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# Investigation of Natural Heating of buildings by Solar Chimney at Various Solar Heating Cases

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**Abstract:** The use of traditional energy becomes more costly and causes pollution for the environment. Nowadays, the whole world thinking about using renewable energy instead of traditional energy. In this work an experimental study has been conducted to study the use of solar energy in heating the buildings by the aid of a solar chimney. The solar chimney was installed with and without using of storing material. The storage material is used in order to store energy for heating purposes during sun shining and after sun set. The study indicates that the temperature inside buildings could be kept higher than the ambient air temperature during the day as well as during the night for many hours. This leads to decrease the demand of classical energy and consequently decreases the cost. The results indicated a decrease in monthly costs of energy use by about 26.73$ per cubic meter in the case of using chimney without storing material and about 60.11$ per cubic meter in the case of use solar chimney with storing materials.

**Keywords:** Natural heating, solar chimney, Storing materials.

## 1. Introduction

There are many things that call for thinking about the use of new and renewable energy. Among these matters is the increase of population and also reducing the use of petroleum products, whether in homes, schools, industry agriculture, as well as animal production and transportation, i.e. in all our lives. The use of petroleum products in these areas increases the cost and also air pollution. All of these things invite us to think about using energy that is less costly and also does not cause air pollution. The heating process in winter months and with the extreme cold needs large quantities of thermal energy. The production of this thermal energy requires very large amounts of non-renewable energy such as electricity, oil and natural gas. The high prices of these traditional energy sources and there uses in various fields tends to think about using a new and renewable energy alternative to this energy. One of the forms of renewable energy is solar energy. It is possible to use solar energy to produce thermal energy and use it in various fields. Therefore, this problem was addressed to find a solution to reduce the use of non-renewable energy and replace it with the use of renewable energy to provide very large quantities of petroleum materials.

Many researches have been studied in this field. Nadia et al [1] conducted experimental and theoretical study on the air flow in solar chimneys. The study was conducted to determine the effect of the tilt angle on the performance of the solar chimney in the state of Ouargla, Algeria. Ngala, et al [2] reviewed the energy technology of the solar chimney and its potential in the semi-arid region of Nigeria, describing the details of solar chimney. The review included the case of empirical and theoretical study, as well as the economics of using solar chimney. Thermal performance of solar chimneys used for heating with phase change materials using CFD simulation was studied by Safari and Torabi [3]. The study was conducted in order to provide constant temperature and air flow rate for the guard room. The simulation was performed for a full day in the winter with/without the use of phase change material. The results showed that using phase change material as an energy storage device greatly enhances the stability of the room temperature. Experimental and numerical study of the performance of a full-scale solar chimney in a real building in Eastern China was conducted by Xinyu et al [4]. It was indicated that solar chimney is an effective approach to save energy for residential buildings in transition seasons in hot summer and cold winter area in China.

Miqdam et al [5] indicated that dust suspended in the air and pollutants deposition affect the performance of the solar chimney as it decrease the solar radiation incidents on the chimney. The effect of using solar chimney on the amount of energy used for heating was studied by Danesh [6]. The interior temperature of the building equipped with solar chimney and without mechanical heating systems was measured to be 22 °C. Ong and Chow [7] proposed a mathematical model of solar chimney to predict its performance under varying ambient and geometrical features. The temperature of the glass glazing and heat absorbing wall as well as the temperature and velocity of the induced air flow in the chimney were predicted. Experiments were carried out outdoors on the roof and the experimental model exposed to both direct and diffuse solar radiation. A prototype of solar chimney with heat storage system for ventilation was designed and developed by Sharma et al [8]. Sodium Sulfate Dec hydrate "$Na_2SO_4.10H_2O$" was used as a storage material. Experiments have been carried out with 45° inclination angle of solar chimney. The results indicated that integration of phase change storage material inside the solar chimney is positive and supply the constant airflow rate. Hans and Jochen [9] studied the heating and cooling of buildings using solar collectors for a hotel to save the use of classical energy. They studied the heating demand and the required collector area. The energy saved per collector area was presented. A two-dimensional numerical investigation on a prototypal solar chimney system integrated with an absorbing capacity wall in a south facade of a building is presented by Bernardo et al [10]. In that study, the capacity wall was composed of a high absorbing plate and an assigned thickness of phase change material. The chimney consisted of a converging channel with one vertical absorbing wall and the glass plate inclined of 2° with respect to the vertical. It was shown that the temperature increase of phase change material is independent of the radiant energy and phase change material. The absorption of energy by the phase change material is enough in hot hours then returns it in the cold hours.

From the previous study it can be noticed that these studies were focused on the variation of temperature in the solar chimney and the study of heating the interior of building has no attention. The study of heating buildings is limited. In this work, the study of heat the buildings by solar chimney is concerned. The temperature changes inside building by solar radiation which reflected on save climate was studied. Also, economical study of using solar chimney for heating buildings was concerned.

## 2. Experimental setup

The experimental setup that used for studying the heating of buildings by solar energy is shown in Fig. (1). It consists of a room with outside dimensions (1.8×1.8×2 m). All sides and ceiling are made of wood with 15 mm thickness. The ground is made of reinforced concrete. The room is divided into three equal and similar small rooms using two wooden walls of 15 mm thickness, as shown in Fig. (1). Each room has a door with dimensions (0.6×1.2 m), as shown in the figure.

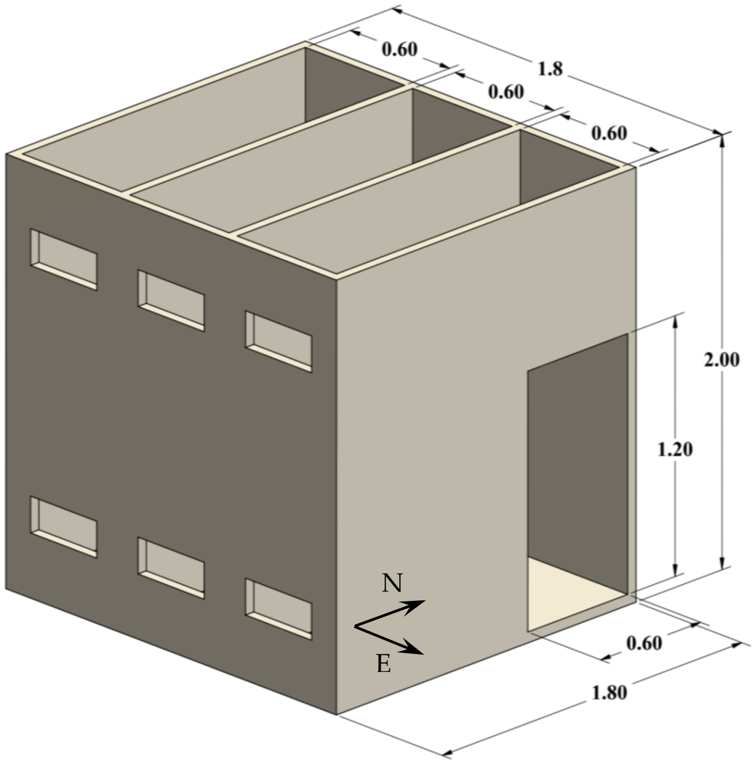


Fig. (1) Tested rooms

The three rooms have internal dimensions of (2×1.8×0.58 m). Each room has in the tribal direction two openings of dimensions (0.33×0.23 m). The first is at a height of 0.5 m measured from the bottom. The second opening is at 0.2 m measured from the ceiling, as shown in Fig. (2).

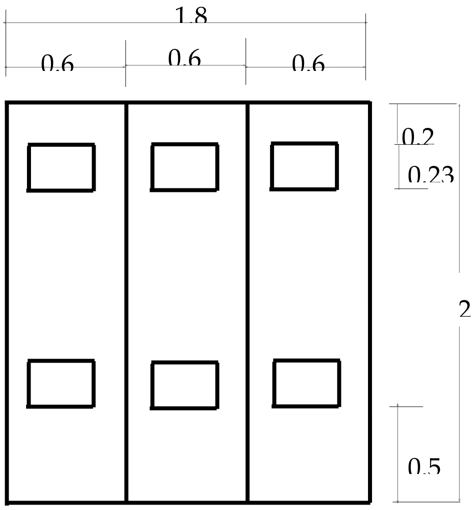


Fig. (2) Vertical section from south direction

An air duct, of cross section area 0.33×0.23 m, and length 1.27 m is installed on the lower opening. All sides of the duct are made of wood with a thickness of 15 mm. Another air duct with the same cross section area and a length of 0.2 m is installed on the upper opening. All sides of this duct were made of wood, whose thickness is 15 mm as shown in Fig. (3).

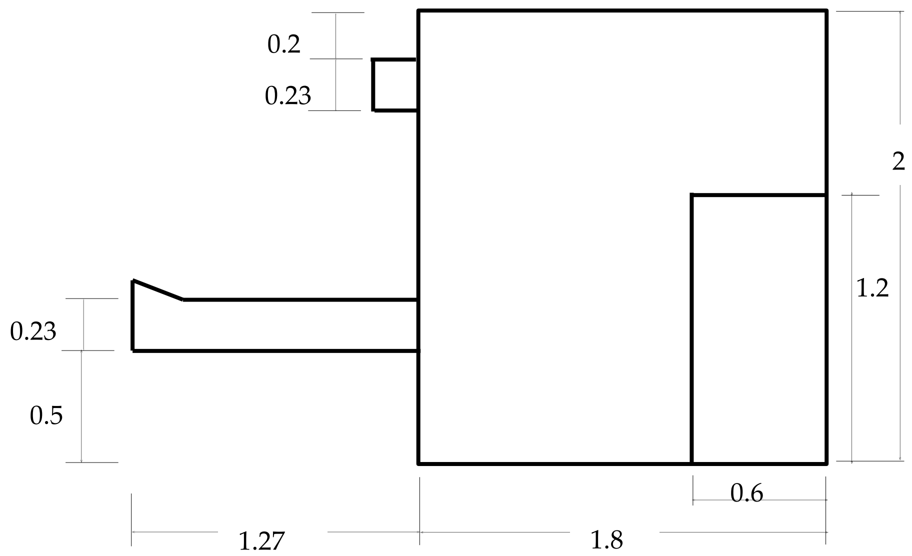


Fig. (3) Sectional side view before chimney installation

A solar chimney was installed between the lower and the upper ducts with inclination angle of 45º with respect to horizontal direction, as shown in Fig. (4). The inclination angle was chosen to be 45º as the optimum thermal pulling is reached at this angle [1]. The figure illustrates an elevation section from the east direction. The solar chimney, Fig. (5), is in the form of a parallelogram with internal dimensions of (0.2×0.3×1.1 m). The bottom side "base" of the chimney was made of wood while the other three sides were made of glass with 6 mm thickness. The base of the chimney was painted with black paint in order to increase the rate of heat absorption. A tank of outside dimensions 1×0.3×0.015 m was fabricated from rust-resistant iron of thickness 1.5 mm. It has an open side at the top with dimensions 0.3×0.015 m. This opening was closed after filling the tank with the absorption materials. The tank was installed on the base of the chimney. It was fully painted with black material in order to increase its absorption capability. The tank was filled with different materials for storing heat. These materials were chosen from two solid materials and three fluids. The aim of using these materials was to store heat during the sun rises and restore this energy at clouded times and after sunset. The duct was closed after placing the storage material. The inner sides of the three rooms were isolated from the inside, as well as the base of the solar chimney, using glass wool.

A tank of dimension 0.29×1×0.015 m was installed in the chimney at a distance of 0.1 m from the two sides of the chimney. The tank was made of rust resistance iron plate of thickness 1.5 mm. It was filled with storage material and then closed.

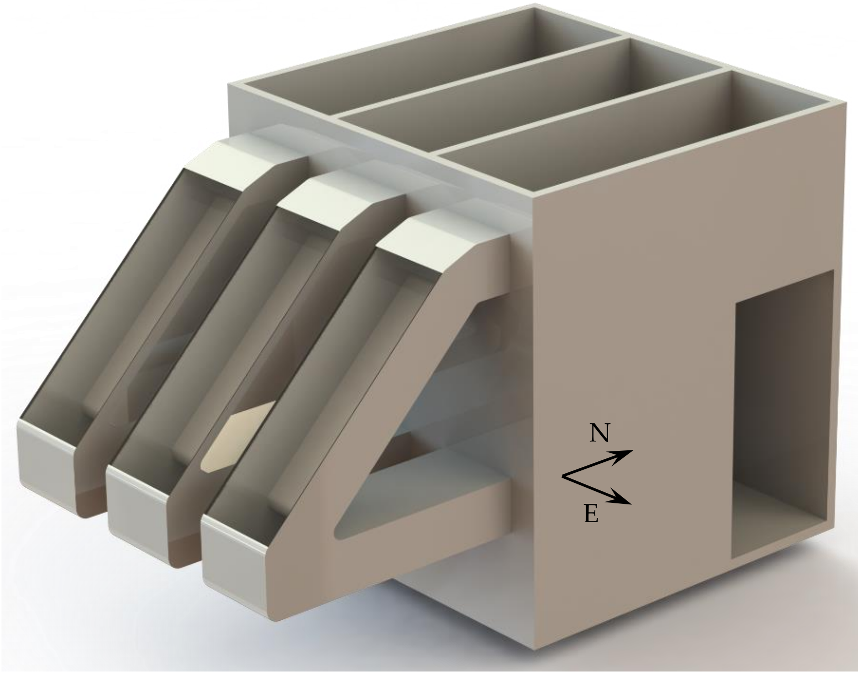


Figure (4) schematic diagram of the isometric of the chimneys

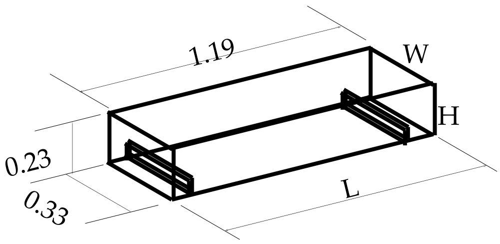


Fig. (5), Solar chimney dimensions

## 3 Experimental Measurements

The outside ambient air temperature was measured and recorded for each experiment. Besides, the temperature was measured at 9 points, distributed at equal dimensions, in each room as indicated in Fig. (6). The temperature in each duct as well as at two points on the chimney was also measured. The temperatures were measured at all mentioned points every half an hour for a period of 12 hours using copper-constantan thermocouples. The readings and the results were recorded and compared. The measurements were carried out with a calibrated copper-constantan thermocouples connected through multi points selecting switch to a digital temperature indicator as shown in Figs. (7 and 8).

The air velocity was measured inside duct. The velocity was measured using portable hotwire, Fig. (9), of accuracy 0.001 m/s. The measuring of both temperature and velocity was taken every half an hour during 12 hours. The readings were recorded. EPPLEY PSP Pyrometer, Fig. (10), was used for measuring the solar intensity per unit area [W/m$^2$].

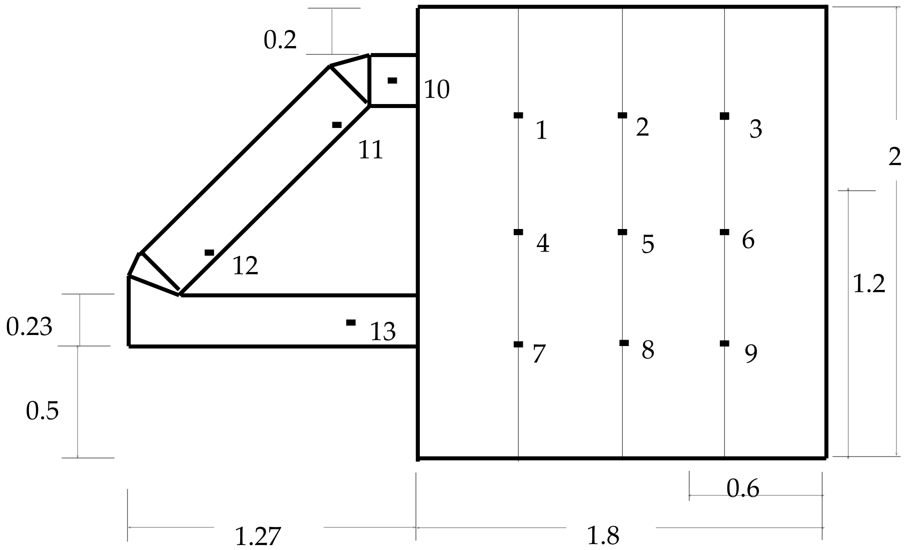

Fig. (6) Temperature measurement points for north direction section


Fig. (7) The selecting switch

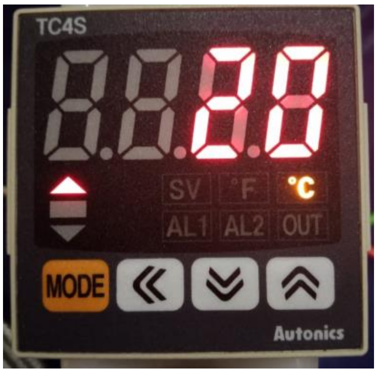

Fig. (8) The temperature indicator


Fig. (9) Hot wire anemometer


Fig. (10) Pyrometer

Four experiments were carried out as follows:

**The first experiment**

In the first room, a solar chimney was installed without fluid or storage material. The second room is without a solar chimney and the lower and upper ducts were closed. In the third room, a solar chimney was installed with water with an amount of 5.25 kg as storage fluid.

**Second experiment**

In the first room, the solar chimney was installed and equipped with small pebbles as storage material. In the second room, a solar chimney was installed with copper tube pieces as storage material. In the third chamber, a solar chimney was installed with water as storage fluid. Equal amounts of the storage materials, 5.25 kg, were used.

**The third experiment**

In the first room, a solar chimney was filled with auto oil as a storage fluid while the second chamber solar chimney was filled with Gela Cole. In the third chamber of the solar chimney water was used as storage fluid. Equal amounts of 5.25 kg were selected.

**Fourth experiment**

In the fourth experiment water was used for all chimneys as storage material with different amounts of 1.05, 3.15 and 5.25 kg respectively.

## 4. Results and Discussions

The heat transfer through the solar chimney for heating is affected, in general, by many factors such as the type of storage material, its quantity and the intensity of sunlight. The main objective of this work is to study the ability of saving energy during the sun shining and restore it at night or clouded day in order to heat residential buildings, factories, farms, office facilities and industries. This tends to decrease the use of traditional energy for heating. Also, the heating capacity of the required air handling units increases in winter. To overcome this problem, solar chimneys can be installed in the previously mentioned places, and benefit from the largest amount of solar energy, whether during the day or in the early hours of the night after sunset, in natural ventilation or heating, thus reducing the consumption of electrical energy or non-renewable energies. The main purpose and the desired goal are to reduce the consumption of non-renewable energies and to exploit renewable energy instead of excluding possible exploitation.

In this work, the factors affecting temperature rise and solar chimney efficiency are studied. These parameters may be the outside air temperature (intensity of sunlight), the presence or absence of a solar chimney, the presence or absence of storage material, types of storage material and its amount. The air temperature inside the chimney and the room changes depending on the weather, the type and amount of storage material. The results obtained in different cases were compared.

The difference in indoor and outdoor air temperature is illustrated by the solar chimney. The test sections differ from each other according to the presence or absence of a solar chimney, the type and quantities of storage material inside the chimney.

**4. 1 Effect of Using Solar Chimney with and without Storing Fluid on Room temperature:**

In this case, a room without a solar chimney, a room with a solar chimney without storage, a room with a solar chimney equipped with a storage fluid, which is 5.25 kg of water. The temperature inside the three rooms was measured at nine points inside each room where the mean value was obtained. Figure (11) indicates the change in the indoor mean air temperature for the three rooms with the change in the ambient air temperature (intensity of sunlight) over 12-hours period with 30 min test interval. It can be seen from this figure that, the inside room temperature without chimney is higher than the ambient temperature. When a chimney is installed, more increase of the temperature is observed. Nearly sudden increase is observed at early hours of the day. During noon period the temperature is nearly stable at higher values except the time where there was cloud or winds. After noon, the inside temperature decreases again because of the decrease of sunset light. When storing fluid is used, the inside room temperature is lower than that of chimney without storing fluid in early hours. This is because of the heat absorbed by fluid. In the afternoon, the storing heat by the fluid liberated again and leads to increase the inside room temperature.

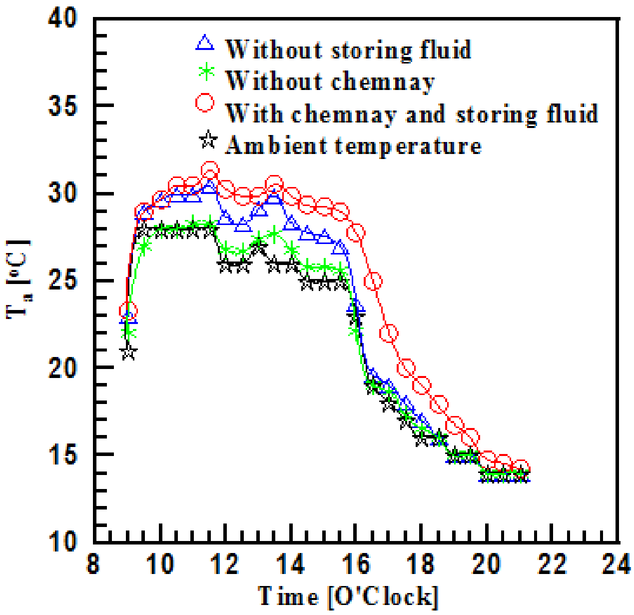


Fig. (11) Variation of the temperature inside the room through 12 hrs

**4. 2 Effect of Using Solar Chimney with and without Storing Fluid on the surface temperature of the chimney:**

Figures (12) and (13) represent the surface temperature of the heat-absorbing surface for the second and third rooms (points 11 and 12) during 12 hours test period and compared with the ambient air temperature. On the other hand the ambient air temperature is affected by the intensity of sunrays. It is seen that, the temperature variation of the chimney is higher than the ambient air temperature in the two cases with and without storing fluid. For the case of no storing fluid, the temperature is higher than that with storing fluid. This because of the heat absorbed. A drop of the temperature is observed between 11:30 to 13:30 because of clouds.

**4. 3 Effect of Using Solar Chimney with and without Storing Fluid on the air temperature at inlet and outlet way of the rooms:**

Figures (14) to (15) refer to the change in the air temperature inside the upper airway (point 10), lower airway (point 13) and also compared with the ambient air temperature (intensity of sunlight) over a 12-hours period for the second and third rooms. It is clear seen that the temperature rises at all points with the rise in the external temperature (the intensity of the sun's rays) in the second and third rooms approaching with each other during the day from saving a quantity of heat energy during the day and then utilizing it after sunset. Figure (15) represents the temperature at room outlet and chimney inlet. The air temperature is higher in the case of storing fluids than that without storing fluid due to the stored heat.

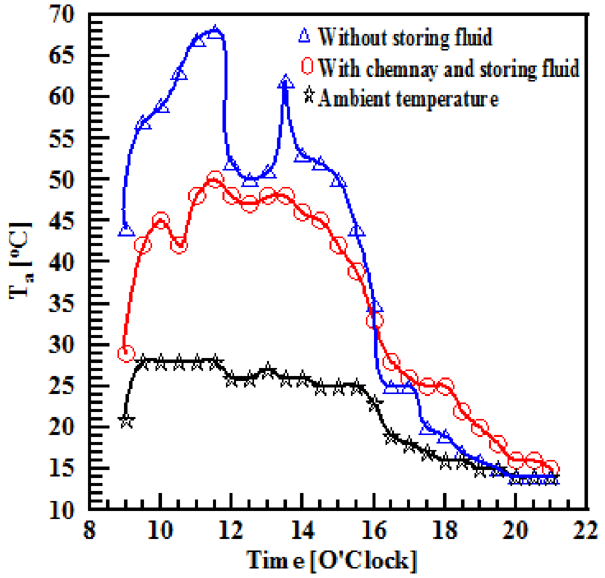


Fig. (12) Variation of the temperature at the chimney high level (point 11) through 12 hours

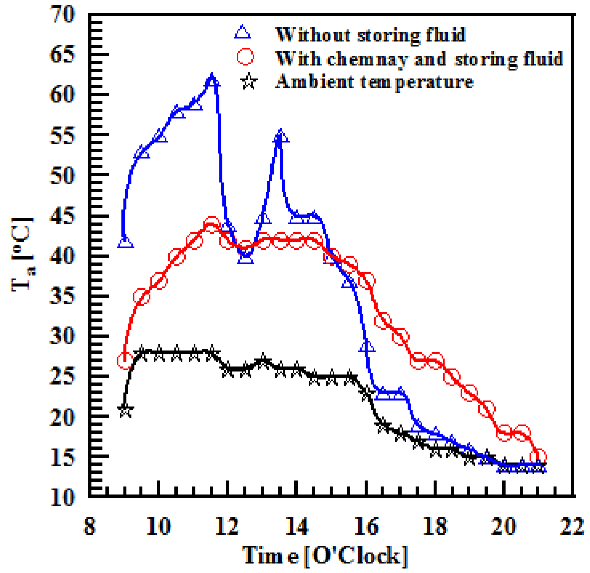


Fig. (13) Variation of the temperature at the chimney at high level (point 12) through 12 hours

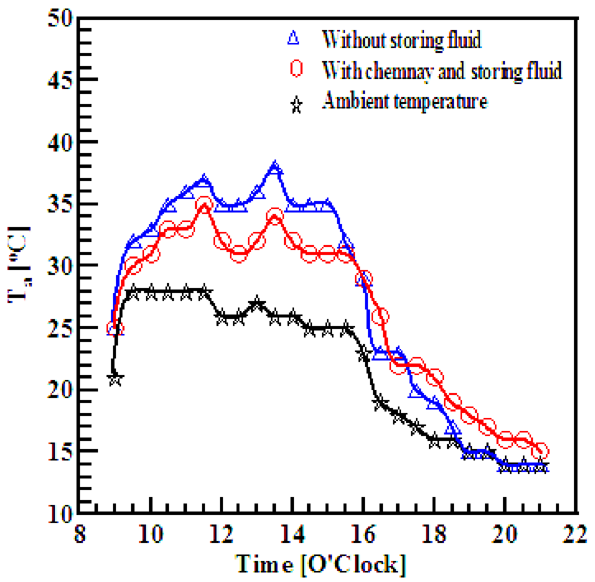


Fig. (14) Variation of the temperature at room inlet (point 10) through 12 hours

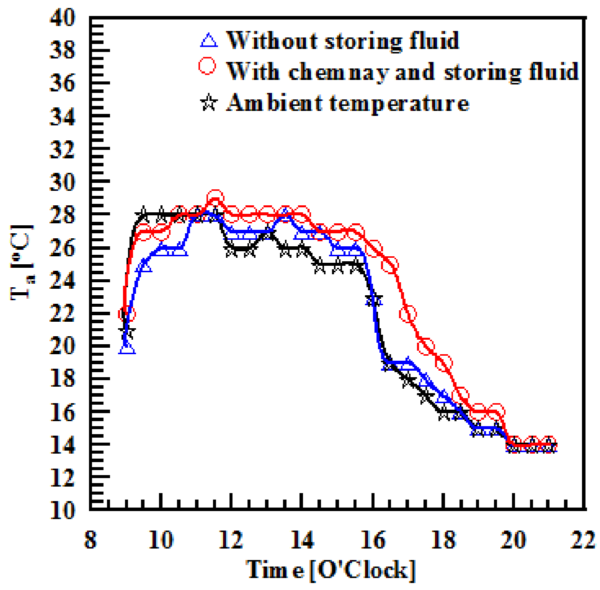


Fig. (15) Variation of the temperature at room outlet (point 13) through 12 hours

**4.4 Effect of Using Solar Chimney with Different Storing Materials on the Room Temperature:**

From the first experiment, it is clear seen that the presence of a solar chimney equipped with a storage material is the best and has a positive result. Therefore, the second experiment was carried out to compare between different storing materials. In this case, the first room with a solar chimney equipped with small pieces of pebbles. In the second room, the solar chimney is equipped with small pieces of copper tubes. In the third room the solar chimney is supplied with water. All storage materials are equal in masses (5.25 kg) in order to determine the preference of solar chimney with these materials. The difference in indoor air temperature and outdoor air temperature is illustrated.

Figure (16) indicates the change in the average indoor air temperature for the three rooms with the change in the ambient air temperature (intensity of sunlight) over a 12-hour period. It is indicated that the indoor air temperature is nearly high for the case of using water as a storing material. The other two cases indicate nearly similar indoor temperature for pebbles and copper as storing materials.

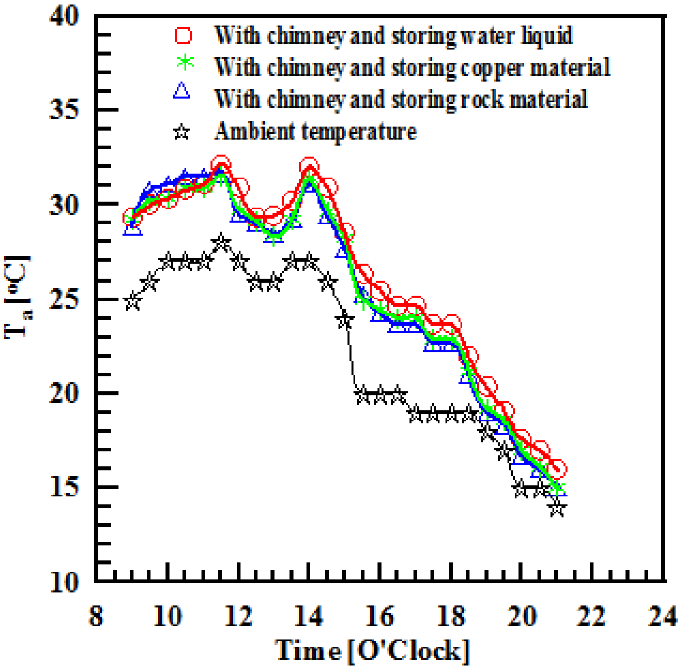


Fig. (16) Variation of indoor temperature for different storing materials

Figures (17 to 20) refer to the change in the air temperature at four sections: inside the upper airway, upper and lower of the heat-absorbing surface and finally at the lower airway. The measurements were conducted for the three rooms at the test period between 9:00 and 21:00 O'clock. It becomes clear that the temperature rises at all points with the rise in the ambient air temperature in the three rooms approaching each other during the day. However, in the case of clouds or sunsets, the third room, which capable of water as a storing material, is the best and the temperature remains relatively high after sunset than the other two rooms for a longer period. This is may be because of the high ability of liquid materials to retain a quantity of heat energy during the day and then benefit from it after sunset**.**

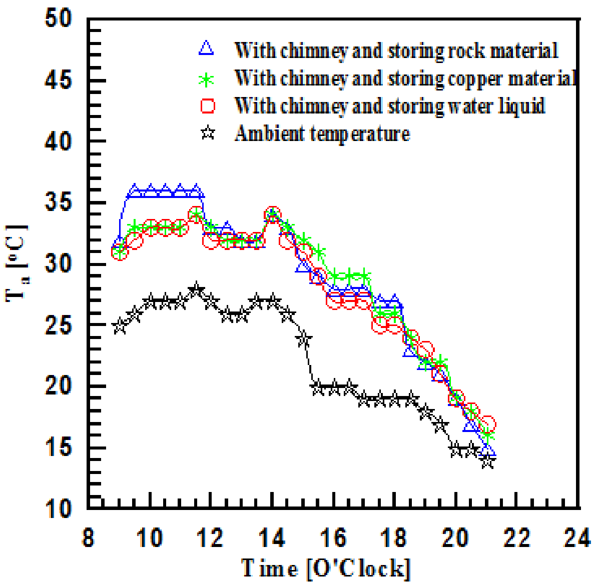


Fig. (17) Variation of the temperature at room inlet (point 10) for different storing materials

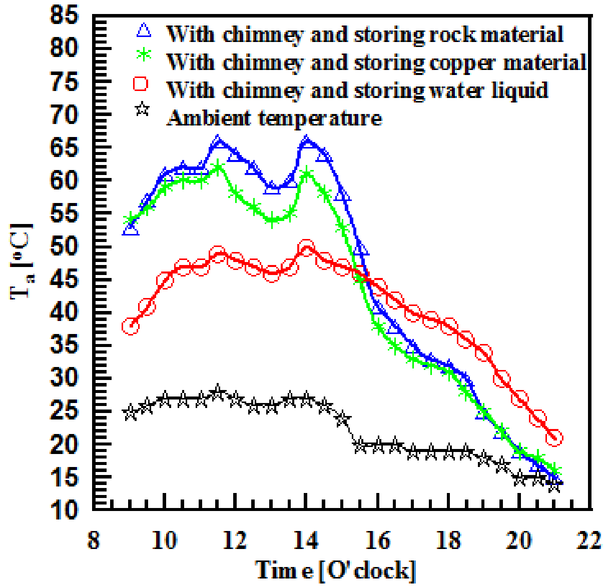


Fig. (18) Variation of the temperature at the upper of the chimney (point 11) for different storing materials

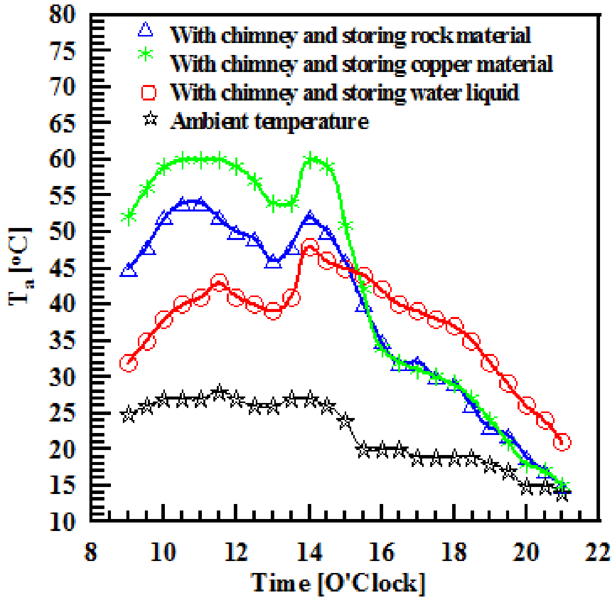


Fig. (19) Variation of the temperature at the lower of the chimney (point 12) for different storing materials

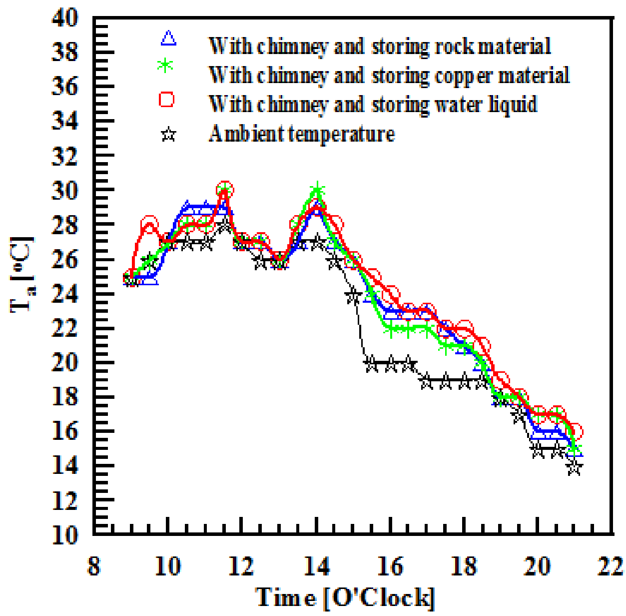


Fig. (20) Variation of the temperature at the room outlet of chimney (point 13) for different storing materials

From the second experiment, it is clear that the presence of a solar chimney equipped with a liquid storage material is the best and has a positive result. Therefore, the third experiment was conducted to compare the effect of using some types of liquid materials keeping the same mass of the all at 5.25 kg. The chosen materials are water, gel cooler and oil. The first room was submitted with a solar chimney equipped with water. In the second room, the chimney was equipped with gel-cooler. In the third room, the chimney was equipped with oil. The difference in indoor air temperature and outdoor air temperature is illustrated by the solar chimney. Figure (21) indicates the change in the average indoor air temperature for the three rooms with the change in the ambient air temperature (intensity of sunlight) over a 12-hour period. It is clearly seen that all storing fluids provide the same result of indoor temperature. This leads to say that water is preferred than the other because of its low cost and low problems.

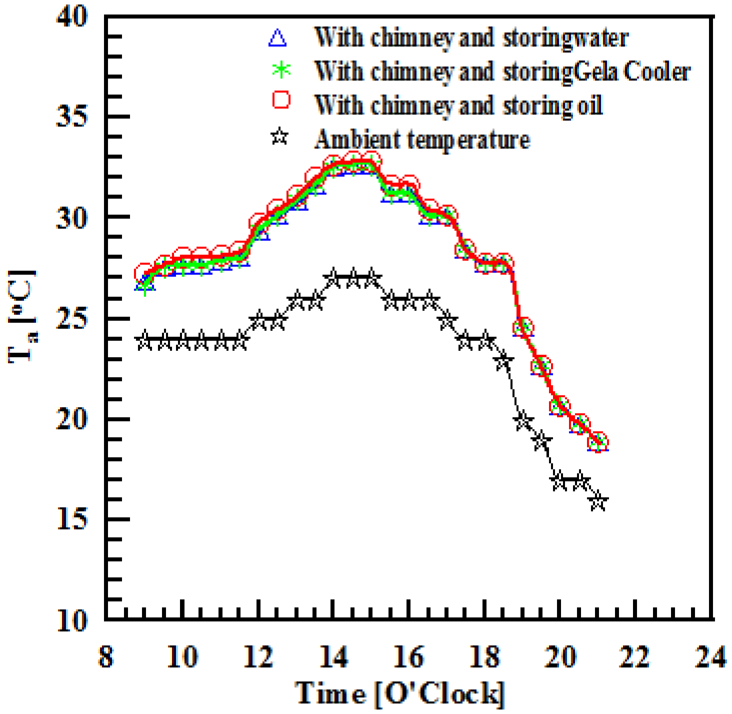


Fig. (21) Variation of the temperature inside the room through 12 hrs

Figures (4-22) to (4-25) present the change in the air temperature inside the upper airway, the lower airway and the temperature at two points on the heat-absorbing surface with the change of the ambient air temperature (intensity of sunlight) over a 12-hour period for the three rooms. It is clear that the temperature rises at all points with the increase in the external temperature (the intensity of the sun's rays) in the three rooms and nearly close to each other during the day. Also in the case of clouds or sunsets, the temperature remains relatively high after sunset in the three rooms for a period up to four hours.

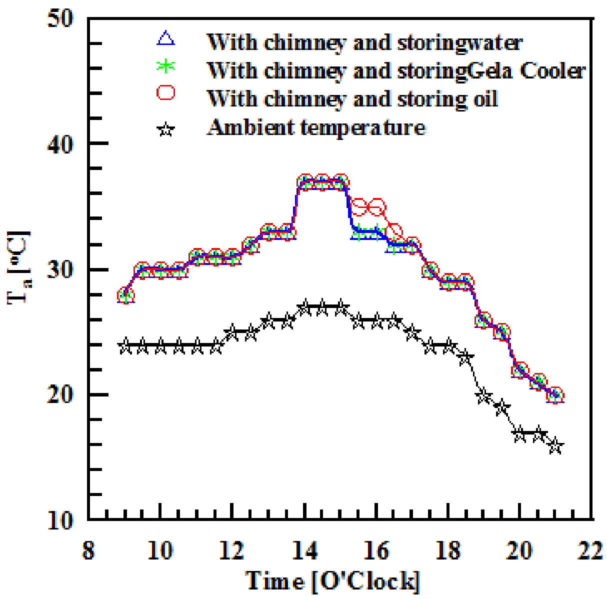


Fig. (22) Variation of the temperature at room inlet (point 10) through 12 hours

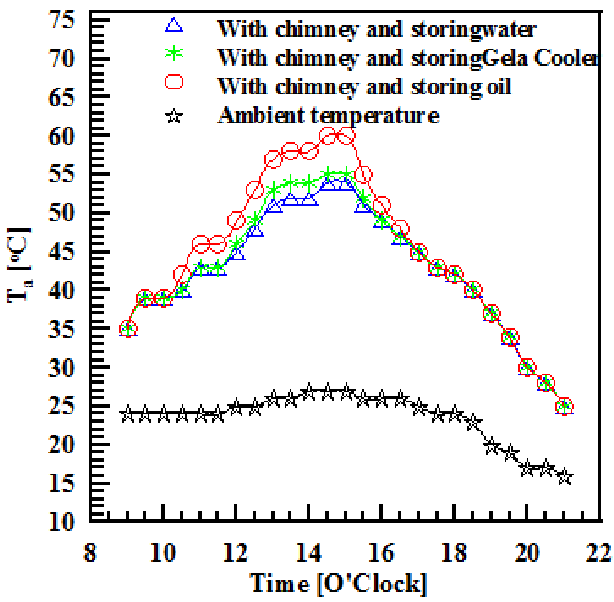


Fig. (23) Variation of the temperature at the chimney at high level (point 11)

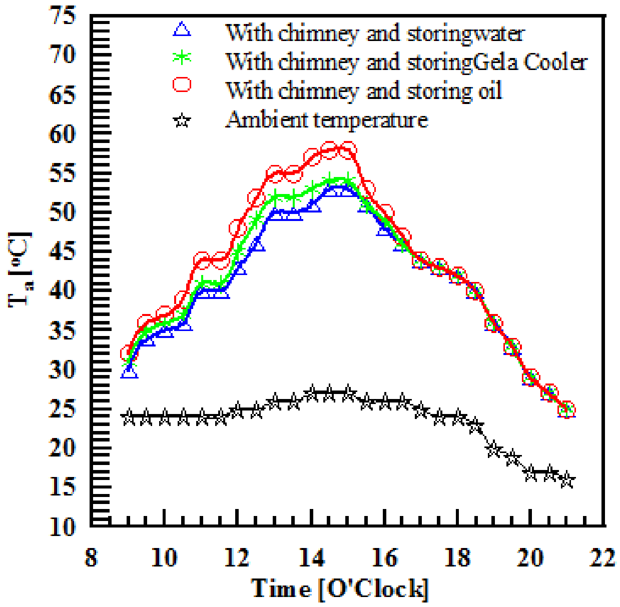


Fig. (24) Variation of the temperature at the chimney at high level (point 12)

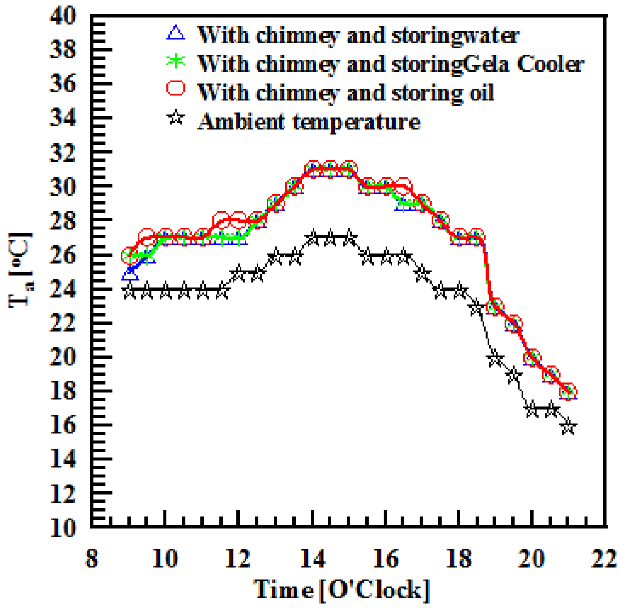


Fig. (25) Variation of the temperature at room outlet (point 13)

From the third experiment, it becomes clear that the presence of a solar chimney equipped with a liquid storage substance, water, gel cooler or oil, has a high ability to store large amounts of heat, which can be used in the event of sun clouds during the day and also benefit from it after sunset for the longest possible time to provide energy for heating the building. It was clear that the results were close to the three types of storing liquids, but water is considered the best in terms of low cost and its availability. One of the characteristics and properties of water is that it retains large amounts of heat and does not lose it quickly. On the contrary, oil acquires heat at a very high speed and also loses it at a high speed. Therefore, the third experiment was conducted to find out the effect of the amount of material used to store heat on the performance of the chimney.

Now, a comparison is made between three quantities of water in order to determine the priority and compare their performance. The first room was equipped with a solar chimney with 1.05 kg of water. The second room was equipped with a solar chimney with 3.15 kg of water. The third room was equipped with a solar chimney with 5.25 kg of water. The difference in indoor and outdoor air temperature is illustrated by the solar chimney.

Figure (26) indicates the change in the average indoor air temperature with the change in the ambient air temperature (intensity of sunlight) over a 12-hour period. Low difference in temperature is observed. The chimney that supplied with 5.25 kg of water maintained nearly the best case.

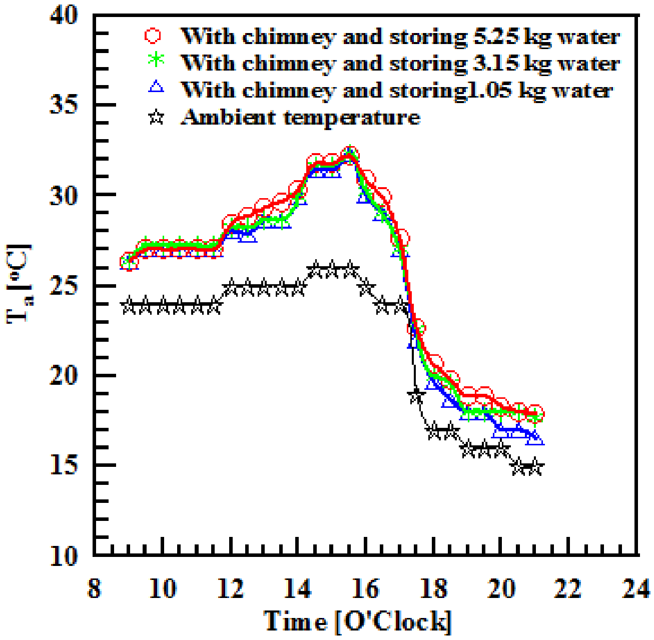


Fig. (26) Variation of the temperature inside the room through 12 hrs.

Figures (27) to (30) present the change in the air temperature at the upper airway, the temperature of the upper and lower of the heat-absorbing surface of the chimney and finally at the lower airway surface by changing the ambient air temperature (intensity of sunlight) over a 12-hour period for the three rooms. It is clear seen that the temperature rises at all points with the rise in the external temperature (the intensity of the sun's rays) in the three rooms approaching each other during the day, but in the case of clouds or sunsets, the temperature remains relatively high after sunset in the third rooms for a period of up to four hours. This indicates the positive effect of the amount of material used to store heat and retain a quantity of heat capacity during the day and then benefit from it after sunset.

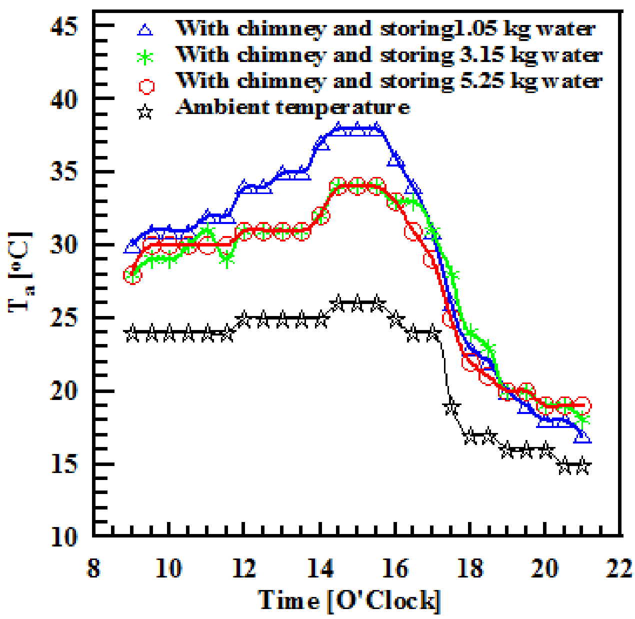


Fig. (27) Variation of the temperature at room inlet (point 10) through 12 hours

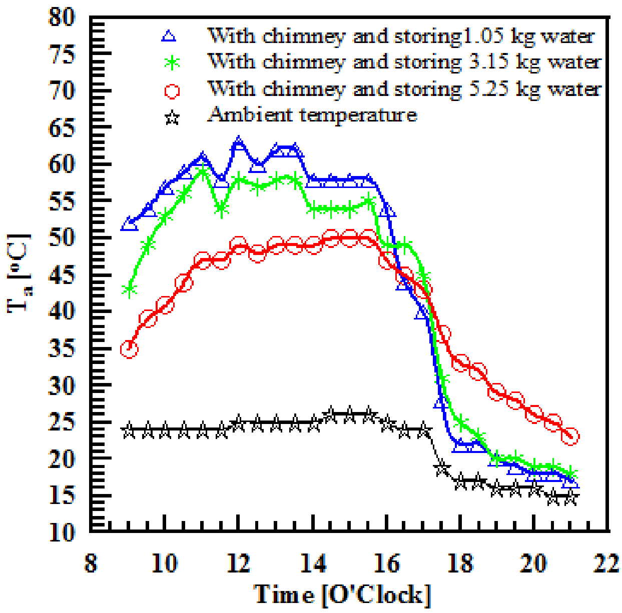


Fig. (28) Variation of the temperature at the chimney at high level (point 11) through 12 hours

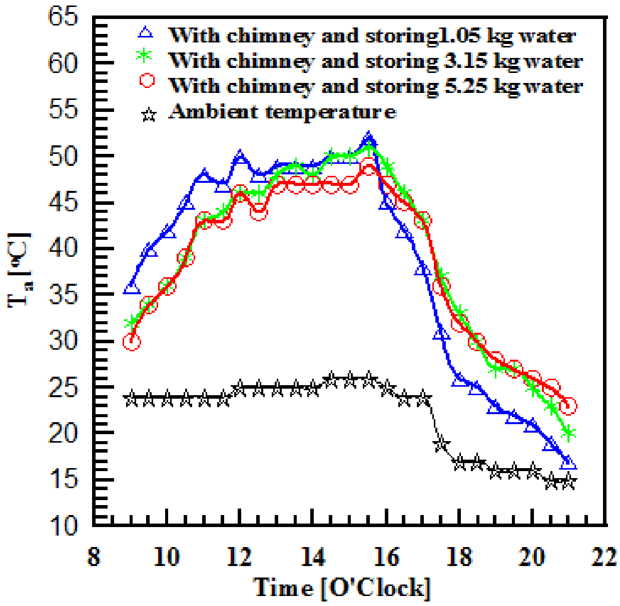


Fig. (29) Variation of the temperature at the chimney at high level (point 12) through 12 hours

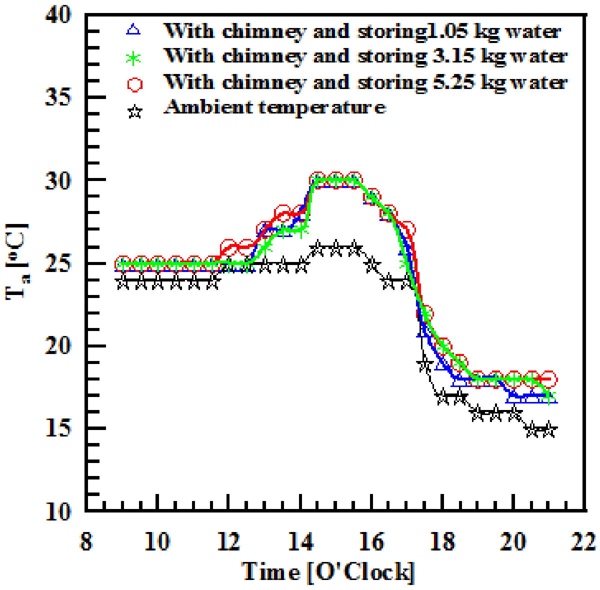


Fig. (30) Variation of the temperature at room outlet (point 13) through 12 hours

**4-5 Heat gained from the suns' rays and Efficiency of the solar chimney:**

The heat gained from solar radiation intensity per unit area was calculated. The air velocity was measured in the flue inlet stream. The cross-sectional area of the air flow through the solar chimney was calculated as:

$$A_1 = W \times H \quad (1)$$

The mass flow rate inside the solar chimney was calculated as:

$$\dot{m} = \rho A_1 V \quad (2)$$

The heat gained from the suns' rays in the solar chimney was calculated as:

$$\dot{Q} = \dot{m}\, Cp \Delta T \quad (3)$$

The efficiency of the solar chimney was calculated from Eq. (4):

$$\eta = \frac{\dot{Q}}{q_s A_2} \times 100 \quad (4)$$

Where: $q_s$ is the solar intensity per unit area and $A_2$ is the solar chimney surface area which calculated as:

$$A_2 = L \times W \quad (5)$$

The heat gained from the suns' rays in the solar chimney was calculated and compared in different cases. Figure (31) represents the heat gained from the suns' rays in the solar chimney with and without storing fluid. Water was chosen as a storing fluid. It is found that at the beginning of the day, the solar chimney without storage fluid is better till about 12:30 O'clock. This is because the heat gained is all directed to the air passing through the chimney. For the chimney with storage fluid, at the beginning of the day, the storing fluid absorbs some of the solar radiation that incidents upon the chimney surface and decreases the heat that transferred to the passing air. After 12:30 O'clock, the heat gained of the solar chimney with storing fluid is better due to the heat absorbed that restored and transferred to the air. It is clear from the figure that the heat gained from the suns' rays in the solar chimney with a storage fluid is nearly stable during the tested period of the day.

Figure (32) shows a comparison between the heat gained of storage materials in terms of their ability to retain an amount of heat throughout the day and benefit from it at the end of the day and after sunset. Water, copper and pebbles pieces were chosen as storing materials. During the period from 12:00 O'clock to 13:30 O'clock, the heat gained in the case of copper as a storing material is the best due to its good ability of storing heat. After that, water becomes the best during the last period of the day and after sunset. This is mean that water restore the heat gradually while solid material restores the heat in short time because of its good heat transfer characteristics.

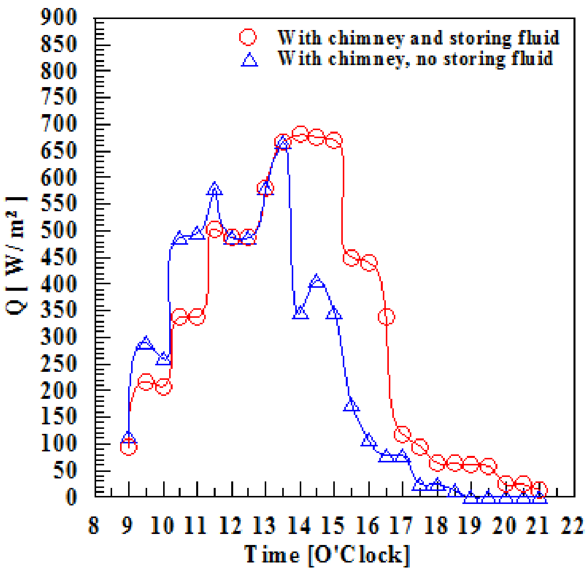


Fig. (31) Solar chimney heat gained with and without storing fluid

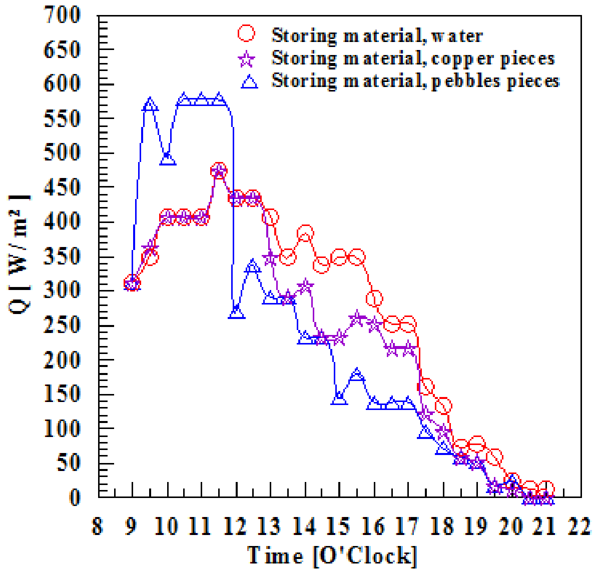


Fig. (32) Comparison of solar chimney heat gained between water, copper and pebbles

Figure (33) indicates the comparison of the heat gained for three liquid materials. Water, jelly cool and cars' oil. It is found that the efficiency of the solar chimney was close for the three chosen fluids. This means that water is preferred as it is available and cheap. Figure (34) presents the comparison between different amounts of water. It is found that the heat gained is nearly closed for all cases till about 15:00 O'clock after that small increase was observed with the increase of mass due to the amount of heat stored.

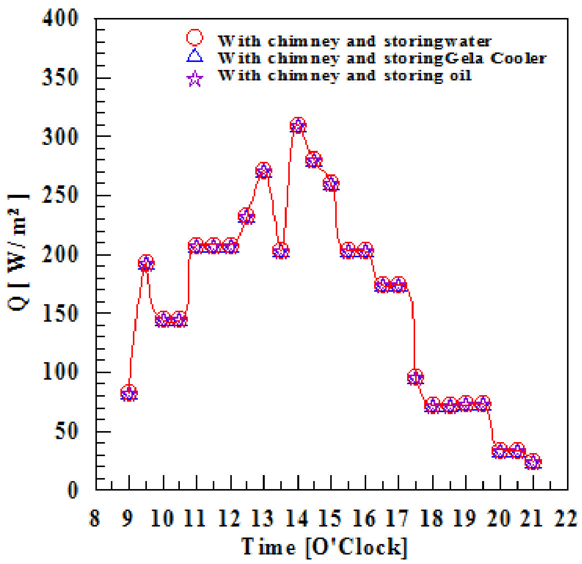


Fig. (33) Comparison of the heat gained of solar chimney for three fluids.

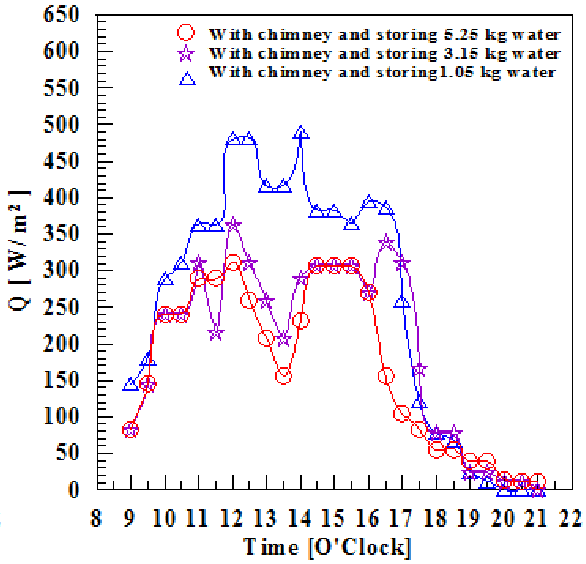


Fig. (34) Comparison of the heat gained of solar chimney for three masses of water.

**4-6 Efficiency of the solar chimney**

In order to know how much the solar chimney gained heat from the solar rays that incident upon it, the solar intensity is measured and the solar chimney efficiency was calculated. The efficiency of the solar chimney is the ratio between heat gained by the chimney to the amount of solar energy incident on the same area. Figure (35) represents the solar chimney efficiency with and without storing fluid. Water was chosen as a storing fluid. It is found that at the beginning of the day, the solar chimney without storage fluid is better tell about 12:30 O'clock. This is because the heat gained is all directed to the air passing through the chimney. For the chimney with storage fluid, at the beginning of the day, the storing fluid absorbs some of the solar radiation that incidents upon the chimney and decreases the heat that transferred to the passing air. After 12:30 O'clock, the efficiency of the solar chimney with storing fluid is better due to the heat absorbed that is restored and transferred to the air. It is clear from the figure that the efficiency of solar chimney with a storage fluid is nearly stable during the tested period of the day.

Figure (36) shows a comparison between the efficiency of storage materials in terms of their ability to retain an amount of heat throughout the day and benefit from it at the end of the day and after sunset. Water, copper and pebbles pieces were chosen as storing materials. During the period from 12:00 O'clock to 13:30 O'clock, the efficiency in the case of copper as a storing material is the best due to its good ability of storing heat. After that, water becomes the best during the last period of the day and after sunset. This is mean that water restore the heat gradually while solid material restores the heat in short time because its good heat transfer characteristics.

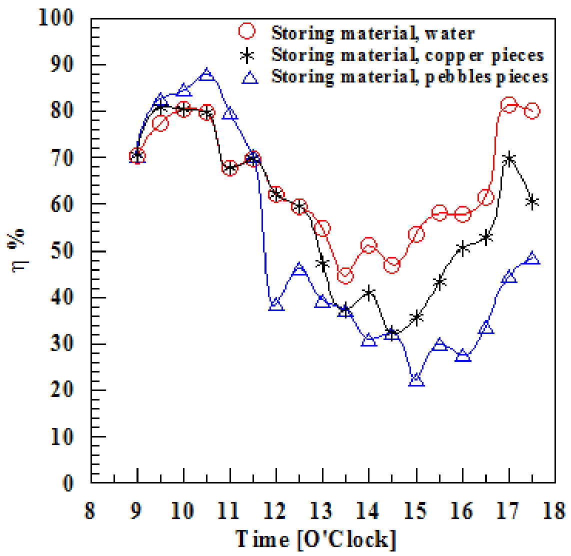


Fig. (35) Solar chimney efficiency with and without storing fluid.

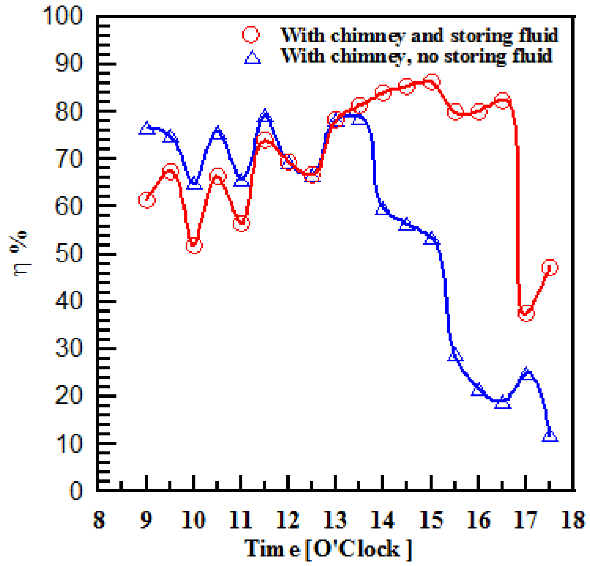


Fig. (36) Comparison of solar chimney efficiency between water, copper and pebbles

Figure (37) indicates the comparison of the efficiency for three liquid materials. Water, jelly cool and cars' oil. It is found efficiency of the solar chimney was close for the three chosen fluids. This means that water is preferred as it is available and cheap.

Figure (38) presents the comparison between different amounts of water. It is found that the efficiency is nearly closed for all cases tell about 15:00 O'clock after that small increase was observed with the increase of mass due to the amount of heat stored.

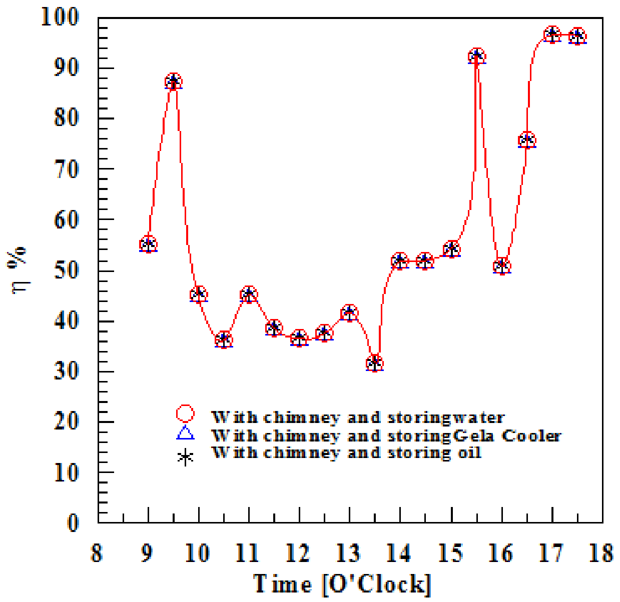


Fig. (37) Comparison of the efficiency of solar chimney for three fluids

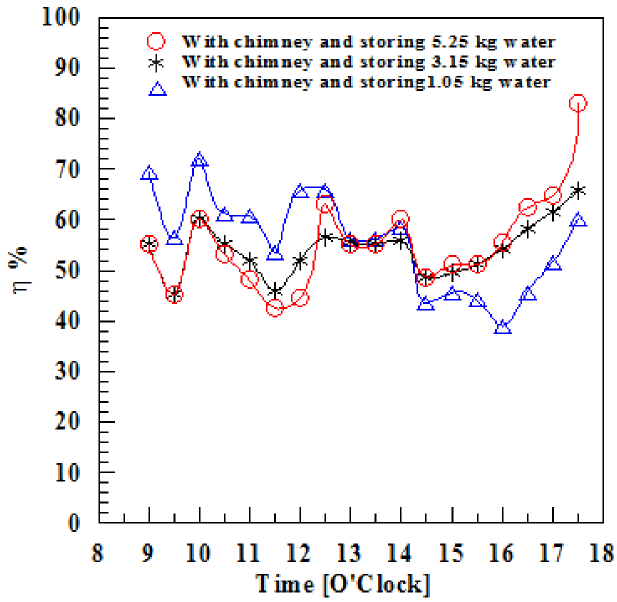


Fig. (38) Comparison of the efficiency of solar chimney for three masses of water

**4-7- Economical study**

To evaluate the importance of natural heating, the energy that supplied to the room per $m^3$ by chimney without and with water as a storing fluid is calculated. Water was chosen as the storing fluid because of its good results obtained. Besides, the cost of electric energy, if electric heating is applied to supply this amount of energy, is calculated. Then, the reduction of cost of energy could be obtained. Fig. (39) illustrates the saving in cost for the cases taking the first room that has no chimney as a reference.

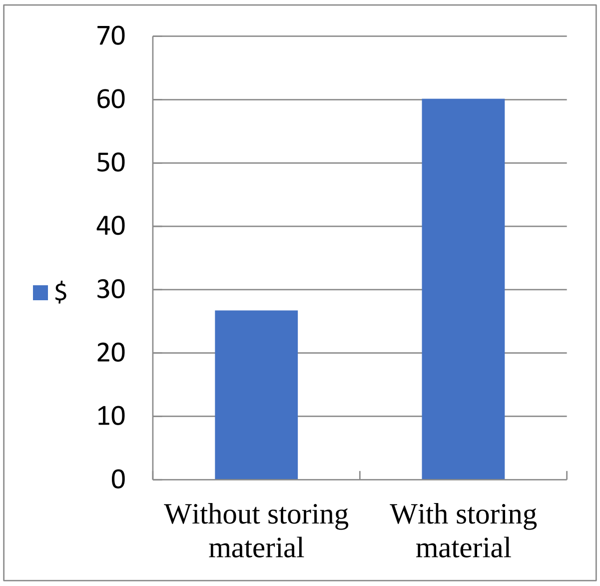


Fig. (39) Saving of the costs of energy supplied per unit volume of the room.

**5- Conclusions**

From the results obtained from this study of natural heating of buildings using solar chimney with and without storing materials, the following conclusions could be obtained:

1- Natural heating of building could be achieved using solar chimney.

2- The use of storing materials tends to increase the inside temperature of the building.

3- Using water as a storing material is preferred as its capable heat capacity.

4- Increases the amount of storing water leads to increase the heat supplied to the buildings.

5- The use of solar chimney with storing materials preserve nearly inside stable temperature for a long time after sunset.

6- The study of heat gained indicates that water is preferred for use as a storing material.

7- Costs of traditional heating could be overcome by using solar chimney with storing material.

**Nomenclature:**

**English symbols**:

A: Area, [$m^2$], Cp: Specific heat, [J/kgK],

H: Height, [m], L: Length, [m],

$\dot{m}$ : Mass flow rate, [kg/s], $\dot{Q}$ : Heat gain, [W],

$q_s$: Solar intensity, [W/$m^2$], T: Temperature, [°C],

W: Width, [m], V: Velocity, [m/s]

**Latten Symbol**:

Δ: Difference, $\eta$: Efficiency,

ρ: Density, [$kg/m^3$]

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