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Effect of Saw Dust on the Physical and Mechanical Properties of China Clay Refractory

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Abstract

Refractories are heat resistant materials used in almost all processes involving high temperatures and/or corrosive environment. Any failure of refractory could result in a great loss of production time, equipment, and sometimes the product itself. Incorporation of carbon rich material into clay has been known for sometimes to be an effective method of producing light weight insulating bricks on firing the carbon rich material burns out and leave both open and closed pore within the clay body. The mechanical and thermal properties of light weight insulating bricks partly depend on the percentage of porosity and the size of the pores in the brick. This research is to find out the optimum weight percentage of saw dust content in the clay composite system for producing light weight insulating bricks from china clay having a good combination of thermal and mechanical properties.

Keywords: Saw dust, SEM, Compressive strength, Thermal conductivity.

1. Introduction

Refractories are materials capable of withdrawing high temperature and not degrading in furnace environment when in contact with corrosive liquids and gases. Refractories can be used for high temperature applications [1,2]. Any failure of refractory could result in a great loss of production time, equipment, and sometimes the product itself. The various types of refractories also influence the safe operation, energy consumption and product quality; therefore, obtaining refractories best suited to each application is of supreme importance [3-5].

The main types include fire-clay bricks, ceramic fiber and insulating bricks that are made in varying combinations and shapes for diverse applications. The value of refractories is judged not merely by the cost of material itself, but by the nature of the job and/or its performance in a particular situation. Atmosphere, temperature, and the materials in contact are some of the operating factors that determine the composition of refractory materials [6].

Incorporation of carbon rich material into clay has been known for sometime to be an effective method of producing light weight insulating bricks [7], on firing the carbon rich material burns out and leave both open and closed pore within the clay body. The mechanical and thermal properties of light weight insulating bricks partly depend on the percentage of porosity and the size of the pores in the brick [8]. Several researchers worked on the local clay and organic materials to produce insulating bricks [9-10, 14-15]. In this research low cost raw materials were used to produce insulating brick material with comparatively high thermal and mechanical properties. This work was undertaken to find out the optimum weight percentage of saw dust content in the clay-saw dust system for producing light weight insulating bricks from china clay, Padma river clay and organic materials (saw dust).

2. Materials and Methods

The raw materials used for the manufacture of the specimens of light weight insulating bricks for this work were China Clay, Padma River clay, Water, Saw dust, Grog and Molasses shown in table 1. In this composition only the percentage of saw dust and clay were varied to observe the effect of changing the amount of saw dust to the clay. China clay is a term applied to a range of refractory clays used in the manufacture of ceramics, especially fire brick. Molasses was collected from local market and used as a binder in the green product. Grog is nothing but broken granulated fired refractory clay and is made from rejected fire clay works, broken saggers and crucibles etc. The clays are especially collected from bank of Padma River. The uniform saw dusts were collected from local saw mill. The equipment used for this study include; Dryer, Furnace, Universal Testing machine (UTM), Thermal Conductivity Meter.

The preparation of the specimens involves the following steps:

- Crushing and grinding: Clays, saw dust, and grogs were crushed and grinded into desired sizes.
- Mixing: Hand mixing was employed to manufacture the specimens. Two type of clays were thoroughly mixed. To facilitate the powder compaction process a small amount (4%) of molasses in water was added to the mixture and then the mixture was again thoroughly mixed.
- Drying 1: Initially the mixture was naturally dried under sunshine in open atmosphere.
- Moulding: Specimens were prepared by moulds made by steel plate and UTM machine was used to compact the material during moulding.
- Drying 2: After mixing, the mixtures were dried naturally for 2 days. After moulding the compact green specimens were naturally dried for 7-10 days. After natural drying the specimens were dried by an electrotherm oven for 12 hours at 250°C to remove the rest moisture content.
- Firing: After the initial drying, the dried specimens were charged in a furnace at 25°C. The specimens were then heated slowly (10°C per minute) to 600°C to make the siliceous content fused. Then the specimens were heated to three firing temperatures i.e 900°C, 1000°C and 1100°C. The specimens were kept at that temperature for 24 hours and then slowly cooled. The specimens were then unloaded from the furnace.
- Cooling: The specimens were cooled slowly.

Table 1. Specimen Preparation Composition

Designation	China Clay	Padma Clay	Molasses	Grog	Saw dust
IA	66.7% (2000 gm)	18.3% (550 gm)	4% (120gm)	4% (120gm)	7% (210 gm)
IIA	56.7% (1700gm)	18.3% (550 gm)	4% (120gm)	4% (120gm)	17% (510gm)
IIIA	46.7% (1400 gm)	18.3% (550 gm)	4% (120 gm)	4% (120 gm)	27% (810 gm)

Apparent Porosity

Test samples from each clay/saw dust blend (for varying proportions) were dried for 12 hours at 250°C. The dry weight of each fired sample was taken and recorded. Each sample was immersed in water to soak and weighed while been suspended in air. The weight was recorded. Finally, the specimen was weighed when immersed in water. This was recorded. The apparent porosity was then calculated from the expression [8]:

$$\varphi = \left(1 - \frac{\rho}{\rho_o}\right) \times 100 \quad (1)$$

Where, Where, φ is the porosity, ρ is the density of the sintered pellet and ρ_o is the theoretical density of the samples.

Bulk Density

It is defined as the weight of many particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume, and internal pore volume. The test specimens were dried at 250°C for 12 hours to ensure total water loss. Their dry weights were measured and recorded. They were allowed to cool and then immersed in a beaker of water. Bubbles were observed as the pores in the specimens were filled with water. Their soaked weights were measured and recorded. They were then suspended in a beaker one after the other using a sling and their respective suspended weights were measured and recorded [9]. Bulk densities of the samples were calculated using the formula:

$$\rho_s = \frac{m_s \rho_w}{m_s - m_w} \quad (2)$$

Where, ρ_s is the bulk density of the sintered sample, ρ_w is the density of water, m_s is the mass of sintered sample and m_w is the mass of the sample in water.

Thermal Conductivity Test

In measuring the conductivity of such poor conductor, a thin layer or slab of the material is used. Lees and Chorlton overcome this difficulty by placing a good conductor such as brass or copper, of exactly the same diameter as the experimental slab on each side of the poor conductor. In this method two metal discs are used and a poor conductor is placed between two discs. There is an oil chamber from where heat is produced. Heat passes to the upper disc and then flows through the poor conductor and then through the bottom disc. When heat is passed through the upper disc, the poor conductor (test sample) is warmed. When the rate of flow of heat through the test sample equals the heat loss from the bottom disc by radiation and convection then steady state will be reached [4,10]. If, T_1 = temperature of the upper disc in the steady state, T_2 = temperature of the bottom disc in the steady state, A = cross-sectional area of the test sample, K = thermal conductivity of the test sample, d = thickness of the test sample, then the quantity of heat conducted per second through the test sample is:

$$Q = KA (T_1 - T_2) / d \quad (3)$$

In the steady state this heat Q is radiated per second from A. if m and s be the mass and specific heat of A and dT/dt be its cooling rate at temperature T_2, then the heat loss (radiated per second) from A is:

$$Q = ms (dT/dt) \quad (4)$$

dT/dt is determined by performing a subsidiary experiment. From the above equations the thermal conductivity of the test sample is:

$$K = ms (dT/dt)\, d / A (T_1 - T_2) \quad (5)$$

The specimen's diameter was 9 cm and thickness was 0.5 cm.

Cold Compression Strength

Cold compression strength test is to determine the compression strength to failure of each sample, an indication of its probable performance under load. The shaped samples of clay blends with saw dust were dried in a dryer at a temperature of 250°C, allowed to cool and then placed between two plates of the compression strength tester. This was followed by the application of a uniform load to it. The load at which a crack appears on the sample was noted and the specimen dimension was 7 cm. × 4.5 cm. × 4.5cm .The cold compression strength (*CCS*) is calculated from the equation [11]:

$$CCS=\frac{Load\ to\ fracture}{Area\ of\ the\ sample}\ MPa \quad (6)$$

3. Results and Discussion

Incineration of saw dust in the clay body was found to yield clay products with a porous microstructure in the sintered bulk and observed to cause a significant modification of the physical, thermal and mechanical properties of the saw dust-clay products.

Bulk Density

As the percentage of saw dust incorporated into the clay body was generally increased from 7% to 27% by weight, the bulk density was found to decrease linearly. The bulk density decreases with the increase of saw dust content due to two reasons: firstly by the addition of lighter material (saw dust) and secondly by the burning up of that lighter material [12]. The addition of the saw dust decreases the bulk density of the unburned specimens, further reduction of bulk density occurs on burning the saw dust during firing. The volumetric contraction may however, slightly compensate this reduction in bulk density [13,14]. As the bulk density of the samples are decreased, the porosity increase for the samples. Increasing the porosity of the samples are due to the high temperature burning of organic materials inside the clay body.

Thermal Conductivity

The effect of saw dust content in clay-saw dust system is shown in the following figure. The thermal conductivity was observed to decrease from 2.0 W/m. K to 1.58 W/m. K for the increase of saw dust from 7% to 27%. The decrement of thermal conductivity with the increase of saw dust content (i.e. porosity in the product) can be explained in terms of the mean free path. With the increase of porosity the mean free path decreases resulting in lower thermal conductivity [11,15].

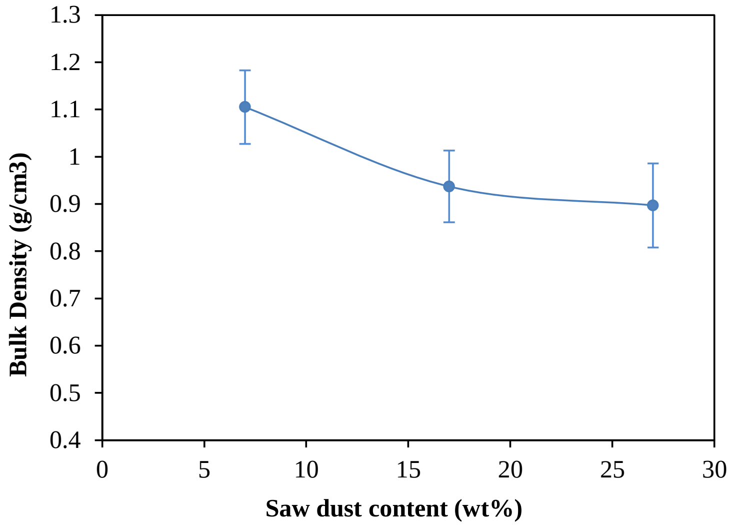


Fig. 1: Effect of saw dust on density

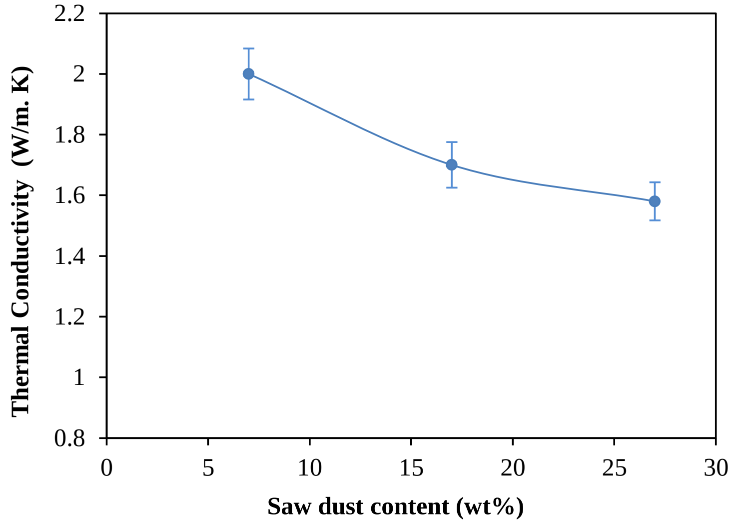


Fig.2 : Effect of saw dust on thermal conductivity

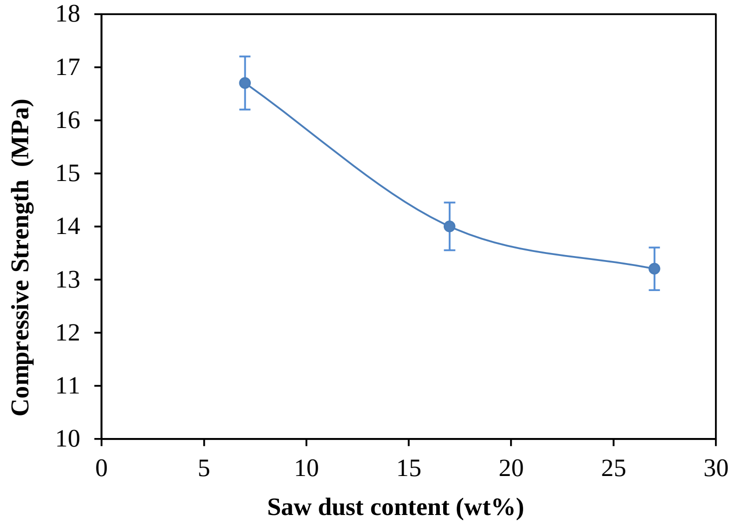


Fig.3 : Effect of saw dust on compressive strength.

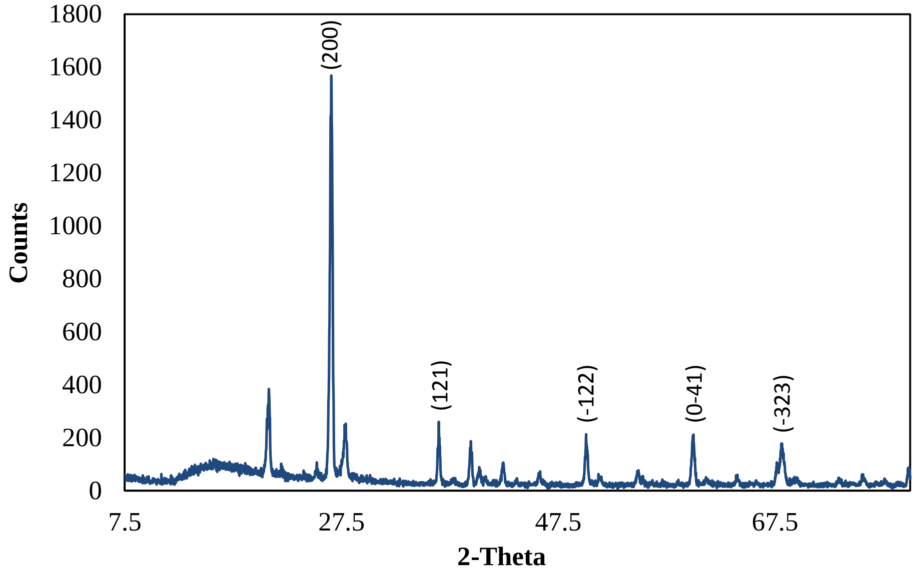


Fig.4 : XRD Analysis of Refractory insulating brick.

Compressive Strength

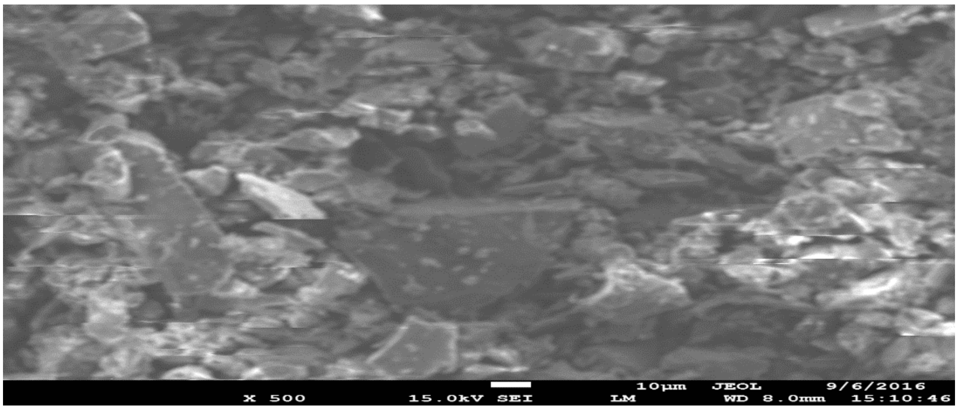
The development of porous microstructure in the clay body was found to affect the compressive strength as shown in the figure 3. The compressive strength of the specimen was found to be reduced from 16.7 MPa to 13.2 MPa with the addition of saw dust to the clay composites.

XRD Analysis

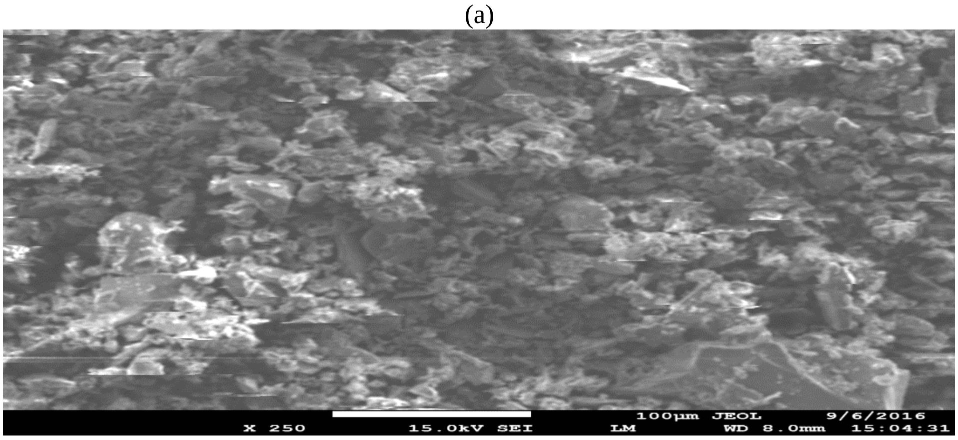
Generally XRD analysis used to investigate the crystallinity of the samples [16]. In this research the crystal structure plane was detected by XRD. From figure 4 it is clearly understood that the highest peak is observed at the (200) plane and here the angle is 26.58°. This figure also shows some other peaks of different crystalline planes.

SEM Analysis

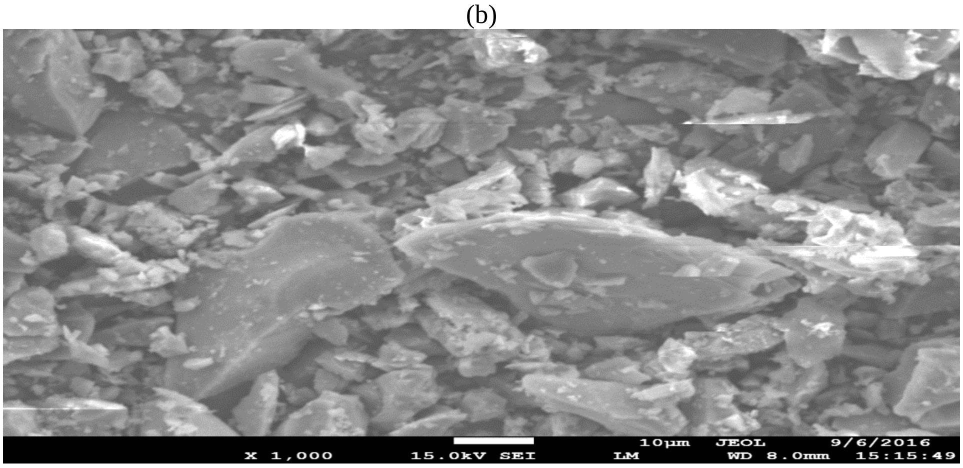
Scanning electron microscopy is done for surface analysis. Figure 5 shows the surface morphology and the porosity of the fired refractory brick.



(a)



(b)



(c)

Fig.5 : SEM images of three different magnifications (a) 500x (b) 250x & (c) 1000x

The SEM images in figure 5 show the morphology of the refractory insulating brick made by adding 17 % saw dust and fired at 1000°C produced by the simple moulding process and compressed by the UTM machine . SEM images indicated that the amount and size of pores increased with increasing mass ratios of saw dust addition.

4. Conclusions

From the research work there we can observed some experimental evaluation. The following conclusions may be drawn from the work done so far:

- Bulk density decreases linearly with the increase of saw dust content. Hence the porosity increase with the addition of saw dust.
- The thermal conductivity decreases with the increase of saw dust.
- The compressive strength decreases with the increase of saw dust.

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