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Thermal Insulating Concrete Tiles.

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Abstract

This paper studies the shape of high-thermal insulating concrete tiles used for roof tiling. The theoretical part consists of a comparison between this invented tiles and ordinary terrazzo tiles. The analysis depends on the values of thermal conductivity of the materials used. The results showed that when these tiles are used for roof tiling, the temperature difference between the outside of roof surface and the inside room can be reduced about (6) times compared with the use of the ordinary terrazzo tiles. In addition, three specimens were fabricated and tested for rupture and absorption tests. The test results showed that, they have a good resistance to the applied test loads, and high resistance to water absorption. The authors believe that, the results are remarkable, highly applicable and should be taken into consideration in building constructions.

Keyword: Concrete, Tiles, Thermal insulating.

Notation

k: thermal conductivity of the material (watt/m.°k)
R_1: thermal resistance, when the 90 mm tiles are used (m^2. °k/watt)
R_2: thermal resistance, when the 30 mm terrazzo tiles are used (m^2. °k/watt)
ΔT_1: difference in temperature between the external invented tile surface and the internal ceiling surface (C°)
ΔT_2: difference in temperature between the external surface of traditional terrazzo tiles and the internal ceiling surface (C°)
y: depth of neutral axis of the tile section measured from the tensioned face (mm)
I: moment of inertia of the section about neutral axis (mm^4)
M: ultimate bending moment of the section (N.mm)
P: maximum tension stress of the section (MPa)

Introduction

The key to maintaining a comfortable temperature in a building is to reduce the heat transfer out of the building in the winter and reduce heat transfer into the building in the summer. Heat is transmitted across confined air spaces by radiation, convection, and conduction [1,2]. Conduction is the direct flows of heat throw a material resulting from physical contact. The transfer of heat by conduction is caused by molecular motion in which molecules transfer their energy to adjoining molecules and increase their temperature.

Heat transfer by conduction is governed by a fundamental equation known as Fourier's law [2- 5].

(Rate of heat flow)=-k x area x temperature gradient. K-value is a measure of a heat conductivity of particular materials, and it is called thermal conductivity. The lower of the k-value for a material, the better it insulates [6].

In Iraq, nominally, the tiles used are either concrete 800 mm x 800 mm x 40 mm or mosaic terrazzo tiles 300 mm x 300 mm laid on roofs with cement mortar.

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But due to the large range of temperature difference between the outside and the comfortable temperature both in summer and winter, a heavy use of air conditioning systems is needed in order to reduce this temperature difference, which demands high power consumption and therefore a high cost to both private and national income.

Thus, the need for proper insulating material is mandatory. People with high standard of living apply insulation to the roofs by using insulating styro pore sheets with various thicknesses; some others use soil as an insulation layer below the tilting. But the problem with this is that when water penetrates through the joints to the insulating layer, it will cause the tiles to be isolated from the insulating sheets and make them come up, and this will render failure. As for the soil (when used), the penetrated water causes grass to grow and hence swelling of earth which will also render failure of roofing. It is the intension of this research to show that an invented shape of a concrete tile provides a high thermal insulation. This will increase the temperature difference between the external tile surface and the internal room ceiling surface. Also the work indicates that the tile resists the applied service loads and has a low absorption percentage of rain water. If water penetrates through tiles joints, it will not cause harm to the roofing system as the tiles (with about 30 Kg weight) are solidly fixed with cement mortar through their perimeters on the reinforced concrete roofs.

Theory

a) Thermal Insulation

The theory on which this research is based depends on the invented shape of the concrete tile with the cross section shown in Fig.(1).

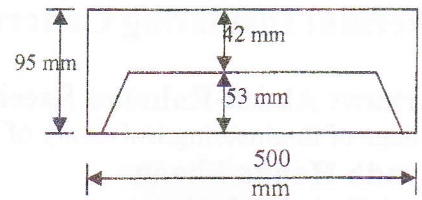

Fig.(1): The invented cross section of the tile.

Assuming 20mm thick mortar is to be used to fix the tiles on the reinforced concrete roof. K-values for variable materials are taken from Ref.[3], with:

1- a 42 mm thick plain concrete of k-values = 1.8 watt/m.°k

2- a 73 mm thick trapped air (formed of 53 mm air contained within the tile plus 20mm additional gap formed by the 20 mm mortar underneath) of k-value = 0.025 watt/m.°k

These values approximately are as same values which are listed in Refs [1,2].

Thermal resistance of the 95 mm tile and the underneath mortar + 15 mm ceiling plaster =R_1

R_1=0.042/1.8 + 0.073/0.025 + 0.15/2.2 + 0.015/0.58 = 3.270 m^2.°k watt

Thermal resistance of the traditional 30 mm terrazzo tiles + the underneath 20 mm mortar + the 150 mm reinforced concrete slab +15 mm ceiling plaster = R_2

R_2=0.03/1.8 + 0.02/1.8 + 0.15/2.2 + 0.015/0.58

R_2= 0.3548 m^2.°k watt

If ΔT_1 is the difference in temperature between the external invented tile surface and the internal ceiling surface, and ΔT_2 is the difference in temperature between the external surface of the traditional terrazzo tiles and the internal ceiling surface, therefore:

$\Delta T_1 : \Delta T_2$ =3.270 : 0.3548 = 9.22 :1

Taking care of the reduction of insulation due to the concrete ribs; By multiplying by $(425/500)^2$=0.7225, where the 425 mm is

average internal dimension of the slab specimen.
Also, taking care of the bad workmanship, by multiplying by 0.9, the ratio becomes: (9.22 x 0.72 x 0.9):1 = 6:1 which is a high ratio. This means that if temperature difference with terrazzo tiles is only 5C°, the difference in temperature with these invented tiles will be (5C° x 6 = 30 C°). That is if the maximum out side surface temperature of tile in summer= 55 C° , the internal ceiling temperature with ordinary terrazzo tiles = 50 C°, then the internal ceiling temperature with the new tiles will be (25 C°).
This means a great reduction in the daily running hours of air conditioning units and a very short yearly running duration. That's, if insulation is applied to walls as well as the roof, it will only be necessary to use air conditioning for nearly 3 months a year (i.e. January, July and August) instead of 9 months (i.e. January, February, March, May, June, July, August, September and December). Also instead of daily running of 18 hours as an average, it will only about 3 to 4 hours as a daily average. This will result in a yearly saving of electric power.
If the normal yearly national consumption of power = W Mega Watts, then the yearly power saving will be giving by:
W x [1-(3/9 x 4/18)] x 100 = 92.5% W when these insulating tiles are used for roofing.

Experimental
A mould was manufactured, made of 3 mm folded steel plate, designed to be 500 mm x 500 mm x 95 mm depth, as shown in Fig.(2). Another mould of smaller dimensions was made to fit inside the previous mould so that the cast concrete inside will have a cavity of 53 mm depth. This cavity is the essence of the design.

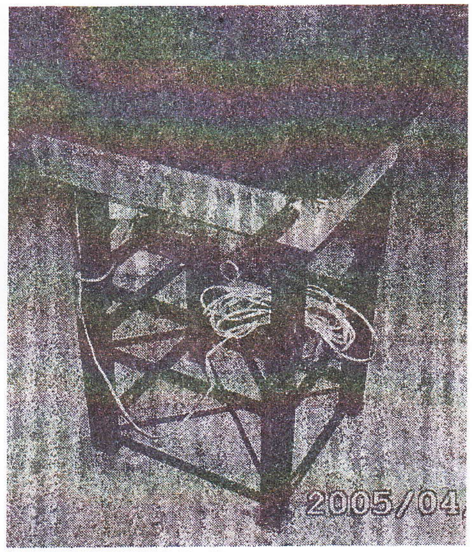

Fig.(2): The mould in which the specimens were cast.

Three specimens were cast using the mentioned pair of moulds and an electrical table vibrator with 1250 mm x 625 mm with frequency 2880 cycles per minute. These specimens were made of 1:2:4 concrete with water cement ratio of 0.45.

Materials
Ordinary Portland Cement: The cement used in the investigation from Marden Turkish Company with fineness 3100 cm^2/gm (Blain method), initial setting time 150 minutes and final setting time was 3.5 hours (Vicat apparatus).
Sand: The river sand used having a fineness modulus 2.73 and specific gravity equal to 2.69 with good gradation.
Gravel: The river gravel with maximum size of 19 mm and specific gravity to 2.7 was used as a coarse aggregate.

1-Rupture test
After 28 days curing, the three specimens were tested for rupture testing machine as shown in Fig.(3).

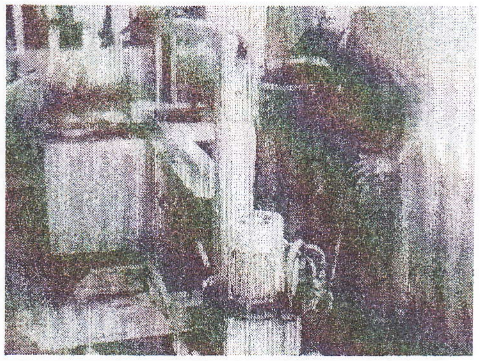

Fig.(3): Rupture testing machine

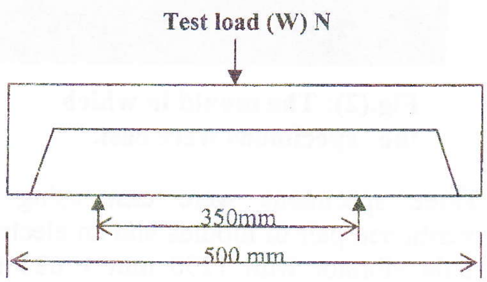

Fig.(4) : Specimen tile under rupture test

The diagrammatic placement of the specimen under the testing machine was shown in Fig.(4). And the specimens after failure have shown in Fig.(5).

The loads under which the tiles failed in rupture were as follows:

1st Specimen = 8830 N
2nd Specimen = 9614 N
3rd Specimen = 11282N

This gives an average value of 9909 N

To evaluate this test result:

The maximum probable load on a tile will be a foot step load on the middle of the tile which is 1000 N (a maximum man load). Multiplying this by a load factor for jerking of 2.5 will give a maximum probable load of 2500N.

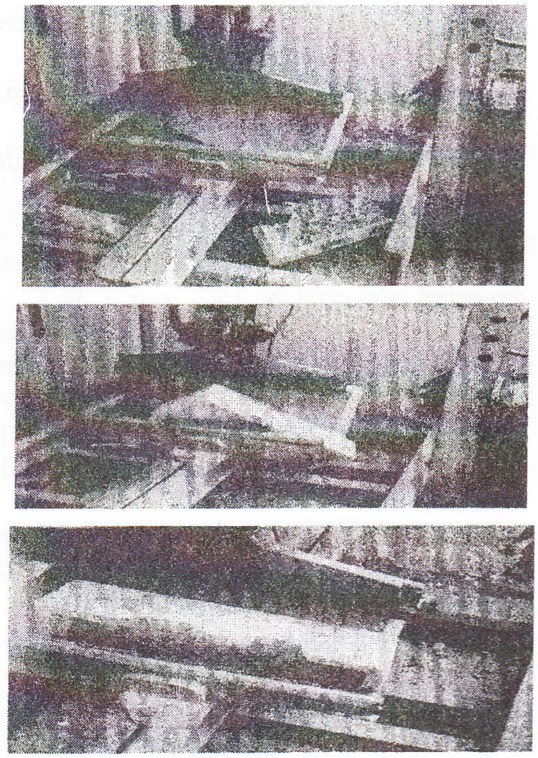

Fig.(5): Specimens after failure

The result of the test shows a resistance of tile nearly four times (i.e. 9909/2500 =3.96) as much as will be needed for this supposed worst loading condition. The calculated resisting flexural stress in the tiles (P), P=M.y/I ; M=WL/4 ; Therefore P=8.56 MPa, which is a high value compared with the allowed of 4.25 MPa according to Ref.[7].

2-Absorption test

Two pieces of the ruptured tiles were immersed in water for (24) hours, then left to dry in an oven:

Sample 1:
Weight when immersed in water = 4.958 Kg .Oven dry weight = 4.778 Kg
Absorption = 3.77%

Sample 2:
Weight when immersed in water = 5.061 Kg. Oven dry weight = 4.882Kg
Absorption = 3.67%

Average absorption = 3.72%
This value within the limit absorption of 6.5% according to Ref.[7].

Conclusions
Thermal Insulation
The above mentioned work indicates that the invented shape (Fig.(1)) of a concrete tile intended to be used in tiling roofs of buildings has a high insulating feature which can change the inside room temperature of the ceiling from 50C° when ordinary terrazzo tiles (i.e. mosaic kashi) are used to only 25 C° when the outside (i.e. external surface temperature is 55 C°), provided that similar insulation is adopted for the walls and the floors. In fact, as most of the heat transfer through walls and floors won't have a great effect on the inner room temperature if insulation is not applied to walls and floors.
This is due to the low temperature gradient across walls and floors compared to that across the roof. To prove successful use of these tiles in tiling roofs, they were subjected to two kinds of tests:

1-Rupture test
The aim of this test is to show that the tiles will take up the imposed load safely. The results of this test show a high resistance for rupture, due to their shape with the 95 mm high ribs in their perimeter. They proved to resist 4 times as much as the maximum probable service load. Also more than twice the resistive stress (8.56 MPa) of what is considered as the minimum accepted of (4.2 MPa) according to Ref.[7]. This is obvious if it takes into consideration the high value of (y) which is 70.5 mm compared with 21 mm for traditional tiles.

2-Absorption test
The tiles show an accepted rate of absorption of water (3.72%), compared with the maximum allowed percentage of (6.5%) according to Ref.[7]. In fact absorption is much less than this value for these tiles if we take into consideration that only the surface of the tile will be in practice subjected to rain water, where as according to the executed absorption test the whole sample was immersed into water.

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کاشی کۆنکریتی گەرمی نەگەیەنەر.

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پوختە

ئەم لێکۆڵینەوەیە باس لە جۆرێك کاشی دەکات کەبەکاردەهێنرێت بۆ داپۆشینی سەربان وە توانایەکی باشی هەیە بۆ نەگەیاندنی گەرمی. بەشی تیۆری لێکۆڵینەوەکە بریتیە لە بەراورد کردنێکی زانستی ئەم جۆرە کاشییە لەگەڵ کاشی مۆزائیکی ئاسایی لە رووی گەیاندنی گەرمیەوە. شیکردنەوەکە پشت دەبەستێت بە نرخی نەگۆری گەیاندنی گەرمی مادده جیاوازەکان کەلە لێکۆڵینەوەکەدا بەرەچاو خراوە. ئەنجامی لێکۆڵینەوەکە دەریخست کە بەبەکارهێنانی ئەم جۆرە کاشییە بۆ داپۆشینی سەربان ئەبێتە هۆی کەمکردنەوەی جیاوازی پلەی گەرمی لەرووی دەرەوەی سەربانەکەو رووی ناوەوەی بنمیچەکە نزیکەی ٦ جار ئەگەر بەراورد بکرێ لەگەڵ کاشی موزائیکی ئاسایی. جگە لەوە ۳ نموونە لەم کاشییە دارێژراوەو تێست کراوە بۆ دۆزینەوەی بەرهەڵستی شکان و توانای مژینی ئاو. دەرکەوت کە ئەم کاشیانە بەرهەڵستێکی زۆرباشی هەیە بۆ شکان و توانایەکی زۆر کەمیشی هەیە بۆ مژینی ئاو. لەبەر ئەوە لێکۆڵینەرەوەکان لەو باوەرەدان کە ئەم ئەنجامانە زۆر گرنگن و ئەبێت بە رەچاو وەربگیرێت لەکاتی دیزاین و دروست کردنی خانوویەرەدا.

البلاطات الخرسانية ذات العزل الحراري.

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أقليم كورد دستان-العراق

الخلاصة

تمت دراسة نوع من البلاطات الكونكريتية التي يمكن استخدامها لتبليط السطوح و تعطي عزلا حراريا عاليا. ان الجزء النظري للبحث يحتوي على مقارنة بين هذا النوع من البلاطة مع الكاشي الاعتيادي او شتايكرمن الناحية العزل الحراري. اعتمدت التحليل على قيم الموصلات الحرارية للمواد المختلفة. استنتج البحث بان استخدام هذا النوع من البلاطة يؤدي الى تقليل الفرق بدرجات الحرارة بين وجه السطح الخارجي و الداخل (٦) مرات بقدر ما يحققه التبليط بالكاشي الاعتيادي. كما تم صب و فحص ثلاث نماذج من هذه البلاطات لايجاد معايير الكسر و نسبة امتصاصها للماء. فقد تبين بان مقاومتها عالية للاحمال المسلطة و امتصاصها للماء قليلة. يعتقد الباحثون بان هذه النتائج ذات اهمية بالغة و قابلة للتطبيق العملي و يجب اخذها بنظر الاعتبار في اي انشاءات العمرانية.

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