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Utilization of Mixed Waste in Fired Brick Manufacturing

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Abstract

Recycling wastes are a practical solution to reduce its detrimental effects. Many problems have arisen recently due to the rapid expansion on the quantity of waste. In this work, a practical solution was presented. The waste was mixed with wet clay to form a mixture that molded under pressure to form a wet brick. The wet bricks were entered into big ovens and during the firing process, porosity was induced inside them. The induced porosity enhanced the thermal insulation, decreasing the density, producing good brick durability with acceptable mechanical properties of the fired brick, in addition to that, a preservation in natural resources could be achieved. Following ASTM standards the values of the specific heat, dry density, thermal conductivity, cold and boiling absorption coefficient and both wet and dry compressive strength were measured with good accuracy.

Keywords: mixed waste, fired brick, thermal insulation, porosity

استخدام الفضلات البيتية فى صناعة الطابوق النارى

الخلاصة

اعادة تدوير الفضلات يعتبر حل عملي لتقليل اثارها الضارة . وقد برزت عدة مشاكل في الاونة الاخيرة نتيجة التوسع السريع في كمية الفضلات حيث تم تقديم حل عملي للتخلص منها حيث تمزج مع الطين الرطب لتكوين خليط متجانس الذى يكبس في القالب تحت الضغط لتكوين الطابوق الرطب الذى يوضع في الفرن وخلال عملية الاحتراق ستنتج المسامية داخل الطابوق والتى تحسن العزل الحرارى وتقلل الكثافة وتنتج طابوق ذو متانة عالية وخواص ميكانيكية مقبولة بالاضافة الى هذا يتم الاقتصاد بالمصادر الطبيعية وباتباع طرق فحص ASTM القياسية فان قيم السعة الحرارية والكثافة الجافة والموصلية الحرارية ومعامل الامتصاص البارد وعند الغليان وكذلك المتانة الجافة والرطبة تم قياسها وبدقة مقبولة.

INTRODUCTION

A highly practical solution in reducing wastes is by recycling them. Waste Recycling can help in saving materials and energy. Many problems have arisen recently due to the rapid expansion on the quantity of wastes. It demands high effort and cost to deal with them efficiently so as not to pollute our environment. In this paper, a practical solution was presented where the main part of the waste was dried and milled to very small pieces and mixed with wet clay to form a mixture that molded under compressive pressure to form a wet brick. The wet brick was entered into big furnaces and during the firing process, porosity inside the brick was induced due to the burning of waste , which enhanced thermal insulation, decreased density and produced good mechanical properties of bricks.

Total Municipal solid waste (MSW) generation in 2010 was 250 million tons in the USA [1]. The weight percent of a different waste kind in MSW are as follow: the paperboard account for 28.2%, yard trimmings 13.7%, food scraps 14.1%, Plastics 12.3 %, metals 8.6 %; and rubber, leather, textiles account on 8.3 %. Wood follows at around 6.5 % and glass at 4.8%. Other miscellaneous wastes are approximately 3.5 % of the MSW generated in 2010[1].

A new strategy was proposed here where waste and their possible emissions were used to induce porosity inside bricks. The waste was gathered from the MSW and collected where they were dried and milled to very small pieces, which were used later to induce porosity inside bricks during the firing process. Many works devoted to induce porosity in the bricks using agriculture waste[2],cigarette butt[3], rubber[4], saw dust[5,6], charcoal [7], fly ash[8] and natural fiber [9] and a good survey was recently done by Aeslina Abdul Kader (et.al.) [10], who reviewed almost all the previous works in this field and the several obtained advantages beyond this strategy. The novel idea of this work is to use a collection of waste parts together to induce porosity inside the fired brick.

Methodology and samples

The metal, glass, rubber, leather and textile were collected from waste. The remainders are paper, card board, food scraps, plastic, yard trimming and foods and their percentage is approximately 75% from the total MSW. The percent of each species is proportional to its percentage in the typical waste content after dismissing the aforementioned parts (i.e. Metal, glass, rubber, leather, textile and other). This means that the weight contents of used waste are 40 % paper, 20% food, 16.5 % plastic, 15.5 % yard trimming and 8% wood.

In the field from which the samples of soil were taken, it was found that its chemical compositions are: SiO_2 (48%), Al_2O_3 (16 %), Fe_2O_3 (4.1%), CaO (21%), MgO (3%) and the reminder is almost a composite of different oxide and LOI.

A weight's percent of 1:10, 2:10, 6:10, and 10:10 for waste to wet clay were tested. A mixture of waste was collected from MSW, dried and milled to very small piece ($\approx 4mm$), which result in small grain size powder. This fine sized waste was mixed with wet clay in different weight percent. The resulting homogeneous mixture which was already crashed and grinded was molded to form wet brick under compressive pressure of

80 Bar. The dimension of the wet brick is approximately equal to (230x115x75mm^3). The bricks were then dried for one day at $90\,^{o}$C before they were sent to the oven where they were fired at $900\ ^{o}$ C for 10 hr, then the fired bricks were cooled naturally in the oven within two days.

The resulting bricks were tested following ASTM standards. ASTM C 62[11] 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 strength is determined by dividing the maximum load by the applied load area of the brick samples. The compression load is applied to the face of sample, having the dimensions of 105 mm x 100 mm with the same thickness of original brick. Furthermore, the same procedure was followed to obtain the wet compressive strength where the samples were immersed into cold water at 25 C for 24h before being subjected to compressive strength. The uncertainties in the compressive strength measurement device were found to be around $\pm 3\%$. The measurement of thermal conductivity is carried out using a guarded hot plate that obeys ASTM Standard C 177-85 [12]. The accuracy of this procedure in the thermal conductivity measurement device was tested to be about ±4.5% of the true value of the thermal conductivity.

A procedure based on ASTM standard C373-88[13] was used to measure the density of the brick where dimensional and mass measurements were used to obtain the density. The uncertainties are found to be around $\pm 0.2\%$.

Following the aforementioned ASTM standard, the percentage of water absorption of bricks could be obtained, where the dry density, cold absorption, boiling water absorption were tested.The average boiling water absorption should not be more than 20% by weight, see ASTM C62. The specific heat for the different brick samples were measured by following ASTM Standard E1269-11[14], with an accuracy of ± 5 % of the true value of the specific heat.

Theoretically, the equation that represents the product of density and specific heat of brick can be written as [15] ;

$$r_b C_b = r_p C_p (1 - j) + r_v C_v j \qquad \ldots(1)$$

Here r, C, j refer to density, specific heat and total porosity and the subscripts b, p, v referred to brick, pressed powder of brick and void, respectively. Due to the low density of gases and the residual, then the second term in the right side of the above equation is ignored. The solid brick was crashed to a very small grain size and pressed at a very high compressive pressure in a steel mold until the volume change is vanished where the measured density, thermal conductivity and specific heat are that of approximate zero porosity brick. The obtained values of specific heat and densities for the five samples and the compressed brick powder enable us to obtain the total porosity depending on eq (1).

Results and discussion:

The cold water absorption was obtained by dividing the difference between the saturated brick weight and dry brick weight by weight of dry brick. An increase in the absorption coefficient was observed as the porosity increased. This is explainable since porous material will absorb more water as its porosity increases. This is due to the increase in voids fraction that are readily filled by water as the material soaked in water. The boiling water absorption is indeed a measure of porosity since boiling water and steam enters most of the pores in the brick and an increase in the mass of the brick is observed much larger than that for cold water absorption. ASTMC62 standard limits the boiling water absorption of 20% for brick that meet severe weather condition.

Saturation coefficient is defined as the ratio of cold water absorption to boiling water absorption. Again, ASTMC62 limits this value to 0.78 for severe weather condition, 0.88 for mid weather, and it has no limit for normal weather condition (usually in internal partition walls). The value of the saturation coefficient provides an indication of durability. It is usually ranging from 0.4-0.95, the smaller the saturation coefficient, the more durable the brick [16]. Saturation coefficient indicates the part of the total pore space occupied by water, then for a low saturation coefficient one can conclude that there is room for expansion on freezing into the remaining pore space without disruption of the material. Then in our samples it could be observed that as porosity increases, the bricks became less durable. The resulting bricks have been tested to obtain its dry and wet compressive strength, see tabel1. A significant reduction in compressive strength is observed as the brick soaked into water for 24h. This is because of that the water will enter the voids that have already filled mainly by the product of burning. So the bricks are softened as they soaked in water, which results in reduction in compressive strength. The reduction in compressive strength is increased as the porosity increases; this is due to the increase in pores that are readily filled by water.

Table [2] shows the dry density for different samples where a clear reduction in dry density is observed as the weight percent of waste in the brick increases. This is due to the increase in the porosity where as waste percent increases, the porosity increased also, see fig 1 which shows the enlarge views of a region that have an approximate dimension of 10 mm width and 7 mm height for sample 1(1:10) and sample 4(10:10), assume the magnification is about 1:8. In this figure, clearly the void fraction increases as the waste weight percent in the wet clay increases. Saturation coefficient indicates the part of the total pore space occupied by water, then for a low saturation coefficient one can conclude that there is room for expansion on freezing into the remaining pore space without disruption of the brick. Then in our samples it could be observed that as porosity increases, the bricks became less durable.

The specific heats of the bricks are reduced also as the porosity increases. This is due to the burning of waste inside the brick which results in a residual of negligible mass and density. The results are shown in tabel2 and the differences between theoretical and experimental values of thermal conductivity are shown to increase as the porosity increases. This is explainable assume the ignored term in eq (1) became a source of error as the porosity increases.

CONCLUSIONS

The use of different wastes in the brick has a significant impact on the final properties of fired brick. This strategy contributes to save in natural resources, and at the same time to a reduction in the amount of landfills. Depending on ASTM standard, measurements on mechanical and thermal properties of bricks have been carried out with good accuracy. It was found that:

1) as the weight percent of waste increased, the porosity of the fired body increased, which significantly reduced the compressive strength.

2) The addition of waste to brick would increase both cold absorption and boiling absorption.

3) It would also decrease the thermal conductivity and finally reduced the specific heat and the dry density.

Different mass fraction of waste to wet clay was tested. It was found that the percent of 1:10 of waste to wet clay produce a brick that met ASTMC62 standard for severe weather condition. Multiple advantages were achieved here; reducing waste, saving in natural recourse, enhancement in thermal insulation and maintain acceptable compressive strength and durability. All these enhancements open a wide gate to draw more attention in this strategy.

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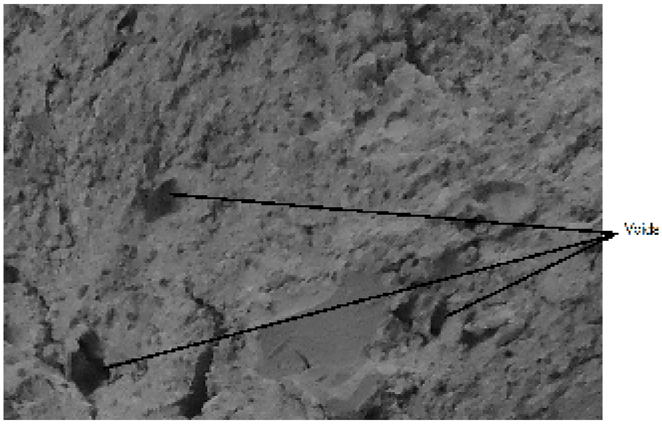
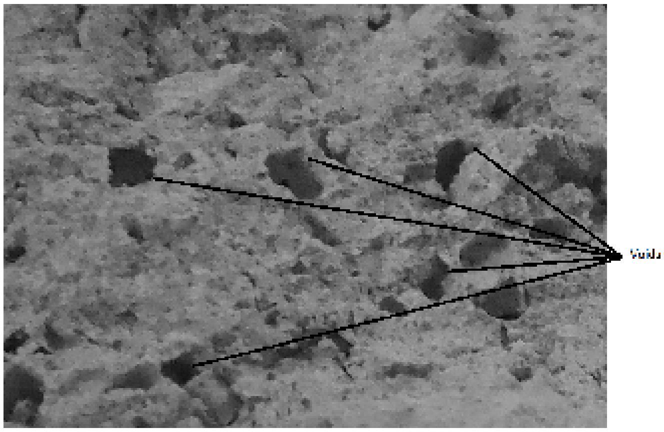


(a) Sample 1(1:10)



(b) Sample 4(10:10)

Figure (1) Images of sample1 and 4

Table[1] Some physical properties of bricks.

Sample	Dry density Kg/m3	Cold absorption %	Saturation coefficient	Dry compressive strength (MPa)	Softening coefficient
Solid	1645	5.5	0.7	51	0.86
Sample1(1:10)	1428.5	15	0.75	35	0.68
Sample2(2:10)	1383.4	22	0.77	33	0.63
Sample3(6:10)	1276	30	0.82	27	0.54
Sample4(10:10)	1231	40.	0.86	23	0.5

Table [2] Physical and thermal properties of bricks

Sample	Dry density Kg/m3	Specific heat J/kg.K	Total porosity %	Experimental Thermal conductivity (W/m.K)
solid	1645	801	26	0.9
Sample1(1:10)	1428.5	675	46	0.69
Sample2(2:10)	1383.4	657	49	0.6
Sample3(6:10)	1276	600	57	0.49
Sample4(10:10)	1231	576	60	0.47