THE REDUCING OF BUILDING COOLING LOAD BY USING THE DRILLED CEMENT MORTAR AS A FINISHING MATERIAL

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The environment has a great effect on the Iraqi buildings through outside walls, roofs, windows, and others. Heat transfer from outdoor to indoor in the summer causes an increase of the space temperature higher than recommended international standards. Therefore, the occupants of those buildings will be using air conditioning units that consume electrical energy, and the rate of their consumption increases with the virulence of the climate impact. Therefore, this study was investigated the effective degree of thermal performance enhancement when used drilled cement mortar finishing materials with dimensions (100 ×100 ×100) mm, which have been drilled 9 holes and were spread regularly on the surface and fixed on the external layer with a 50 mm air gap. The ambient air passes through that drilled hole to the air gap and moves to an opening at the top of that wall System.

The study has occurred at Baghdad city (latitude 33.2 N°), and an experimental test of the wall has been done on the summer months (may month to September month / 2020) on the 21st day from each month. Data was collected for 5 types of drilled holes cement mortar materials (2 to 10) mm, with changed the opening system 3 times (Normally Closed, Opened Night with Closed Day, and Normally Opened).

The results showed that the drilled face of the finishing material gave a good result, and the more efficient wall that was drilled hole with 6 mm, as well as the more efficient opening systems were opened day and night closed. That caused electric energy consumed for summer cooling purposes to be the least, and the savings rate was about 23%.

Keywords: Cement mortar finishing materials, Air gap walls, Electrical energy consumption, Reducing cooling load, Energy conservation studies.

1. Introduction

Air Conditioning systems consume big amount of electrical energy for cooling and heating the space of buildings in summer and winter, respectively. Therefore, should be reduced heat transfer from outside to indoor in the summer, and from inside conditioned space to outside in the winter. So, it's important to

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reduce the effects of the environment on the interior conditions of that building in order to reduce the average electrical energy consumption by reducing the working time of air conditioning systems. This research gives one of the methods of reducing building cooling load in the summer. As well, many studies have looked at this topic and suggested the following concepts, as summarized next. The first concept was using thermal insulators, adding a layer of thermal insulating materials to the external or internal surface will help to increase the thermal resistance of that wall, the economical thickness varied with many variables, in general in range (50 - 110) mm,[3-6], and this leads to increasing the wall thickness and wall area within building floors, due to the limited area of land on which it is constructed, finely will lead to reducing actual room dimensions, to address this problem, the insulating materials were added to the core of building materials as [7], with thickness in range (65)mm. The second aspect focuses were reused and recycling materials that end of initial life and were thrown into the environment as industrial, agricultural and natural Waste as it reused directly or after re spectate manufacturing stages, and was, eventually mixed with cement mortar to reconstruction new building materials that were characterized by low thermal conductivity and low density [8], production light weight cement materials (environmentally friendly and sustainable products) duo to replacing the natural aggregates with waste plastic materials [9], or Using mixing of waste plastic, fly ash and silica fume to cement mortar for increasing the compressive strength [10], using crushed Waste glass powder for improved the mechanical resistance of cement mortar building materials [11], while waste eggshell can be used with soil cement bricks to produced building materials at excellent technical properties [12], or additional of rice straw to cement mortar helps in reducing greenhouse emissions and energy consumed [13], and the compressive strength show steep decrease by 1% RH and began increase from 2% to 3% RH and decrease again [14], or Using local clay Waste with soft sludge from fiber cement industries to produced building materials with high values of compressive strength and can save natural resources decreasing fuel consumption and reduce CO2 emissions during delivery [15], leather powder residue with 10% to soil in order to apply it in soil cement bricks was most satisfactory results [16], the benefit of using sunflowers seed peel powder particles (4x10-6) m to (4x10-9) m [17], or powder particles of Eucalyptus Camaldulensis bark (1-5x10-6) m [18], with sand cement mortar building materials reduced the density and annual electrical energy for cooling purposes by 40%, to constructed the transmit sunlight cement building materials by embedding optical fibers during the manufacturing this materials was saving in lighting energy by around 50%, and can cut down energy expenditure by 18% [19], using waste ceramics as organic insulation was installed as exterior wall, and energy saving by 18.6% and fire resistance performance was secured [20], papercrete was used to produce light weight cement building materials and can be used an infill materials in high rise building [21], and using feathers as chicken residues with sand-cement mortar building materials in range (2.5 - 7.5)% by volume gave reducing density and annual electrical energy for cooling purposes by 37.6% [22], to produce the composite sand cement containing recycle concrete aggregate and waste Polyethylene Terephthalate, the density decrease, water absorption increase, and compressive strength was highest [23], and recycled concrete aggregate replacement of natural sand at level 55% leads to increase compressive strength [24]. The third axis adopted to reduce the environment on interior conditions of the building or frame building was used nationwide ventilation to reduce the energy demand for cooling and mechanical ventilation and can provided thermal comfort conditions for up to 90% of occupancy to reduce the electrical energy [25], or using hot and cold box for sandwich ventilation wall can be saving by 12.3% [26], using mechanical fastener in ventilation facade system to increase the heat transmission through walls [27], or using sky court as a ventilation free heated and free cooled buffer zone in an office building gave reduced about 55% saving per year [28], or utilizing of waste water which washed the walkway of residential building to humidifying the ventilation air that supplied to the building gave reduced in electrical energy for cooling purposes annually by 50% [29], using several models of hollow limestone wall with closed or opened air gap system with one or more interior reflective surfaces can gave reductions in electrical energy for cooling purposes by 36% annually [30], the opaque ventilation facade systems can achieve (16.3 - 23.5)% energy saving [31]. In addition to shading building for purpose of eliminating the direct impact environment on the building using greenery, technology can be saved by around 34% of annual load [32], and egg crate is more external shading devices [33], or using light solar reflective paints for building facade can reduce the external surface temperature by as high as 8.1 °C and decreasing cooling load by 31.24% [34]. The presence of gaps within the solid building blocks achieves a reduction in the values of both density and thermal conductivity, thus reducing the amounts of heat transmitted through them. Porous materials are found naturally as pumice or zeolite rocks, and their use in the manufacture of concrete building blocks will reduce the density in the range of 44%, and reduce the amounts of heat transmitted through them by about 40% [35- 36], while what is industrially generated from porous materials causes a density reduction in (40-65) %, and the amount of heat transmitted through it will decrease in the limits (40-55) % [37]. Because of the moderated technical in Iraq area, the researchers in this work used the cement mortar to cover the wall after drilling it and made holes to allow the environment air to pass through it and absorbed heat which accumulated in the first finishing layer and air gap. Which separated finishing materials (holed cement mortar) and main building materials. Thus, achieving decreasing in heat transferred to room space, and reducing space cooling load, then this study comes to determine the effectiveness of the drilled cement mortar thermal performance.

2. Material and methods

For the purpose of achieving the goal of this research projection regards to the effectiveness degree of Thermal performance enhancement, drilled cement building materials were used (which are used as finishing materials in Iraqi constructions). The concrete material's surface received 9 drilling holes invariable diameters, as shown in Fig. (1), from 2 mm to 10 mm (a penetrating hole), that were spread regularly on the surface.

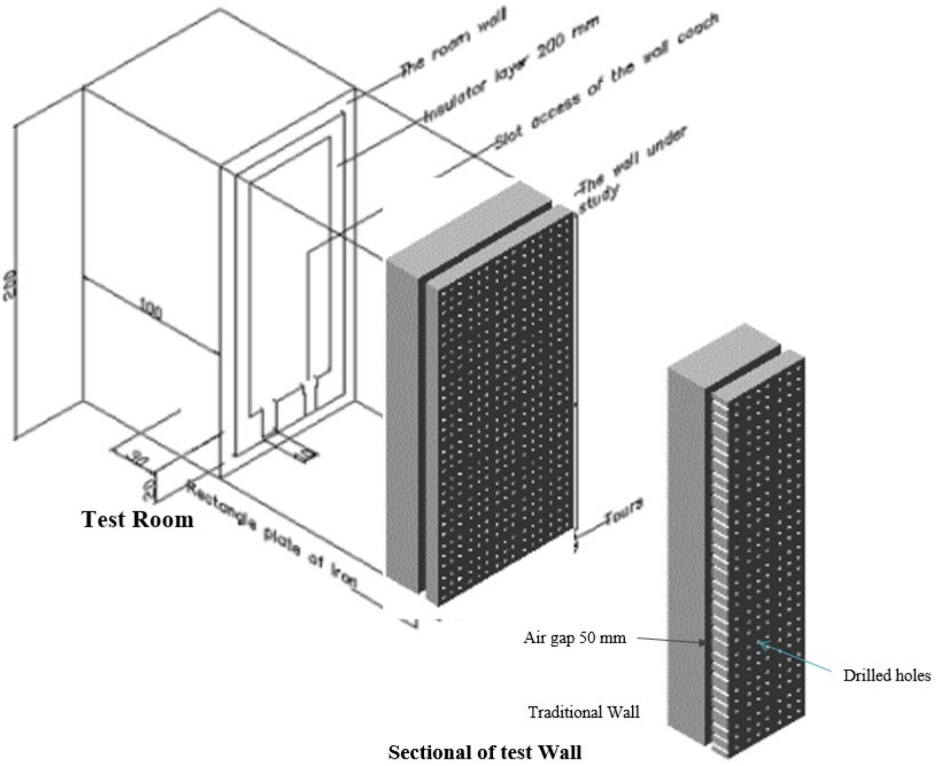

Fig. 1 Test room and testing wall details

These holes allow for ambient air to pass through and reach an air gap that lies behind it and separates it from the traditional (main) wall of the building, thickness of that air gap about 50 mm, the space of fixing Iran frame to support (holding) the cover materials (finishing materials). This functioned as an air tunnel that ends with an opening above the wall, that was Opened or Closed according to experimental conditions. The experimental wall was constructed using those drilled cement building materials (1×2) m. As shown in Fig. (1), facing the Eastern orientation of experiment room (1×1×2) m. As shown in Fig. (1) on the third floor of the building in Baghdad city (latitude 33.2 N°).

All the surfaces of that room were covered with thermally insulating materials, 200 mm thickness (polystyrene board) except for the experimental wall. A window type air conditioning unit (ACU), cooling capacity of 3.5 kW, (1 Ton of refrigeration) used to create the standard thermal comfort condition level inside the room (26.5)℃ [38]. The consumed electrical energy level for (ACU) was measured by electrical digital meter in kWh, which connected directly to (ACU).

The two calibrated thermocouple and digital thermometer were used to measure both temperatures for air room (Tr), and building materials facing to exposed air room (Ti), moreover, the intelligent auto digital thermometer was used to measure the ambient temperature in the shaded area (Tsh), and external face of building materials (drilled cement mortar materials) which exposed to ambient (To).

The experimental reading was recorded through summer months (may month to September month / 2020), for the 21^{th} day per month from 6 Am to 7 Pm. The free convection heat transfer coefficient (h) between the interior surface of the test wall into the room environment can be calculated as [39]:

$$h = 1.31\ (T_{i-r})^{1/3}$$

Then, the cooling load for test wall (Q), will be equal to [39]:

$$Q = h.A.\Delta T_{i-r}$$

The thermal properties of that drilled cement mortar finishing materials (density, (ϕ) Time lag and decrement factor (DF)) was obtained as:

Density was measured in building materials laboratories/ institute of technology/ Baghdad, while, Time lag and decrement factor was calculated as illustrated in Fig. (2), from Fig. (3), as [38]:

$$\phi = t_{[T_{in}(\max)]} - t_{[T_{out}(\max)]}$$

were, $t_{[T_{in}(\max)]}$ and $t_{[T_{out}(\max)]}$ are the time of day when the inside and outside surface temperatures reach maximum.

$$DF = \frac{T_{in}(\max) - T_{in}(\min)}{T_{out}(\max) - T_{out}(\min)}$$

were, $T_{in}(\max)$ and $T_{in}(\min)$ are the maximum and minimum inside surface temperatures, $T_{out}(\max)$ *and* $T_{out}(\min)$ are the maximum and minimum outside surface temperatures.

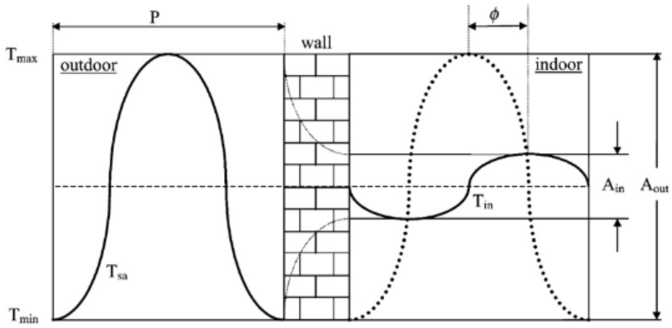

Fig. 2 Time lag and decrement factor calculation.

The parameters which were studied, the effect of hole diameter and opening systems (Normally Closed, Opened Night with Closed Day and Normally Opened) on the heat transferred to the room.

3. Results and discussion

For the accomplishment of this paper goal, the hourly thermal behavior for all Studied walls was measuring on the 21th day from each summer month, as shown in Fig. (3) at June month as a sample of it. The thermal properties were illustrated in Table (1), which was calculated from Fig. (3), and Table (2) was illustrated the dimensions of drilled holes area.

Table 1

Thermal properties of Studied drilled cement materials.

Type		Density kg/ m^3	Time lag hours	Decrement factor
Solid		2000	2.3	0.4
Drilled	2mm	1950	3.1	0.442
	4mm	1920	4.0	0.493
	6mm	1890	5.15	0.540
	8mm	1860	5.05	0.530
	10mm	1720	5.00	0.510

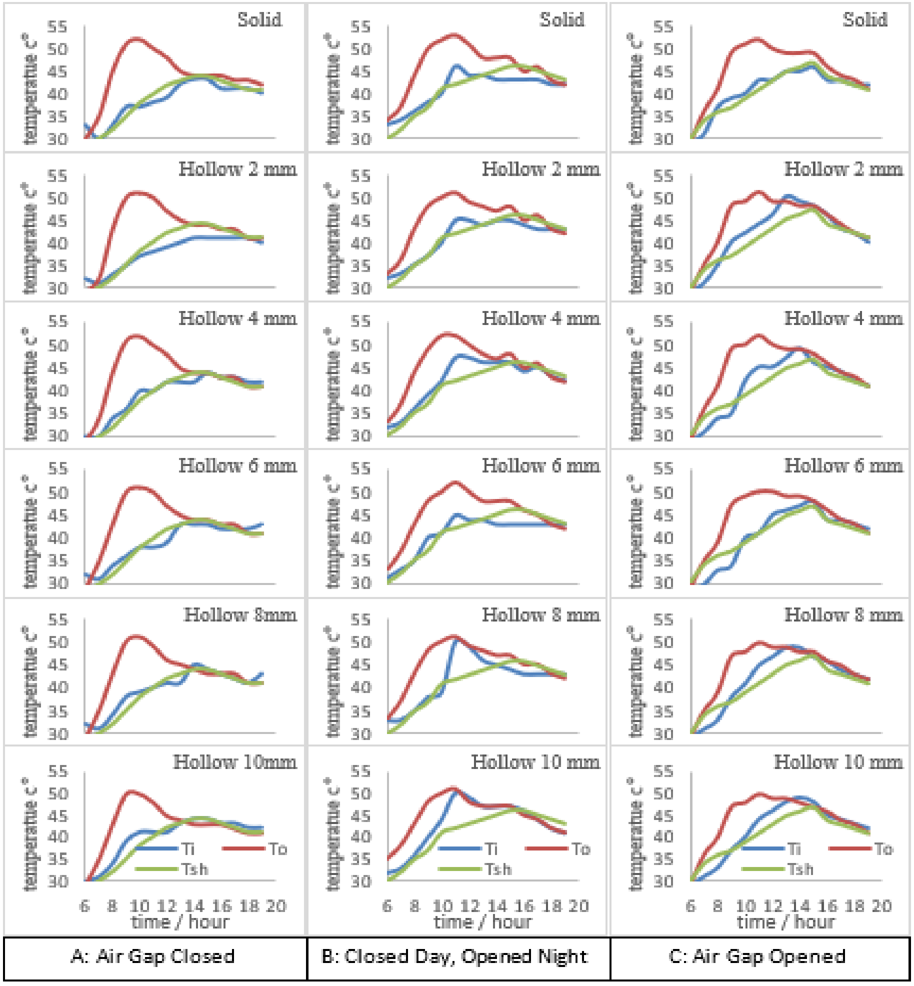

Fig. 3 Hourly Thermal behavior of all Studied wall at June month

Table 2

Dimensions of drilled holes

Holes diameter mm.	Cross sectional area mm^2	Total cross-sectional area mm^2	Area percentage %	Total surface area mm^2	Air volume mm^3
2	3.14	28.26	0.3	628	5652
4	12.56	113.1	1.13	1256	11304
6	28.26	254.4	2.6	1884	16956
8	50.24	452.16	4.5	2512	22608
10	78.5	706.5	7.1	3140	28260

The monthly average for external, interior wall surfaces temperatures and Temperatures differences between that surfaces were shown in Fig. (4), but seasonally average were shown in Fig. (5), and the electrical energy consumption and savings (according to electrical energy were consumed at traditional Wall were shows in Fig. (6).

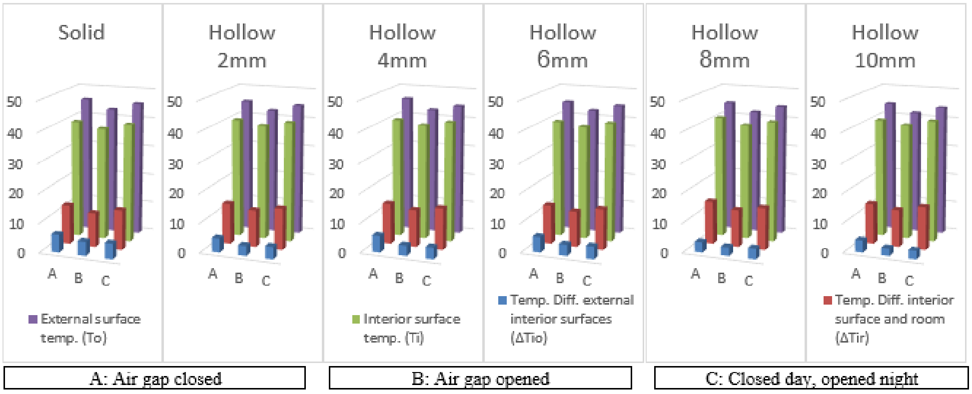

Fig. (4) Temperature values of wall surfaces for all studied cases at June month.

4. Variables Discussed

Thermal properties

Thermal properties of all kinds of cement mortar finishing materials with the traditional wall which were Studied illustrated in Table (1). The density of solid type was 2000 kg/m^3 and will be decreased to 1950 Kg/m^3, by decreasing percentage 2.5% at drilled holes 9 in numbers and 2 mm diameter, drilled holes 4mm gave density 1920 Kg/m^3, decreasing percentage 4%, and drilled holes 6mm, the density was 1890 Kg/m^3, and decreasing percentage 6%, and the density became 1860 Kg/m^3 and decreasing percentage 7%, and became 1720 Kg/m^3 and decreasing percentage 14% for drilled holes 10 mm. Table (2) was illustrated the hole cross-section area and percentage from face surface area of cement mortar materials.

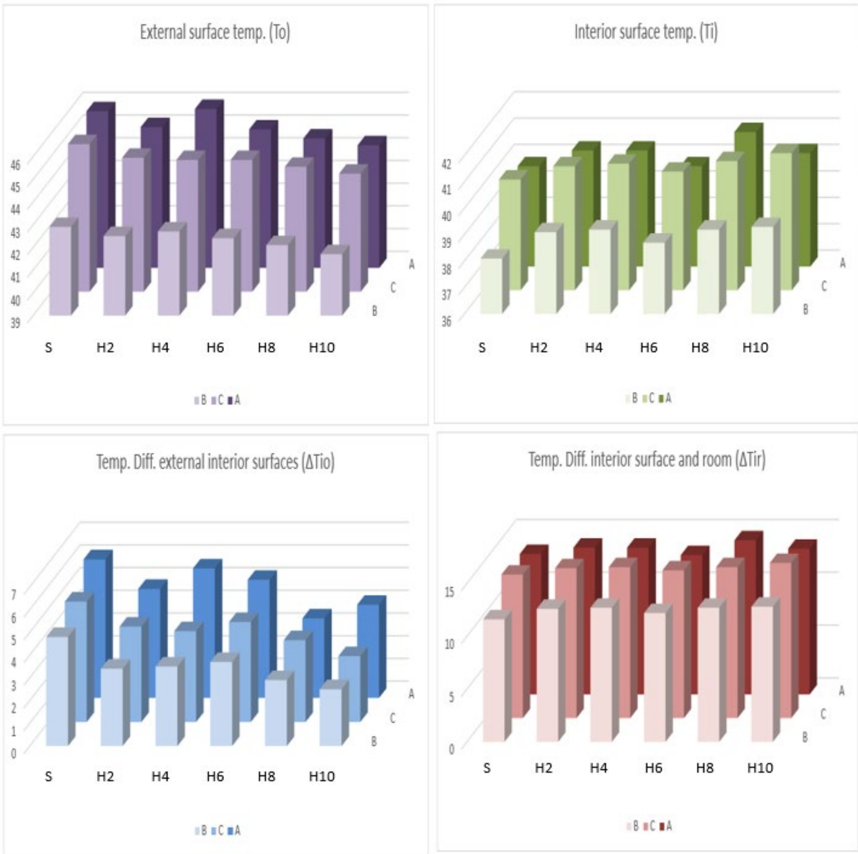

Fig. 5 Seasonally average temperature values of wall surface.

The time lag of the wall when using solid cement mortar finishing materials was 2:30 hr and decrement factor 0.4, but became 3:10 hr time lag, decrement factor 0.442 for drilled holes 2mm cement mortar finishing materials, for 6mm drilled holes, 4 hr time lag, decrement factor 0.493. While when drilled holes 8mm, the time lag and decrement factor were reduced to 5:15 hr, 0.540, and also, reducing values at 10 mm drilled holes and became 5:05 hr, 0.530. The reason for this decrease was returned to big air quantity in holes.

more efficient drilled holes diameter

At the drilled hole diameter of 2 mm, a cross-sectional area which exposed to ambient effect was 3.14 mm^2, for one hole, that area for 9 holes was 28.26 mm^2,

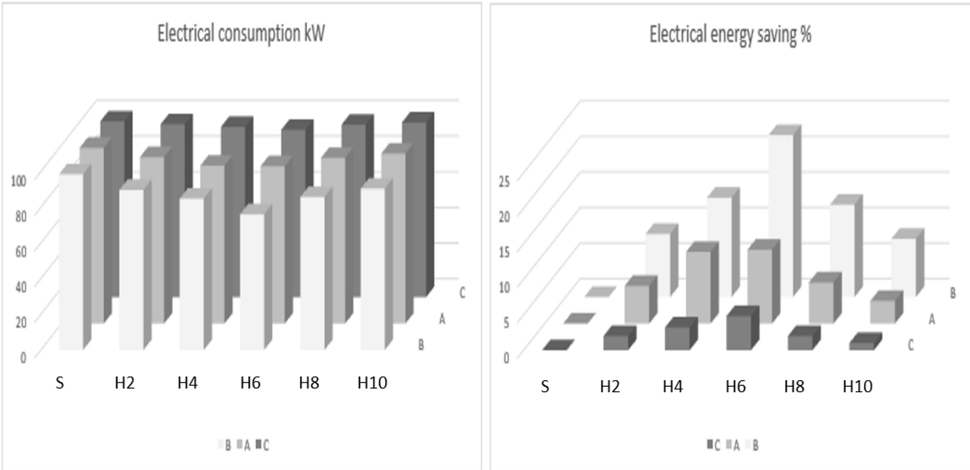

Fig. 6 Yearly electrical energy consumption (kW) and percentage saving (%)

that area formed 0.3% from the face surface of cement material shown in Table (2). That area was exposed to the ambient condition and heated, and moving through-hole length, the air volume in that hole was 2826 mm^3, and the surface area of holes was in contact with cement particles by 5652 mm^2. The ambient effects act upon the face surface (solid and holes), the heat flux transferred by conduction and convection, the results of this, heated air gap and transferring to another component of that wall, the increasing drilled holes diameter leads to increased surface area and air volume, but the effect was limited until 6 mm, more of that, the big effect appeared (8 mm, 10 mm). the holes have increased the heat transferred at Closed opening systems or Opened opening systems, but in the Opened air gap in the Night and Closed in the Day, ventilation air absorbed the accumulated heat in the gap and carried outside

External, Interior Surfaces Temperature

As shown in Fig. (5), the seasonally average values of the external surface of cement mortar finishing materials which exposed to ambient conditions, for solid material was indicated 45.9 °C, and reducing to 45.2 °C for 2 mm drilled holes cement mortar material, and became 45.07 °C, 45.025 °C, 44.63 °C, 44.35 °C for 4 mm, 6 mm, 8 mm, 10 mm drilled holes cement mortar materials (as respectively). That means, the big holes reducing the solid area and absorbing the temperature, and transferring it directly back to the air gap.

While the seasonally average values of interior surface temperature, which exposed to air room were shows in Fig. (5), as denoted, for solid cement mortar finishing materials 39.82 °C, and raising to 40.35 °C, for using the drilled holes

2mm cement mortar finishing materials, and raising to 40.37 °C, at drilled holes 4mm, and the reason of this results to return to the air in holes heated directly from ambient conditions and reducing its density and movements to back to the air gap and raising its temperature, which was caused the interior temperatures increase ingredient.

Temperatures Differences (ΔTio), (ΔTir)

As shown in Fig. (5), the temperature differences between external interior wall surfaces (ΔTio), was 6.097 °C, for solid cement mortar materials, and was became 5.697 °C, for 4mm drilled holes cement mortar material, 5.24 °C, 4.05 °C, 3.5 °C, for 6 mm, 8 mm and 10 mm respectively. That means the smaller drilled hole diameter was more effective than the largest.

The temperatures differences between the interior surface and designed air room (ΔTir) were shows in Fig. (5), it was inducted to space cooling load, for using a solid cement mortar finishing material was caused 13.3 °C, and became 13.84 °C, for using 2 mm drilled holes cement mortar finishing materials and recorded 13.85 °C, for 4 mm drilled holes, and reduced to 13.3 °C, for 6 mm drilled holes, but raised to 13.79 °C and 14.63 °C for 8mm and 10 mm drilled hole, respectively.

Opening systems

As shown in Fig. (5), the external surface temperature was recorded at 45.9 °C, when using a Normally Closed gap System, and became 45.4 °C, when using a Normally Opened gap System, and became 42.8 °C, when using an Opened gap at Night, Closed gap in Day System, that the efficient system, because the opening of the gap in the Night was allowed to enter the ambient air and absorbed that heat which accumulated in the gap from the Day, in results, the ventilation process would decrease that heat level.

Energy consumption and energy saving

As shown in Fig. (6), the traditional wall was used solid cement mortar as finishing materials, consumed 98.5 kW, electrical energy for seasonally cooling purposes per unit facade area (1 m^2), but that load would be decreased at 2 mm, 4 mm, and 6 mm drilled holes cement mortar finishing materials were 89.7 kW (8.9% saving percentage), 84.7 kW (14% saving percentage), and 76 kW (22.8% saving percentage) as respectively, but, at Using 8 mm and 10 mm drilled holes cement mortar finishing materials was Reducing energy investigation 85.7 kW (13% saving percentage) and 90.4 kW (8.2 saving percentage).

5. Conclusions

From above discussion, could be fixed many facts, that is: -

- The drilled cement mortar finishing materials gave a good result in energy consumption reduction by passing the ambient air through that holes and absorbing the heat which was accumulated in air gap occurred at backward finishing materials.
- The temperature of the external wall surface (exposed to environment) was 45.9 °C, for traditional Wall, while decreasing for using drilled cement mortar between (1.53-3.4) % for Normally Closed opening ventilation air gap System, and became (2.1-3.9) % for Normally Opened opening ventilation air gap System, and decreasing to (7.06-9.15) %for Opened Night and Closed Day ventilation air gap system.
- The temperature of the interior wall surface (exposed to room) was recorded 40.13 °C, for traditional wall, and would be decreased for using drilled cement mortar finishing materials in range (0.4-2.5) % for Normally Closed opening ventilation air gap System, and became (1-2.7) % for Normally Opened opening ventilation air gap System, and the reducing was (2.2-3.5) % for Opened Night, Closed Day ventilation air gap system.
- The electrical energy consumption for annual Cooling purpose was recorded 98.5 kWh, for traditional wall per unit area(m^2), and would be decreasing for using drilled cement mortar finishing materials in range (3.2-10.41) % for Normally Closed opening ventilation air gap system, and became (1-4.73) % for Normally Opened opening ventilation air gap system, and that reduced in range (8.2-22.82) % for Closed Night, Opened Day opening ventilation air gap system.
- Density of traditional wall was 2000 Kg/m^3, while the density of drilled cement mortar finishing materials was reducing in range (2.5-14) % according to holes diameter.
- Time lag of traditional wall was 2.30 hr, while, that value for drilled cement mortar finishing materials was increased in range (3.10-5.15) hr, for holes diameter between (2-6) mm, and cut down to (5.05-5) hr., for holes diameter (8-10) mm.
- Decrement Factor for traditional wall was calculated 0.4, while for drilled cement mortar finishing materials was increased to (0.441-0.540), for holes diameter in range (2-6) mm, and cut down to (0.53-051), for holes diameter (8-10) mm.
- The more efficient opening ventilation air gap was Opened Night, Closed Day.
- The more efficient drilled holes were 6 mm, at any types of opening ventilation air gap system

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