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Using crashed bricks to increase the thermal resistance of building roofs in hot countries

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Abstract: In hot countries like Iraq, during the summer season, the temperature reaches about 50 °C, which has a direct impact on energy consumption due to the usage of cooling systems. Therefore, this study aims to reduce the solar radiation that is absorbed by the building's roof by using an insulator made of crashed bricks. In this research, a small model was created to replicate the roof properties, and then a heater set at the appropriate temperature was used to mimic the amount of heat coming from the sun. The amount of heat transfer is calculated for the roof with and without the insulator, and the study determines the different thicknesses and sizes of crashed brick as an insulator.

Keywords: building roof, crashed bricks, energy storage, heat transfer.

استخدام حطام الطابوق لزيادة المقاومة الحرارية لأسطح المباني في الدول الحارة

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كلية الهندسة || جامعة بابل || العراق

المستخلص: في البلدان الحارة مثل العراق، تصل درجة الحرارة خلال فصل الصيف إلى حوالي 50 درجة مئوية، مما يؤثر بشكل مباشر وكبير على استهلاك الطاقة نتيجة استخدام أنظمة التبريد. لذلك تهدف هذه الدراسة إلى تقليل الإشعاع الشمسي الذي ينتقل عن طريق أسطح المباني باستخدام بقايا الطابوق الحجري من عمليات البناء والتصنيع كعازل حراري. في هذا البحث، تم إنشاء نموذج صغير يحاكي الاسقف في المباني العراقية، ثم تم استخدام جهاز تسخين وضبطه عند درجة الحرارة المناسبة تتلائم مع كمية الحرارة القادمة من الشمس. يتم حساب مقدار انتقال الحرارة للسقف مع وبدون عازل، اخيرا فحصت الدراسة العزل الحراري لطبقات مختلفة السمك وكذلك باستخدام حطام الطابوق الحجري بأحجام مختلفة. وجدت الدراسة أن سمك الطبقة العازلة أكثر تأثير من اختلاف حجم حطام الطابوق.

الكلمات المفتاحية: سقف المبنى، الطوب المحطم، تخزين الطاقة، نقل الحرارة.

1. INTRODUCTION

In recent decades, for hot and cold climate countries, there is an increase in power consumption due to the use of air conditioning devices that is used during the day and night (1) (2). Energy consumption varies according to the energy load such as in residential activities, commercial and industrial (3) (4).

Nowadays, the world faced an energy crisis because of the limitation quantities of fossil fuels that led to more interest to study the ways of reducing the energy consumption. So this research aims to reduce the energy usage from air conditioning by insulating the building's roof with crashed brick insulator (5). Many researches have been done to reduce the solar radiation that absorbed by the building's roof. New plastic foam, granular, fibrous insulating materials, PCM, spraying water on the roof, double roofs, roof pond, green roof and layer of gravel on roofs are presently applied (1) (6) (7) (8) (9) (10).

Because of Iraq commonly a hot dry weather zone where in Iraq central areas, summers are very hot where temperature about 50°c in July and August (11). Therefore, this research study the possibility of reducing the heat load over the buildings roofs by adding a crashed bricks layer and increasing thermal resistance of roofs. The effects of the thickness of the bricks crashed and the size of crashed of bricks upon the transfer of heat through concrete roof are examined and compared the results with heat load for concrete roof (grey roof).

2. METHDOLOGY

Study methodology included simulating roof design for the climate of Iraq. This research examined the effects of crushed brick layer mass and size on roof heat transfer performance.

2.1 Experimental apparatus

The assembled apparatus and devices that used in the experimental work for wholly testing case consist of (the reduced scale model with electrical heater coated with glass wool as thermal insulation at the upper and side surface), (control system for power supply to heat source), (portable digital ammeter and portable digital voltmeter), (the temperature reading (interface) and recording system) as shown in figure (1).

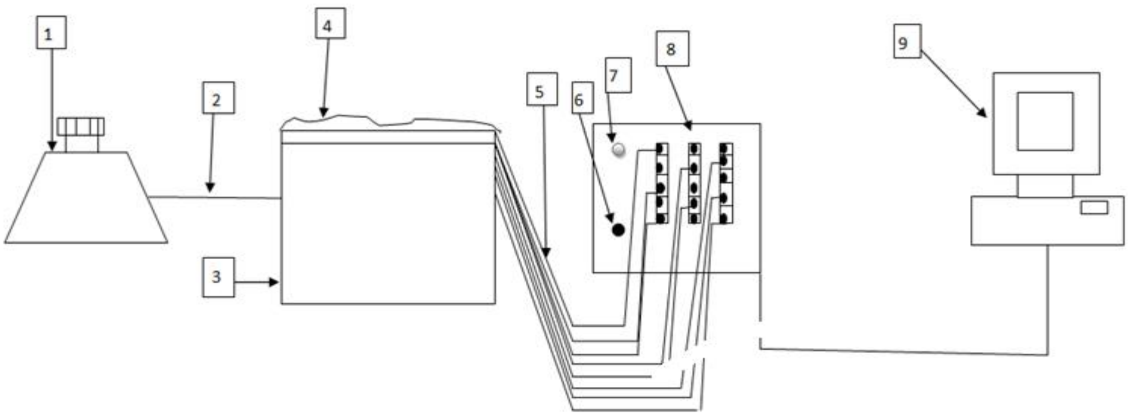


Fig (1) Schematic arrangement of experimental system

1-power supply	2-cables	3-experimental model
4-insulation	5-thermocouples	6-on/off switch
7-power on	8-interface	9-pc

2.2 Experimental work

To measure the effectiveness of adding a layer of crashed of bricks the reduced scale model was built especially for this reason as shown in figure (2) in begin the roof model without adding a layer of crashed bricks was used and used roof model with different size and different mass per weight of crashed of bricks then the performance was determined.

The values of power supply to the heater obtained by using a transformer to change the voltage value. The temperature of the heater and the heat apply on the roof outer surface is dependent on the power supply. Therefore, the temperature values of outer surface roof change depending on the power itself. For each value of power, the temperatures of thermocouples recorded by using a thermometer device for each 15min.

Before recording the results many readings were performed in order to reach the steady state for the thermal behavior of the model materials. many experments were performed in the expermintal work. First the expermintal was done with out add a layer of the crashed of bricks ,applying heat flux values which are mentioned in table (1) (12),during 15 minutes for each one hour and recorded the results by thermometer . two expermintals with added a layer of crashed of bricks with (9.5, 12.5)mm size and equal mass 7.5g/cm^2 ,with applied the same values of heat flux and recorded indoor and external surface temperatures by thermometer. The last two experments is added a layer of crashed of bricks with (3.75 , 7.5) g/cm^2 mass and with 12.5mm size and reapeat the same procedure.

Fig (2) experimental system

3. Previous Work:

Many types of components have been used in roof of building to minimize the problem of increasing load of cooling. Pisello ,et al (2014) were recommended reflecting local gravel, due to its inherent, relatively high albedo qualities, might constitute a sustainable and affordable alternative to standard urban pavement and roofing materials. Yesilata , et al(2019) concluded that the addition material waste such as polyethylene bottle improve the performance of thermal insulation and the change in insulate depend on size and shape of pieces. Mahmoodzadeh et al (2020) examined the using of green roof and they found one of the most important variables, the leaf area index (LAI), has a climate-specific impact on how well a green roof performs in terms of energy efficiency. It significantly affects the reduction in cooling in cities. The present research is considered supportive to these studies in addition it will study the possible to decrease heat transfer from roof of Iraqi buildings.

4. Results and Discussion

4.4-1 Effect of crashed of bricks size on heat transfer through roof:

The effect of size of crashed bricks on the gradient in temperature within the slab is demonstrated in figures (4-1, 2, 3). The roofs were covered by equivalent quantities of crashed of bricks (7.5 g /cm2) of diverse sizes (9.5 and 12.5 mm equivalent diameter). By applying heat flux values which are mentioned in table (1) the gray roof is high in temperature, as seen by the gradient of the temperature with time graph, figure (4-1).

The layer of crashed of bricks reduce the roof temperatures at both at external surface and at interior (indoor) surface, see figures (4-1) and (4-2) respectively. The layer of crashed bricks traps amount of air cause increasing in thermal resistance.

The temperature difference variation as displayed in figure (4-3) is directly proportional to the amount of heat transfer through every roof.

4.4-2 Effect of crashed of bricks mass on heat transfer through roof:

Figure (4-4) presented the gradients of temperature for the same size of crashed bricks layers but with different masses. It's presented the variation for a layer of crashed bricks of 12.5 millimeter in same average size with diverse quantities, 3.75 and 7.5 g cm-2, associated to the measured ΔT of concrete roof. When increase mass of crashed of brick decrease heat transfer through roof

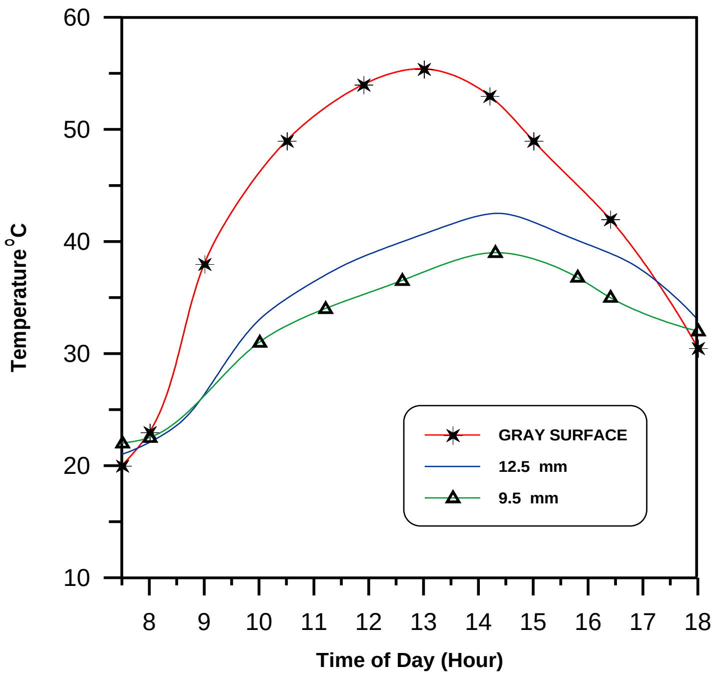


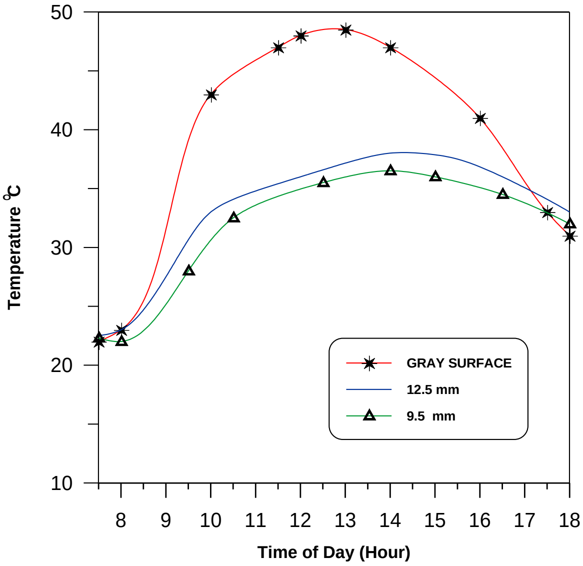
Fig (4-1): Daily Temperature Variation at External Surface for Different Crashed brick Size of equal mass, 7.5 g/cm^2

table (1) actual values of heat flux applied to experimental model

Time(hour)	$I_{tH}(w/m^2)$
6	13.311
7	29.646
8	43.992
9	56.196
10	63.513
11	68.508
12	69.264
1	68.031
2	63.531
3	55.98
4	43.596
5	28.665
6	12.528

The size of the layer of crashed bricks had been an influence upon both the peak of the temperature gradient and the response time of the roof. It is not possible from the variation shown in Fig. (4-3) to describe the effect of layer of crashed of bricks on the basis of a measured parameter or quantity.

To examine mass of the layer of crashed effectiveness the integrated ΔT variation with 10 h period was compared with that of the reference gray roof.



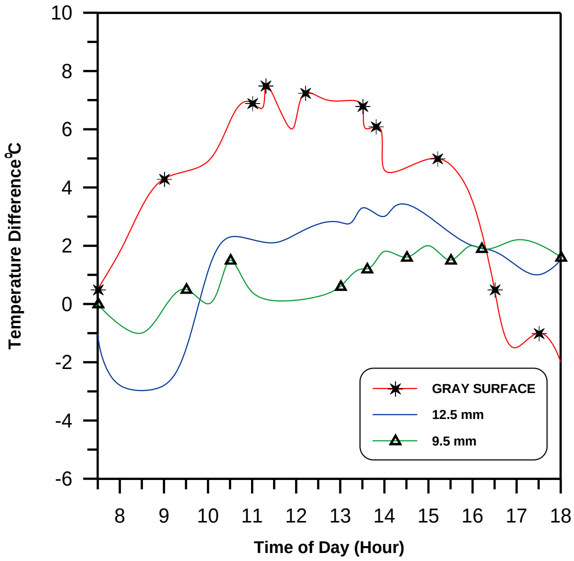


Figure (4-2) **Figure (4-3)**

Fig (4-2): Daily Temperature Variation at Interior (indoor) Surface for Different Crashed brick Size of equal mass, 7.5 g/cm2

Figure (4-3): Temperature Difference Variation for Different Crashed brick Size of equal mass, 7.5 g/cm2

Therefore, using G factor which define as the relation between the total energy transferred through any roof, Q_c to that for a gray roof one, Q_r,

$G=Q_c/Q_r$

For steady conditions the Fourier equation gives (13)

$Q=-k\,A\,dT/dx=\Delta T/R$

ΔT is the temperature difference between the External and Interior surface, for variation in time with limited period (15min periods), the G factor is then

$G=\int \Delta T_c\,dt / \int \Delta T_r\,dt$

The integral is in degree-hour units. The subscripts c and r refers to a layer of crashed of bricks covered roof and reference roof. The proposed G factor here showed directly the result of crashed bricks size, quantity and/or color upon the heat transfer across a layer of crashed of bricks covered roof. However, the G factor, that represented the area under the ΔT-time graph and gave a straight signal as to the amount of heat transferred through the concrete roofs. For one size of gravel, 12.5 mm diameter, increasing the mass from 3.75 to 7.5 reduced the temperature gradient to half its value, Figure(4-4), and G varies from 0.83 to 0.42.

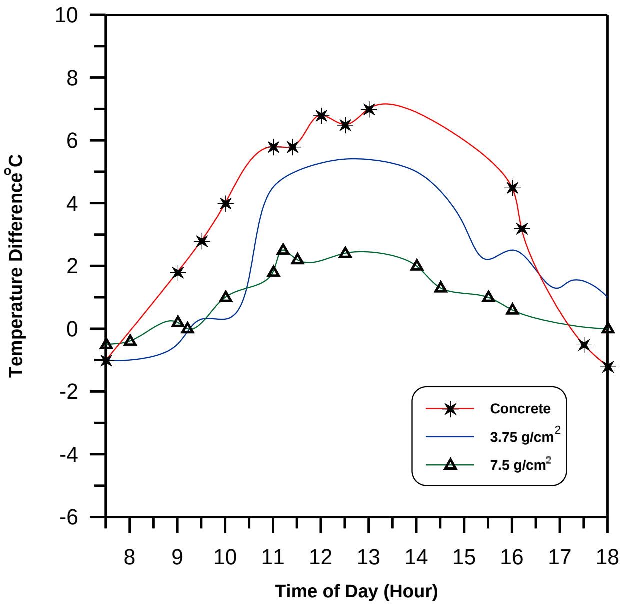


Fig (4-4): Daily Temperature Difference Variation for 12.5 mm Crashed brick Size of Different masses.

The increase in mass of the crashed bricks is more than effective in increasing the thickness of the crashed bricks; the G factor increases from 0.34 to 0.67 as the crashed brick size increases from 9.5 to 12.5 mm in average diameter. The smaller the size of the crashed brick layer for the same mass of crashed bricks, the more air cavities it had compared to a layer with larger crashed bricks. As the movement of the air is very limited in the packed layer, compared to the large bricks with a high percentage of air, the heat transferred in the layer with the large bricks was greater than that of the small bricks, as shown in figure 4-3.

5. Conclusions

Experimental results were presented to consider the effect of covering concrete roofs with a layer of crushed bricks. The present results covered a range of parameters, including: Gravel diameters of 9.5 and 12.5 mm; mass distribution fluxes of 3.75 and 7.5 g m^{-2}. Adding a layer of bricks decreases the energy transferred through a roof. The data was measured for concrete roofs with different cover layers under the same heat flux. The effect of a layer of bricks covering the roof is calculated on the basis of a comparison with a reference concrete roof.

The G, factor is the ratio between the energy transferred through a layer of crushed bricks covered by a non-covered concrete roof.

G=Qc/Qr

Using G factor as proposed factor, it was shown that the thickness of the brick layer is more effective than the size of the brick layer.

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