases with increasing tempering water (Figure 4). This should be expected; as more water molecules will fill the voids (interstices) between the sand grains, thereby impairing gas permeability. It is expected that any additional water will cause a decrease in strength. Moisture content is vital in moulding sand for ensuring ease of moulding, good quality moulds and good casting. When the moisture content is too much, the particles of the sand will not bind; insufficient moisture will result in defects in castings produced from such formed mould. Thus optimum moisture is essential for good moulding sand.

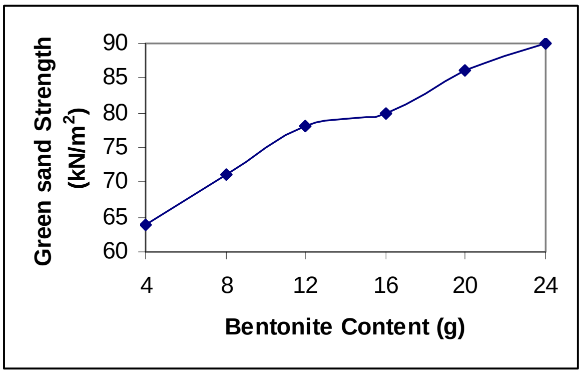

***Figure 1**. Influence of bentonite content on the green compression strength of the moulding sand*

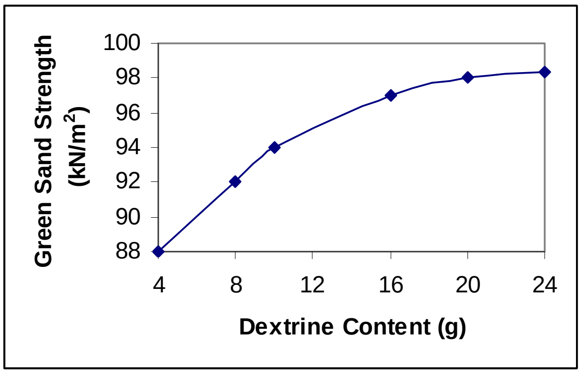

***Figure 2**. Influence of dextrin content on the green compression strength of the moulding sand*

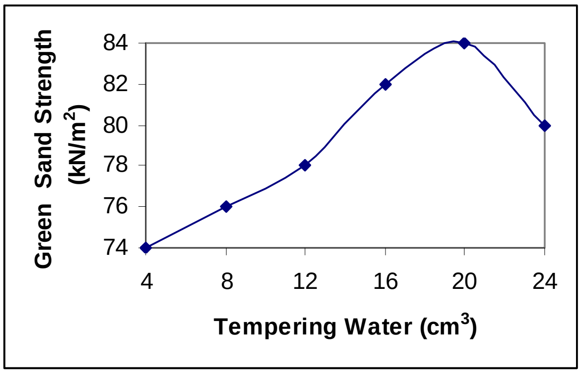

***Figure 3**. Influence of tempering water on the green compression strength of the moulding sand*

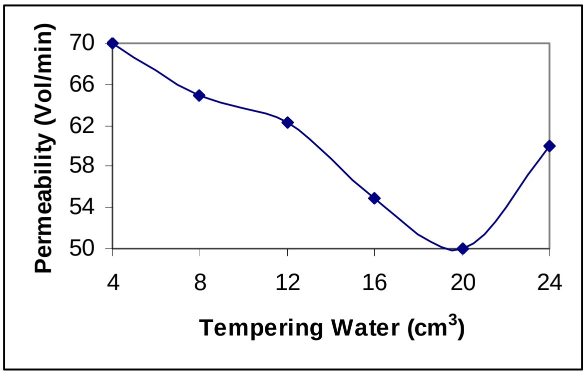

Figure 4*. Effect of tempering water on the permeability of the moulding sand*

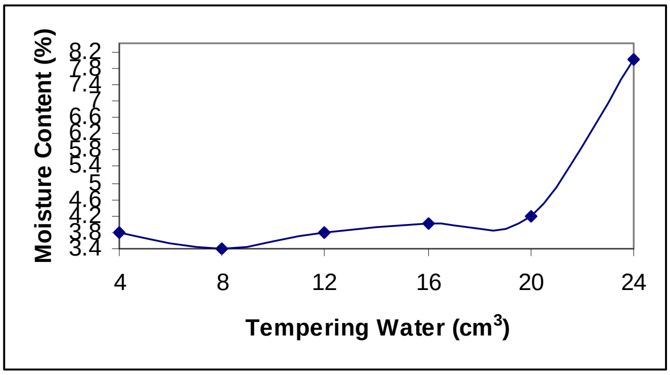

Figure 5*. Effect of tempering water on the moisture content of the moulding sand*

Shatter index increases generally with increases in strength as shown in Tables 2 and 4. Shatter index (this is a measure of sand toughness, particularly ability of sand to withstand rough handling and strain during removal of pattern) was found to be increasing as the percentage composition of the binder increases in the moulding sand mixture. According to Jain [10] and Khanna [13], too low and too high index are deleterious to moulding sand.

Figure 5 relates the effect of tempering water on the moisture content of the moulding sand; from the Figure it is seen that the moisture content of the moulding sand initially reduced from 3.8% at 4 cm^3 tempering water to 3.4% at 8 cm^3 tempering water, further increase in the amount tempering water used resulted in gradual and then later rapid increase in the moisture content of the moulding sand. This is explained by fact that initial water added to mix was absorbed by the dry powdered grain mixture of sand, bentonite and dextrin for effective bonding. After reaching the water saturation level for the mixture, further addition of water resulted in the formation of free water thereby accounting for the continuous increase in moisture content [8].

Conclusions

Based on the results obtained from the moulding sand analysis, the following conclusions are made:

÷ Recycled Ilaro sand (after several cycle of usage) has grain Fineness Index (GFI) of 50 and that makes it suitable for medium and heavy casting.

÷ The recycled sand can still be reused by minimum addition of binders.

÷ Optimum green strength and permeability (two essential properties of a moulding sand) of the recycled sand were achieved when 12g of bentonite and 8g of dextrin, 12cm3 of water were added to 200g of recycled sand.

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