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Effect of Clay and Moisture Content on the Properties of Molding Sand

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Abstract

The work was done to understand the effects of molding sand characteristics (percent clay and moisture content) on the properties of green sand molding mixture. Locally found sand was used for this experiment. Sieve analysis was done to calculate the American Foundry men's Society (AFS) grain fineness number and to know the particle size distribution. Percent clay content and percent moisture content of the as received sand was determined to make different types of sand mixtures. Initially two batches of sand were taken. The first one was using as received sand (B_1) and other one was using only two sieve fractions that retained the maximum amount of sand (B_2). Six different types of sand mixtures were prepared from each batch. For first three mixtures (B_{11}, B_{12} and B_{13}), moisture content was fixed (3.5%) but clay content varied to 8, 12 and 16% respectively. On the other hand, for the other three mixtures (B_{14}, B_{15} and B_{16}), clay content was fixed (8%) but moisture content was 2, 3.5 and 4% respectively. Same procedure was followed for making the second batch mixtures (B_{21}, B_{22}, B_{23}, B_{24}, B_{25} and B_{26}).Finally those samples were taken for permeability, hardness, green compressive strength testing. The experiment found that, mechanical properties like hardness and green compressive strength was higher for B_1 than B_2. Clay content had significant effect on permeability, hardness or GCS while moisture content had a little effect.

Keywords: Sieve analysis, AFS fineness number, Mesh, Hardness, Permeability.

1. Introduction

One of the best-known applications of clay is in the manufacture of such articles as pottery. Another major application of kaolinite is in the paper industry where it may be used either as filler or for coating paper. The metallurgical industry employs clay mixed with sand to form molds that are used for casting operation [2-3].
The major production of castings is in sand molds. Molding sands are mixtures of three basic ingredients. Green sand contains clay, water as well as the principal constituent, silica. These components provide the bulk and plasticity required of the molding sand. Other materials may be added to the sand mixture to enhance certain of the properties [1-2].
Molding sand may contain about 2 to 50% of clay. With suitable water content, it is the principal source of the strength and plasticity of the molding sand. Clay is thus the bond or binder of the molding sand which increases the strength of molding sand. But after the saturation point, further increase in clay content will not cause an increase of strength of the aggregate [3-5].
Water, present in amounts of about 1.5 to 8%, activates the clay in the sand, causing the aggregate to develop plasticity and strength. The water is adsorbed by the clay up to a limiting amount. Excess water can act as a lubricant, and makes the sand more plastic and more moldable though the strength may be lowered [1].
The size and distribution of sand grains is determined with the AFS sieve analysis test. A well distributed sand grain will have higher strength but lower permeability. For ferrous castings, the AFS number should be low so that the permeabilityof the molding sand will be high. On the other hand for non-ferrous castings, the number should be higher to lower the permeability [6-7].

2. Experimental procedure

Sieve analysis

Sieve analysis was done to make two different batches of sand. The test of determining the AFS grain fineness number was performed on a dried locally found sand sample (B_1). A set of standard testing sieve was used toscreen the sand. These sieves were stacked in sequence with the coarsest sieve at the top and placed in sieve shaker. About 200 grams of sand was placed at the top sieve and after 15 minutes of both horizontal and vertical vibration, the weight of the sand retained in each sieve was carefully weighted. The second batch of sand (B_2) was made using two sieve fractions that retained the maximum amount of sand.
AFS grain fineness number was calculated by the following equation:

$$\text{AFS grain fineness no.} = \frac{\text{Total product}}{\text{Total percentage of sand retained}} \quad (1)$$

Calculation of percent clay content

A portion of the sand samples of both batches were thoroughly dried at 220^{o}C for about 4 hours. 50 grams of the dried sand was placed in a wash bottle and then 475 cc of distilled water and 25 cc of 3% caustic soda solution were added in it. The mixture was stirred for 5 minutes in a rapid sand washer. Sufficient water was added up to the level line marked on the bottle. The liquid was then siphoned off after 10 minutes. It was repeated twice. Then the sand was dried and its weight was taken. The difference between the initial and final weight gave the percent clay content.

Measurement of percent moisture content

50 grams of sand sample was placed in a pan. The timer for the blower of the moisture teller was set for approximately 5 minutes and air at 110^{o}C was blown over and thorough the sand. The sand was weighted again. The difference between two weights gave the moisture content in it.

Permeability test

To determine the permeability of sand batches, samples of 2 inches diameter and 2 inches height was prepared by ramming the required quantity of sand in a tube with three blows of standard rammer. The specimen was placed in the mercury cup of the permeability meter. The air drum was raised to take 2000 cm^3 of air into the air drum. Then the whole air was allowed to escape through the specimen with a pressure of 10gm/ cm^3 and the time was recorded. The following equation gave the permeability number:

$$P = \frac{Vh}{Apt} \quad (2)$$

P= Permeability number
V= Volume of air=2000 cm^3
h=Height of specimen=5.08 cm
A=Cross sectional area of specimen=20.268 cm^2
p=Air pressure=10gm/ cm^3
t=Time in minutes

Hardness test

The hardness of the rammed samples was measured by using an indentation type mold hardness tester where a spring loaded 0.5 inch diameter steel ball was pressed into the samples. The hardness number was read directly from dial gage.

Green compressive strength test

Green compressive strength was measured by using Universal sand strength machine. This machine contains a pusher arm and a weight arm. The weight arm applies load on specimen. The specimens were loaded until break.

3. Result and discussions

Table 1 shows the data obtained during sieve analysis. From equation 1 AFS grain fineness number was calculated. It was found 65 which mean the average grain size of sand was 65 and it corresponds to the sieve number whose openings would just pass all the sand particles if all were of the same size. It can be also seen from the table that, Batch 2 (B_2) was 2-screen or mesh type. That means only two sieves had retained sand more than 10%. So, it was clear that, the distribution of particles of Batch 2 (B_2) was poor compared to Batch 1 (B_1) as B_2 contained only two sizes of particles. Distribution of particles played significant role in other properties like permeability, hardness, green compressive test etc.

Table 1. Experimental data of sieve analysis

US series equivalent sieve no.	Sand retarded (grams)	Percent retained (A)	Cumulative percentage	Multiplier (C)	Product (AxC)
6	0	0	0	3	0
12	0	0	0	5	0
40	11.86	5.93	5.93	30	177.9
70	131.92	65.96	71.81	50	3298
140	50.63	25.32	97.21	100	2531.5
200	4	2	99.21	140	280
270	0.57	0.29	99.49	200	57
Pan	0.62	0.31	99.80	300	93
Total		**99.80**			**6734.40**

The data can be used in two ways. First, a distribution curve showing the total percent retained on each sieve may be plotted as in Figure 1 or the cumulative percentage showing the total percent obtained which is coarser than any particular screen may be plotted. Second, the average grain fineness may be computed.

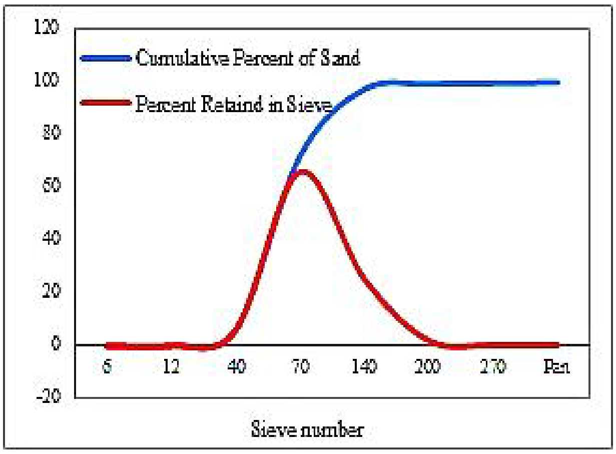

Fig. 1. Graphical representation of sieve analysis data

Effect on permeability

Figure2 and 3 shows the variation of permeability with clay and moisture content for both B_1 andB_2 batches.Permeability remained more or less unchanged when percent clay contentwas varied (Fig.2). On the other hand, when percent clay content was fixed (8%), permeability increased with increase in moisture content for both B_1 and B_2 batches (Fig. 3).

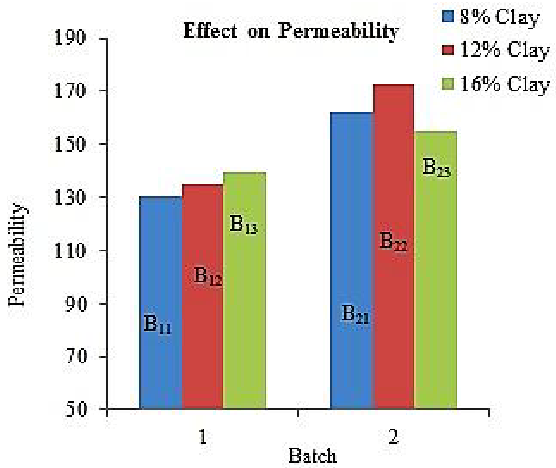

Fig. 2. Variation of permeability with %clay

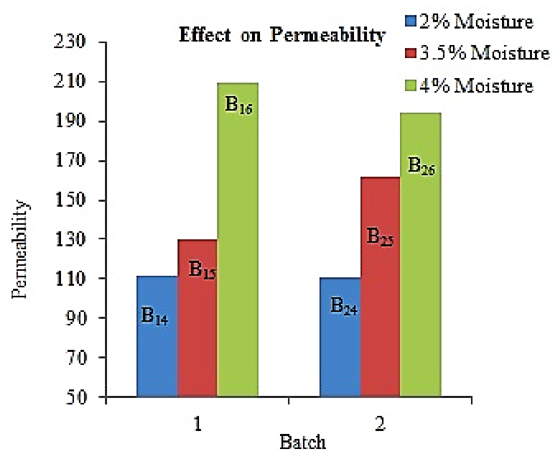

Fig. 3. Variation of permeability with % moisture

Effect on hardness

As the percent of clay content increased, the mold hardness increased for both batches (percent moisture content 3.5%). But B_1showed higher hardness than B_2(Fig. 4). Figure 5 shows the increase of mold hardness with moisture content. Again B_1gave better result than B_2. Mold hardness was higher when percent clay content was varied.

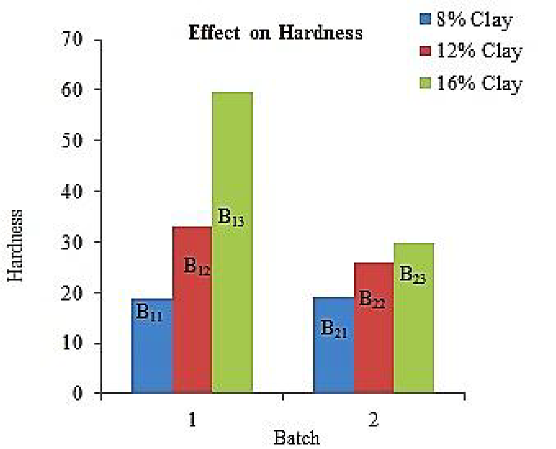

Fig. 4. Variation of hardness with %clay

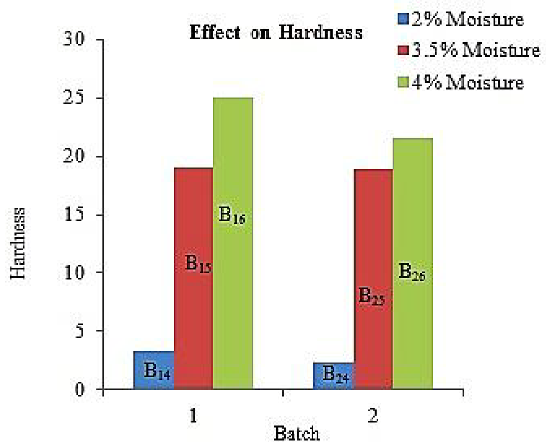

Fig. 5. Variation of hardness with %moisture

Effect on green compressive strength (GCS)

Figure6 and 7shows the variation of green compressive strength with percent clay and moisture content respectively. The clay and moisture content had significant effect on GCS. For fixed 3.5% moisture, B_1showed higher GCS. While for B_2,GCS was lower and it decreased with increase in clay content (Fig. 6). Moisture content had a little effect on green compressive strength. So, changing the content of moisturegave almost same result for both B_1 and B_2 (Fig. 7).

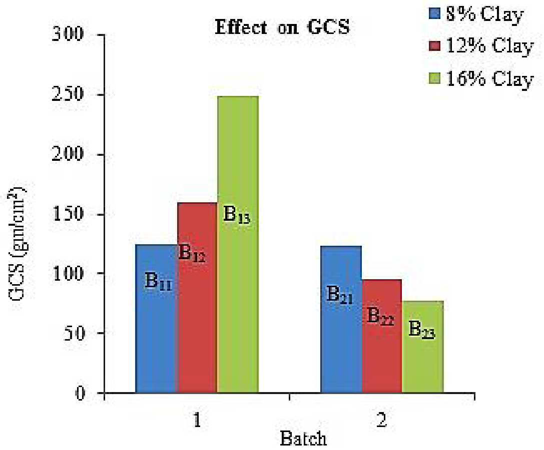

Fig. 6. Variation of GCS with % clay

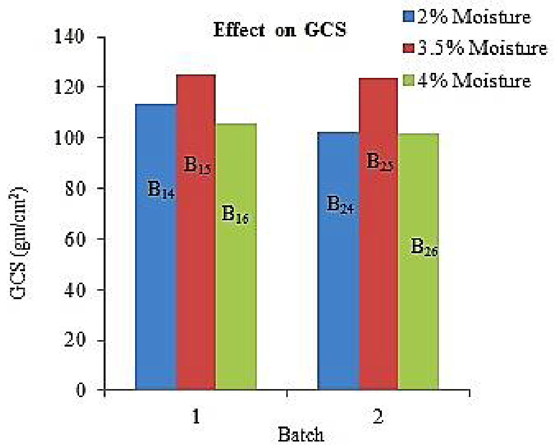

Fig. 7. Variation of GCS with %moisture

4. Conclusions

Clay particles are basically finer than sand particles. So, permeability should decrease by the addition of clay. But as B_2 had only two sizes of particles its distribution was poor and permeability was higher than B_1. So particle size and distribution was the major factor for the variation of permeability. Addition of clay particles had a little effect on permeability.

Clay acts as binder. Normally with increasing clay content mold hardness increases. This is because with increasing clay content bonding also increases. This was true for B_1 but again due to the poor distribution of particles B_2 didn't give any significant result. On the other hand, moisture played a vital role in increasing mold hardness.

In case of green compressive strength, 16% clay content gave around 250 gm/cm^{2}GCS of molding sand for batch 1 sample. While when moisture content was varied the GCS value varied from 100-120 gm/cm^2. Variation of moisture had almost the same effect for Batch 1 and 2. Again poor distribution of particles caused lower green compressive strength for batch 2 samples when clay content was varied.

5. Acknowledgement

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6. References

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