ENHANCEMENT IN THERMAL AND MECHANICAL PROPERTIES OF BRICKS

by

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A new type of porous brick is proposed. Sawdust is initially well mixed with wet clay in order to create voids inside the brick during the firing process. The voids will enhance the total performance of the brick due to the reduction of its density and thermal conductivity and a minor reduction of its compressive stress. All these properties have been measured experimentally and good performance has been obtained. Although a minor reduction in compressive stress has been observed with increased porosity, this property has still been larger than that of the common used hollow brick. Data obtained by this work lead to a new type of effective brick having a good performance with no possibility that mortar enters inside the holes which is the case with the common used hollow bricks. The mortar has a determent effect on thermal properties of the wall since it has higher thermal conductivity and density than brick.

Key words: *porous brick, sawdust, compressive stress, density, thermal conductivity*

Introduction

Thermal and mechanical brick properties play an important role in designing modern buildings, especially when wall properties such as insulation, rigidity, weight, and cost are considered. Heat losses to or from buildings occupy an important factor in air-conditioning science. One of the main factors that affects cooling load in air-conditioning space is the thermal properties of building material such as thermal conductivity and density. Decreasing thermal conductivity is the dominate factor in reducing heat that could be transfer to or from the building [1, 2].

To enhance brick thermal properties several methods have been suggested to create voids within the brick [3-6]. The most common method is to create uniform cylindrical holes inside the brick. This type of brick has a disadvantage that the mortar can enter the holes of the brick during wall building which is undesirable due to an increase of the wall density and thermal conductivity.

The enhancement of the thermal insulation of bricks produces a significant reduction in a building cooling load, so many researchers focus their attention in this field. One of the main advantages of the thermal conductivity reduction is that a thin wall of low thermal conductivity can replace thick wall where both may reduce heat that could be transmitted through them. The existence of voids inside the bricks makes an advantage of a higher strength/weight ratio, better tensile strain capacity and lower thermal expansion, as well as superior heat and sound insulation characteristics [7-9].

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Phonphuaka *et al*. [10] ,study the effect of adding charcoal on mechanical and physical properties of brick, they found that an increase in porosity result from adding charcoal which result in decreasing in density, water absorption and compressive stress. Bánhidi [11], shows that increasing the quantity of agricultural wastes byproducts in the clay mixture significantly decreases the thermal conductivity of the final bricks, while only a minor reduction in the mechanical strength was observed. Okunade [12] study the effect of addition of sawdust and wood ash admixtures to a 30:70 parts by weight laterite-clay mix, the admixtures added in various combinations of proportions by volume(from 0 to 10%), a reduction in density (from 1755 to 1512 kg/m^3) was observed also a reduction of compressive stress was observed (~18 MPa to ~10 MPa).

In this work, new technology involves using lightweight construction materials which, in comparison to the common used brick, have lower thermal conductivity and bulk density and higher compressive stress values where a new method is proposed; the clay is initially mixed with sawdust with different mass fraction in order to obtain good performance brick. The proposed method maintains a high compressive strength, which results in high load bearing wall, enhancement of thermal insulation properties, lower densities, lower transport costs, and higher brick production per tones of clay.

Methodology and samples

The main idea in creating porosity in brick is that the sawdust of wood will be mixed with wet clay and when the created wet brick enters the oven, the wood will be burnt inside the brick after it occupies an original volume inside the clay and after firing process the volume of the sawdust will be filled by the product of burning (ash and gases). The voids volume will be filled by gases since the resulting ash will occupy about 6% of the original volume also the mass reduction is calculated and it is found to be about 90%. The sawdust will be burnt which result in gases and ash that have negligible weight and density, the porosity of the brick can be controlled by the initial mass fraction of sawdust that mixed with wet clay.

Tests have been made for solid, hollow, and proposed bricks to measure their apparent porosity, density, thermal conductivity, and compressive stress.

A simple procedure has been used to measure the density of the brick where dimensional and mass measurements are used to obtain density also apparent porosity can be obtained as conforms to ASTM standard C373-88 [13]. The uncertainties are found to be around ±0.2%. The thermal conductivity measurement presented in this paper was measured using a guarded hot plate that conforms to ASTM Standard C 177-85 [14]. The accuracy of this procedure in the thermal conductivity measurement device is tested to be about ±4% of the true value of the thermal conductivity.

The compressive stress of bricks produced in the United States ranges from about (7 to 105 MPa), varying according to the use to which the brick are to be put. In England clay bricks can have stress of up to 100 MPa although a common house brick is likely to show a range of 20-40 MPa. High compressive stress indicates good quality bricks and reduces crack formation.

The typical range of compressive stress is 10-140 MPa. ASTM C 62 specifies minimum compressive strength requirements which are for severe weather 21 MPa, for moderate weather 17 MPa and for normal weather (Interior) 10 MPa.

The compressive stress test procedure is:

(1) Test brick flat wise under compressive load.

(2) The brick must be dried and its surfaced coated with shellac to prevent moisture absorption, which can reduce the measured strength.

(3) The bearing surface must be capped with capping material to provide smooth surface. Compressive stresses can be affected by many parameters such as porosity, firing procedure, type of clay. The dry compressive strength of brick samples is determined by using the compression test machine. The compression load is applied onto the face of the sample having a dimension of 115 mm × 110 mm × 75 mm. The compressive strength is determined by dividing the maximum load by the applied load area of the brick samples (*i. e.* 115 mm × 110 mm). The uncertainties in the compressive stress measurement device are found to be around ±3.5%.

Brick manufacturing

The raw material (clay) is crushed and grinded, then the blend of ingredients desired for each particular batch is selected and filtered then the wet clay is mixed with a proper mass of sawdust before being sent to brick shaping processes (pressing) , then the samples are dried to remove excess moisture that might cause cracking during the firing process. Next, they are fired in big furnace (900 °C) for ten hours and then naturally cooled within two days.

Clay and brick composition

The composition of dried sample of the clay (before mixed with sawdust) is tested and its chemical composition is found to be: SiO_2 (35.4%), Al_2O_3 (10.7%), Fe_2O_3 (4.1%), $CaCo_3$ (40.6%), MgO (3.5%) and the reminder is almost a composite of different oxide. A test on the final product (brick) by XRD-6000 (X-ray diffractometer) shows that the dominate component in the product (brick) is wollostonite ($CaSiO_3$) and minor components of quarts (SiO_2) and corundum (Al_2O_3).

Result and discussion

Figure 1 shows images of the samples. The created voids inside brick reduce the effective thermal conductivity of brick, tab. 1. The created voids shown in fig. 2 are filled by the product of the burning which has a negligible weight and density. Voids will decrease the thermal conductivity since the void has a significant effect on effective thermal conductivity of the brick, so a reduction in thermal conductivity is expected as the porosity increase. The reduction in thermal conductivity is even better than the common used hollow brick.

Figure 1. Image of different bricks (a) sample 1, (b) sample 2, (c) sample, 3 (d) sample 4

Concerning density a reduction in density is observed as mass fraction of sawdust in the original wet clay brick increases; this is clear since more volume will be occupied by sawdust before it burns leaving voids inside firing brick. This reduction in density will decrease cost and size necessary to achieve the task of insulation as thermal conductivity reduces. It is found experimentally that the escape of burning product from the porous brick due to high pressure which generates inside voids will leave voids having negligible mass of ash and gases with a pressure near the atmospheric pressure. A special brick is made to verify this situation where its core is filled with sawdust only then a vacuum camber that has a double volume than that of the brick is used where the brick is crashed inside the chamber. Insignificant increase in the pressure is observed which may verify that a high pressure could not accumulate inside the voids.

Table 1. Some thermal and mechanical brick properties

Sample	Original mass fraction of sawdust with wet clay	Density ρ [Kgm^{-3}]	Apparent porosity φ	Compressive stress σ [MPa]	Thermal conductivity k_{ex} [Wm^{-1}K^{-1}]
Solid brick	–	1782	0.312	43.95	0.9
Hollow brick*	–	1355	Same as solid brick	30.87	0.64
Sample 1	0.05	1466	0.372	37.7	0.67
Sample 2	0.1	1398	0.416	36.05	0.62
Sample 3	0.15	1280	0.483	34.23	0.55
Sample 4	0.2	1207	0.556	33.28	0.46

* Hollow bricks are commonly used type in middle east having 10 holes of diameter 2.5 cm through the depth of the brick (brick dimensions are is 230 mm × 115 mm × 75 mm)

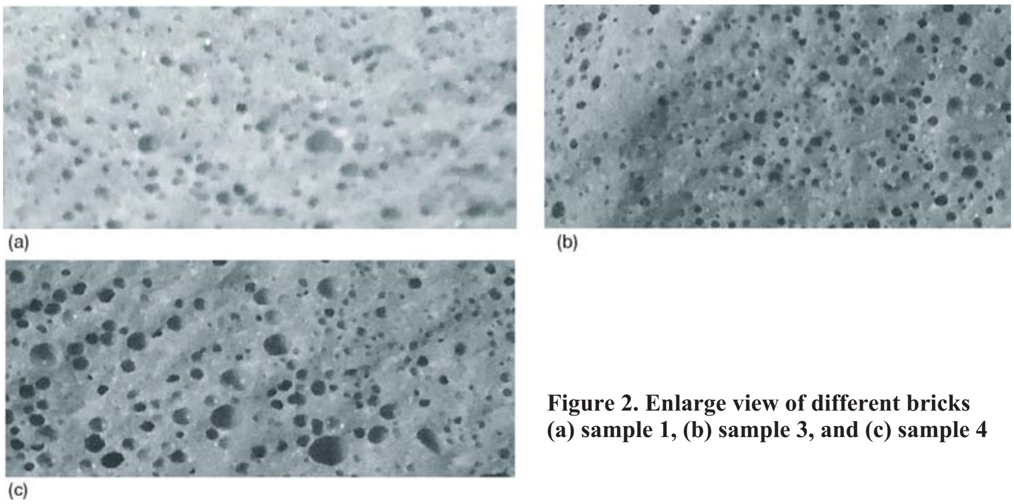

Figure 2. Enlarge view of different bricks (a) sample 1, (b) sample 3, and (c) sample 4

In the new proposed type of brick, a reduction in compressive stress is observed as porosity increased, tab. 1.This is explainable since the bearing material in the brick will be reduced. The compressive stress of the proposed bricks is still higher than that of hollow brick.

It is to be note that the sawdust that mixes with clay used in this work is of large size (*i. e.* ~5 mm) and the future work is that to reduce the size of the sawdust (*i. e.* less than 1 mm) where an enhancement of the properties is expected. This will be the topics of our future work.

Conclusions

A new type of porous brick is proposed where sawdust is initially mixed with wet clay to induce voids inside the brick during the firing process. The proposed types are found to have low density, low thermal conductivity, and high compressive stress which may be the best choice for a brick and the proposed brick is even better than the common type of hollow brick used in Middle East. From this work, it has been obtained experimentally that, as porosity increased, the thermal conductivity and density are reduced and a margin reduction in compressive stress is observed. The compressive stress of the new proposed bricks is still larger than that of the hollow bricks widely used in developing countries. The new brick has no holes assume they allow some mortar (having higher thermal conductivity and density than bricks) to enter holes that may increase the effective thermal conductivity and density of the wall and its cost. This determinate effect will not be existed in our new proposed type of brick where the effective thermal conductivity and density of the brick will be almost equal to that of the wall.

Nomenclature

k – thermal conductivity, [$Wm^{-1}K^{-1}$]

Greek symbols

φ – porosity, [–]
ρ – density, [kgm^{-1}]

σ – compressive stress, [MPa]

Subscript

ex – experimental

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