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THE EFFECT OF SLAG ADDITION ON THE MOULDING PROPERTIES OF GREEN SAND

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ABSTRACT
Slags generated by small, medium and large scale foundries across the country are in huge volumes, and constitute severe environmental menace. Each foundry expends part of its revenue for the disposal of these slags, while it still needs to procure green sand for moulding at a cost. This paper explores the possibilities of using particulate admixture slag for foundry green sand production. Sample basic slag was pulverized in a ball mill and classified into a range of particle sizes between 80-300 British Standard (BS). Each grade of particle size was used to prepare blends containing varying percentages by weight of slag ranging from 1–10%. The mechanical properties such as permeability, green strength, moisture content and shatter index were assessed, using standard laboratory practice. The results reveal that the particle size of the added slag has more influence on the moulding properties of the slag-bearing sand. However, when slag addition is above 1.5 percent, all the moulding properties of the green sand (permeability, green strength, moisture content and shatter index) fall outside the accepted ASTM (America Society for Testing and Materials) D2216 and D2434 Standards,. It is recommended that not more than 1.5 percent particulate slag by weight per batch of green sand of 150BS particle size should be added to the moulding sand

Keywords: Slag, moulding properties, permeability, moisture content, hydrophilic

1.0 INTRODUCTION
1.1 General
Steel foundry slag is an undesirable by-product formed during the purification or melting of iron or steel scraps in iron melting furnaces. Slag from melting and holding furnaces arises from the oxidation of extraneous materials in the charge such as rust, dirt, coatings and other impurities. Slag can also be formed from erosion and wear of the refractory lining, oxidized ferroalloys and other sources(Andrews, Gikunoo, Ofosu-Mensah, Tofah, & Bansah, 2012)(Katz, 2004). Iron and steel slag can be broadly categorized as basic and acidic slags. Excessive slag formation as a result of dirt and impurities contributes greatly to the erosion of furnace lining especially in electric induction furnaces. The severity of the erosion often leads to furnace leak and outright damage of the burst-bar. Also, high nickel content slag corrodes iron and steel in the presence of moisture. Slags containing sulphurous leachate discolour water resulting in poor drainage condition (Andrews, Gikunoo, Ofosu-Mensah, Tofah, & Bansah, 2012). Besides, most foundry operators in Nigeria often incur huge losses on transportation for slag disposal. Apart from the millions of naira spent annually on transportation, the huge piles of slags still lying in some companies constitue environmental pollution (Sanya , Akinruli, & Oke, 2014). However, in some developed nations, furnace slags are widely utilised as raw materials for cement production, concrete manufacturing, soil conditioners, fertilizers and in road construction (Mohammed & Arun , 2012) (Sofilic, Sofilic, & Brnardic, 2012).The consumption of slag by cement and construction industries helps in reducing the problem of environmental pollution (Mohammed & Arun , 2012). The attempt to cut down expenses on slag disposal by resource recovery and recycling has not received adequate attention by researchers, particularly in Nigeria. In this present study, an attempt has been made to investigate the

possibility of utilising foundry slag as an admixture to produce green sand moulds.

2.0 EXPERIMENTAL PROCEDURE

2.1 Materials

A deliberate effort was made to source for basic foundry slag from some selected foundries within Lagos metropolis. Lump slags of different sizes were collected. 20kg pure silica sand was sourced from a sand mine and used for the preparation of the green sand mould. Other additives for the green mould include bentonite, fine coal dust, boiled cassava starch and water. Samples were taken from batch discharged conveyor belt of 1 ton capacity sand mixer in Nigeria Foundries Limited. 500g samples were put into a measuring cup and covered with damp cotton to avoid loss of moisture through evaporation. American Society for Testing Materials (ASTM) standard test sieves with vibrator were used to grade the starting materials; a calibrated digital weighing balance measuring up to 0.05g accuracy was used for weighing the batch constituents. The Hydraulic Powered Ramming Machine, Universal Strength Testing Machine, Shatter Index Equipment and Permeability Machine used were of the standard prescribed by the Foundry Association of Nigeria.

2.2 Experiment and Methods

Prior to permeability, green strength and shatter index laboratory test, 150g of each sand sample was weighed out on the electronic weighing scale and transferred to the specimen sleeve, with the base already plugged in. Standard ramming method was employed to prepare 100mm height by 50mm diameter cylindrical specimens.

Permeability which is determined by measuring the quantity of air that passes through a given sample of sand in a prescribed time and under standard condition was tested by passing air through each rammed sample. Each rammed sand specimen was placed in the mercury cup of the permeability meter. The permeability test procedure adopted was in accordance with American Foundry Society (AFS) Universal Sand Strength machine. This machine consists of a pusher arm and weight arm, both hanging from a pivot bearing at the top of the machine. As the weight arm was pushed up higher, the load increased until the specimen was crushed. Then the compression strength in ton/in^2 was read at the magnetic marker end on the graduated scale.

A fresh rammed specimen was prepared to determine the shatter index value. The specimen was allowed to fall freely from a height. The shatter index equipment and the lever were pulled such that the sand was removed from the sleeve on to the receiving sieve placed directly below the equipment. Then the lumps of the sand on the sieve were collected and weighed on the weigh balance to determine the weigh X of the sand. The value of the shatter index was computed using Eq. 1.

$$Shatter\ index = \frac{X}{150} \times 100 \qquad (1)$$

To determine the moisture content of the blend, 50g of sand specimen was accurately weighed, W_1, on the electronic weighing scale and poured in a pan according to ASTM D2216 specification. The timer for the blower of the moisture teller was set for the required time to dry the sand (approximately 5 min) and air at 110℃ was blown over and through the sand. Thereafter, the dried sand was taken out of the oven and re-weighed, W_2. The percentage of moisture content in the green sand was determined using Eq. 2.

$$Moisture\ content = \frac{W_2 - W_1}{W_1} \times 100 \qquad (2)$$

Standard. For green compression strength test, the test was performed on the slag incorporated sand specimens by using.

3.0 RESULTS AND DISCUSSION

The properties of the control samples are shown in Table 1. Results from the other experimental samples are presented in the sections below.

3.1 Permeability

The permeability results are shown in Figure 1. It is evident from the result that the permeability of the slag bearing moulding sand showed no significant difference with coarser slag addition for mesh sizes of 80BS and 100BS. Conversely, for pulverised slag particulates of 150BS and 300BS, the permeability decreased with increase in percentage of slag added to the blend. This shows that the addition of powdered slag particles reduced the permeability of the blend fairly significantly. The addition of coarser slag aggregates will permit gases to pass out of the mould during pouring. However, inclusion of high quality pulverised slag particulates will hold gases in the mould during pouring resulting casting defects.

3.2 Green Strength

The green strength of the moulding sand decreased as the percentage of slag addition increased (see Figure 2). The experimental result also shows that green strength for 80 BS mesh size is 61.00KN/m^2 and 300BS mesh is 37.00KN/m^2 for 10% slag addition.

This implies that the green strength of the slag incorporated moulding sand varies with grain size and percentage weight of the slag. In other words, the finer the slag, the lower the green strength. Thus, addition of finer slag to the green sand blend would lower the moulding properties in terms of green strength significantly compared to the coarser slag aggregates. Like the permeability results, addition of very fine slag (below 150BS) would make the moulding sand unsuitable for casting purpose. However, backing sand would retain its strength when slags of 80-100BS mesh sizes are added in relatively low percentage (within 1-2.5% range).

Table 1 Control test results of Permeability, Green Strength, Moisture Content and Shatter Index

Trial	*Permeability (mmH_2O)*	*Green Strength (KN/m^2)*	*Moisture Content (%)*	*Shatter Index (%)*
1	72.00	69.00	5.20	65.10
2	88.00	78.00	5.00	65.50
3	70.00	73.00	4.40	67.50
4	80.0	63.00	4.00	63.10
Average	77.50	70.75	4.65	65.30

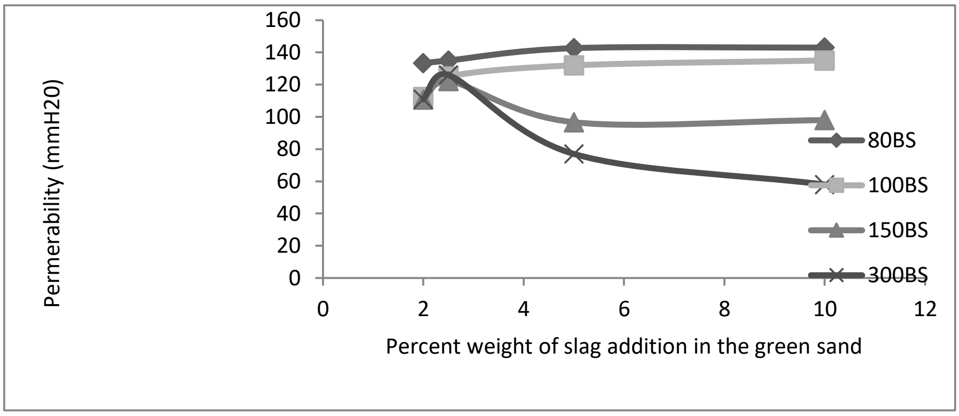

Figure 1 Plot of permeability of moulding sand against percentage weight of slag addition

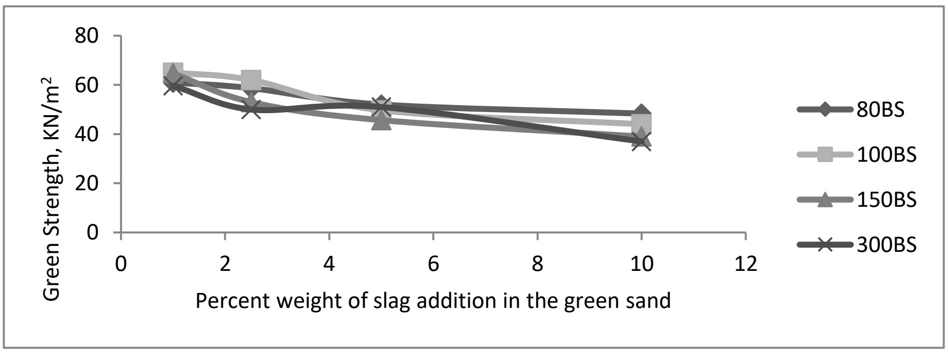

Figure 2 Plot of Green Strength of moulding sand against percentage weight of slag addition

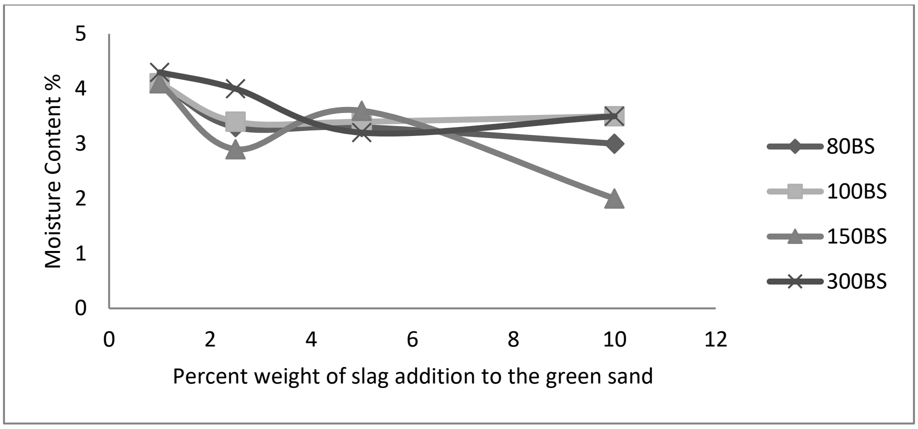

Figure 3 Plot of Moisture Content of moulding sand against percentage weight of slag addition

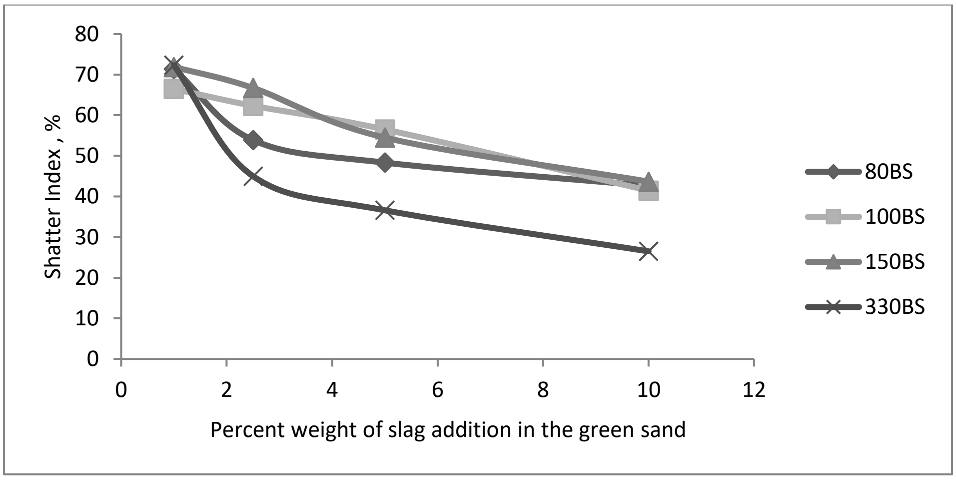

Figure 4 Plot of Shatter Index of moulding sand against percentage weight of slag addition

3.3 Moisture Content

The moisture content data that were collected are shown in Figure 3. From the graph, there is a sharp decline in moisture content on slag addition. The reduction in moisture content readings when pulverised slag particles were added is because of the hydrophilic nature (showing strong affinity to absorb water) of slag grains. Low quantity (not more that 1% of the blend) of slag for all mesh size ranges may be added to green sand to regulate its moisture content.

3.4 Shatter Index

The values of the shatter index of the slag bearing sand decrease with increase in percentage of slag addition as shown in Fig 4. Addition of low quantity of 80-100BS mesh size of slag would yield an appropriate blend that can effectively resist shock.

4.0 CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

The following conclusions may be deduced from this study:

1. The grain size of the added slag has more influence on the moulding properties of the slag-bearing sand.
2. Except for the permeability result, the moulding properties examined (green strength, moisture content and shatter index) decline with increase in slag addition.
3. The permeability of the slag incorporated blend increases as percentage of slag increases for 80-100 BS mesh size; however, the blend permeability decreases as percentage of slag increases for 150-300BS mesh size.

4. The addition of granulated slag reduces the moisture content of the blend. Slag addition is hydrophilic in nature.
5. Slag addition not more than 1.5% of the blend could be used to regulate moisture content of the moulding sand.

4.2 Recommendation

It is recommended that slag to be added to moulding sand should be graded into particle size of 150BS and the moulding sand should not contain more than 1.5 percent by weight per batch.

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