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Structural Properties of Baked Clay Bricks Fired with Alternate Fuels

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Abstract

Coal is used as a traditional fuel for firing of clay bricks in kilns. The cost of coal is high and is increasing continuously. This paper describes the effect of alternate fuels on compressive strength, water absorption and density of fired clay bricks. The alternate fuels used in this study were 1) rapeseed husk (Type I), 2) combination of sugarcane-bagasse, rice husk and used clothes (Type II) and 3) coal (Type III). The results show that compressive strength of bricks fired using Type I and Type II fuels was decreased to 11% and 7%, respectively, compared to those fired with coal. However, the values of water absorption and density of bricks fired with Type I and Type II fuels were almost same as exhibited by those baked with coal. This study shows that a saving of 25%, and 18% could be achieved when the bricks were fired using Type I and Type II fuels, respectively, compared to those fired with coal.

Keywords

Baked Clay Bricks, Compressive Strength, Water Absorption, Density, Alternate Fuels, Coal

1. Introduction

Baked clay bricks are generally used as a walling material in buildings. Commercially the clay bricks are fired in a kiln at a temperature of 1000˚C [1]-[3]. Thus, a huge amount of fuel is needed to fire clay bricks. Traditionally, coal is used as fuel for firing of clay bricks in the kilns [4]. But, the cost of coal is high. Therefore, the use of coal as a fuel results in the increase of the cost of bricks. Consequently, the cost of construction of buildings will be increased. In order to reduce the cost of baked clay bricks, alternative and low cost fuels are to be sought [5]-[13]. The structural properties of baked clay bricks depend upon firing temperature and firing time [3].

Rice husk, rapeseed husk and sugarcane-bagasse are agricultural byproducts, of which rapeseed husk is generally disposed-off at once from an agricultural farm in order to prepare seed bed for the next crop. Rice husk and sugarcane-bagasse are produced as byproducts at rice mills and sugar mills, respectively. When these byproducts are accumulated in vast quantities, they need to be dumped. These byproducts are available at very low cost. Usual practice in Sindh Pakistan is that these byproducts are used as a fuel in kilns, as an alternate to coal, for baking of clay bricks. In addition, used clothes are generally dumped with municipal solid waste. This may require more space for dumping. In order to solve this problem, the used clothes are also utilized as an alternate fuel in the kilns for firing of clay bricks.

If the above mentioned fuels are utilized for firing of bricks, the cost of firing could be reduced and the problem of safe disposal could be resolved. But, it is interesting to investigate whether the structural properties of bricks would be affected if they are fired with these alternate fuels instead of coal. The authors are of the opinion that no such study is reported in the literature. For this purpose, an experimental programme was undertaken to investigate the effect of these alternate fuels on compressive strength, density and water absorption of baked clay bricks. The fuels used for firing of bricks were 1) rapeseed husk (Type I) and 2) mixture of sugarcane-bagasse, rice husk and used clothes (Type II). The results of structural properties of bricks fired with these alternate fuels were compared with those of the bricks fired with coal (Type III).

2. Materials and Methods

2.1. Manufacturing of Baked Clay Bricks

The study was conducted at a commercial Hoffman's kiln (**Figure 1**) situated in the vicinity of Hala, district Matiari, Sindh, Pakistan. On average, this kiln produces about 30,000 baked clay bricks per day. For this purpose, large amount of clay is needed at the site of the kiln for casting of bricks. Clay was collected from a site about ten kilometers away from the kiln. Clay was provided by the contractor and dumped at the site of kiln (**Figure 2**). The quantity of water added was about 24% of clay to form a workable paste for casting of the bricks (**Figure 3**). A thin layer of pit-sand was spread on the surface of level ground to put the freshly cast bricks for drying (**Figure 4**). After the bricks were dried in sun for four days, they were collected and placed in the kiln for firing (**Figure 5**). Three batches of clay bricks were fired, each with 1) rapeseed husk (Type I), 2) sugarcane-bagasse, rice husk and used clothes (Type II) and 3) coal (Type III). The bricks were fired at a temperature of 1000˚C in kiln. The time of firing was two hours, two and half hours, and three hours when the fuels were Type I, Type II, and Type III, respectively. After firing, bricks were collected from each batch and tested for compressive strength, density and water absorption.

2.2. Testing Programme

The compressive strength and water absorption of bricks was tested in accordance with ASTM C67 [14]. Compressive strength of the bricks was tested in the Universal Testing Machine. Half bricks were cut along the length using cutter machine (**Figure 6**). These

Figure 1. A view of a commercial Hoffman kiln.

Figure 2. Clay is being dumped for casting of bricks.

Figure 3. Moist clay paste prepared for casting of bricks.

Figure 4. Clay bricks are being placed on ground for drying.

Figure 5. Sun dried clay bricks are being placed for firing in kiln.

Figure 6. A baked clay brick is being cut into two halves using cutter machine.

Figure 7. A baked clay brick specimen is being tested for compressive strength in Universal Testing Machine.

brick specimens were used for testing of compressive strength (**Figure 7**). To determine water absorption, the brick specimens were immersed in clean water for 24 hours. Surface water was wiped off with damp cloth and the brick specimens were weighed.

3. Results and Discussions

Three batches of clay bricks were fired using different fuels, *i.e.* 1) rapeseed husk (Type I), 2) combination of sugarcane-bagasse, rice husk and used clothes (Type II) and 3) coal (Type III). The bricks were tested for compressive strength, apparent density, and water absorption ratio. To conduct each of the tests mentioned above, ten samples were taken from each batch of baked clay bricks fired with different fuels.

3.1. Compressive Strength of Baked Clay Bricks

The values of the compressive strength of the bricks fired with different fuels are presented in **Table 1**. The results show that the compressive strength of bricks fired with Type I and Type II fuels is about 11%, and 7% lower than those baked with coal, respectively.

3.2. Water Absorption and Density of Bricks

The average values of water absorption and density of the bricks fired using different types of fuels are given in **Table 1**. The results show that there is no significant difference in values of water absorption and density of bricks fired with alternate fuels compared to those baked with coal. The values of water absorption of the bricks mentioned in this study are in accordance with IS 3495 (Part 2): 1992 [15]. The criteria mentioned in this standard state that water absorption of the bricks immersed in water for 24 hours should not be more than 20% of the dry weight of the baked clay bricks having compressive strength up to 12.5 MPa.

Since the average density of baked clay bricks is about 2000 kg/m^3 depending upon the method of manufacture, specific gravity of the clay, water added in the clay at the time of casting and firing temperature [3]. The values of the density of baked clay bricks described in this study are on average 23% lower than the average density of baked clay bricks.

It is to be noted that the difference in structural properties (compressive strength, water absorption and density) of baked clay bricks may be attributed to time of firing. The more the time of firing, the better were the structural properties of baked clay bricks.

3.3. Saving in Cost of Bricks Fired with Alternate Fuels

The cost of materials and fuels for manufacturing of clay bricks are presented in Table 2. The labour charges for manufacturing of bricks are given in Table 3. It is observed

Table 1. Effect of different fuels, used for firing, on structural properties of baked clay bricks.

S. No	Type of fuel	Compressive strength (MPa)	Decrease in compressive strength (%) of bricks compared with those fired with coal	Water absorption	Density (kg/m^3)
1	Rapeseed husk (Type I)	12.5	11	20	1533
2	Sugarcane-bagasse, rice husk and used clothes (Type II)	13	7	18	1565
3	Coal (Type III)	14	0	17	1578

Table 2. Cost of materials and fuels used for manufacturing of clay bricks.

S. No	Item	Cost per 1000 bricks (PKR)
1	Clay	250
2	Pit-sand	60
3	Water	50
4	Rent of the kiln	46
5	Rapeseed husk (Type I)	800
6	Sugarcane-bagasse, rice husk and used clothes (Type II)	1000
7	Coal (Type III)	1500

Table 3. Cost of labour required for casting and firing of clay bricks.

S. No	Type of work	Cost per 1000 bricks (PKR)
1	Casting of bricks	500
2	Loading of bricks in the kiln	200
3	Unloading of bricks from the kiln	100
4	Priming of the kiln	14
5	Service and maintenance charges	60

Table 4. Total cost of manufacturing of 1000 bricks fired with alternate fuels.

S. No	Type of fuel	Total cost of 1000 bricks (PKR)	Saving in cost of 1000 bricks (%) compared with those fired with coal
1	Rapeseed husk (Type I)	2080	25
2	Sugarcane-bagasse, rice husk and used clothes (Type II)	2280	18
3	Coal (Type III)	2780	0

from Table 2 and Table 3 that the cost of materials and labour charges per 1000 bricks excluding fuel charges is 1280 PKR. Total cost of fuel, materials and labour charges per 1000 bricks when fired using different fuels is described in Table 4.

4. Conclusions

A study was conducted to investigate the effect of firing, using alternate fuels, on structural properties of baked clay bricks. The clay bricks were fired using the following fuels: 1) rapeseed husk (Type I), 2) combination of sugarcane-bagasse, rice husk and used clothes (Type II) and 3) coal (Type III). Following conclusions can be drawn:

1) The bricks fired with Type I and Type II fuels exhibited compressive strength as high as 89% and 93% of those baked with coal, respectively.

2) The values of water absorption and density of bricks fired with Type I and Type II fuels were almost similar to those fired with coal.

3) Saving in cost of bricks fired using Type I and Type II fuels was about 25% and 18%, respectively, as compared to those fired with coal.

4) Besides temperature, the time of firing is an important parameter that governs the structural properties of baked clay bricks. It is suggested to investigate the effect of time of firing using these fuels to achieve economy.

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