Investigation of thermal behaviour for various exterior walls materials and their impact on rationalization of energy consumption of Kirkuk city, Iraq

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Abstract. The present study aims to make a comparison of the thermal behaviour for various exterior Packaging materials (Local or Imported) or a new proposed (a phase change material), which are used in covering the facades of buildings in Kirkuk city/Iraq. And thus know how much those materials effect on energy conservation (rationalization in energy consumption). In this study the focus was on making comparison of heat dissipation and power consumption (Save energy) when using the conventional and proposed materials and which of them has the greatest ability to withstand various environmental conditions. The study was carried out (from the beginning of January 2017 until the end of February, 2017) which this period represents the cold months in the year. (Where temperatures ranged from -2 to 15 °C) which within those months all facilities, buildings need to be heated. The thermal conductivity of various classical covering materials samples was measured and compared with the values of the other certified project sources. It was found through analysis of the results that the use of proposed material which is a phase change material (Paraffin Wax) exceeds in terms of energy reduction than other classical covering materials. It was also shows that the use of classical and proposed covering materials reduces heat loss through the exterior walls (reducing demanded heating load in the comfort zone), thus minimizing the consumption of (save) expended energy within the comfort.

1 Introduction

In light what the world is witnessing of the enormous revolution in the architecture field and especially what our beloved country and particularly what our beloved country witnesses of large urban renaissance because of population growth, and there for the demand have increased for building and facilities, and this increase was accompanied by consumption of fuel for needed generation power electricity for air-conditioning and heating those buildings and facilities which use high-quality materials in construction and therefore it requires a relatively high cost. It has been therefore the subject of keeping the thermal energy in the buildings of the topic most important at the present time due to the increased consumption of energy in buildings as a result of the use of means of heating and air conditioning to ensure a comfortable and healthy atmosphere to humans where is the using of heat insulation materials in buildings is

most important economic means used to reduce the growing energy consumption, as it provides a saving in energy consumption for heating and cooling, which in turn ease the growing burden on the citizen, and especially those who have limited income and in return the construction materials have far away developed which is the packaging materials which is use to cover the exterior walls is one of them and which characterized of enduring the different environmental conditions. But there is some of the packaging materials have drawbacks which are related to its thermal properties, for example there are some of them which own a very high thermal conductivity , and its dissipating heat rapidly, therefore using them in building construction without adding and heating insulation or air-conditioning will be uncomfortable for the human comfort, on contrary of that in case of using a primitive construction material like clay or stone which characterize by their high ability to store the heating energy for the surrounding environment moreover

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their huge slow in heat conductivity compared to the modern Tech. which are not thermally isolated. At the present time, there is a lot of packaging imported materials like from (China, Turkey) or local which are used in covering the buildings. Therefore, researchers noticed it necessary to develop the method of building and use modern materials to get the utmost usage from energy through improving the thermal properties of the construction materials in order to reduce the possible dissipated heat through it. But improving the thermal properties of the construction materials require new style of available local materials which are cheap and can accomplish the same purpose [1]

Thermal energy is transferred through the solid medium represented by the wall by thermal conductivity, and thermal energy conductivity is the very huge and profound forked study. So thermal energy conduction is very important in engineering application which depends on it. So this science occupied a large part in engineering mechanics and physics science which study it and need some application, for example in increasing heat transfer in a possible big way, like in evaporative cooling or in residential heating or even reject heat gained in electric and computers devices, whereas in other applications we need to maintain heat energy inside it, like for example in residential water heating or inside the houses in winter season [2].

There are a lot of researches and studies which discussed to analyze and study different types of packaging materials for exterior classical walls (imported and local materials). All of those studies aims is economic feasibility through saving more energy by using packaging materials with the capability of saving high thermal energy for the surrounding environment in addition to the great slow in its thermal conductivity with the comparison to the unisolated modern Tech.

Reference [3] Had carried out a study and made a comparison in thermal performance between modern and classical Iraqi building walls. Where results showed that the amount rate in load reduction when using interior packaging walls is ranging (1%- 12%) which is the highest comparison in a cording to in reducing the cost of packaging materials which didn't exceed (2%). and the study had declared the necessity of using the thermal isolation during wall covering for making Iraqi thermal properties wall within the international measurements. Reference [4] also carried out a study about the wall thermal behavior (implemented currently and suggested for implementation) within the climate conditions for Baghdad city (North 33.2 degree latitude) with the presence and without the presence of the thermal isolation which is thickness (40 mm), and the study was carried out through the day work for one day (21) of July and for a wall faced to the west. The researcher was able scheduling the results, which included total thermal energy coefficient, the weight of each wall per area, and the difference in temperature with finishing interior wall materials and an air temperature of the designed room according to hours changing of day and their daily average.

Reference [5] Carried out a study about energy conservation by using Polyurethane material as an isolation material which characterized with a low thermal conductivity in comparing with other isolating material used, and through the laboratories tests the thermal conductivity was (0.024 watts per meter. Percentage) whereas these results were assured through

experimental tests, the difference was ranged between two values (experimental and measured) ranged (5-7%) also the researchers study thermal loads of faculty of dentist in Tishreen/Syria university, without the thermal isolation and with thermal isolation by using Polyurethane , the results showed that using this isolating material(Polyurethane) caused in decreasing in thermal loads ranged about 46% and therefore ensuring energy saving consumed with rate about of 46%.

Reference [6] Carried out a study to evaluate the artificial stone product, which one of the Iraqi local factories to produce it and compare it with natural Granit stone, to explore the involved material to produce this material and knowing their costs and their suitability for packaging. The researcher carried out the experimental test, which included (total absorption test, density broken criteria), the following results were obtained: absorption (5.182 % , compression 2.1 N/mm², density 2159.92 Kg/m³, broken criteria's 6.32 N/m²). Those results was so far good and within the limits of American description for Granit stone which has the number C99-87 and C217-85 and C170-87 , and the researchers found out it was more close to half (B) according to Iraqi description which has the number 1387-1989 for the Granit stone in all tests except the compression test, whereas the thickness of the stone is 2.5 cm, therefore, the researcher depend on the cement tile gradual compression and it was successful in that test, and from the side of the cost it is half cost of the natural Granit stone.

The present study is an extension of previous studies. In the present research a thermal behavior comparison were held in the winter for several different packaging exterior classical walls (local and ready- made imported) which are used in packaging facades of Kirkuk / Iraq city or a suggested unused material as PCM (a paraffin wax), and therefore knowing the amount of impact using those materials for energy saving (conservation in energy consumption) in this study it was focused on making comparison between heat dissipation and energy consumption when using those materials (classical and suggested) and which of them have the large ability to withstand the different environmental condition. The study was carried out from the beginning of (January 2017 until the end of February 2017) which those months represent the cold months in the year (temperature is ranged from (−2 to 15 °C) which are needed to heat the building in the winter season.

2 Practical part

In order to study the thermal behavior of different exterior wall packaging materials (classical and suggested), a practical test station was designed which simulate the process of heat dissipation for rooms facing the south side. A packaging materials were installed on the southern wall (building façade), whereas most buildings are surrounded by three walls of other buildings (to the both sides of the building and the rear side of the building), time of the study was carried out in winter and according to Kirkuk / Iraq city climate. this station is consisting of five rooms (50x50x50cm) five different packaging materials were installed on the exterior walls for each room a packaging material, in addition to the measurement and control unit. As it shown in " Fig."(1).

Testing rooms (five sample rooms) were designed and constructed and were placed in second floor in the building of air-conditioning and refrigeration department in Kirkuk technical college, on 4m high of ground level, in order to expose those rooms to be exposed to the environment all the day and faced to the southern side Kirkuk city with dimension (50x50x50 cm) and in order to reduce heat transfer (limited transferring) through room spaces in five sides (eastern wall, western wall, northern wall, ground and ceiling), the five sides had been packed with three layers of (a, b, c) as it shown in the " Fig." (2) as following:

- a. Wooden layer type of (MDF) thickness of (18mm).
- b. Layer of trapped air (inert gas) with thickness of (2cm).
- c. Wooden layer of (MDF) with thickness of (4mm).

as for the southern wall (sixth) its consists of pure Aluminum with thickness (0.9 mm) of high thermal conductivity value in order to allow a large amount of heat to transfer through this wall (wall in process of study) which represent the source or the influential side in a big manner on the comfort level inside each room with comparison with other walls for the same room. Different Packaging materials were placed (classical and suggested) on the southern wall for each sample, as shown in " Fig."(3).

Types of packaging materials used in the current study, as shown in " Fig."(4):

- a. Classical packaging materials, it was divided as follow, shown in " Fig."(4) The first pattern (R₁): installing (Limestone) with a dimension of (5x50x50 cm). The second pattern (R₂): installing Granit stone with a dimension of (2x50x50x cm). The third pattern (R₃): installing Ceramic packaging materials front side with a dimension of (1x 50x50 cm). The fourth pattern (R₄): installing kind of cork (Styrofoam) with dimension of (4x 50x50 cm).

The fifth / suggested material (R₅): Installation packaging material type phase change material (PCM) called Paraffin wax. The wax installed adjacent to the southern Aluminum wall and was trapped with transparent glass of a thickness (4mm) to inform a rectangular basin made of transparent glass with a thickness of (2cm) only the side which is adjacent room to be from Aluminum as for the dimension of this a rectangular box its (2x50x50 cm) as it shown in " Fig."(5).

2.1 Control and measurement unit

An electronic control panel was constructed for the control and measurement unit and for each room has an independent control panel which consists of:

- a) Temperature sensor placed by a socket on a programmable electronic panel in order to adjust temperature degree according to inside rooms requirement and sensor bulb was placed in the middle of the room from above on a high of (45cm), electronic panel is fed with electrical power of (12v), through an electrical depressor transformer to transform electrical power from (220 v) to (12v). The main function of the electronic panel is to control the electrical load's work. (electrical bulb of thermal wire which represent the heat source simulate the heating system inside testing room placed beneath the rear wall for the room in the middle, supplied with an electrical source of (220 v) and electrical power of (100 watts). Which when the temperature room reaches the

demand degree(for example 32 °C) the programmable electronic panel will command to stop (open) the electrical unit which supply the electrical load (turn off), whereas if the temperature is decreased below the demanding temperature then it will give a command to connect the electrical unit which supplies the electrical load (turn on).

- b) A four intake temperature measurement was used supplied with thermocouples type of [k] with a diameter of (0.3mm) to measure temperature degree in different spots for the testing room (the exterior and interior surface testing southern wall (sixth wall)) those couples were calibrated according to the criteria and of a range of temperature (0 – 100 °C).

- c) Power meter device multi-function with (watt/h) units was imported from outside of Iraq (USA) its purpose is for knowing the amount of energy per hour which will be consumed (spend) inside each room through a certain time (heating load) where measures each of (current in amperage units, voltage in volt unit, electrical power in watt units, energy in watt per h) the device is fed with (220v) electrical power. This device is consisting of inductive loop its function to measure the value of the electrical current which passes through it. The electrical unit was placed inside a box made of plastic kind of (PVC) with dimension of (7x1.5x1.5) as it's shown in " Fig."(6)

2.2 Control and measurement units work mechanism

The electronic circle is connected as it's mentioned above, for example, a temperature sensor is adjusted on (32 °C) inside testing room in the winter season (likely with residential air conditioning units). So when the temperature of the room reaches the demanded temperature the programmable board of the temperature degree sensor will issue a command to cut the electrical source which supplies the electrical bulb with the thermal wire (turn off), but in case the temperature is lowered from the demanding one the mechanism will connect the circle which supplies the bulb with electricity (turn on). The difference in degree between activation and shutting down the circuit was adjusted (2) degree. The feeding wire is passed to the electrical bulb to the negative side (-) from inside of inductive looping for the power meter, which will take its role and measure the passing electric current, and the power which the electrical load consumed (electrical bulb with thermal wire) and measure the energy which will the electrical bulb consumed in each hour in (watt/h), which is the amount of heating load in each hour the room consumed it.

3 Research plan

Plans to carry out experiments on the system for the interval from (the beginning of January 2017 until the end of February2017) which those months represent the cold months of the year temperature degree were ranged from (-2 to 15 °C) which is needed to heat the buildings in the winter season.

Measurements in this research were carried out on stages:

First stage

In the first stage primer tested was conducted on the suggested design without adding packaging materials on the southern wall (layer of pure Aluminum with the thickness of 0.9 mm)

to evaluate the performance and the possibility of the amendment in the design in order to reach the best design.

Second stage

This stage included studying the thermal performance and the amount of consumed energy in each hour for the five patterns in a similar working condition and then comparing the results obtains from those patterns (suggested and classical) with each other.

Tested were conducted for the stages in different days and in a uneven environmental condition (sunny day, cloudy day, partial cloudy, rainy day, snowy day) and number of tests became (30) test, all the reading were registered in every hour for all variables (electrical current, voltage, electrical power, energy for each hour, temperature of the room and temperature of the surrounding area, temperature of the exterior testing wall surface with the interior wall of the room) all the tests begin at 9 am and continue to several hours in a day and several days to acknowledge the capability of each packaging material to store and lose the thermal energy moreover and the extension of ability to endure all the different environmental conditions.

4 Theoretical part

The wall has been analyzed using the accurate analytical method (Exact solution) in order to calculate the overall heat transfer coefficient (U) and the amount of heat dissipation (rate of heat transfer through the constructed placed area), to know the amount of power needed to supply inside the comfort zone [7], on the following way:

4.1 The heat transfer through a composite wall

The thermal properties of the structure of architectural building are accounted the most important basics which any air-conditioning system (heating and cooling) rely on it. The heat is transferred from inside the heated building to outside the same building in winter and in opposite way in summer by two ways through exterior structural covering material for the building. First of them is heat transferred through the walls of the air from one of its sides to the air of the other side, secondly is through leaking (infiltration) the cold air to outside the building. Therefore, if its demand to shrink the heat transfers we must improve the walls thermal properties and reduce air infiltration through the cracks and gaps through the doors and windows. And the heat transfer occurs between two bodies their temperature by conduction or convection or radiation or more than one method in one time.

And the heat is transfer in conduction by direct contact between the molecular without displacing them from their places. And the first scientist who put the heat transfer conduction is J.B. Fourier.

$$\frac{dQ}{d\theta} = -KA \frac{dt}{dx} \dots \dots \dots (1)$$

Where ($dQ/d\theta$) is the rate of heat transfer per time and (A) is the cross-sectional area which heat transfers occur through it and (dt) is the deferent in temperature which causes heat to transfer and (dx) the path which through the heat passes and the thermal conductivity. And it's seen that the rate of heat

transfer inversely proportional to the thickness of the material, which it means heat transfer is reduced with the increasing the thickness of the material and vice versa. And if the temperature changed with time and location once, therefore, it's called unsteady state. But if the temperature changed only with the location it will call steady state and in the steady state, the amount ($dQ/d\theta$) will remain constant and which its symbol is (q) with watt units. And the negative sign in equation (1) means that temperature degree is moving in a bounded direction from high-temperature side to the lowest temperature side, therefore the equation will be put on this way:

$$q = K \frac{A}{-x} (t_1 - t_2) \dots \dots \dots (2)$$

Where (A) is in square meters, ($t_1 - t_2$) is the temperature difference in Celsius degrees and (K) is the thermal conductivity of the material with (W/m. °C) units.

The idea of thermal resistance is used to find heat transfer across the composite walls, where equation (2) can be rearranged as follows:

$$q = \frac{(t_1 - t_2)}{x/KA} = \frac{1}{R} (t_1 - t_2) \dots \dots \dots (3)$$

Where (x/KA) is called thermal resistance with (°C/W) units.

An experimental test was conducted for the classical packaging materials used in this research in the Kirkuk/ Technical Institute laboratory (Laboratory for measuring solid materials thermal conductivity) Japanese source, in order to reach to the real value of the thermal conductivity (K) for each material and then making comparison for those values and dependent values in books and previous sources.

Table (1) indicated values of thermal conductivity of the classical packaging materials for exterior which is trusty in the sources and previous research [3,7], also the values thermal conductivity of packaging materials during the laboratory test. The value of the thermal conductivity of the suggested packaging material for the sixth pattern (a wall of Aluminum layer with thickness of 0.9mm + Paraffin wax packaging material with a thickness of 2cm + glass thickness of 4mm) as following: the value of pure Aluminum thermal conductivity layer is (202W/m. °C) and for the regular glass is (0.78 W/m. °C) [2], and for Paraffin wax is (0.21W/m. °C) [8].

And compound wall case (structural wall consists of several materials) whereas the heat is flowing in constant rate in the steady state through the neighboring wall. Also there is an additional resistance resulted from a thin fluid layer (Air adjacent to the neighboring wall from inside and outside) this semi-static layer try to stick to the wall and hinder heat transferring and thickness of this layer depends on the

condition of the heat transfer with load naturally of forced and also depends on the roughness and the inclination of the surface. And it was the Coefficient of heat transfer through the film thinks layer indicated with the letter (f) and its unit in $W/m^2 \cdot ^\circ C$ and its thermal resistance as follows:

$$R_f = \frac{1}{f} \dots \dots \dots (4)$$

As customary when the heating load need to be calculated a general value is given for the coefficient (f_i) considering the inside air is static, and giving two values each of them for the cretin wind velocity which represent winters condition and the second for summer season and those values are

Static air

$$f_i = 9.37 \text{ W/m}^2 \cdot ^\circ C$$

In the winter – wind with velocity 24 km / h

$$f_o = 34.1 \text{ W/m}^2 \cdot ^\circ C$$

In the summer – wind with velocity 24 km / h

$$f_o = 22.7 \text{ W/m}^2 \cdot ^\circ C$$

And now it is possible to write a general equation for thermal resistant for any compound wall contains thermal resistant for the air layers (inside and outside the space) and the homogenous and not –homogenous for walls material as following:

$$R_t = \frac{1}{f_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \dots + \frac{x_n}{k_n} + \frac{1}{f_o} \dots \dots \dots (5)$$

4.1.1 The overall heat transfer coefficient

The total inverted resistant known as the overall heat transfer coefficient in units $W/m^2 \cdot ^\circ C$ as following:

$$U = \frac{1}{R_t} \dots \dots \dots (6)$$

And therefore for to determine heating load (Heat dissipation) for the structural area (walls, ceiling, and floor) within the American Society of heating, refrigeration and air-conditioning Engineers criteria (Ashrae), the amount of heating load for the structural area was calculated for the structural are (thermal loss through compound structure) as following:

$$q = U \cdot A \cdot (t_i - t_o) \dots \dots \dots (7)$$

Table (2) indicated values of the overall heat transfer coefficient and Heat dissipation through wall in process of study (sixth wall).

But thermal loss through the other structural area for the designed room (remain walls in addition to the ceiling and floor) is very small compared with the sixth wall which is assigned for study, the total thermal loss was found through other structural area (30 watts) , and the amount of the thermal loss because of the air infiltration through the cracks and holes around the doors and windows wasn't calculated because there isn't any doors or windows in the design room. It was found through results analyzing the followings as it shown in " Fig."(7), using suggested material (Paraffin wax) from the side view of reducing energy consumption the material exceed some of the packaging materials and also found the packaging materials (classical and suggested) reduces the amount of thermal loss through the exterior walls (reducing the heating load inside the comfort zone) and therefore reducing energy consumption inside the comfort zone.

In the practical side the design room was supplied the heat energy (heating load) through electric bulb with thermal wire (100 watts for each hour) this value was measured with a power meter multi-function. And the thermal loss (the consuming energy for each hour) for the design room with and without packaging material for the exterior wall and for all the five included patterns (R_1, R_2, R_3, R_4, R_5) for the study the results were analyzed.

5 Results and discussion

5.1 Results

In this study, the results were obtained through conducting (30) test and a long two months and according to Kirkuk /Iraq environment. The experiments was conducted on the system for the time interval (from the beginning of January 2017 until the end of February, 2017), those months represents the cold months in the year (the temperature were ranged from -2 to 15Celsius degree) where heating is needed to warm the building, in the winter, tests were conducted on different days and uneven circumstances (sunny day, cloudy day, partially cloudy, rainy day, snowy day, tests were conducted through 24hrs day &night), tests were registered each hour for all variables which are (electrical current, voltage, electrical power, consuming energy for each hour, temperature inside room and temperature of the climates surrounding design room, temperature of the exterior and interior surface of the room) all the experiments start at nine am and continue several hours of a day and sometimes several days in order to know the capability of each packaging material on storing and losing the thermal energy and their extensibility on enduring all the different variable condition , the study included five patterns of design room without packaging materials for with them for the five patterns (R_1, R_2, R_3, R_4, R_5) and with same operating

conditions, in the analytical solution it was calculated the amount of the thermal resistances and the overall thermal conductivity coefficient through the sixth designed southern wall for the fifth study patterns, and also the amount of the thermal loss through those walls. and through the practical results we found out, that using the suggested material (Paraffin wax) exceeds some of the classical packaging materials from the side of reducing the consumption of energy, and it was also noticed that using classical and suggested packaging materials reducing the rate of thermal loss through the exterior walls (reducing the demanded heating load inside the comfort zone), and therefore reducing the consumption of electrical energy disbursed inside the comfort zone.

5.2 Discussion

Fig. (8) illustrates the relation between the time for each hour (from nine am until five pm) and energy consumed (watt per hr.) inside the five design rooms (R1, R2, R3, R4, R5) and with same operating condition, and the time of study was a sunny day. And through the practical results it was noticed that the pattern (R2) is the least energy consumed and this is because of the falling solar radiation impact on the polished Granit stone surface which in turn leads raise its temperature (heated it) and therefore a reverse conduction occurred in the direction of the thermal energy from outside to inside (adding a thermal load inside the room), and because of the chemical composition of the stone which makes him thermal energy reservoir in a very good way, therefore the designed temperature degree inside the room will be semi-stable (at 32 °C) and this, in turn, leads to reduce the consuming of energy inside the room. Following it in less consuming energy the pattern (R5) which includes the packaging material (Paraffin wax), and that is because of the falling solar radiating impact on Paraffin through the glass (absorbing thermal energy from reaching solar radiation on the surface of the Paraffin) and in turn, leads to change its phase gradually (phase change) from the solid state to liquid state (storing a potential energy) and therefore a reverse transferring occurred in the direction of the energy from outside to inside (adding heating load in the room), therefore the design temperature (at 32 °C) inside the room will be semi-stable which it means reducing energy consumption inside the room. Following it in less energy consumption the pattern (R4) which has a high thermal isolation of Styrofoam, and after it the pattern (R1), but the highest energy consumption is the pattern (R3) because of the highly thermal loss through packaging material (Ceramic facade) which have a very high thermal conductivity.

Fig. (9) illustrates the relation between the time for each hour (from nine am until five pm) and energy consumed (watt per hr.) inside the five design rooms (R1, R2, R3, R4, R5) and with same operating condition, and the time of study was a partially cloudy day. And through the practical results it was noticed that the pattern (R2) is the least energy consumed and this is because the intermittent effect of the falling solar radiation impact on the polished Granit stone surface which in turn leads raise its temperature (heated it) and therefore a reverse conduction occurred in the direction of the thermal energy from outside to inside (adding a thermal load inside the room), and because of the chemical composition of the stone which makes him thermal energy reservoir in a very good way, therefore the designed temperature degree inside the room will be semi-stable (at 32 °C) and this, in turn, leads to reduce the consuming of energy inside the room. Following it in less consuming energy the pattern (R5) which includes the packaging material (Paraffin wax), and that is because the intermittent effect of the falling solar radiating impact on Paraffin through the glass (absorbing thermal energy from reaching solar radiation on the surface of the Paraffin) and in turn, leads to change its phase gradually (phase change) from the solid state to liquid state (storing a potential energy) and therefore a reverse transferring occurred in the direction of the energy from outside to inside (adding heating load in the room), therefore the design temperature (at 32 °C) inside the room will be semi-stable which it means reducing energy consumption inside the room. Following it in less energy consumption the pattern (R4) which has a high thermal isolation of Styrofoam, and after it the pattern (R1), but the highest energy consumption is the pattern (R3) because of the highly thermal loss through packaging material (Ceramic facade) which have a very high thermal conductivity.

Figures (10, 11, and 12) illustrate the relation between time in each hour (from nine am until five afternoons) and the consuming energy (watt per hour) inside the five design rooms (R1, R2, R3, R4, R5) and in the same operating condition, time of the study was during (cloudy day, rainy day, snowy day). Through the practical experiments we noticed that the less energy consuming is the pattern (R5) because of the effect of thermal energy transferred in conduction manner from the heat source inside the design rooms through the Aluminum on the packaging suggested material (Paraffin wax) and therefore, the Paraffin wax gradually turning in from the solid phase to the liquid phase, and after changing his phase to a liquid it started to inform an adjacent thermal layer adjoined to the Paraffin wax for inside (Aluminum layer side) and which acts as an isolating layer prevent heat transferring from inside toward paraffin wax, and then the temperature inside the design rooms then stabilize at (32 °C), following it the less energy consumption the pattern (R4) because of the high thermal

isolation of the Styrofoam following the Styrofoam the pattern (R2) and for the same mention reason in fig (2) , following it the pattern (R1), but the more energy consumption is the pattern (R3) because of the high thermal loss through packaging material (Ceramic facade).

6 Conclusions and recommendations

Through the results which were obtained, we concluded the followings:

1. It was noticed through analyzing the results that using the suggested materials (Paraffin wax) from the view of reducing energy consumption it exceeds some of the classical packaging materials, it is noticed that the consuming energy for each room of the five rooms along five days in a different environmental circumstances and uneven(sunny day, cloudy day, partial cloudy day, rainy day, snowy day)and the results as following: for the room(R1) which was included by Limestone as a packaging material , the consuming energy was (57453 watt per hr) for the room (R2) which included (Granit stone) as a packaging material, the consumed energy was rated to (566397 watt per hr), for the room (R3) which was the Ceramic the facade was as a packaging material the consuming energy was (55853 watt per hr) for the room (R4) which was packed with (Styrofoam facade core) the consuming energy reached (52351watt per hour), but for the room (R5) which was the (paraffin wax) as a packaging material the consumed energy reached (50140 watts per hr)

2. It was noticed also the using the suggested and classical packaging materials are help to reducing the thermal loose the exterior walls (reducing the missing thermal energy) and therefore reducing the consumption (saving) energy the consuming energy inside the comfort zone.

3. The possibility of using two phase material (Paraffin wax) as an isolated material inside the walls for areas and structure.

4. We can observe, that through the practical results there are some of the packaging materials for the exterior wall like Granit stone is very suitable for use in winter and cold areas because it added a thermal load for the comfort zone attributed to his ability for storing energy. Therefor we advise not to utilize it in the hot regions which are exposed to sunlight because it will add in the summer a heat load to the comfort zone.

5. It is advised to use Paraffin wax within the walls (which it means not exposed to the sunlight and the outside climate environmental condition), for using the paraffin was in energy storing at the time of loads and rejected them to the surrounding area in shadow and night times, and also it can be used for thermal isolation.

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Fig.1. Test station

Fig. 5. Suggested material / R5

Fig. 6. Control and measurement unit

Fig. 2. Testing rooms

Fig. 3 Southern wall (sixth)

R1

R2

R3

R4

Fig.4 Classical packaging materials

Table (1) the values of thermal conductivity (sources and previous research & during the laboratory test.)

packaging materials for exterior walls	Thermal conductivity which is trusty in the sources and previous research ($W/m \cdot ^\circ C$)	Thermal conductivity during the laboratory test
Limestone	1,3	1
Granit stone	3	2
Ceramic	1	1.2
Styrofoam	0,033	0.025

Table (2) indicated values of the overall heat transfer coefficient and Heat dissipation through wall in process of study (sixth wall)

No	Type wall	Overall heat transfer coefficient ($W/m^2 \cdot ^\circ C$)	Heat dissipation through wall in process of study (W)
1	Model R_0 without packaging materials for exterior walls (a wall of Aluminum with thickness 0.9 mm)	7.3	49.6
2	Model R_1 with packaging materials for exterior walls (+ wall of Aluminum with thickness 0.9 mm+ wall of Limestone 5 cm)	5.37	36.29
3	Model R_2 with packaging materials for exterior walls(wall of Aluminum with thickness 0.9 mm + wall of Granit stone 2 cm)	6.84	46.23
4	Model R_3 with packaging materials for exterior walls(wall of Aluminum with thickness 0.9 mm+ wall of Ceramic 1 cm)	6.92	46.76
5	Model R_4 with packaging materials for exterior walls(wall of Aluminum with thickness 0.9 mm+ wall of Styrofoam 4 cm)	0.71	4.74
6	Model R_5 with packaging materials for exterior walls (wall of Aluminum with thickness 0.9 mm+ wall of Paraffin wax 2 cm + wall of transparent glass 4 mm)	3.64	24.59

Fig.7. Energy consumption inside the comfort zone for the six patterns

Fig.8. Relation between the time for each hour and energy consumed for a fifth patterns in a sunny day

Fig.9. Relation between the time for each hour and energy consumed for a fifth patterns in a partially cloudy day

Fig.10. Relation between the time for each hour and energy consumed for a fifth patterns in a cloudy day

Fig.11. Relation between the time for each hour and energy consumed for a fifth patterns in a rainy day

Fig. 12. Relation between the time for each hour and energy consumed for a fifth patterns in a snowy day