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Effects of Additives on Some Selected Properties of Base Sand

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Abstract

In this study, effects of sawdust, coal dust and iron filling additives at varied proportions on some selected properties of moulding sand were investigated. Consequently, cylindrical specimens with different percentages of additives were prepared based on standard procedures. The prepared specimens were subjected to basic moulding sand testing including moisture content, bulk density, porosity, permeability, green compression strength and green shear strength using standard methods and equipment. From the obtained test results, all the experimental additives were found to improve the selected moulding properties of the base (silica) sand. Moulding sand specimen with sawdust additive revealed a relatively better compaction as compared to moulding sand specimens with coal dust and iron filling additives respectively. The moisture absorbing strength of the moulds was also found to increase with increasing percentage of sawdust. Addition of coal dust to the moulding sand was found to improve sand porosity and permeability which results in less casting defects, and due to improved moisture absorbing strength of sawdust, moulding sand specimens that contained sawdust were equally found to exhibit good compaction with maximum green compressive strength of 108.99 kPa. Also, the combination of 25% sawdust, coal dust and iron filling in the moulding sand was found to produce mould with optimum green shear strength value of 54.49 kPa.

Keywords

Moulding Sand, Sawdust, Coal Dust, Iron Filling, Porosity, Permeability, Bulk Density, Green Compressive Strength, Green Shear Strength

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1. Introduction

The most common casting process used in the foundry industry is the sand cast system [1]. The principal constituents of moulding sands are: silica sand grains, clay (bond), moisture, and organic additives. Virtually all sand cast moulds for ferrous castings are of the green sand type [2]. Green sand consists of high-quality silica sand, about 10 percent bentonite clay, 2 to 5 percent water and about 5 percent sea coal; other materials may be added to the sand mixture to enhance certain properties [3], and for defects free cast products, foundry sand for mould making must be carefully prepared to meet certain basic requirements such as refractoriness, cohesiveness, permeability, collapsibility, green strength dry strength, thermal stability and reusability [1]. Moulding sands are specified based on average size and shape. Finer grains lead to more intimate contact and lower the permeability, but tend to fortify the mould and lessen its tendency to get distorted and the shapes of the grain may vary from round to angular [4].

A good moulding sand always represents a compromise between conflicting factors, and to obtain an acceptable compromise of the four basic requirements, the size of the sand particles, the amount of bonding agent (such as clay), the moisture content, and the percentage of organic matter are all selected [3]. The composition is carefully controlled to assure satisfactory and consistent results (A typical green-sand mixture contains about 85% silica sand, 9% clay, and 3% water and 3% organic additives). Moulding material is often reclaimed and recycled, the organic material that has to be added again as a portion of it will burn during the pour [5]. When moulding sands are used for mould making without additives, some important characteristic may be absent in the sand [6]. When additives are added to moulding sands, certain properties including high temperature plasticity, metal penetration property and surface finish are improved [2]. Additives are mixed during sand preparation based on the requirement of molten metal and base sand to obtain specific characteristics in the sand [3].

In spite of the property-enhancing influence of additives on castings from sand cast system, it is regrettable to note that while efforts by researchers on inoculation practice are on the increase, only scanty information on sand additives is available in literatures. Hence, qualities of cast products from the local foundries are found to come with some defects that are preventable when some specific properties are introduced into the base sand through additives.

This study, therefore examines the influence of sawdust, iron filling and coal dust (which are cheap and available) at varied proportions on the moisture content, permeability, porosity, bulk density, green compressive strength and green shear strength of the base sand that is silica sand with a view to determining the best mould(s) with correct additives proportion for sand cast system.

2. Materials and Methods

The materials used were silica sand, bentonite, coal dust, iron dust and sawdust. The equipment used included molding box, rammer and vent wire. The chemical composition of the silica sand used for this research is shown in **Table 1**.

2.1. Sample Preparation

Wooden patterns of 50 mm length, 30 mm breadth and 20 mm thickness with contraction allowance of 1.5% were used to produce the test specimens. The sprue and riser were tapered to allow for easy withdrawal of pattern from the mould. Silica sand, bentonite (binder), water and additives (iron filling, sawdust and coal dust) at different proportions were added to the mould materials, manually mixed and rammed together, blows were used for each of the ramming operation, and ramming was carried out with sand rammer in accordance with AFS specifications. Upon removing the specimens from the sand rammer, they were tested for moisture content, permeability, porosity, bulk density, compressive strength and shear strength. A specimen without additives (control) was equally prepared, and the results of the additive constituents of the produced moulding sand specimens used for the tests are depicted in **Table 2**.

Table 1. The chemical composition of the silica sand sample.

Main Constituents	SiO_2	Al_2O_3	NaO	K_2O	MgO	CaO
Wt %	97.21	0.36	0.73	0.12	0.36	0.47

Table 2. Constituents of moulding sand specimens additive.

Moulding Sand Specimens	Additives	Proportions of Mould Additives (%)
A	None	0
B	Iron dust	20%
C	Iron dust	25%
D	Sawdust	20%
E	Sawdust	25%
F	Charcoal dust	25%
G	Iron dust and charcoal dust	20%
H	Sawdust and charcoal dust	25%
I	Sawdust, charcoal dust and iron dust	20%
J	Sawdust, charcoal dust and iron dust	25%

2.2. Moulding Sand Testing

Standard procedures and equipments were used to evaluate the moisture content, permeability, bulk density, green compressive strength, green shear strength and refractoriness of the moulding sand specimens.

2.3. Moisture Content

Specimens weighing 50 gm were carefully prepared and put inside an oven which was maintained at a temperature of 110˚C for 2 hours to allow for the escape of moisture. After which, they were taken out of the oven and reweighed. The percentage of moisture was calculated from the difference in the weighs of the original moist and consequently dried sand samples using the expression:

$$\text{Moisture Content} = \frac{w_1 - w_2}{w_1} \quad (1)$$

where,

w_1 = weight of the moist sand specimen

2.4. Permeability

w_2 = weight of the dried sand specimen

Air of volume 200 cm^3 held in the bell jar was forced to pass through test specimens of dimensions 50.8 mm diameter and 50.8 mm long at a pressure of 980 Pa (10 g/cm^3) indicated by the manometer reading, and the time required for the air to pass through the specimens was determined. The permeability number calculated using the formula:

$$P_A = \frac{V \times H}{A \times P \times t} \quad (\text{Gupta}, 2005) \quad (2)$$

where, V = Volume of air = 200 cm^3,
H = Height of the sand specimen = 50.8 mm = 5.08 cm,
P = Air pressure = 10 g/cm^2,
A = Cross sectional area of sand specimen = Π/4 × (5.08)^2,
t = Time in minutes for complete air to pass through.

2.5. Green Compressive Strength

A portion of the rammed specimens were maintained in the green condition by taken them out of the moulding box, and without delay putting them immediately on the universal testing machine. Compressive loads were then applied until the specimens failed, and the force required to cause the compression failure were determined and recorded.

2.6. Green Shear Strength

The universal testing machine was fitted with a different adapter in order that loading can be made for the shearing of the rammed sand specimens. The stresses required to shear the specimens along the axis were determined and recorded as the green shear stress.

2.7. Bulk Density

Rammed specimens were weighed in air and the weights were recorded (*D*). Thereafter, each of the specimens were transferred to a beaker of water and heated for 40 minutes to release any trapped air and they were allowed to cool. The specimens were soaked in water, and the soaked specimens were weighed and their weights were recorded (*W*). The specimens were subsequently suspended in water and the suspended weights were measured (*S*). The bulk density was determined using the expression:

$$\text{Bulk density} = \frac{D}{W - S} \tag{3}$$

where: D = Weight of specimen in air (dried sample),
W = Weight of soaked specimen (in air),
S = Weight of suspended specimen (in water).

3. Results and Discussion

Highest moisture content value of 39.2% was obtained for the specimens with 25% sawdust as compared to specimens with 25% iron filling and charcoal with moisture content values of 33.7% and 32.5% respectively. The observed improved moisture contents of all the specimens with varied percent of sawdust is an indication of the relative better moisture absorbing ability of sawdust [3], and as a consequence, mould sand compaction is increased due to reduction in the resistance developed by the bonding agent [1]. Hence, better mould strength requirement may be achieved in moulds with sawdust additive. **Figure 1** shows the selected properties of moulding sand specimen relative to the varying quantity of additive addition.

Permeability, porosity and bulk density are critical to the strength requirement of sand moulds [7]. Generally, the specimens' permeability was observed to increase with increasing air filled porosity and decrease with bulk density [8]. Permeability is a function of the size of the sand particles, the amount and type of clay or bonding agent, the moisture content, and the compacting pressure [8]. In this study, variations in the moulding sand specimens' permeability, porosity and bulk density characteristics were observed to be direct consequence of the specimens' constituents. Relative improved permeability and porosity were obtained with charcoal dust containing moulding sand specimens as compared to iron filling and sawdust enriched specimens respectively. Specimen with 25% coal dust additive showed highest permeability and porosity values of 6.53×10^{-5} cm/s and 45.8% respectively, and the lowest values of 5.06×10^{-5} cm permeability and porosity 33.2% was revealed by specimen with 25% sawdust. High moisture content in the mould has been found to decrease with increasing porosity and permeability [1]. Hence, relative less casting defects may be obtained with moulding sand that is rich in coal dust. The bulk density characteristics obtained for all the additive aided moulding sand specimens were seen to vary slightly, but comparable with that of the moulding sand specimen (control) without additive. The results obtained indicated that the specimens' bulk density characteristic was increased with increasing moisture content. At a very high moisture contents, maximum bulk density is achieved when the sand is adequately rammed to drive off all the air in the mould, and at low moisture contents, sand particles interfere with each other, such that addition of some moisture may be necessary for improved bulk density [1].

The relative improved green compressive and shear strength characteristics of the moulding sand specimens may have been influenced by the effects of the additives [9]. While the maximum green compressive strength value of 108.99 kPa developed in the moulding sand specimen with 25% sawdust additive may be due to better mould compaction resulting from better moisture absorbing strength of sawdust [3], that of shear strength of value 54.49 kPa revealed by specimen with 25% sawdust, coal dust and iron filling may be due to synergic effects of the additives which includes good moulding sand compaction, better moisture absorbing characteristics

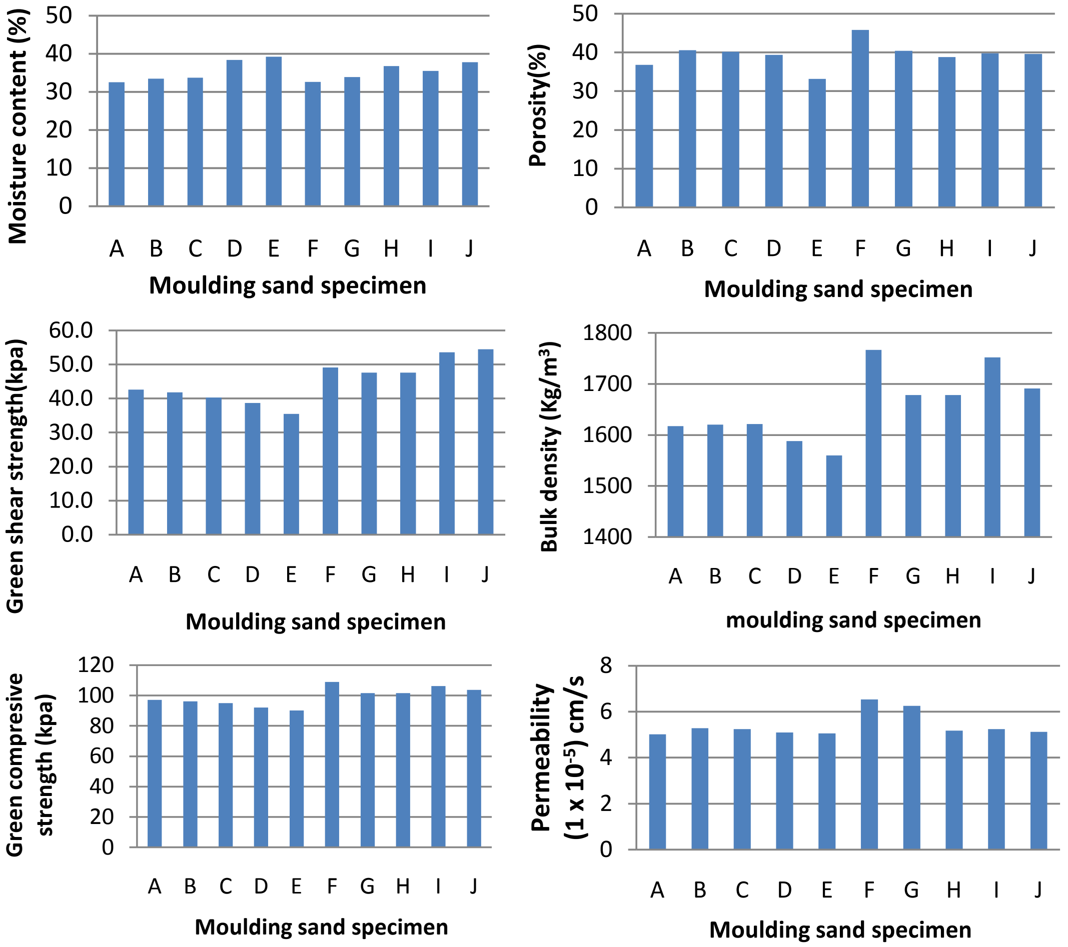

Figure 1. Selected properties of the moulding sand specimen.

of sawdust and resistance developed in the mould resulting from the relative poor moisture absorbing strengths of coal dust [3] and iron filling respectively. Consequently, sand moulds with optimum required moisture content, bulk density, porosity are produced.

4. Conclusions

Based on the obtained results of the moulding sand properties in this study, the following conclusions are made:

1. All the experimental additives were found to improve the moulding properties of the base (silica) sand.

2. Moulding sand specimens with sawdust additives revealed a relatively better compaction. Hence, improved mould strength requirement is achievable in moulds with sawdust additives.

3. The presence of coal dust in the moulding sand was found to improve sand porosity and permeability. Therefore, relative less casting defects including blow hole may be obtained with moulding sand that is rich in coal dust.

4. Due to improved moisture absorbing strength of sawdust, moulding sand specimens that contained sawdust were found to exhibit good compaction with maximum green compressive strength of 108.99 kPa.

5. The synergic effect of 25% sawdust, coal dust and iron filling on the moulding sand gave the optimum green shear strength value of 54.49 kPa. Hence, this combination should be preferred where what is optimally required is green shear strength.

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