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Investigation of natural ventilation using a solar chimney in various solar cases

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Abstract

The high cost of conventional energy production, its uses, and its negative environmental impact led scientists to look for many ways to solve this problem. The main issues are environmental pollution, the high cost of air treatment, and the high cost of energy production. An essential solution is using renewable energy instead of traditional energy (petroleum, coal, natural gas, and electric power). As it is a permanent energy source, it causes no air pollution and is cheaper. In this work, an experimental study was conducted on using solar energy as an energy source in the natural ventilation of buildings and the factors affecting this ventilation. A solar chimney has been installed with and without storage materials to store energy for natural identity during sunrise and after sunset. In this work, the difference in air density with different temperatures is the main factor for energy production, which leads to a change in the airspeed (natural ventilation). The study indicates that indoor air velocity can remain higher than ambient air velocity during the day and at night for several hours. This reduces demand and dependence on conventional energy usage, which leads to cost reductions and a reduction in air and environmental pollution.

Keywords: Air treatment, Environmental impact, Environmental pollution, Natural ventilation, Solar chimney.

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1. Introduction

Process ventilation in the summer months is very much required, especially in residential buildings, educational facilities, and industrial facilities. It is required in all year-round months, especially for chemical industries. The process of industrial ventilation is achieved by using fans for residential buildings, educational facilities, and industrial facilities, whether chemical or non-chemical industries; they need fans in addition to using hoods or air blowers to renew the air. Industrial ventilation in this facility consumes enormous amounts of electrical energy. In addition, industrial ventilation leads to a rise in the place's temperature due to the lost energy. So, it is essential to consider using other ventilation methods, such as natural ventilation, using new and renewable energy. One of these methods is natural ventilation, which is an application of solar energy using a solar chimney. In the last few years, solar energy applications have increased due to the increased demand for energy. Natural ventilation may occur from air penetration through buildings due to a difference in air density or a pressure difference.

Many studies have been conducted in this field. Khedari, et al. [1] experimentally studied the solar chimney's ventilation effect on indoor temperature fluctuation and air change in a school building. It was indicated that the induced ventilation reduced room overheating by about 50%. However, the room temperature was about 2–3 °C above ambient. A micro-solar chimney was designed and built by Sagredo and Sprakker [2] using concentric vacuum tubes. Their work aimed to study the ventilation performance of the solar chimney and stored heat. Kaneko, et al. [3] conducted experimental and theoretical studies on ventilation performance in solar flues to study the solar chimney's ventilation performance and stored heat. They explained that combining solar chimneys with buildings can provide solar ventilation. This technology was widespread in new constructions aimed at utilizing renewable resources to save traditional energy without sacrificing internal thermal comfort or air quality. Bassiouny and Korah [4] studied the impact of the solar chimney angle on the flow pattern and ventilation rate numerically and analytically. The results showed that the optimum air flow rate value was achieved when the flue slope was between 45 and 70º at a latitude angle of 28.4º.

Gontikaki, et al. [5] studied experimentally and analytically the optimization design of solar chimneys for natural ventilation in a multi-zone office building. The study involved the effects of inlet size, wall height and properties, inclination angle, glazing type, solar intensity, and wind. Hassanein and Abdel-Fadeel [6] studied natural ventilation experimentally using multiple solar chimneys in different directions. The study was conducted to investigate the effects of the number of solar chimneys, the height of chimneys, the width of the air gap, and the direction of chimneys on the natural ventilation in space. The temperature and velocity profiles were illustrated through both the chimney channel and the channel-connected room under different boundary conditions. The results showed that improvements in natural ventilation could be achieved by using multiple solar chimneys. One, two, or three chimneys can reduce room temperature by 6%, 10%, and 12%, respectively. Using two smokers and three instead of one chimney increased the ventilation rate to 13% and 33%, respectively. The use of rooftop solar chimneys for natural ventilation was experimentally investigated by Al-Kayiem and Heng [7]. The measurements were carried out on a modified solar chimney surface with double, horizontal, and vertical absorption surfaces. The system's performance was evaluated in different configurations and different operating states.

Justin and Demba [8] used the Computational Fluid Dynamics (CFD) [SA1] program to study the optimization design of solar chimneys for elementary school classrooms. A passive ventilation system using solar chimneys was designed to provide ventilation to several classrooms in an elementary school in Washington. The results showed potential heating, ventilation, and air conditioning (HVAC) energy savings of up to 5% and up to 1,200 occupied hours that the classrooms could have adequate natural ventilation. Al-Neama and Farkas [9] studied using solar chimneys for drying. It was indicated that the rate of water evaporating from the products inside the drying chamber was related to the air stream velocity inside the drying chamber. The objective of the chimney is to increase the air velocity naturally, increasing drying efficiency. However, increasing airspeed beyond the limits will have harmful side effects for some products.

An experimental and numerical study of the performance of a full-scale solar chimney in an actual building in Eastern China was conducted by Zha, et al. [10]. The simulation results showed that during the transition seasons (from April to October), solar chimneys can save energy at around 14.5% in Shanghai. It was shown that solar chimneys are a practical approach to saving energy for residential buildings in transitional seasons in China's hot summer and cold winter areas. Danesh [11], Okasha, et al. [12], Abed, et al. [13], Taha, et al. [14], and Ebyan, et al. [15] studied the effect of using solar chimneys to reduce the heating load in cold climates in many countries. The buildings were adapted to the local climate conditions using sustainable architectural techniques and materials; thereby, the highest level of climatic comfort was provided.

Regarding the energy crisis and the necessity of saving non-renewable energy, the reduced need to use heating/cooling systems was assumed to be one of the critical goals in advanced building design. The present study was conducted based on causal research and simulation. Design builder thermal simulation software was used as the tool to this end. Therefore, a building with/without solar chimneys was modelled and analyzed to identify the effect of solar chimneys on the amount of energy used for heating [SA2].

In this work, the use of solar chimneys with and without storage materials for natural ventilation has been investigated. The type and quantity of storage materials were studied. Besides, economic study due to saving power has been studied.

2. Experimental Setup and Experimental Work

The experimental setup on which the study of natural ventilation of buildings using solar energy has been conducted is shown in Figure 1. It consists of a room with external dimensions (1.8×1.8×2 m). All sides and ceilings of the room were made of 15 mm thick wood. The ground is made of reinforced concrete. The room is divided into three equal and similar small rooms using two wooden walls 15-mm-thick, as shown in the Figure. Each room has a door with dimensions (0.6×1.2 m), as shown.

The three rooms have internal dimensions (2×1.8×0.58 m). Each room in the tribal direction has an opening of dimensions (0.33×0.23 m) at a height of 0.5 m measured from the bottom.

An opening with dimensions of 0.3×0.2 m was made in the north direction. At a height of 0.2 m measured from the ceiling, as shown in the Figure 2.

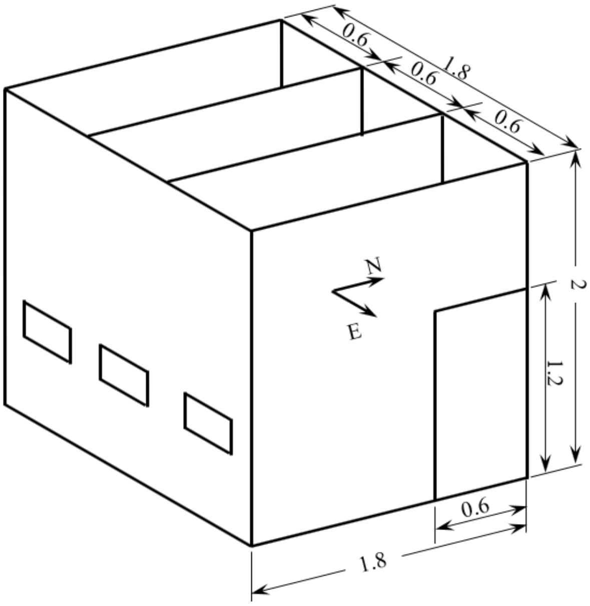

Figure 1.
Tested section.

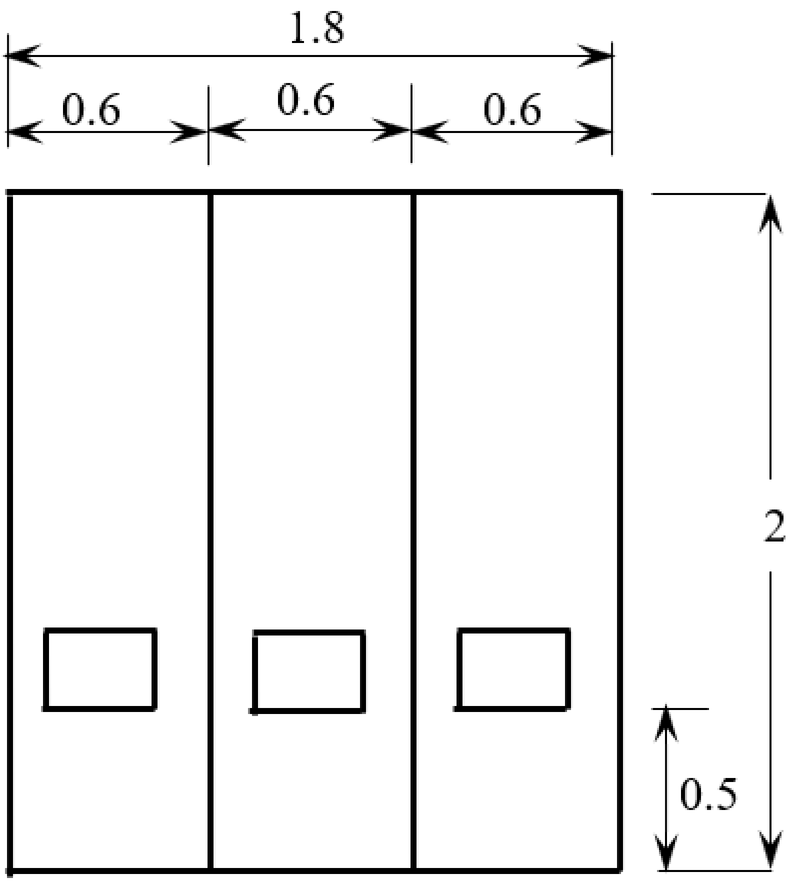

Figure 2.
Vertical section from south direction.

An air duct with a cross-sectional area of 0.33×0.23 m and a length of 1.27 m was installed in the front opening. All sides of the air duct are made of wood with a thickness of 15 mm. As shown in Figure 3.

A solar chimney was installed on the tribal duct at a 45° inclination angle concerning the horizontal direction, as shown in Figure 4-a. The figure shows the elevation section from the eastern direction. The solar chimney is a parallelogram with internal dimensions (0.23×0.33×1.19 m), as shown in Figure4-b. The bottom side of the chimney "base" was made of wood, while the other three sides were made of glass of 6 mm thickness. The base of the chimney is painted black to increase the heat absorption rate. A tank with external dimensions of 1×0.3×0.015 m is made of 1.5 mm thick stainless steel. It has an open side at the top with dimensions of 0.3×0.015 m. This hatch was closed after filling the tank with absorbents. The tank is installed on the base of the chimney. It is completely coated with a black substance to increase its absorbency. The tank was filled with different energy storage materials. These materials were selected from two solids and three liquids. These materials were used to store heat during sunrise and recover this energy during cloudy times and after sunset. The channel is closed after the storage material has been placed. The inner sides of the three rooms and the base of the solar chimney were insulated from the inside with glass wool.

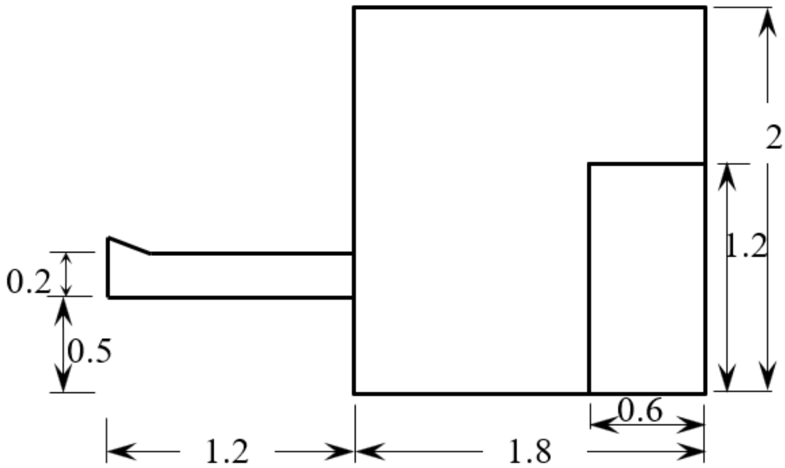

Figure 3.
Sectional side view before chimney installation.

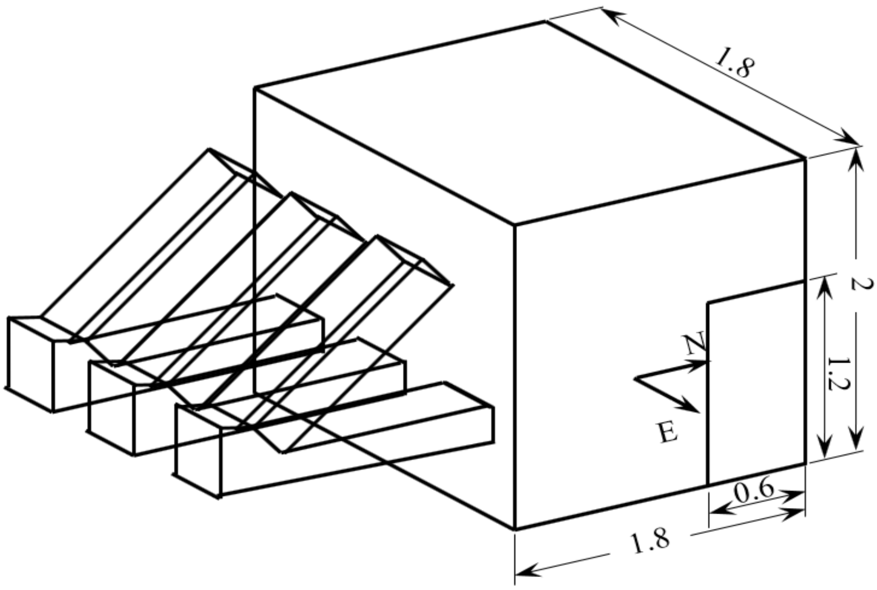

Figure 4-a.
Schematic diagram of the isometric of the chimneys.

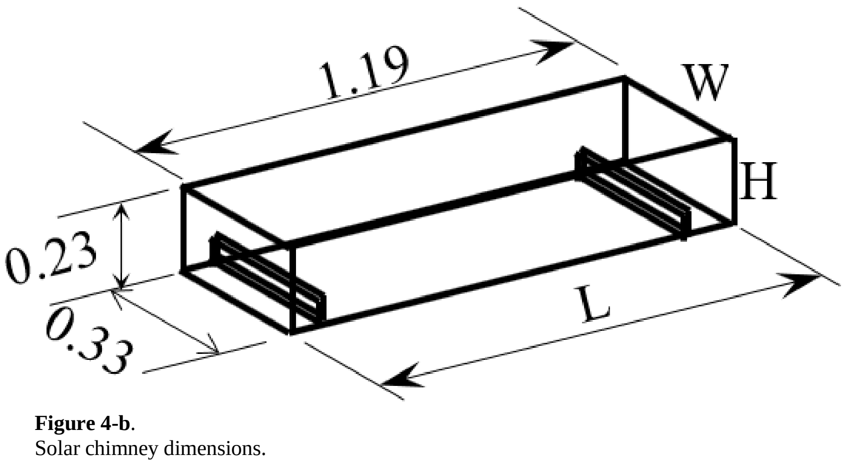

Figure 4-b.
Solar chimney dimensions.

3. Experimental Measurements

The outside ambient air temperature was measured and recorded for each experiment. Besides, the temperature was measured at 9 points, distributed in equal dimensions in each room and in the duct. At two points on the chimney, as shown in Figure 5. The temperature was measured using calibrated copper-Constantan thermocouples. The thermocouples were connected through a multi-point selector switch, Figure 6, to a digital temperature indicator, Figure 7.

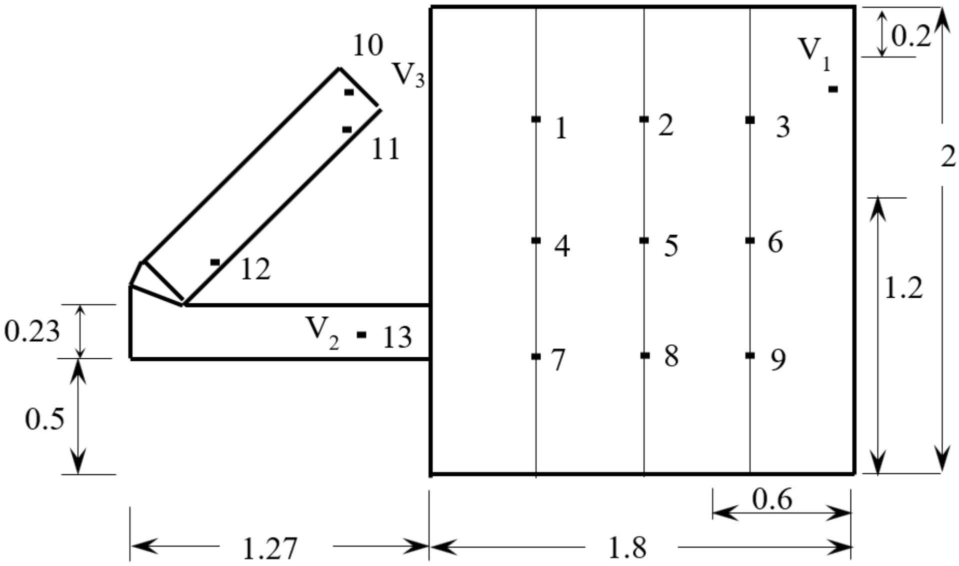

Figure 5.
Temperature measurement points for north direction section.

Figure 6.
The selecting switch.

The air velocity was measured at the north opening, at the tribal channel, and at the end of the solar chimney from above, as well as the velocity of the outside air. The velocity was measured using a portable hotwire, Figure 8, 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 Precision Spectral Pyranometer (EPPLEY PSP) Pyrometer, Figure 9, was used for measuring the solar intensity per unit area [W/m^2].

Figure 7.
The temperature indicator.

Figure 8.
Hot wire anemometer.

Figure 9.
Pyrometer.

Four experiments were carried out, as follows:

First Experiment

In the first room, a solar chimney was installed without storage material. The second room has no solar chimney. A solar chimney was installed in the third room with 5.25 kg of water as storage fluid.

Second Experiment

The solar chimney was installed in the first room and equipped with small pebbles as storage material. A solar chimney was installed in the second room with copper tube pieces as storage material. 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 a 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

Natural ventilation occurs from air penetration through buildings due to a difference in air density or a pressure difference. In this work, we rely on the effect of solar radiation on air density, including the effect of changing air density on air penetration. The type and quantity of storage material, as well as the amount of sunlight, have an impact on heat transfer through the solar chimney for ventilation. The main objective of this work is to study the ability to provide energy during the shining sun and restore it on a cloudy day or night to ventilate residential buildings, factories, farms, offices, and industries. This tends to reduce the energy use of conventional ventilation. The required air handling units' ventilation capacity also increases in the summer. To overcome this problem, solar chimneys can be installed in the previously mentioned places and benefit from the most significant 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 primary purpose and desired objective are to reduce the consumption of traditional energies and to exploit renewable energy rather than exclude potential exploitation.

In this work, the factors affecting the increase in temperature and efficiency of solar chimneys, which results in an increase in air velocity inside the place and the solar chimney due to the change in density, were studied. These parameters may be the outside air temperature (sunlight intensity), outside air velocity, presence or absence of a solar chimney, presence or absence of storage materials, and types and quantities of storage materials. The air velocity changes, and consequently, the air temperature inside the chimney and the room changes also according to the weather and the type and quantity of the storage material. The results obtained in different cases were compared.

4.1. First Test

- A room without a solar chimney.
- a room with a solar chimney and storage material.

- a room with a solar chimney supplied with 5.25 kg of water as a storage fluid.

The air velocity was measured at the north entrance V1, the duct entrance V2, and the solar chimney exit V3. Also, the temperature inside the three rooms was measured at nine points inside each room, where the average values were similar to the ambient air temperature. Figure 10 shows the change in indoor air velocity for the three rooms with the change in ambient air temperature (sunlight intensity) and ambient air velocity over 12 hours with an interval of 30 minutes. It is evident from this figure that the air velocity inside the room without a chimney is approximately equal to the velocity of the surrounding air. When a chimney is installed, an increase in air velocity is observed. Almost a sudden increase was observed in the early hours of the day due to the increase in the ambient air speed at the beginning of the day and the temperature. During the afternoon, the air velocity stabilizes. In the afternoon, the airspeed increases again due to the temperature rise.

After 15:00 at sunset, the air velocity decreases, almost reaching the velocity of the surrounding air. When using liquid storage, the air velocity is similar to the room without storage fluid until 15:00, and then it becomes partially stable even after sunset; it decreases slowly but remains higher than in the two rooms and higher than the surrounding air. This is due to the heat that the liquid absorbs throughout the day. The increase in air velocity at the room inlet compared to the ambient air velocity leads to air movement, resulting in natural ventilation and decreasing the room's relative humidity.

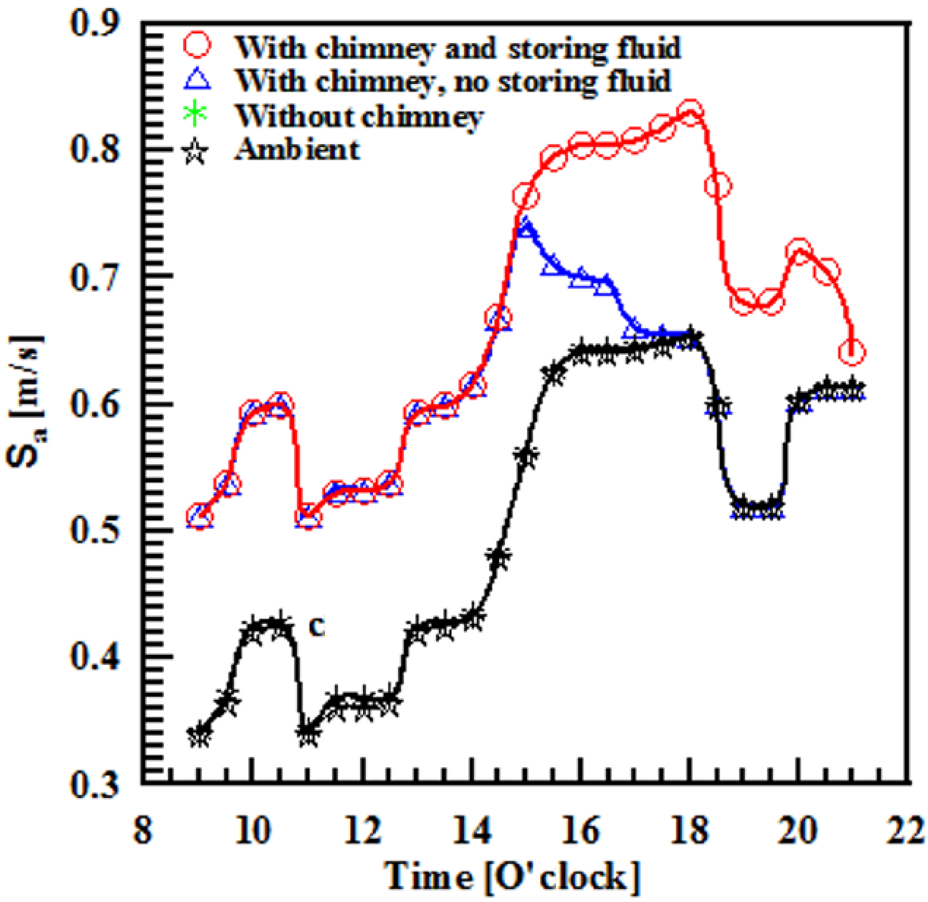

Figure 10.
Change in air velocity inside the room during 12 hours.

Figures 11 to 13 indicate the change in the temperature of the air leaving the upper airway (point 10) and the change in the temperature of the heat-absorbing surface (points 11 and 12) with the change in the ambient air temperature (sunlight intensity) during 12 hours for the second and third rooms. In Figure 11, it is shown that the temperature of the air leaving the solar chimney of the second and third chambers rises at all points with the rise in the outside air temperature (intensity of sunlight). They approach each other at the beginning of the day. The temperature of the chimney installed in the second room is higher than that of the third one by a relatively small rise until two o'clock in the afternoon. The temperatures approach each other until approximately four o'clock in the afternoon. The temperature of the third-room chimney rises more than that of the second, with a relatively slight rise. The temperature of the second is equal to the temperature of the surrounding air with the approach of sunset and after sunset. The temperature of the chimney installed in the third room remains relatively higher than that of the second one and the surrounding air after sunset due to the heat energy stored during the day and utilized after sunset. The higher air temperature from the solar chimney than the ambient air temperature helps to increase the air velocity inside the room due to the change in density.

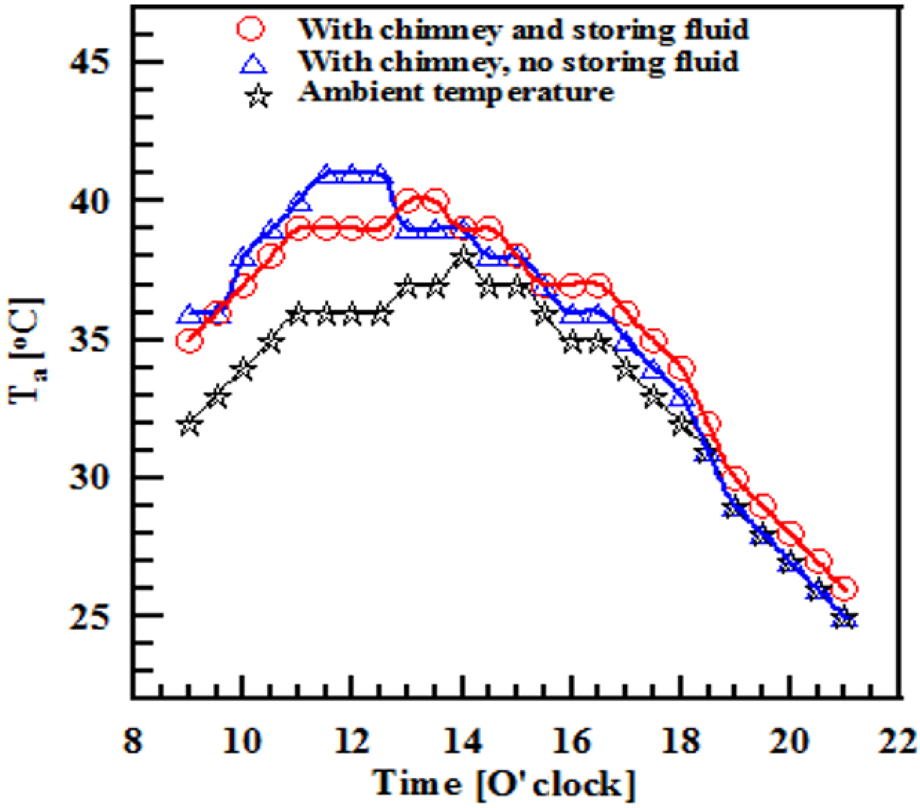

Figure 11.
Temperature change at the outlet of the solar chimney (point 10) during 12 hours.

Figures 12 and 13 represent the temperature change at the chimney surface (points 11 and 12) over a 12-hour period. The chimney temperature is higher than the ambient air temperature in both cases, with and without liquid storage. If liquids are not stored, the temperature is higher than the temperature of liquids until two o'clock in the afternoon. It is almost equal until three thirty O'clock in the afternoon, then the storage of liquids rises even after sunset.

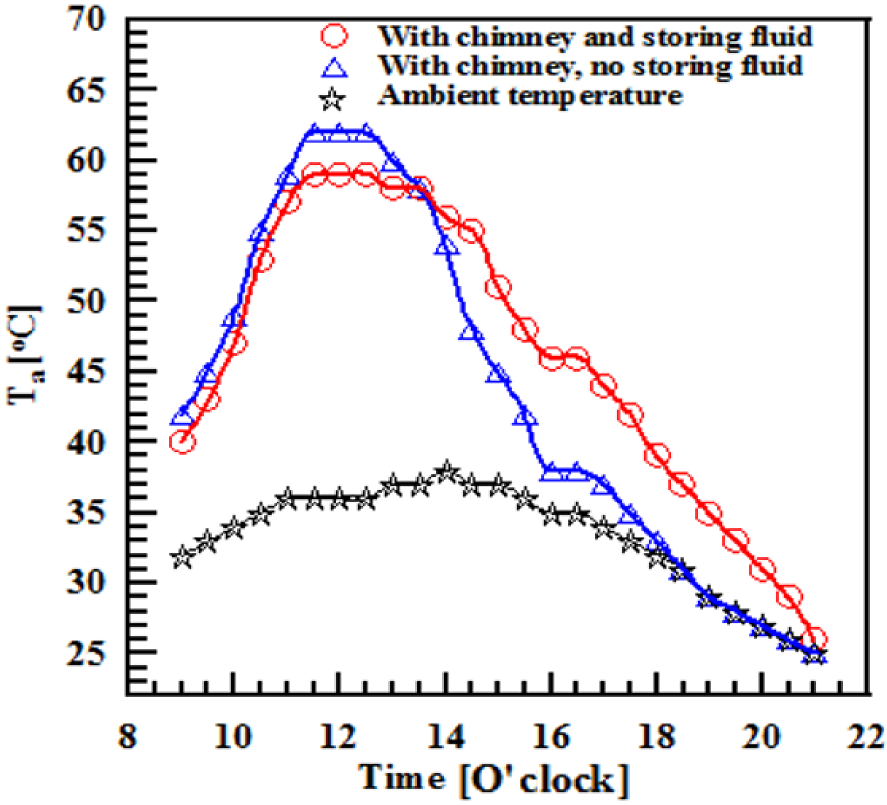

Figure 12.
Variation of the temperature at the chimney at high level (point 11) through 12 hours.

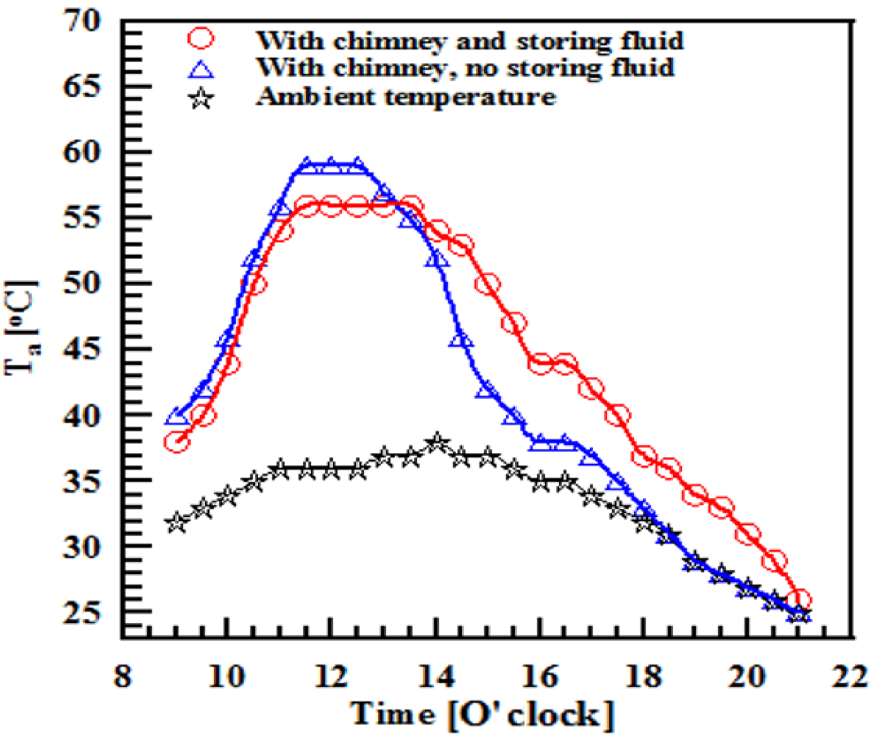

Figure 13.
Variation of the temperature at the chimney at high level (point 12) through 12 hours.

It is clear from the first experience that a solar chimney with storage material is preferable and has a positive result. So the second experiment was conducted to compare the different storage materials. In this case, the first room with a solar chimney is equipped with small pieces of pebbles. The solar chimney is equipped with small pieces of copper pipe in the second chamber. In the third chamber, the solar chimney is supplied with water. All storage materials are equal in mass (5.25 kg) to determine the preference of the solar chimney with these materials. The difference in air velocity and air temperature as it passes through and exits the chimney, as well as the speed and temperature of the outside air, are explained.

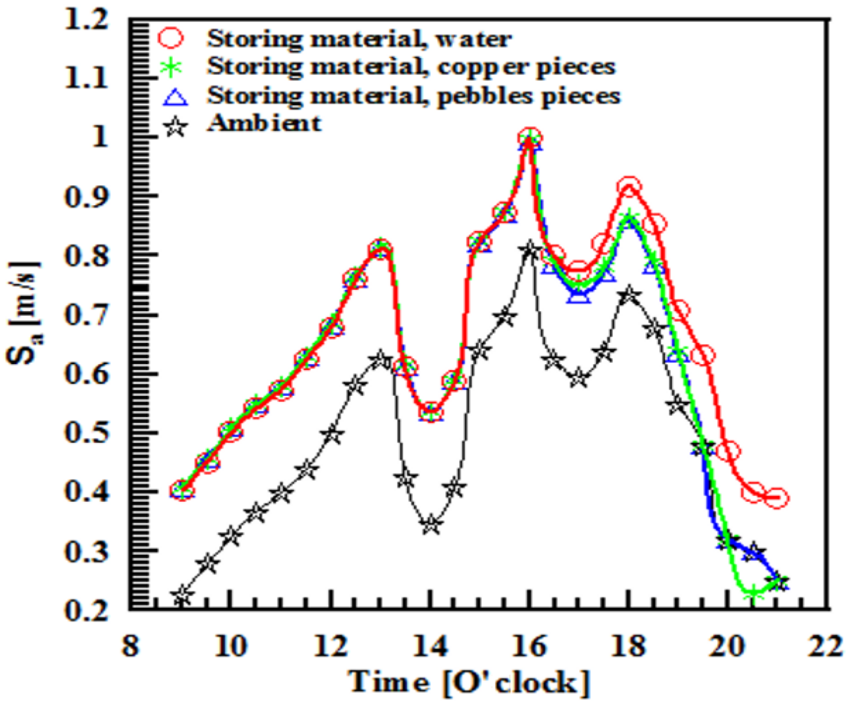

Figure 14.
The change in air velocity inside the room during 12 hours.

Figure 14 shows the change in the velocity of the air entering the three rooms at point (V1) with the change in the velocity of the surrounding air during a 12-hour period. It is noteworthy that the air velocity is high and almost equal in all cases until four O'clock in the afternoon compared to the velocity of the surrounding air. The air velocity remains approximately high if water is used as storage material, even after sunset in the other two states. The other two cases indicate an air velocity almost identical to that of pebbles and copper as storage materials.

Figures 15 to 17 indicate the change in air temperature in three sections: the upper airway outlet and the upper and lower heat-absorbing surfaces. Measurements were made for the three chambers during the 12-hour test period. The temperature rises at all Points with the ambient air temperature (intensity of sunlight) in the three rooms. The temperature of the second case, the copper storage material, rises from the other two cases, a minimal increase from the beginning of the day until one O'clock in the afternoon, and then approaches each other during the rest of the day. However, the third chamber, which can store water, is the best, and the temperature remains relatively higher after sunset than the other two chambers for a longer time. This may be due to the liquid materials' higher capacity to retain heat energy during the day and then utilize it after sunset.

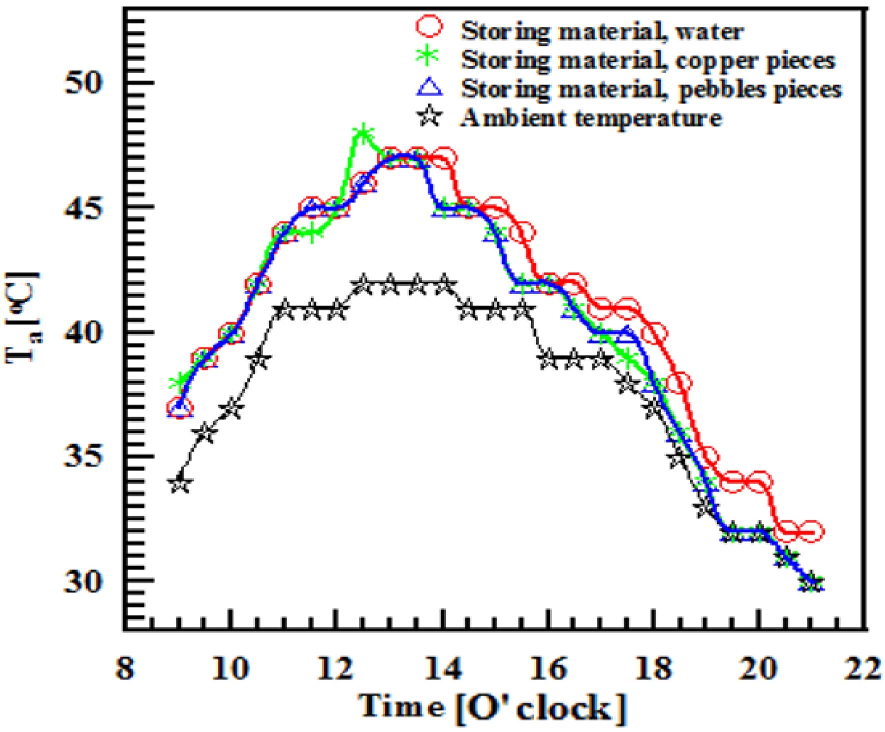

Figure 15.
The temperature change at the outlet of the solar chimney (Point 10) during 12 hours.

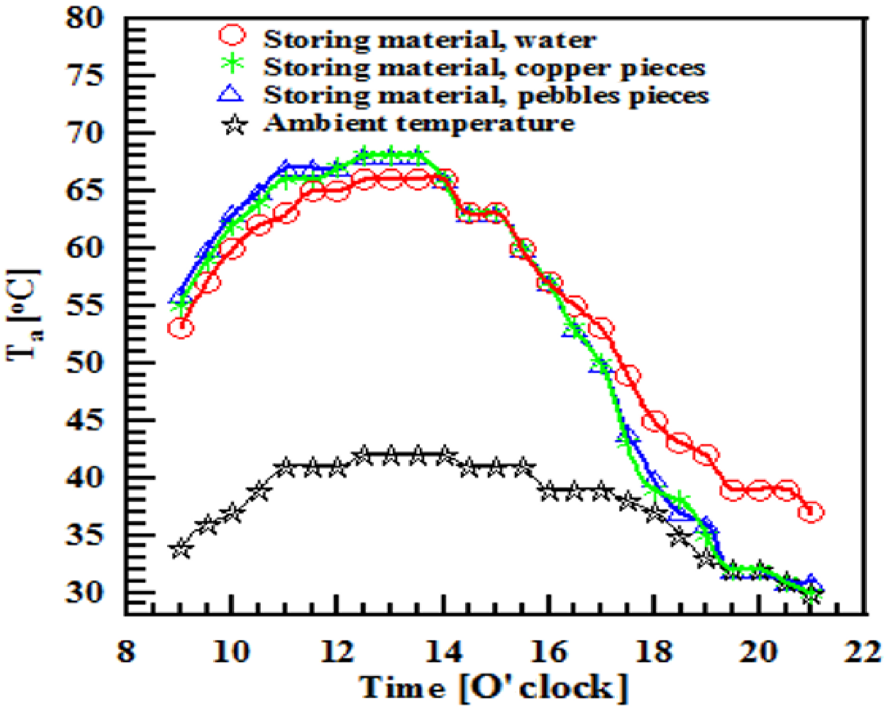

Figure 16.
Variation of the temperature at the chimney at high level (point 11) through 12 hours.

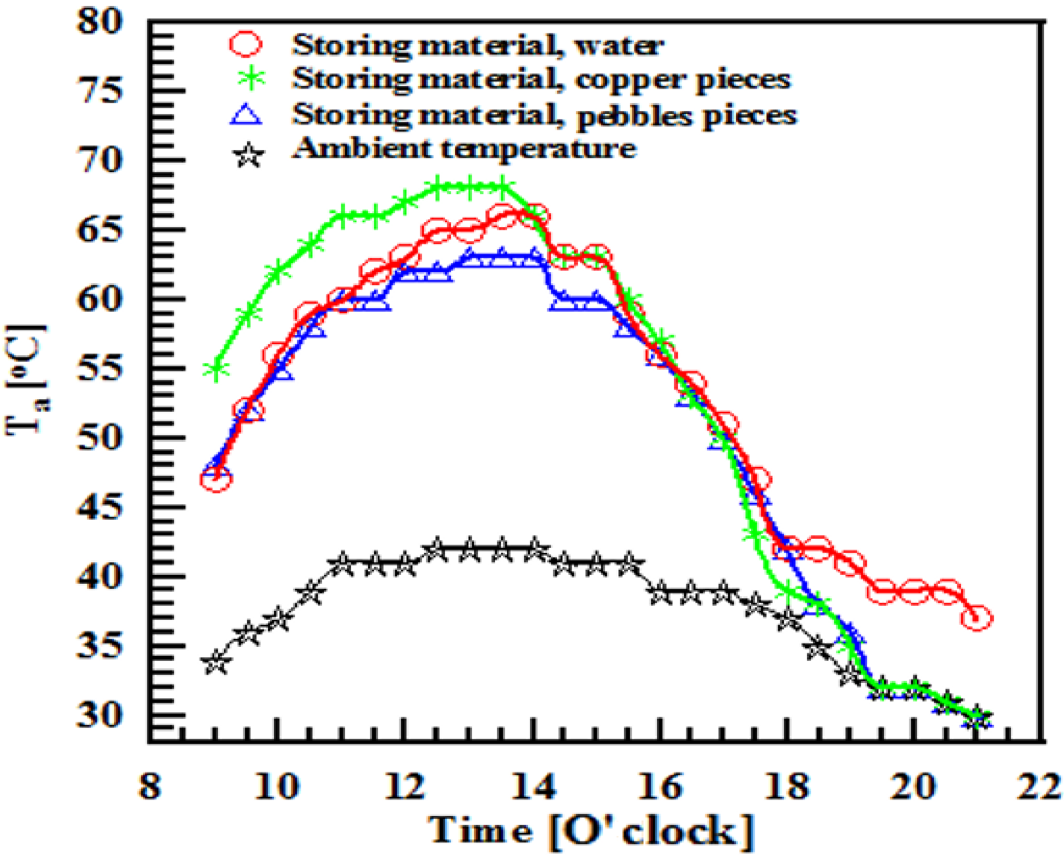

Figure 17.
Variation of the temperature at the chimney at high level (point 12) through 12 hours.

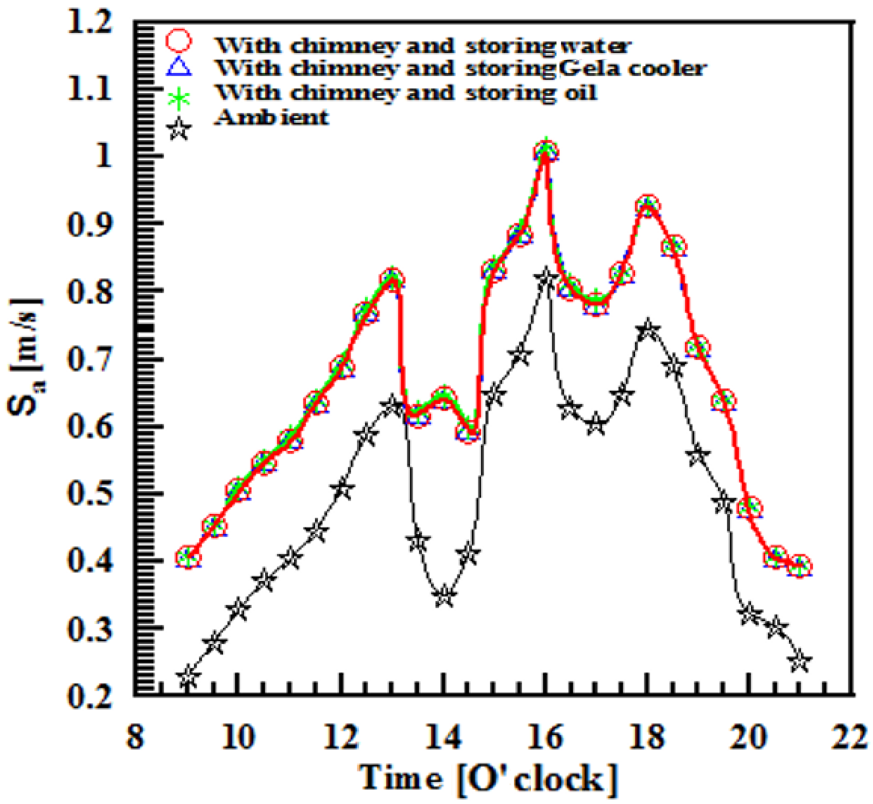

Figure 18.
The change in air velocity inside the room during 12 hours.

It is clear from the second experiment that the presence of a solar chimney equipped with liquid storage material is preferable and has a positive result. Therefore, the third experiment was conducted to compare the effect of using some types of liquid materials while keeping the whole mass at 5.25 kg. The materials chosen are water, a Gela cooler, and car oil. The first room is equipped with a solar chimney and a water supply. In the second chamber, the chimney is equipped with a Gela cooler. In the third chamber, the chimney is equipped with oil.

The difference in the velocity of the air entering the room at point (V1) and the velocity of the air outside through the solar chimney is illustrated. Figure 18 shows the change in the velocity of the air entering the three chambers with the change in the velocity of the surrounding air over a 12-hour period. It is seen that all storage fluids give approximately the same result for the velocity of air entering the room. This leads us to say that water is preferred over the other two types because of its low cost, joint problems, and easy access anywhere and anytime.

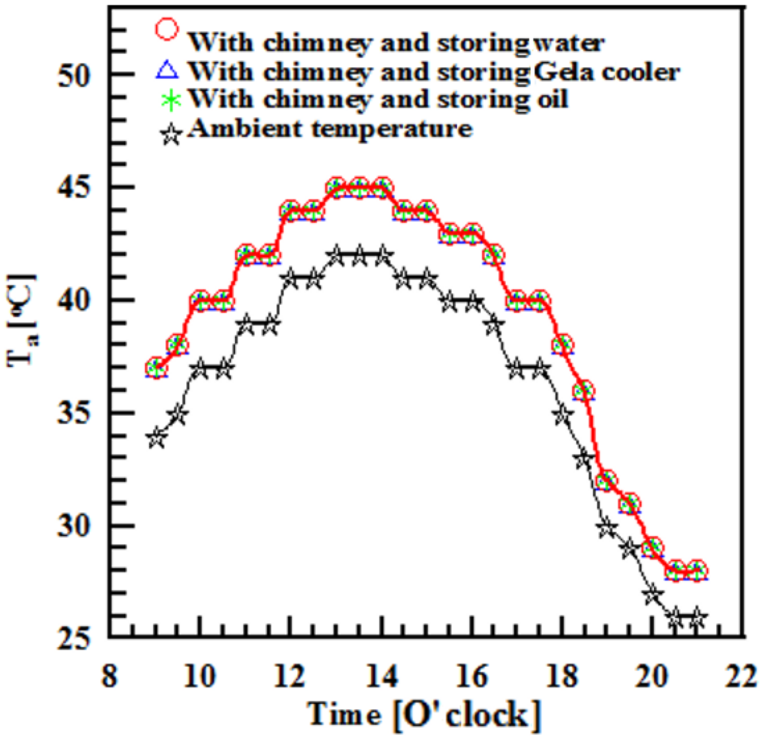

Figure 19.
Temperature change at the outlet of the solar chimney (point 10) during 12 hours.

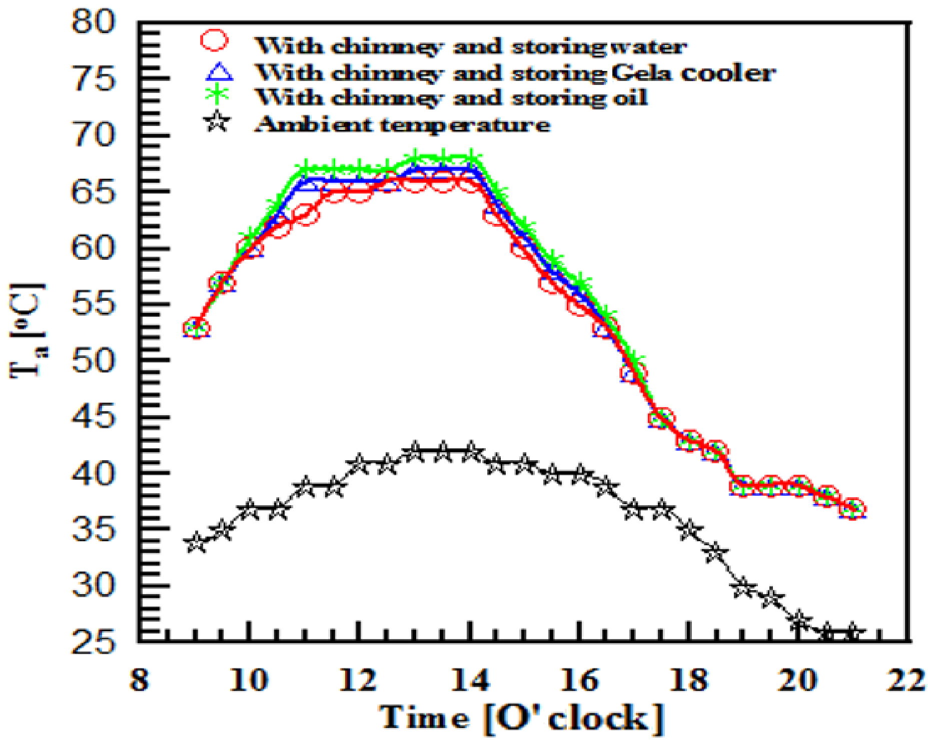

Figure 20.
Variation of the temperature at the chimney at high level (point 11) through 12 hours.

Figures 4-19 to 4-21 illustrate the change in the temperature of the air leaving the upper air stream of the solar chimney at point (10) and the temperature at two points on the endothermic surface at points (11 and 12) with the change in ambient air temperature (sunlight intensity) over a 12-hour period for the three rooms. The temperature rises at all points as the external temperature (intensity of sunlight) increases in the three rooms and approaches each other during the day. Also, after sunset, the temperature remains relatively high in the three rooms for up to approximately four hours. This height helps the density difference between the air inside the chimney and the outside air, which leads to an increase in the air velocity inside the rooms compared to the air outside.

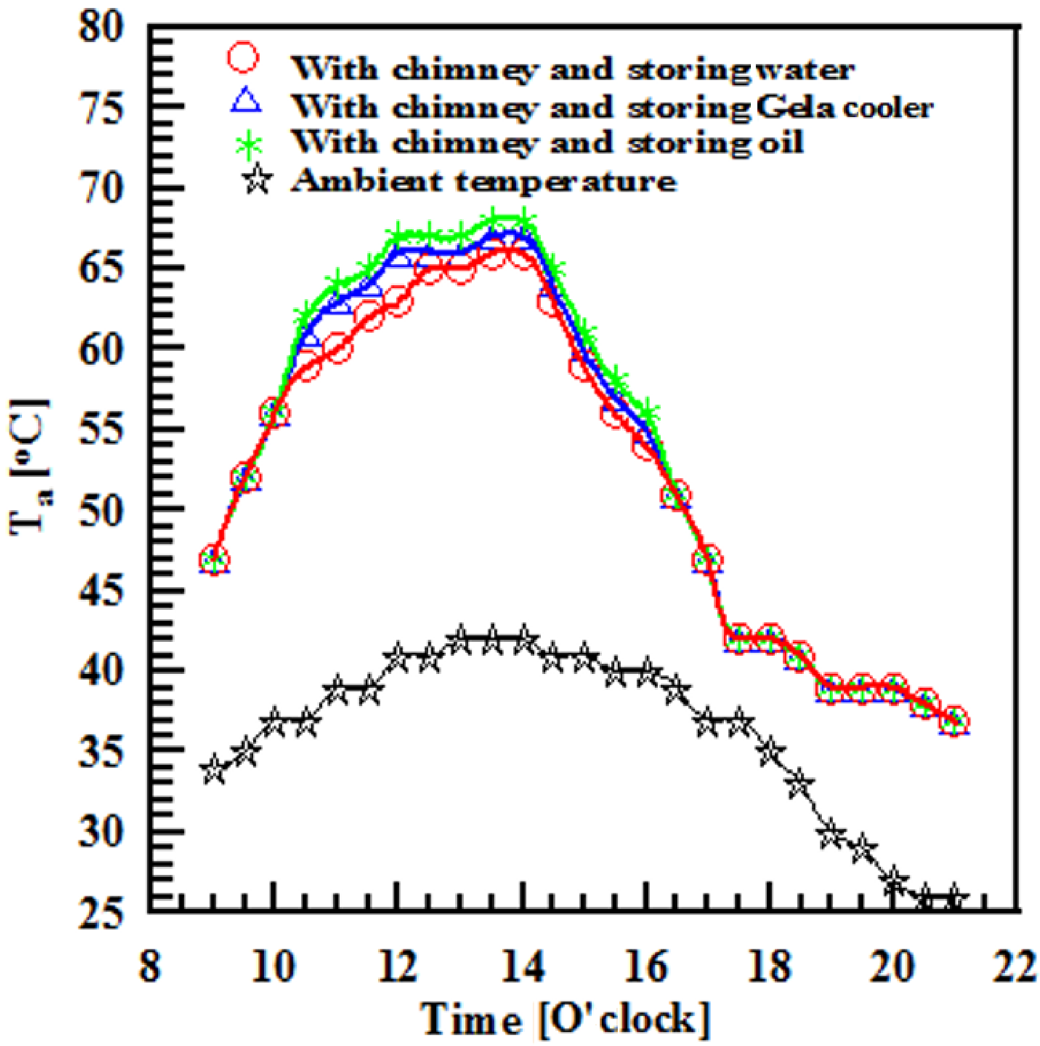

Figure 21.
Variation of the temperature at the chimney at high level (point 12) through 12 hours.

From the third experiment, it is clear that the presence of a solar chimney equipped with a liquid storage material, such as water, gel, or oil coolant, has a high capacity to store large amounts of heat, which can be used in the event of drawing the sun during the day and also benefiting from it after sunset for the longest time possible to save energy for natural ventilation of the building. It was also clear that the results of the three types of liquid storage were very close, almost equal most of the time, and accordingly, water is considered the best in terms of low cost and availability. One of the properties of water is that it can retain large amounts of heat and does not lose it quickly. On the contrary, oil acquires heat at a very high speed and loses it at a very high speed. Therefore, the fourth experiment was conducted to determine the effect of the amount of material used to store heat on the work and performance of the chimney.

In the fourth experiment, a comparison is made between three quantities of water to determine their priority and compare their performance. The first room has a solar chimney with 1.05 kg of water. The second room has a solar chimney with 3.15 kg of water. The third room had a solar chimney with 5.25 kg of water. The difference in air velocity inside the rooms and outside through the solar chimney is evident.

Figure 22 shows the change in the velocity of the air entering the three rooms at point (V1) with the change in the velocity of the surrounding air during 12 hours. A meager difference was observed in the air velocity entering the rooms until four O'clock in the afternoon. Evidently, the chamber with the chimney, which was supplied with 5.25 kg of water, was still relatively higher than the other two cases. The chimney, supplied with 5.25 kg of water, was kept in almost perfect condition.

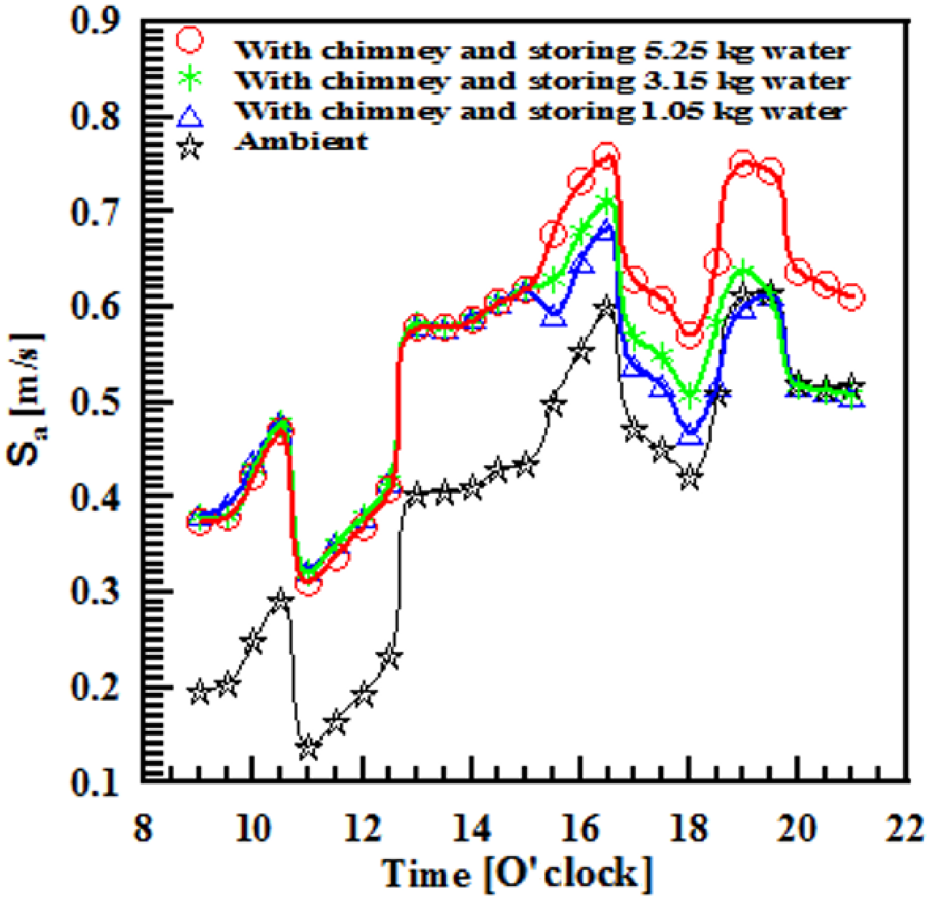

Figure 22.
The change in air velocity inside the room during 12 hours.

For 12 hours, Figures 23 to 25 show how the temperature of the air changed at the top of the solar chimney (10), where the upper duct opens, and at the top and bottom of the chimney's heat-absorbing surface (11 and 12). They also show how the temperature of the room air changed (sunlight intensity).

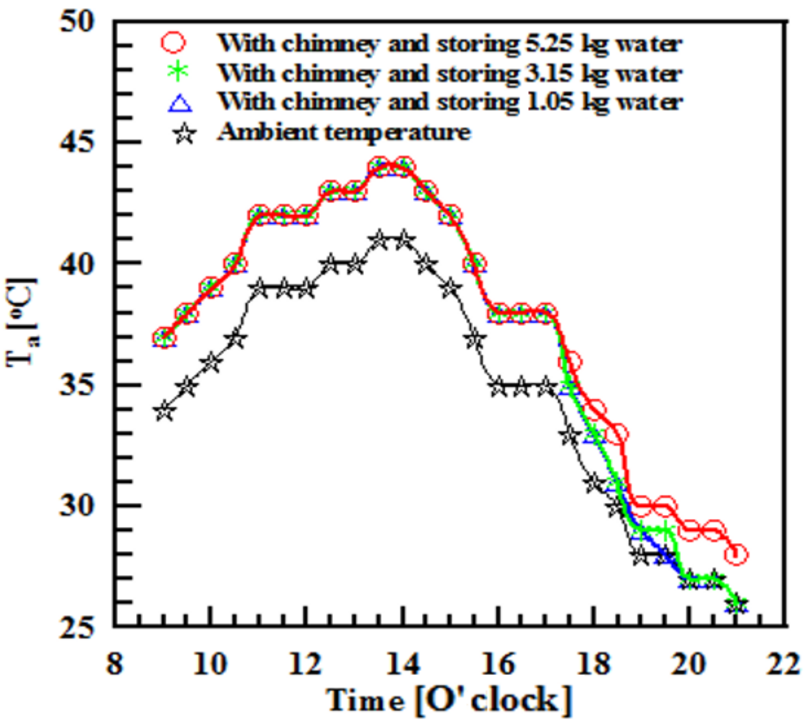

Figure 23.
The temperature change at the outlet of the solar chimney (Point 10) during 12 hours.

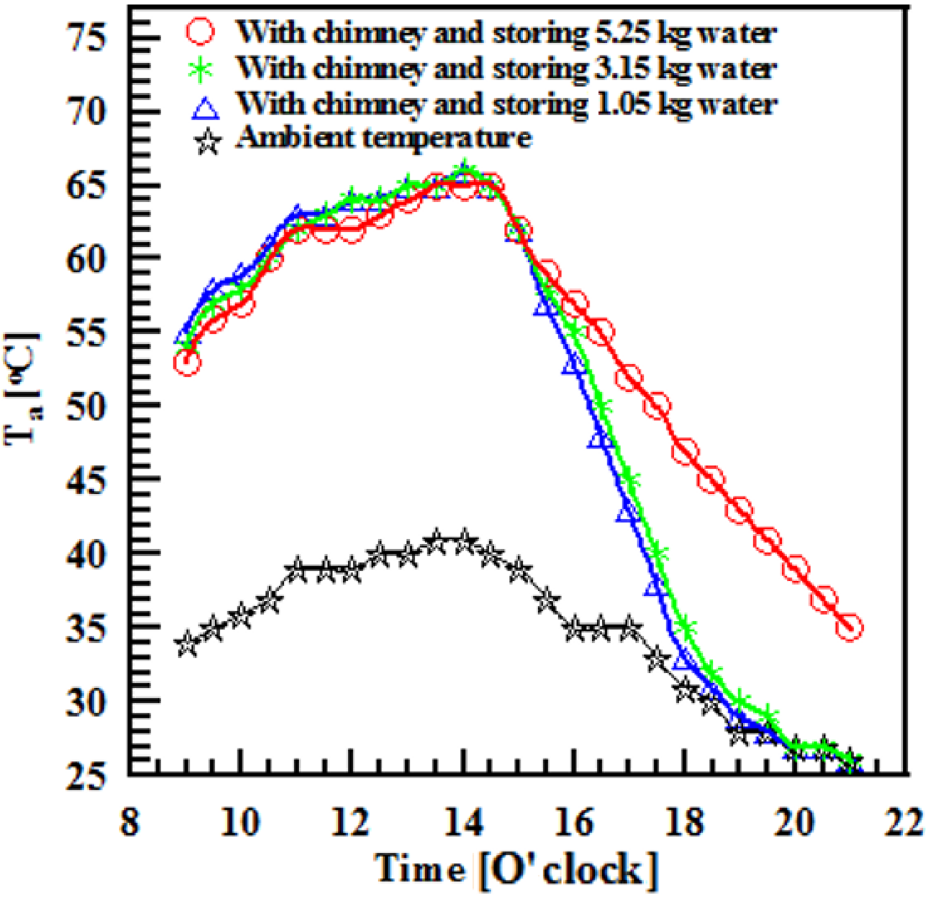

Figure 24.
Variation of the temperature at the chimney at high level (Point 11) through 12 hours.

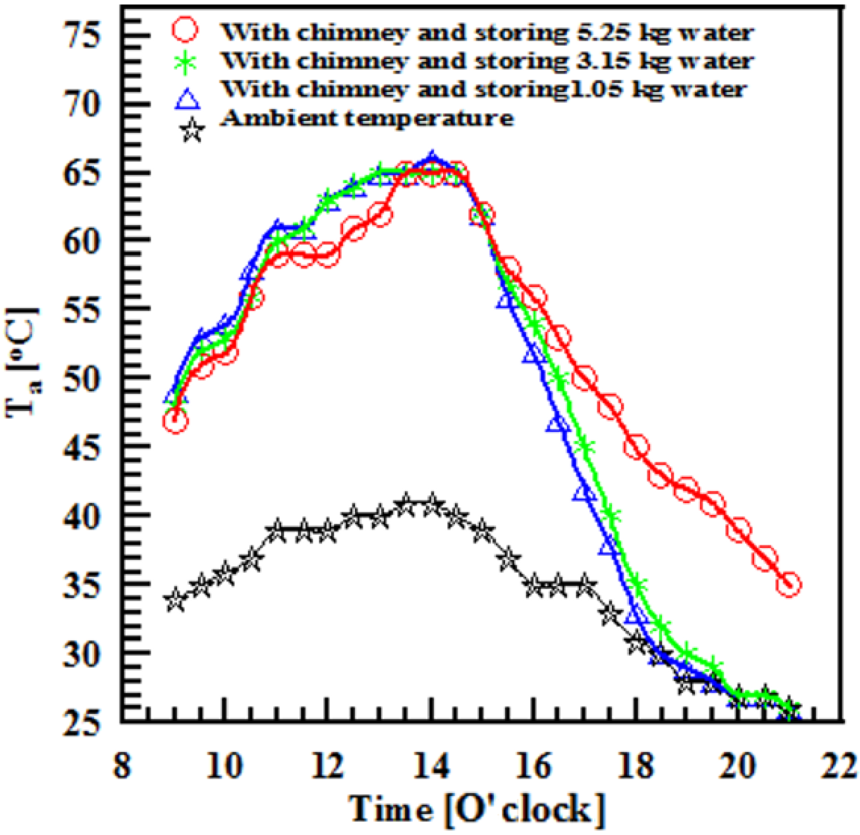

Figure 25.
Variation of the temperature at the chimney at high level (point 12) through 12 hours.

The temperature rises at all points with the external temperature (intensity of sunlight) in the three rooms. The two rooms with a water volume of less than 5.25 kg were slightly elevated until two o'clock in the afternoon. The temperature of the three chimneys was equal from two O'clock to three thirty in the afternoon; then the chimney was 5.25 kg, which is higher than the other two cases even after sunset. The temperature remains high after sunset in the third case for up to four hours. This indicates the positive effect of the amount of material used to store heat and retain an amount of heat capacity during the day and then utilize it after sunset.

4.2. Efficiency of the Solar Chimney

The solar radiation intensity per unit area (q_s) was measured every day that the experiment was conducted. 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 Equation 4:

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

Where: q_s is the solar intensity per unit area and A2 is the solar chimney surface area which calculated as:

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

The efficiency of the solar chimney was calculated and compared in different cases. Figure 26 represents the solar chimney efficiency with and without storing fluid. Water was chosen as a storage fluid. At the beginning of the day, the solar chimney without storage fluid is better at 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 is incident upon the chimney and decreases the heat transferred to the passing air. After 12:30, the efficiency of the solar chimney in 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 chimneys with storage fluid is nearly stable during the tested period of the day.

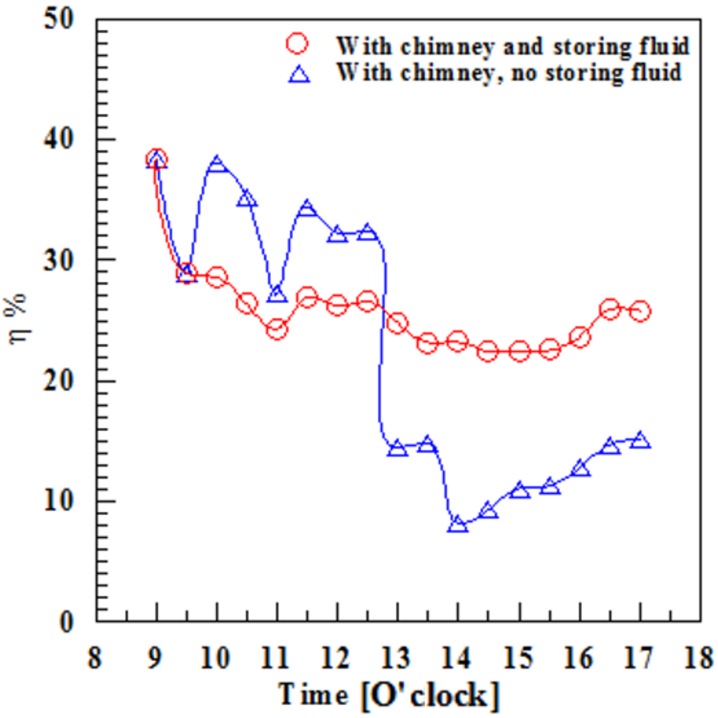

Figure 26.
Solar chimney efficiency with and without storing fluid.

Figure 27 compares the efficiency of storage materials in terms of their ability to retain heat throughout the day and benefit from it at the end of the day and after sunset. Water, copper, and pebble pieces were chosen as storage materials. During the period from 12:00 O'clock to 13:30, the efficiency of copper as a storage material is the best due to its good ability to store heat. After that, water becomes the best during the last period of the day and after sunset. This means that water restores the heat gradually, while solid material restores it quickly because of its good heat transfer characteristics.

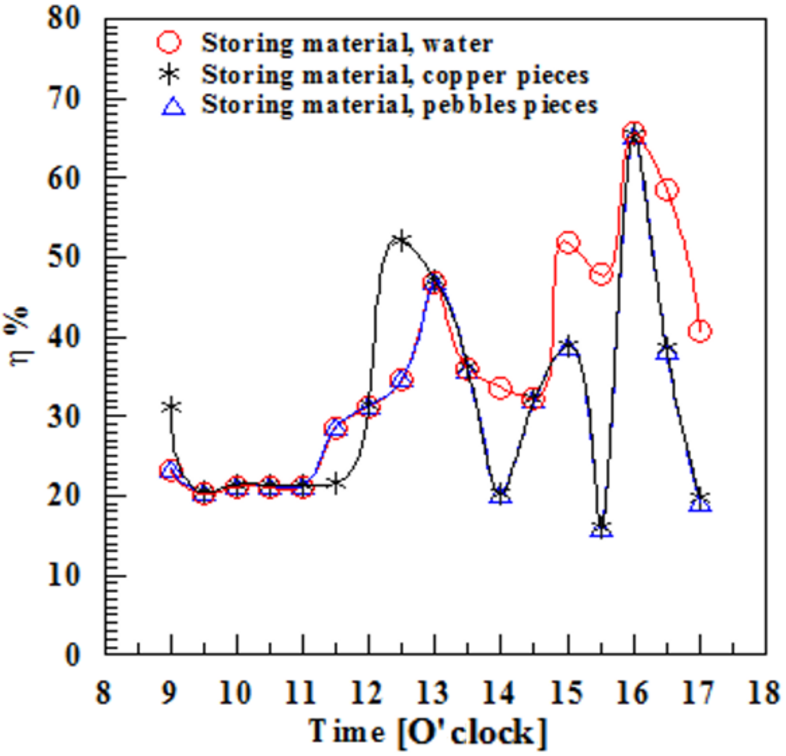

Figure 27.
Comparison of solar chimney efficiency between water, copper and pebbles.

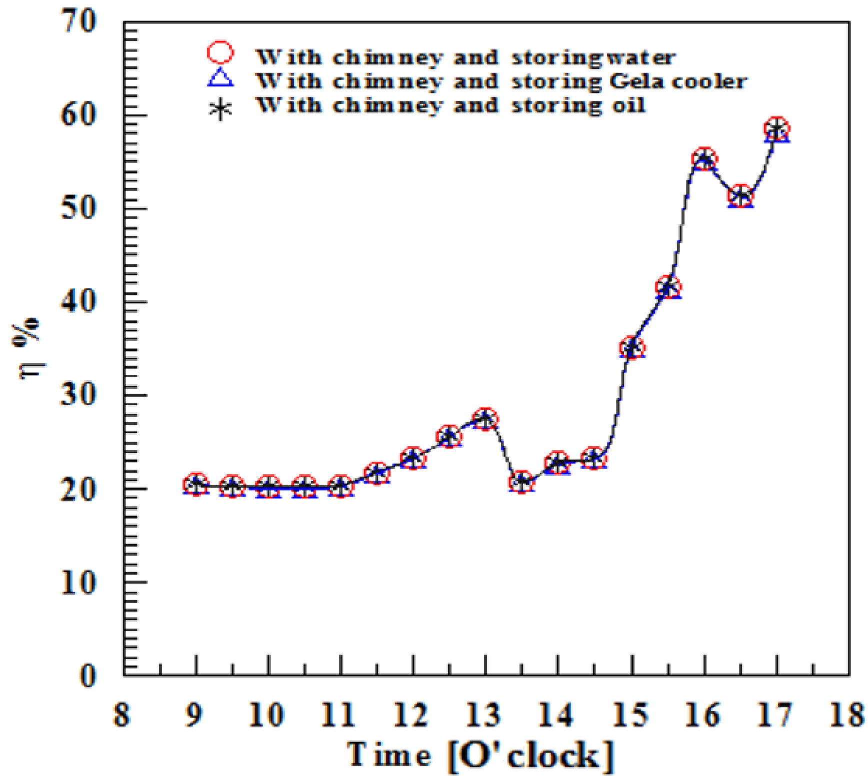

Figure 28.
Comparison of the efficiency of solar chimney for three fluids.

Figure 28 compares the efficiency of three liquid materials. Water, jelly cooler, and cars' oil. It was found that the efficiency of the solar chimney was close for the three chosen fluids. This means that water is preferred because it is available and cheap.

Figure 29 presents the comparison between different amounts of water. It is found that the efficiency is nearly closed for all cases at about 15:00. After that, a slight increase was observed with the increase in mass due to the amount of heat stored.

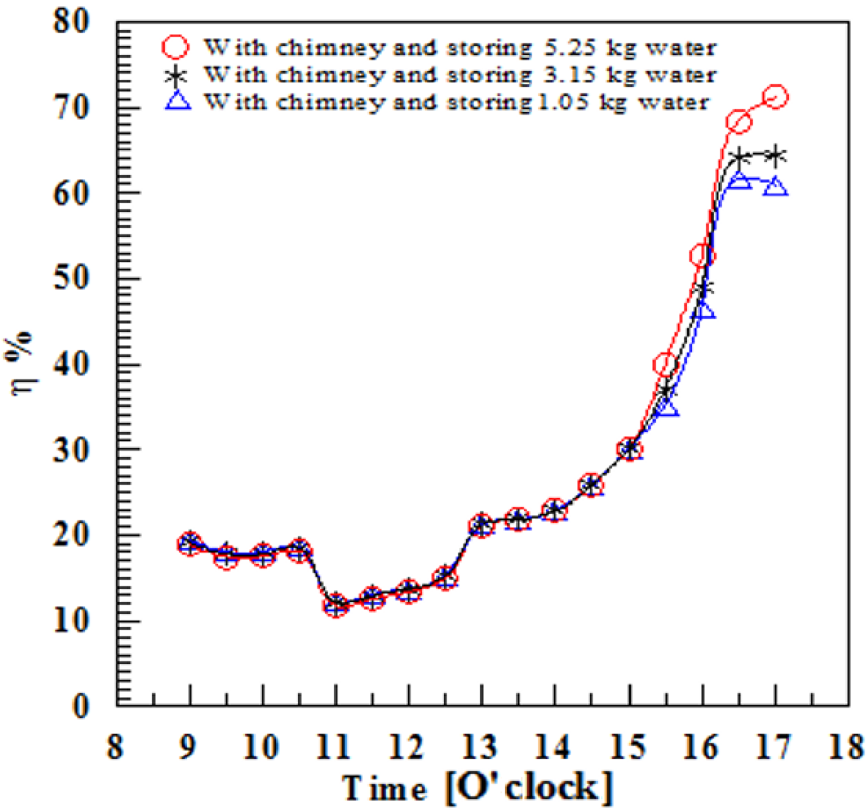

Figure 29.
Comparison of the efficiency of solar chimney for three masses of water.

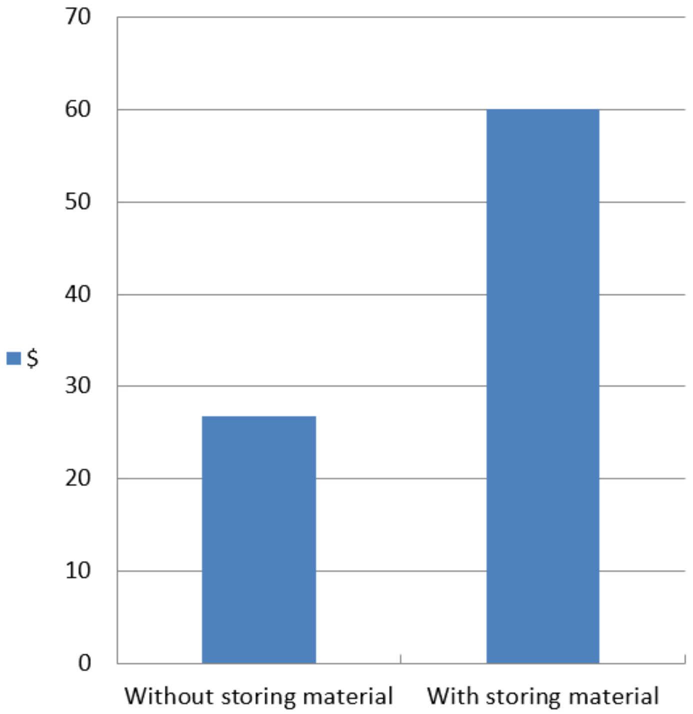

Figure 30.
Saving of the costs of energy supplied per unit volume of the room.

4.3. Economical Study

To evaluate the importance of natural ventilation, the energy supplied to the room per m3 by the chimney without and with water as a storage fluid is calculated. Water is chosen as the storing fluid because of the good results obtained. Besides, the cost of electric energy, if used for ventilation, is calculated. Then, a reduction in the cost of energy could be obtained. Figure 30 illustrates the cost savings for the cases, taking the first room with no chimney as a reference

5. Conclusions

The results obtained from this study of natural ventilation of buildings using solar chimneys, with and without storing materials, led to the following conclusions:

1- Natural heating of the building could be achieved using solar chimneys.
2- The use of storing materials tends to increase the inside temperature of the building.
3- Using water as a storage material is preferred because of its capable heat capacity.
4- Increases in the amount of stored water lead to increased heat supplied to the buildings.
5- Using a solar chimney for storing materials preserves them at a nearly stable temperature for a long time after sunset.
6- The study of efficiency indicates that water is preferred for use as a storage material.
7- The costs of traditional heating could be overcome by using solar chimneys to store material.

References

[1] J. Khedari, B. Boonsri, and J. Hirunlabh, "Ventilation impact of a solar chimney on indoor temperature fluctuation and air change in a school building," *Energy and Buildings,* vol. 32, no. 1, pp. 89-93, 2000. https://doi.org/10.1016/s0378-7788(99)00042-0

[2] E. D. Sagredo and J. Sprakker, "Micro solar chimney using concentric vacuum tubes," presented at the In 3rd LACCEI International Latin American and Caribbean Conference for Engineering and Technology, 2005.

[3] Y. Kaneko, K. Sagara, T. Yamanaka, H. Kotani, and S. D. Sharma, "Ventilation performance of solar chimney with built-in latent heat storage," *In Proceedings of 10th International Conference of Thermal Energy Conference (ECOSTOCK)*, 2006, pp. 105-111.

[4] R. Bassiouny and N. S. Korah, "Effect of solar chimney inclination angle on space flow pattern and ventilation rate," *Energy and Buildings,* vol. 41, no. 2, pp. 190-196, 2009. https://doi.org/10.1016/j.enbuild.2008.08.009

[5] M. Gontikaki, M. Trcka, J. L. M. Hensen, and Hoes, "Optimization of a solar chimney design to enhance natural ventilation in a multi-storey office building," presented at the 10th International Conference for Enhanced Building Operations, Kuwait, 2010.

[6] S. A. Hassanein and W. A. Abdel-Fadeel, "Improvement of natural ventilation in building using multi solar chimneys at different directions," *Journal of Engineering Sciences,* vol. 40, no. 6, pp. 1661-1677, 2012. https://doi.org/10.21608/jesaun.2012.114607

[7] H. H. Al-Kayiem and Y. M. Heng, "Experimental investigation of rooftop solar chimney for natural ventilation," *Journal of Engineering and Applied Sciences,* vol. 10, p. 10249, 2015.

[8] C. D. Justin and N. Demba, ""CFD-assisted design and optimization of solar chimneys for elementary school classrooms," presented at the 14th Conference of International Building Performance Simulation Association, Hyderabad, India, Dec, 2015.

[9] M. Al-Neama and I. Farkas, "Influencing of solar drying performance by chimney effect," *Hungarian Agricultural Engineering,* vol. 30, pp. 11-16, 2016. https://doi.org/10.17676/hae.2016.30.11

[10] X. Zha, J. Zhang, and M. Qin, "Experimental and numerical studies of solar chimney for ventilation in low energy buildings," *Procedia Engineering,* vol. 205, pp. 1612-1619, 2017. https://doi.org/10.1016/j.proeng.2017.10.294

[11] M. Danesh, "The effect of using solar chimney on reduced heating load in cold climate of US," *International Journal of Innovation Engineering and Science Research,* vol. 2, no. 4, pp. 56-63, 2018.

[12] S. A. Okasha, A. A. Faheim, M. H. Monged, M. R. Khattab, N. S. Abed, and A. A. Salman, "Radiochemical technique as a tool for determination and characterisation of El Sela ore grade uranium deposits," *International Journal of Environmental Analytical Chemistry,* vol. 103, no. 4, pp. 737-746, 2023. https://doi.org/10.1080/03067319.2020.1863388

[13] N. S. Abed *et al.*, "Geochemical conditions and factors controlling the distribution of major, trace, and rare elements in sul hamed granitic rocks, Southeastern Desert, Egypt," *Minerals,* vol. 12, no. 10, p. 1245, 2022. https://doi.org/10.3390/min12101245

[14] S. H. Taha, O. R. Sallam, A. E. A. Abbas, and N. S. Abed, "Radioactivity and environmental impacts of ferruginous sandstone and its associating soil," *International Journal of Environmental Analytical Chemistry,* vol. 101, no. 15, pp. 2899-2908, 2021. https://doi.org/10.1080/03067319.2020.1715377

[15] O. Ebyan, H. Khamis, A. Baghdady, M. El-Feky, and N. Abed, "Low-temperature alteration of uranium–thorium bearing minerals and its significance in neoformation of radioactive minerals in stream sediments of Wadi El-Reddah, North Eastern Desert, Egypt," *Acta Geochimica,* vol. 39, no. 1, pp. 96-115, 2020. https://doi.org/10.1007/s11631-019-00335-z