MSA UNIVERSITY ENGINEERING JOURNAL

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جامعة أكتوبر للعلوم الحديثة والآداب

UNIVERSITY of GREENWICH

# Improving thermal performance and air flow inside the solar chimney by CFD simulation

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## Abstract

University buildings require a study environment prepared for students that helps improve student concentration and academic achievement, as the most important thing that may help improve thermal comfort is sufficient ventilation of the space and an appropriate temperature. Solar chimneys play a major role in improving thermal comfort for university spaces. The research dealt with the design of eight Solar chimneys on the southern facade of a classroom in the university campus in Sohag, Arab Republic of Egypt, to achieve the maximum indoor air velocity and the lowest temperature during the summer, with a special focus on thermal comfort for students, as the ANSYS program was used to simulate and analyse air movement, fluid flow, temperature distribution, and electromagnetic efficiency, and the study of other effects over time. A 3D model of the hall was created using Solid Work, and a solar chimney was proposed using PCM panels to achieve the best passive ventilation. First, the CFD numerical analyses were performed within the ANSYS program to test the best solar chimney dimensions and compare the results with field measurements. (DOE) experiments were conducted on two fixed dimensions with chimney widths 20 cm and 40 cm, with testing the chimney entrance openings of 20 cm x 20 cm and 40 cm x 40 cm and testing the internal temperature and air velocity in the hall over the study months in summer and winter and understanding the mechanism. The physical phenomenon of atmospheric buoyancy. The experiments also included the design of a solar chimney with a 45-degree inclined roof attached to a runway without considering the humidity factor. for the effect of wind speed in a vacuum with a deviation (RMS) of 0.8% between the two values. Runway temperatures were reduced by 2.5°C by a solar chimney and results of an improved solar chimney design to enhance indoor air movement, optimization results also showed that maximum indoor air velocity in the runway area is achieved by using a 20x80 chimney with 20x20 void and opening western windows in this case study. A solar panel with a height of 4 meters, a width of 0.8 meters, an inclination of 45 degrees, and an air gap of 0.2 meters. The proposed solar chimney and its advantages deserve further research. Based on this innovative concept, the solar chimney on the south façade can be redesigned, PCM panels assembled, the chimney width changed and the number of air intake holes in the chimney increased to form an efficient solar chimney, to serve as passive ventilation without much cost and make full use of solar energy., then reaching the maximum internal wind speed of the vacuum achieving thermal comfort by changing several parameters of the chimney.

**Keywords:** Solar chimney, natural ventilation, University Buildings, Thermal comfort, Thermal Performance, natural ventilation, CFD simulation, ANSYS FLUENT.

## 1. Introduction

Egypt is located in a dry climate according to the Köppen world classification as shown in Figure 1. And it was once an exporter of oil and gas, and is now struggling to meet its energy needs. While it has proven oil reserves of 4.4 billion barrels and proven natural gas reserves of 78 trillion cubic feet, an ever-increasing proportion of its daily production is being used to meet the country's growing energy needs. Egypt's demand for electricity is growing rapidly, and the need to develop alternative energy sources is more urgent than ever. It is estimated that demand is increasing at a rate of 1,500 to 2,000 MW per year (Fig. 2), due to rapid urbanization and economic growth. The development of the renewable energy industry has become a priority for the Egyptian government in recent years. The current energy strategy in Egypt. aims to increase the share of renewable energy, a goal that is expected to be achieved to a large extent by expanding the scope of renewable energy projects and exploiting solar radiation as one of the main sources of energy in Egypt.

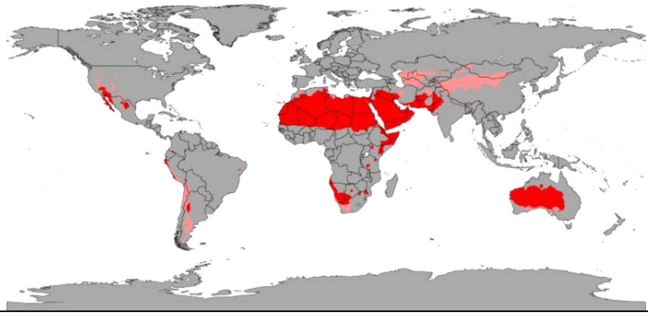


fig. 1 The dry climate by distribution Köppen climate classification.

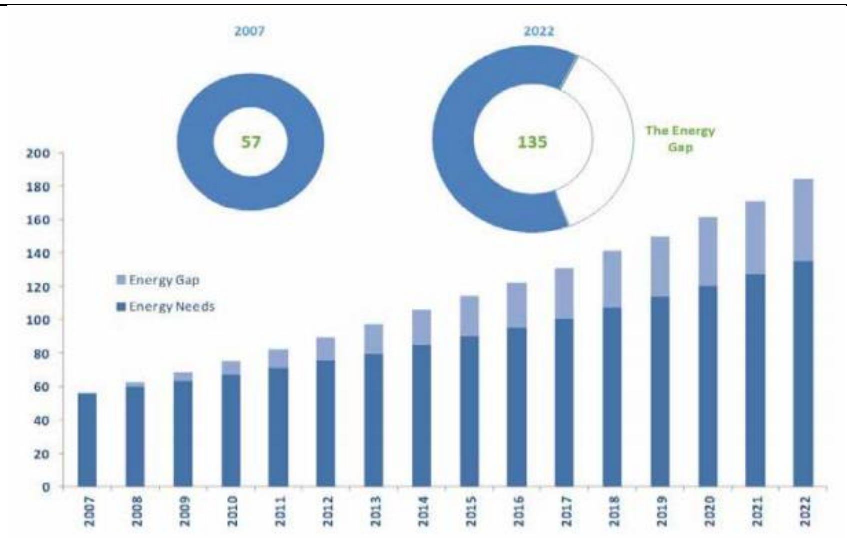



fig. 2 The demand for electricity in Egypt is increasing at the rate of 1,500 to 2,000 MW per year.

This country has high potential in solar energy production, and its exploitation is critical to national sustainable development through efficient energy planning and gradual independence from fossil fuels. Optimal access to energy is a prerequisite for economic development and an important condition for stimulating the growth of its economy. Demographic trends in Egypt require informed long-term planning of energy sector investments at the national level to expand existing electricity production capacities and meet growing demand. Egypt has one of the best environments conducive to the largest production of renewable energy in the world. The competitive advantage of Egypt and the Middle East in the field of solar energy is among the highest in the world in terms of solar radiation rates throughout the year. Specialized studies have shown that the exploitation of an area of 10 km2 in producing energy from concentrating sunlight in Egypt in the Western Desert is equivalent to the energy generated from the production of solar energy. About 15 million barrels of oil annually, as the region is characterized by high rates of solar radiation as in (Fig.3) during the months of the year in the region, except for the months of January and February, when it drops to 85%. Despite that, the system of using solar energy in development is negligible compared to many countries worldwide.

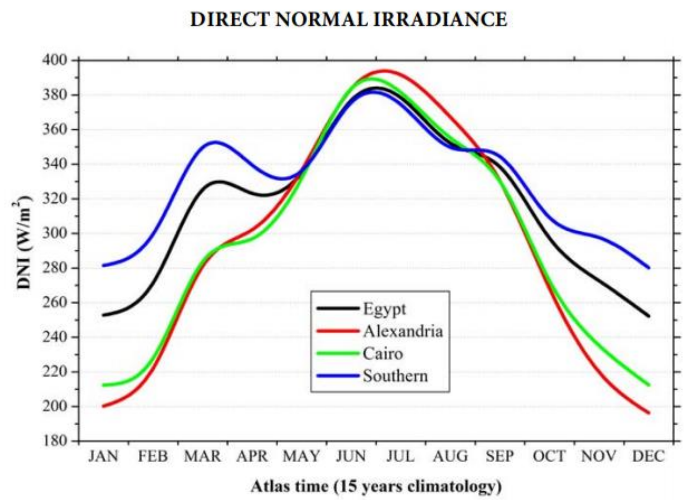



fig. 3 (A): The DNI for the 15-years period (Jan 1999 - Dec 2013) for the whole Egypt region as compared with the three sub-locations.

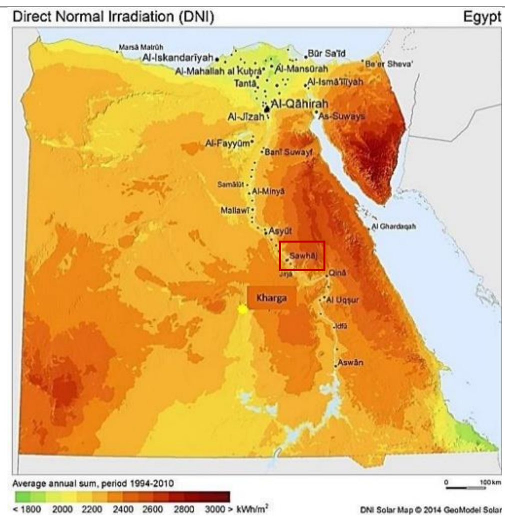



fig. 3 (B): Solar radiation on Egypt "This map was developed from the CRU TS 3.21 dataset produced by the Climatic Research Unit at the University of East Anglia, UK."

## 2- FORMULATING THE PROBLEM AND GOALS

The above review reveals that optimizing the performance of a solar chimney depends primarily on achieving the height, width, angle of inclination and spacing of the duct, as well as the optimal hot air outlet location. However, previous studies have clarified the simplified composition of studying the phenomenon of natural convection of the solar chimney in particular, as the criteria for determining the optimal design of the solar chimney in these studies differed. Moreover, the optimum design parameters were mainly based on the design that achieves maximum air flow rate and thus optimum thermal comfort for the users The relationship between air speed and operative temperature upper limit is depicted in Fig.4. However, such a design cannot be determined with hypotheses, especially because of the difference in the area of space in each study and the number of users in particular so this study aims to develop a mathematical model, to derive the optimal design of a solar chimney for a classroom in a university building with an area of approximately 200 square meters, As this model is able to check each parameter with others such as depth, width, air gap and air entry direction under actual weather data.

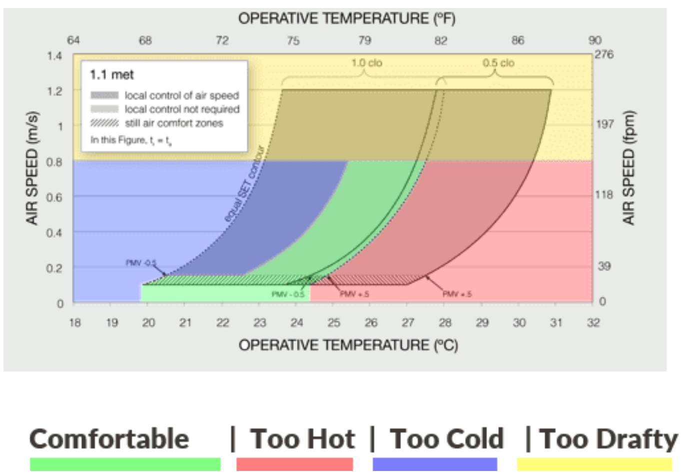



fig. 4. Air speed required to offset the thermal comfort zone (ASHRAE, 2010).

## 3- Basic operation of the solar chimney

Solar chimneys are usually placed on the southern facades most exposed to solar radiation, as shown in Figure (5), where the solar radiation passes through the glazing and is absorbed on the surface of the black wall. The air in the chimney is then heated by convection and the radiation is absorbed by the roof from the sun. This leads to a difference in pressure and a decrease in the density of the air, which leads to its rise, and then it is replaced by air from below and its temperature is lower, that is, from the air entering the vacuum window. Solar chimneys are also generally used to provide ventilation for cooling and improve the thermal performance of a vacuum, but also sometimes for heating, when a fan can be used to direct warm air into the building. An important advantage of a chimney used only for cooling is that the demand for cooling and the supply of solar radiation is developing. In this work, computer simulations were performed to aid in the design process. The studied variables were the width and depth of the bore, the increase in the number of chimneys on the facade, the change in the size of the outlet opening and air inlet holes from the room into the chimney. The solar chimney can be considered a special case of Trump's wall. However, trump wall usually forms part of the building wall and has the disadvantage that it occupies the wall space normally occupied by glass, causing a loss of daylight and visibility. They usually also have a large thermal mass. While the solar chimney is far enough from the wall of the building, it does not allow heat transfer, and the chimney section is usually small and does not take up much space on the façade.

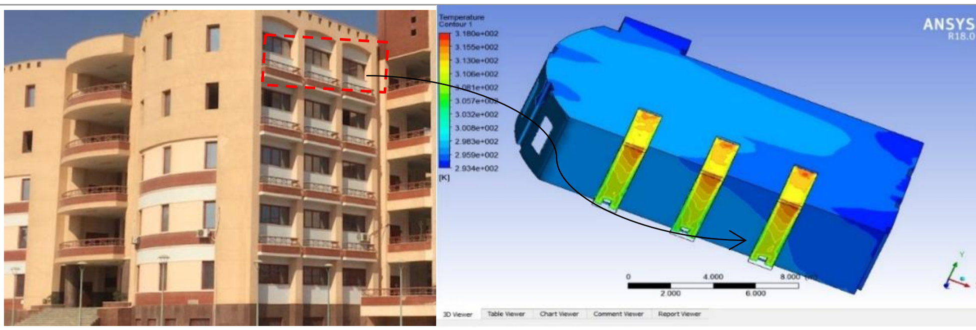



fig. 5.: A/ The geographical location of the building and the basic operation of the solar chimney on the southern facades

fig. 5.: B/ Model of the reference building developed in ANSYS FLUENT.

## 4- Geometric Model

The surrounding effects of the building are site-specific, since there are geographic differences in solar radiation Fig. 6, outside temperatures and sun angle. The conditions used here for the new city of Suhag in Egypt were at latitude 26° N and longitude 31° E. One of the educational halls at Al-Kwamel University located in New Suhag in particular (College of Education) was studied after one of the researchers made field measurements on this building and through those The study revealed that there is a problem in thermal comfort for students resulting from high temperatures and inappropriate ventilation, as the hall was on the fourth floor and used as a computer lab, with an approximate area of 17.10 x 11.88m, Fig. 6 and it is located in the south of the building as shown (Fig.7) and it has Three facades, a southern facade, a western facade and a northern facade, its openings are windows of 2 meters' x 2 meters on the southern and western facade only. The field measurements that were made on this building were used in one of the published researches that were measured over a period of five months (February, March, April, November October) from 9 am to 3 pm and these results were compared with the results of CFD The calculation procedure was choosing one day per month and it was the highest day in temperatures (24 February,10 March, 17 April, 19 November, 15 October).

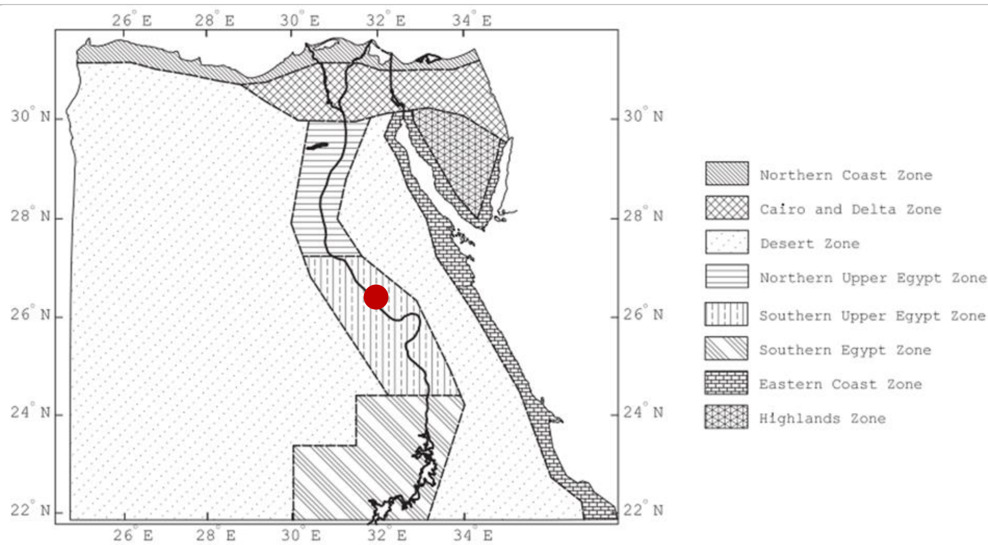
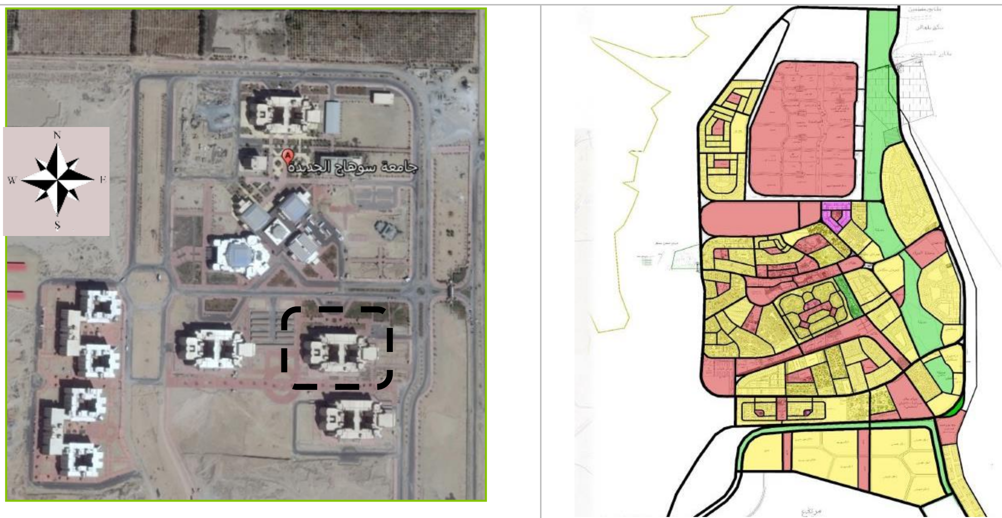



Fig 6. The climatic regions of Sohag in Egypt classified by HBRC (1)




**B** **A**

Fig 7: A/ the geographical location of the new Sohag city of, B/ the location of the building of the College of Education in Kwamel in relation to the north direction.

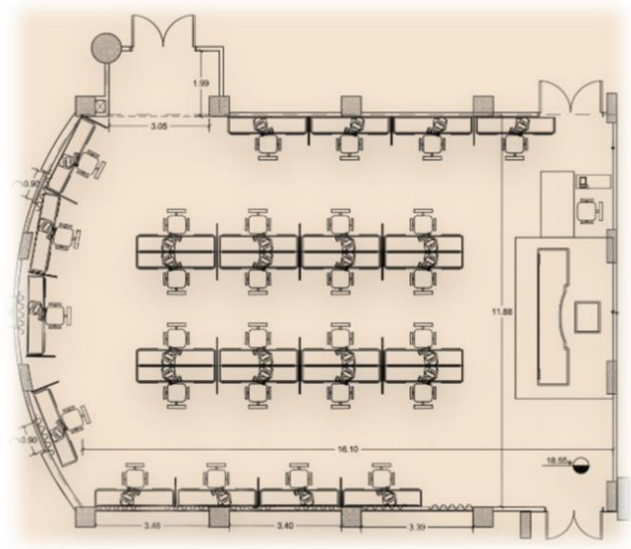


Fig. 8: The study hall is located on the fourth floor

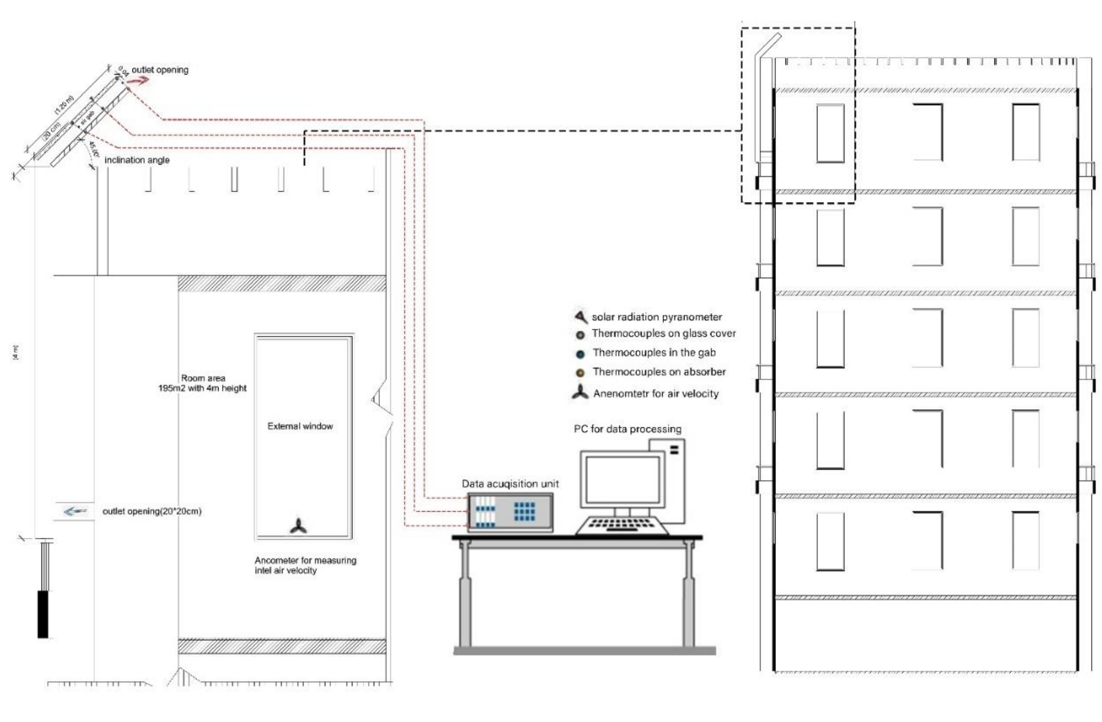



fig. 9. Measurement instrument configuration in the experimental set-up.

## 5- Discussion

Natural ventilation is one of the most important elements of thermal comfort, as it provides a healthy and comfortable environment for users in buildings in general and in university buildings in particular. the country’s primary energy consumption is rising alar-mingle, having tripled in the last two decades [1] and experienced an 8.6% deficit between electricity generation and demand in 2013 In public buildings, and especially in educational buildings, indoor comfort conditions must also be taken into account, given the growing interest in hygrometric thermal comfort and indoor air [2]. Domestic energy consumption is about 51% of total energy consumption. Air conditioning used mainly in refrigeration accounts for about 23% of total domestic energy consumption [3]. Negative heating, cooling and ventilation systems have received considerable attention in recent years, particularly with the significant increase in energy demand and energy prices. In Egypt, maximum pregnancy increased by 7.3% in 2014/15. As a result, the number of fashion designers increased from 30.6 million in 2014 to 31.4 million in 2015 [1] Fig. 10 This is due to the fact that the renewal of air in the space has a high effect on the concentration of the student and thus increases the daily production rate. A body of research has shown an imbalance in the thermal comfort of users in university buildings. This is due to the presence of overcrowding in the buildings to a large extent. According to another study, the requirement of daily fan shaft in a house in Tokyo can be reduced by 50% annually due to the implementation of natural ventilation [4]. In addition to that, buildings rise over large areas and divide each floor into independent units, which hinders natural ventilation and limits air movement and renewal of air inside the building. Hence the need to find a solution to this problem and conduct a study on how to renew the air inside the spaces naturally in order to help achieve User thermal comfort, mechanical ventilation requires electrical energy, while natural ventilation relies on wind and thermal buoyancy as the driving force [5]. This research is based on the idea of how to use the best design of solar chimneys and employ them in the facades of the southern university spaces, so that they naturally renew the air, which reduces electrical energy consumption and provides healthier natural ventilation for the user in hot summer periods. As a result, the research provides a case study for the design process and improvement of thermal comfort, by analyzing one of the classrooms in the Faculty of Agriculture at Suhag University and studying the factors affecting thermal comfort such as temperature, humidity, and air velocity entering a vacuum, and through previous research on this building, other research results have been proven. There is a problem with thermal comfort [6]. In order to perform the improvement process through the analytical approach, therefore, modifications are assumed in the design of the vacuum so that a fish chimney mechanism is added that works to change the rate of air velocity and renew the air inside the vacuum and obtain a lower temperature. This was done by simulating it on ANSYS computer program. Therefore, a study was adopted. The presence of a semi-chimney on the southern facade of the space and studying its effect on a multi-story building through the thermal siphon property, where the results of previous research showed that the thermal performance of the working air temperature decreased by 0.81 ° C and the room air velocity improved after the introduction of the solar chimney by 50% in the hottest hour Heat [7]. In order to evaluate these modifications and measure their actual effect on activating natural ventilation, a computer model was made in all details through the use of ANSYS simulation program. Thermal simulations and air movement analysis were performed using the CFD Computational Fluid Dynamics tool for the various hypotheses and systems that will be studied and analyzed.

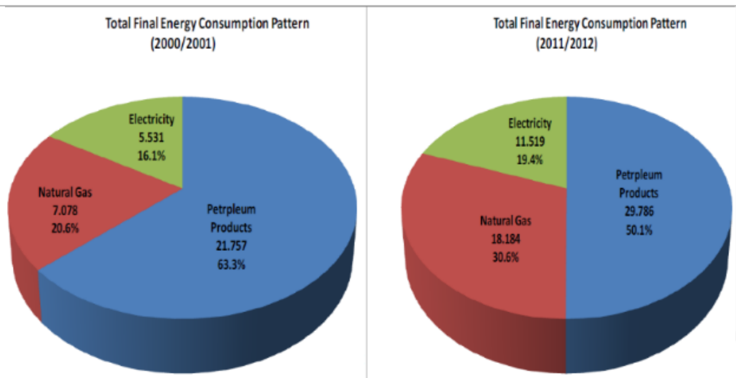



Fig. 10 total final energy consumption is 63.3% in 2000/2001 and 50% in 2011/2012 in Egypt [8].

[9] studied the effect of the improved solar chimney on two floors by computational CFD simulation program, where it was found that changing the angle of inclination of the roof is important whenever the length of this part is sufficiently large and the air in the vacuum was enhanced by an average of 24% when the funnel shape took more than traditional designs. [10] has studied the relationship between home ventilation and respiratory health and the need to achieve natural ventilation in spaces to achieve maximum health protection for users. In the study of a solar chimney on 3 floors, simulating 3 cases [11] To design a solar chimney using the dynamic fluid calculation program. Also [12] studied the effect of the solar chimney on a classroom in Singapore that connected the classrooms with channels where it had an effect in the case of low solar radiation and the effectiveness of this system decreased with strong solar radiation. [13] designed a solar chimney and tested the air inlet openings, which are the bottom inlet, side inlet, bottom and side inlet both and the effect of incorporating the solar chimney with paraffin (phase changing materials) [14] on its thermal behavior by CFD and concluded that the side inlet solar chimney gives Better thermal performance. Incorporating a solar chimney with PCM to extend the ventilation period after sunset. An experimental and numerical study was conducted. SC for ventilation in Iraq and the effect of an angle of inclination of 75 degrees on the ventilation of SC (Kora NC et al., 2009) studied the effect of the angle of inclination of the solar chimney on the ventilation rate and air flow and using a numerical simulation using ANSYS, where it was concluded that the optimal value of the air flow rate was achieved when the chimney inclination ranged from 45 degrees and 70 degrees' inclination to 28.4 degrees' latitude. (A.B. Sacconido, et al., 2008) developed a mathematical model to determine the slope that increases the natural air flow inside a SC solar chimney by CFD for a length of (1-1.2) and a mile (30-90). (Leila Moosavi, at all, 2020) [15] designed a small-scale chimney model and analyzed it by CFD for a chimney designed with a water spray system for a two-story office building in a warm and arid climate, which gave reasonable results and a temperature reduction of 5.2 degrees Celsius. (M. Krzaczek, at all, 2015) [16] conducted a field study during June between spring and summer in northern Poland and suggested a modified model for a tilted pivot window. The results confirmed the feasibility of the proposed approach and found that wind reduces the efficiency of the work of the ACH. (U Drori, at all, 2004) [17] conducted an induced ventilation experiment on a one-story building with a chimney directly attached to the ceiling, and it had an effective effect by the presence of openings in the space. Also (Azadeh Jafari, at all, 2017) [18] studied the cooling of one-story buildings by a cooler side by side with a solar chimney and showed that the temperature of the interior room can be maintained within the limits of thermal comfort and using three cooling panels that reduced the room temperature by 26.8% and consumed 37% less electrical energy compared to air conditioning. (Serageldeer, at all, 2018) [19] studied a solar chimney along with a ground-to-air heat exchanger by conducting a three-dimensional and semi-stationary CFD simulation of a small wooden room with a solar chimney and a ground-to-air heat exchanger EAHA. Nayara Rodrigues Marques, at all,2021, used the CFD computational fluid dynamics program to evaluate natural ventilation with the integration of 3D modeling and found that the effectiveness of the natural ventilation of the

building, and wanted to achieve the idea of providing a practical CFD application to enhance assessments of wind-driven ventilation in the design phase of the building. (Wim Zeiler, at all, 2009) [20] has developed a new approach to designing thermal comfort solutions for students in schools through active building systems because of studies he conducted that proved that there is a growing interest in solving the problem of air quality in schools (IAQ) and conducted the study on 14 schools equipped with systems different from ventilation. (Jeffery K. Sonne, Atall, 2006) [21] studied indoor air quality in schools in the United States of America and made a questionnaire for two groups consisting of 16 schools and 15 schools and found that there is a problem in indoor air temperature and air quality also for classrooms, according to the comfort-adaptive approach recently developed in ASHRAE (2010), the operative temperature comfort limits are based on a 0.2 m/s indoor air speed. However, elevated indoor air speeds are capable of augmenting these comfort limits.

### 5.1- MATHEMATICAL MODEL

For the air modelling, the air is treated as an ideal gas and the Eulerian form of the governing equations namely, the Reynolds averaged Naiver Stokes equations (RANS), for the air being modeled as non-polar compressible Newtonian fluid are:

The continuity equation:

$$\frac{\partial \rho_a}{\partial t} + \nabla \cdot (\rho_a \mathrm{V}_a) = 0, \qquad (1)$$

and the linear momentum equation is:

$$\rho_a \left( \frac{\partial \mathrm{V}_a}{\partial t} + \mathrm{V}_a \cdot \nabla \mathrm{V}_a \right) = -\nabla p + \nabla \cdot (\tau_l + \tau_t) + \mathrm{F}, \qquad (2)$$

while the energy equation, with no source terms, reads:

$$\rho_a c_v \left( \frac{\partial T}{\partial t} + \mathrm{V}_a \cdot \nabla T \right) = Q + \nabla \cdot \mathrm{q}_l + \nabla \cdot \mathrm{q}_t - ptr(\mathrm{D}) + (\tau_l + \tau_t) : \mathrm{D}, \qquad (3)$$

where $\rho_a$ is the air density, $\mathrm{V}_a$ is air velocity vector, p is the thermodynamics pressure to be determined from the perfect gas equation of state, and D is the rate of strain tensor defined by:

$$\mathrm{D} = \frac{1}{2} [grad\mathrm{V}_a + (grad\mathrm{V}_a)^T] \qquad (4)$$

in which the laminar extra stress tensor $\tau_l$ and heat flux for compressible fluids are defined by:

$$\tau_l = 2\mu \mathrm{D} + \lambda tr(\mathrm{D})\mathrm{I}, \qquad (5)$$

$q_l = -h\nabla T,$ (6)

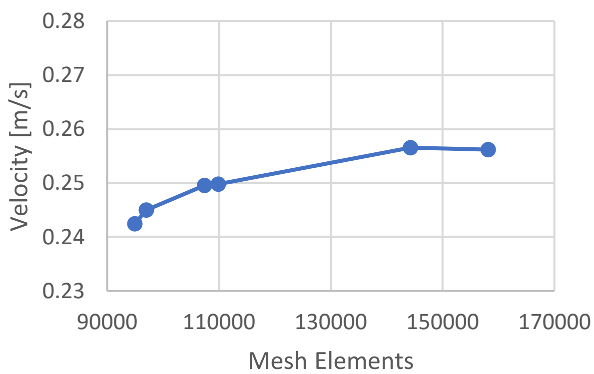
with $\lambda$ being the dilatational viscosity and is related to the shear viscosity $\mu$ by the Stokes assumption $\lambda = -{}^{2}/_{3}\,\mu$ and k is the thermal conductivity. The turbulence model is set to be k-omega, because it is more suitable for such kind of problems [2].

### 5.2- ASSUMPTIONS:

- The air is ideal gas.
- The walls and ceiling transfer heat to the home interior.
- Heat enters the aforementioned walls uniformly.
- The dark wall of the solar chimney transfers all of the absorbed energy from the sun.
- The glass wall of the solar chimney is adiabatic; heat-insulated surface.
- Humidity is omitted since the air circulation is more important.
- The heat is transferred from the sun to the chimney wall through radiation.
- The heat is transferred to the air through convection.
- The buoyancy force is considered.
-

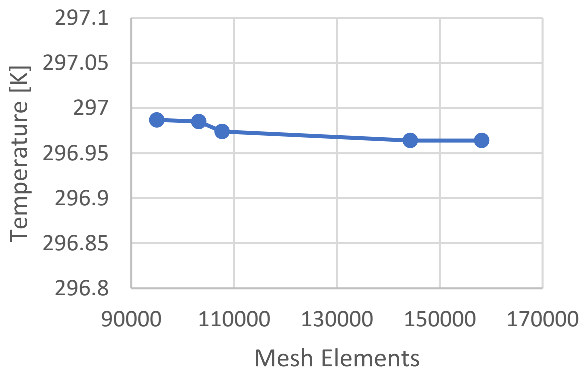
### 5.3- MESH DEPENDENCY TEST:

Several meshes were investigated to stand on the most suitable mesh for the current studies. The mesh elements vary from 90 to 160 thousand elements. The different meshes show convergence for the measured parameters, as shown in Figures11 a and b, where the velocity and temperature inside the domain versus the mesh elements are depicted. It is shown that the variation is almost neglected, and hence, the mesh of 14.5K elements is used hereafter.




( a)

Fig 11:/ **(**a) Variation of velocity inside the computational domain versus the number of **elements.**




(b)

(b) Variation of temperature inside the computational domain versus the number of elements.

The final mesh is described as follows. The inner space of the room is divided into small cells. These cells are used to help in computing Navier-Stokes equations in every cell. The mesh size of the chimney is 0.06m and up to 0.35m everywhere else. This leads to an average mesh quality is 82.2% And the standard deviation is 1%. The mesh is shown in Fig**.**

### 5.4- BOUNDARY CONDITIONS:

The air stream enters from the western windows to the home interior. Through its motion it is subjected to the heat generated by the walls and ceiling, while the floor is an adiabatic surface. The air stream finally exits from the three chimneys, as shown in Fig. the chimney is modelled as follows. The energy-absorbing wall of the solar chimney transfer all of the absorbed energy from the sun to heat energy added to the system, while the glass wall of the solar chimney is treated as heat-insulated surface, as shown in Fig.13 and fig.14 The amount of heat generated by the walls and solar chimney and the inlet air speeds and temperatures are variables governed by the studied cases mentioned later.

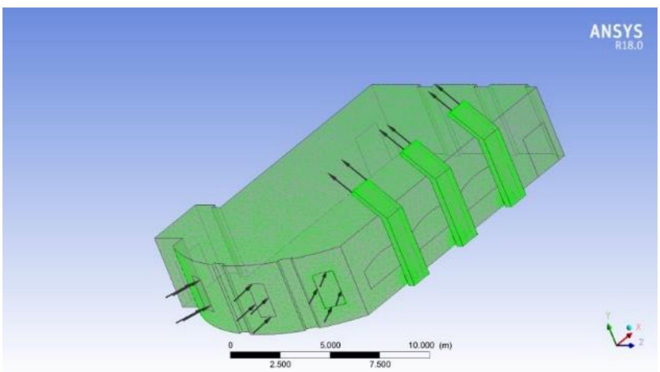



Fig. 12: The computational domain of the home.

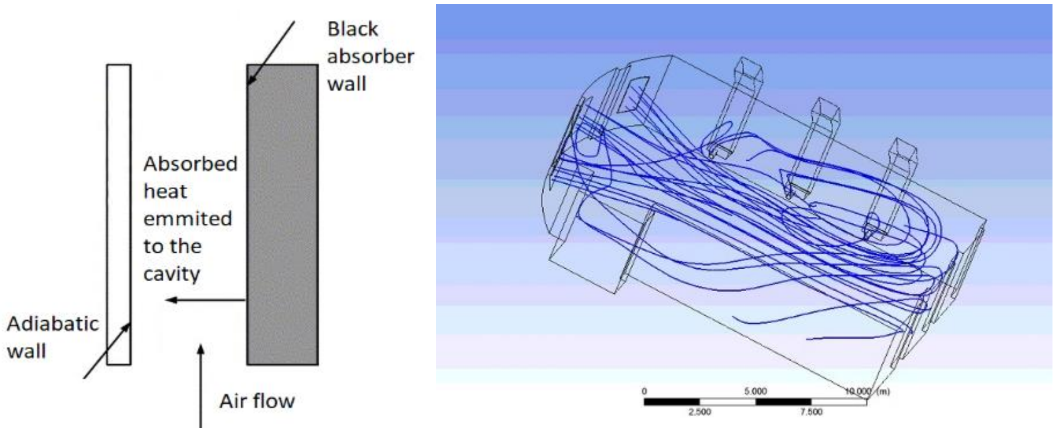



Fig.13: The computational model of the solar chimney

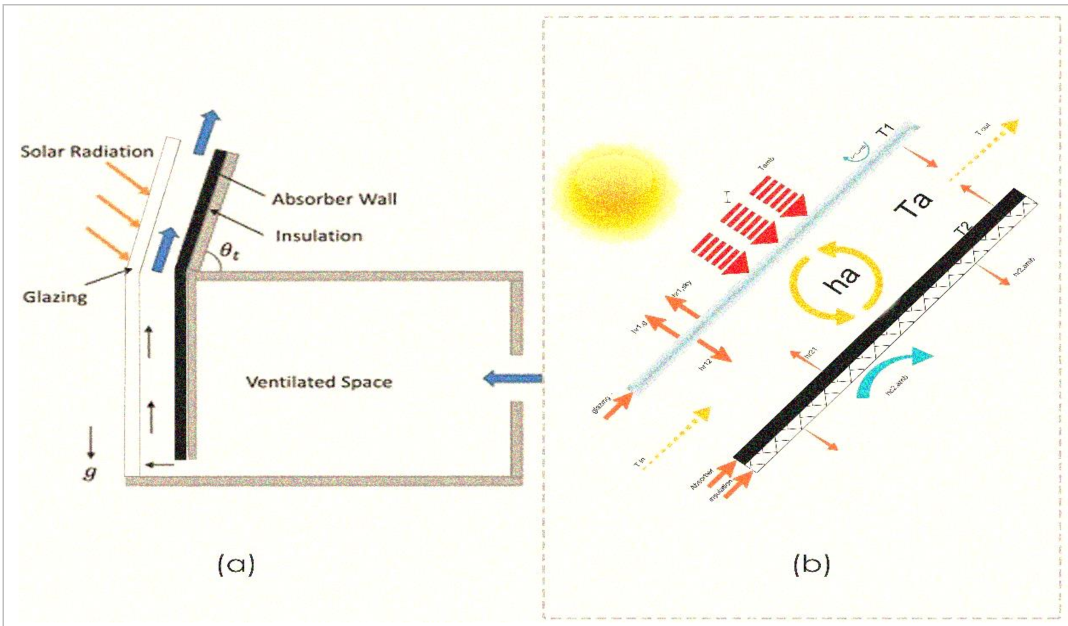



Fig 14:(a): the basic operation of a solar chimney,

(b): Boundary Conditions of the solar chimney

*Table (1): Boundary Conditions Types of solar chimney model.*

| ***Boundary*** | ***Condition*** |
|---|---|
| floor | Adiabatic wall |
| Chimney - glass side | Adiabatic wall |
| Chimney – black side | 1Heat source, according to the experimental data |
| walls | Heat source, according to the experimental data |
| windows | Air speed and temperature according to the experimental data |

*Table (2): Boundary Conditions Temperature & humidity.*

| unmassaged | Device | used Precision | Range |
|---|---|---|---|
| Temperature & humidity in spaces | TR-76Ui 1%, | ±1°C± | (0 to 45°C) (10% to 90% RH) |
| Temperature of earth surface | Infrared Thermometer 42515 | 2%, ±2°C± | -50 to 800°C |

The air stream enters from the western windows into the house. The amount and speed of the air and the temperature of the inside air are variables that are governed by the studied cases mentioned later. We find that when comparing the field-measured wind speeds with the wind speeds found in the simulation program, there is a difference due to the continuous weather change of hours. measured by it, and this must be taken into account in the final results of the measurements: The relationship between wind speeds in field measurements and wind speeds within the CFD program as shown in Fig.15

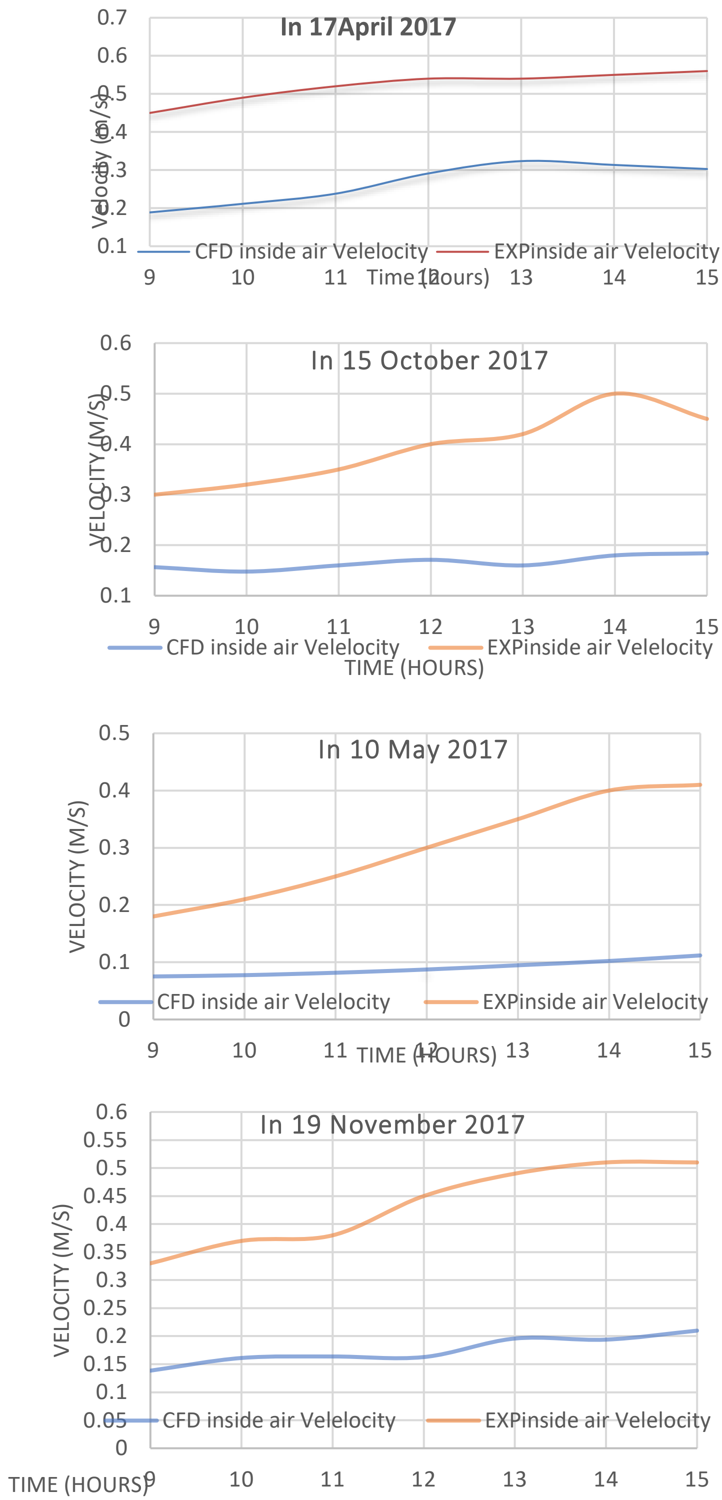


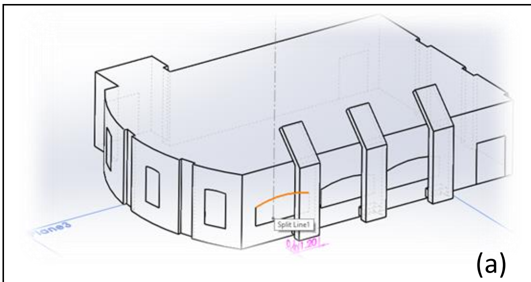
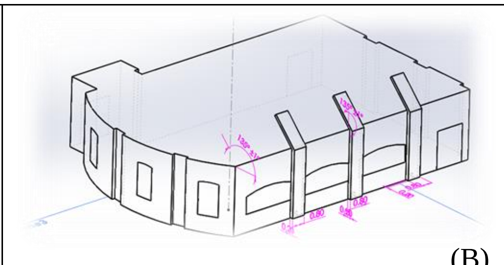

Figure 15: Relationship between wind speeds in field measurements and wind speeds within the CFD program.

### 5.1- Results and Discussions

Availability of general simulation codes to solve both thermodynamics and fluid dynamics in a single model is still limited to a few applications, so the model used here follows others in combining the heat network solution with the CFD model, the thermal network has been traditionally solved using basic equations and heat transfer correlations. The CFD model used was the Naiver Stokes equations with Reynold's average (RANS) and nine different states of the solar chimney were used by CFD: Real conditions within the CFD from field studies were applied to the building in the event that the chimney was not working and calibration worked. The dimensions of the solar chimney design were changed by installing one of the sides as a fixed dimension (20 cm and 40 cm) on the southern facade to be (1.60 m, 0.8 m) x 0.2 m, with a tilted roof angle of 45 degrees and a distance of 50 cm from the building. The dimensions of the chimney solar chimney on the south facade were changed to be 0.4 m x (1.20 m, 0.80 m, 1.60 m) with a pitched roof angle of ∘45 and a distance of 50 cm from the building. The square shape is 1.00 m x 1.00 m & 0.80 m x 0.80 m based on the Doe design principle.

### 5.2- Cases Study

Basically, in CFD model, the field is divided into nodes and approximate solutions to the governing flow equations are found by numerical methods, mainly finite differences, finite elements or finite volume methods. The principles behind this and other CFD models are well known in the literature, and will not be described in more detail here. In using the model, the traditional convergence and stability criteria were used. The heat network used is shown in Figure 16.

| | |
|---|---|
|  (a) |  (B) |
| Fig 16/ (a): the basic operation of a solar chimney 40cm | (a): the basic operation of a solar chimney 20cm |

### 5.3- Design of Experiments (DOE)

**table 3: The chimney size changes to study the effect of each of the geometric parameters.**

| Case | Width | Length |
|---|---|---|
| 1 | 20 | 80 |
| 2 | 40 | 120 |
| 3 | 40 | 80 |
| 4 | 40 | 160 |
| 5 | 20 | 160 |
| 6 | 80 | 80 |
| 7 | 100 | 100 |

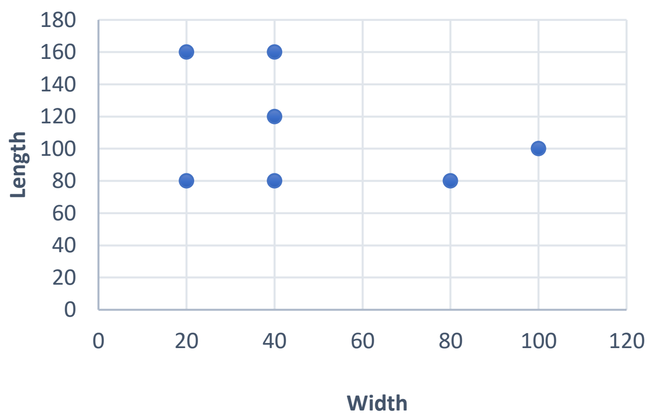



Figure 16: Studied Cases of Chimney Sizes

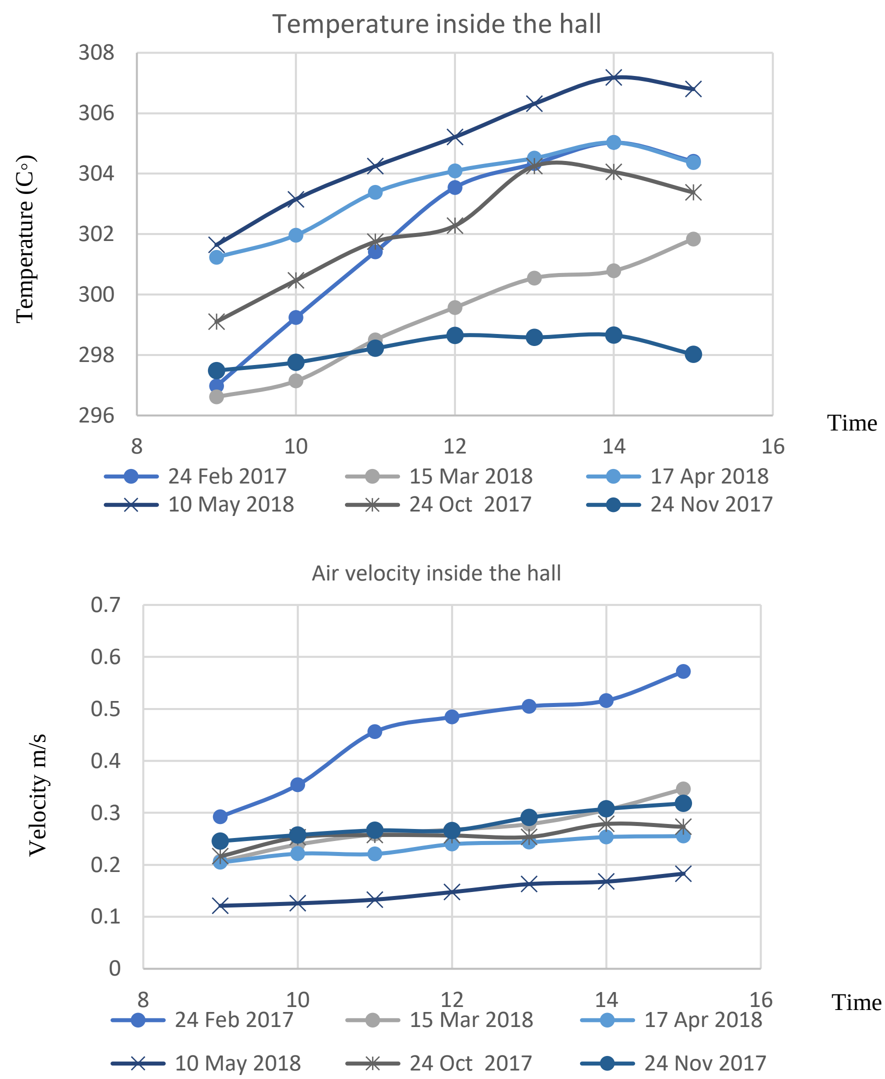



*Figure 17: Temperature inside the hall & Air velocity inside the hall Studied Cases of Chimney Sizes 20cm×80cm*

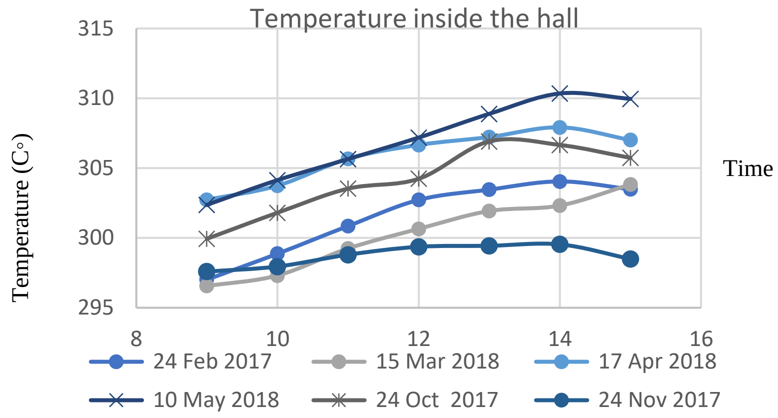



*Figure 18: Temperature inside the hall* & *Air velocity inside the hall* Studied Cases of Chimney Sizes *40cm×160*cm

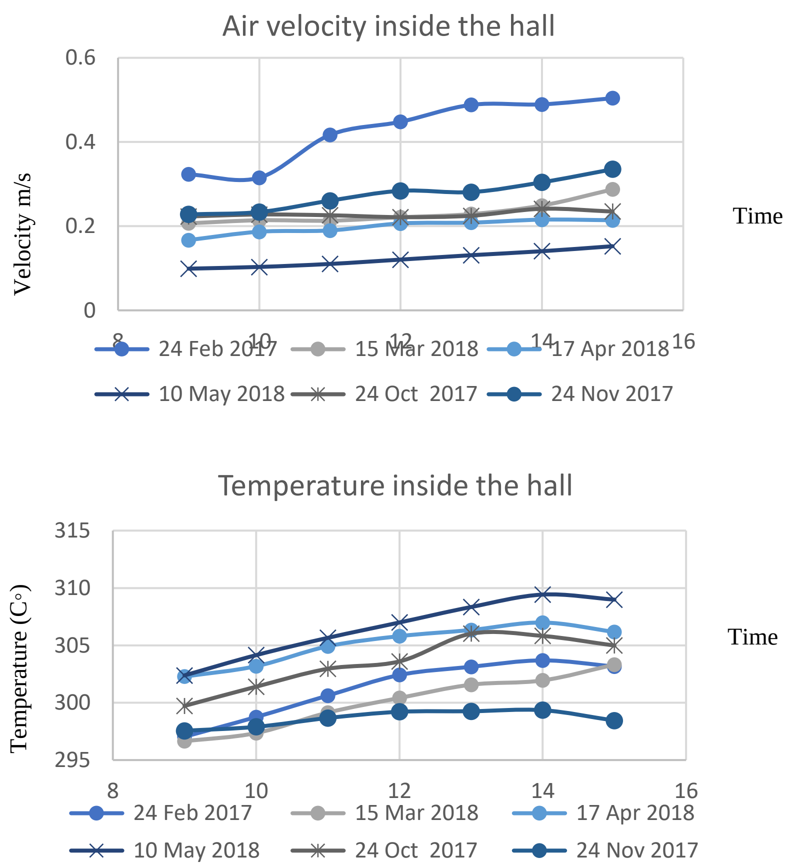



*Figure 19: Temperature inside the hall* & *Air velocity inside the hall Studied Cases of Chimney* Sizes 20cm×160*cm*

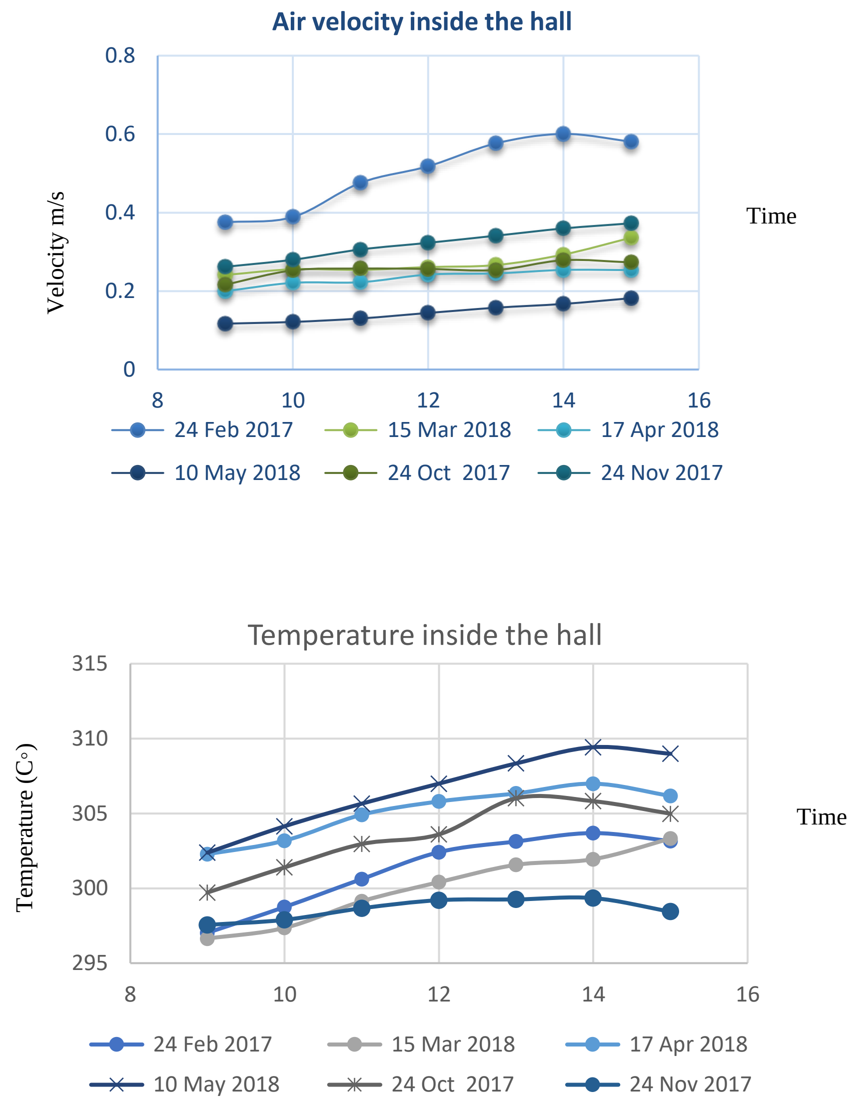



*Figure 20: Temperature inside the hall* & Air velocity inside the hall *Studied Cases of Chimney* 80cm ×80cm

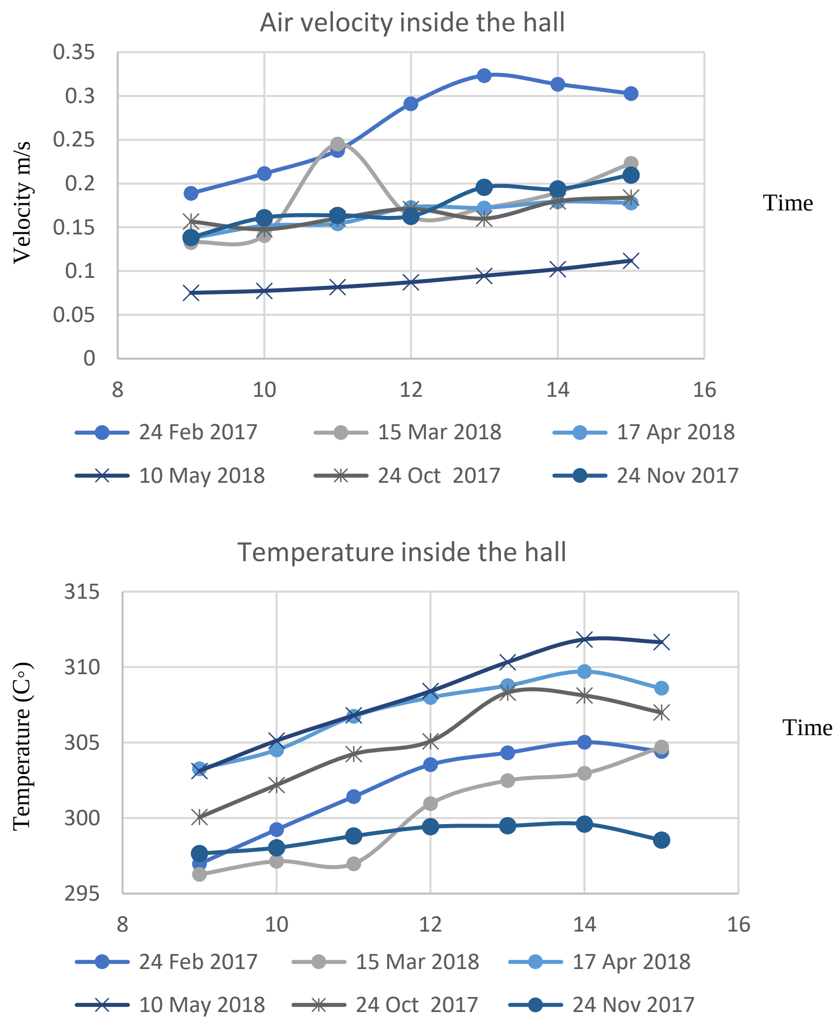



*Figure 21:* Temperature inside the hall *&* Air velocity inside the hall *Studied Cases of* no Chimney

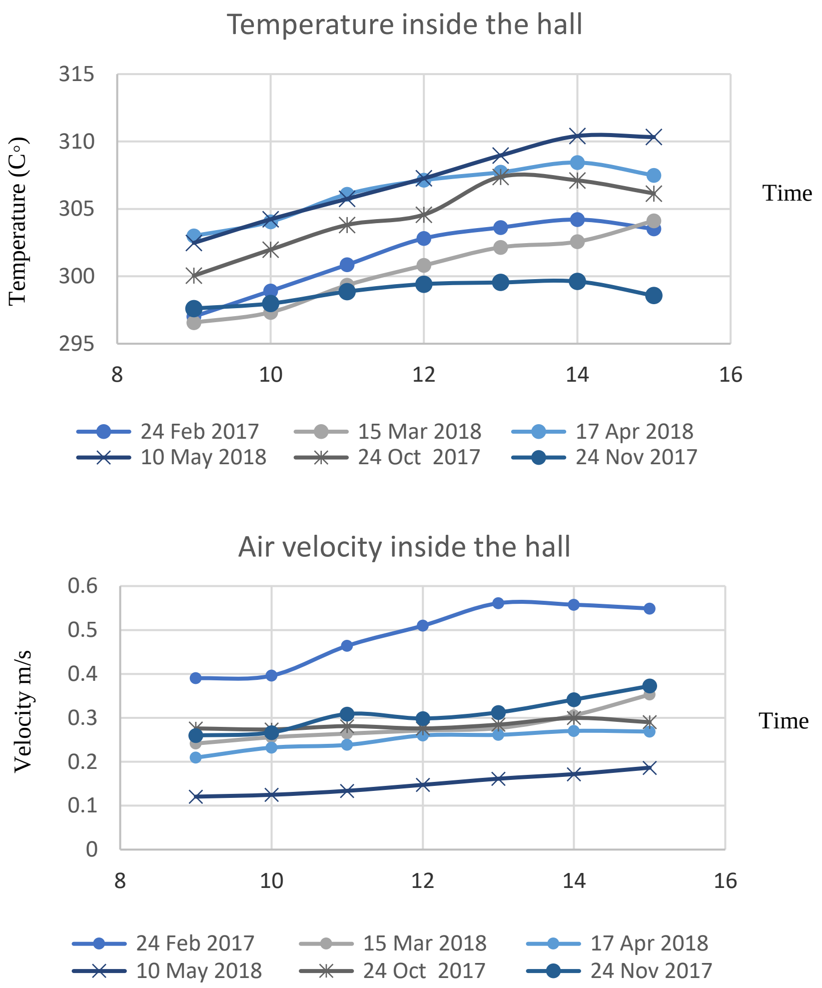
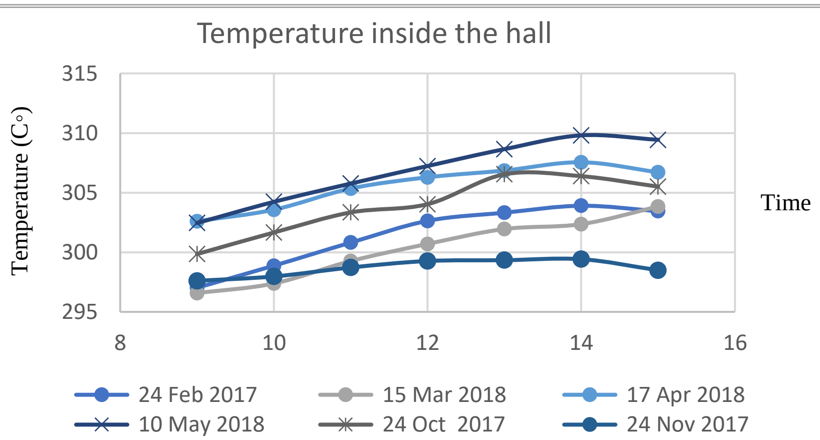



*Figure 22:* Temperature inside the hall *&* Air velocity inside the hall *Studied Cases of Chimney Sizes* 100cm×100cm



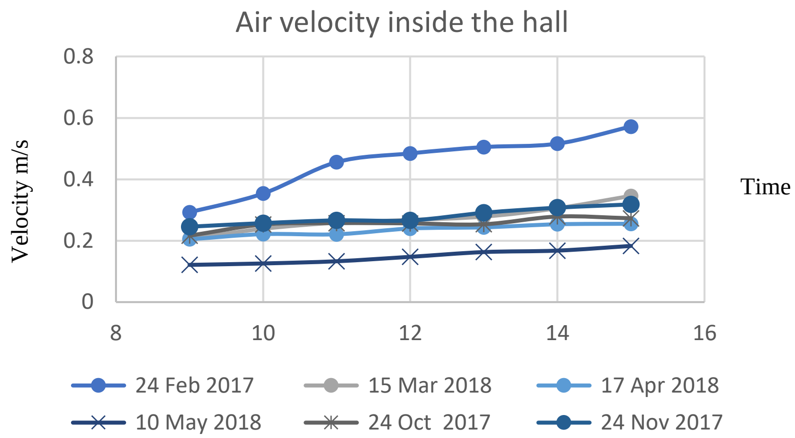
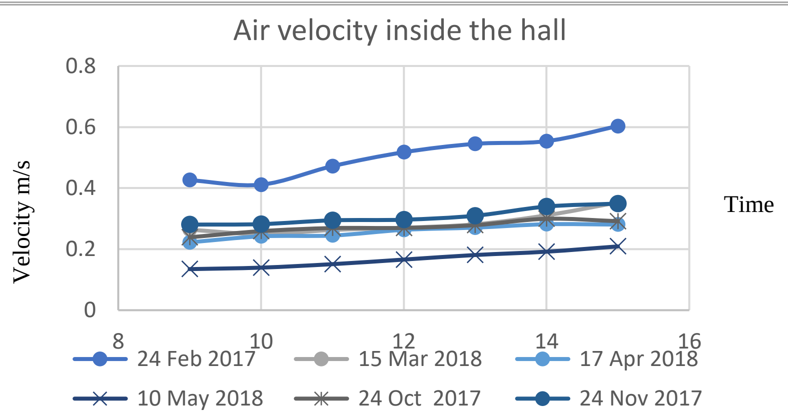



*Figure 23:* Temperature inside the hall & Air velocity inside the hall *Studied Cases of Chimney Sizes* 40 cm ×80 cm



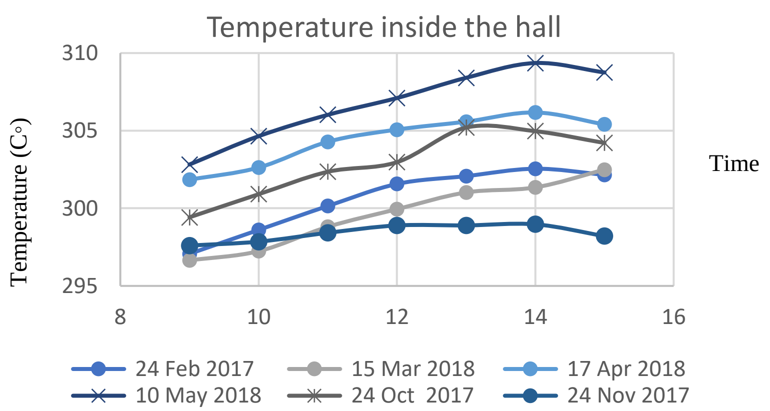
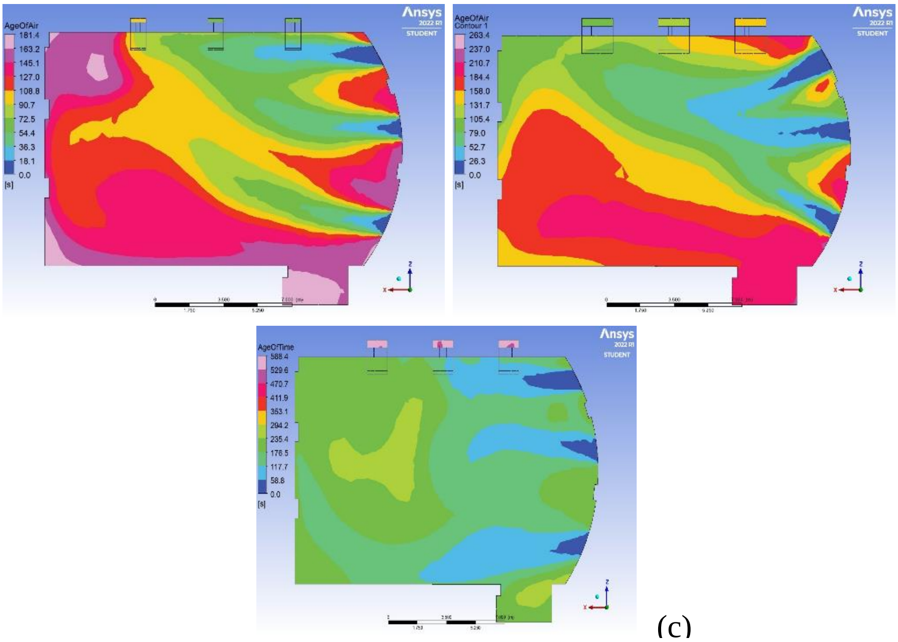




*Figure 24:* Temperature inside the hall & Air velocity inside the hall *Studied Cases of Chimney Sizes* 40×120 with opening 20×20

Real-time weather data was used by one of the field measurements taken by previous researchers on the building for different days over five months, from 9 a.m. to 3 p.m., where the outside temperature is greater than or close to the indoor temperature and the outside wind speed is higher than Air velocity inside the vacuum, and therefore it is important to measure the velocity of the air flow into the vacuum and the amount of air entering the windows, as the figure shows the lifespan of air in the vacuum for its chimney 20 ×80m & 40×160m.

(a)




(b)

(c)

Fig 25: Age of air in solar chimney (a)model 20×80, (b)model 40X160 & (c)chimney closed.

The solar radiation was adjusted according to the climate of Egypt and the amount of radiation specific to that area and calculated over the months and days (nrea.gov.eg) in which the basic field measurements were made, keeping other variables constant, the bore size was also varied, with the smaller bore (0.20 m) × (0.80 m) results are better than (0.40 m) × (1.20 m); A chimney roof with a slope of 45 degrees is optimal (DJ Harris, 2007). The presence of a narrow cavity may have greater effects on temperature, air flow and heat exchange between the chimney and the vacuum. Once the model was created and subjected to basic verification by CFD, the parameters selected were changed to assess the effects on airflow for different forms of construction and the focus was placed on the hatch connected to the airflow from the room to the chimney. Figure 13 shows the effect of using glass and a Low-E coating on absorption. Low-emissivity coatings allow radiation to be absorbed but limit the emission of long-wavelength infrared rays into the surroundings. Thus, the absorber and the surrounding air retain more heat from the inlet. The maximum air flow is obtained through a low-emissivity surface and a cavity width of 0.20 m × 0.8 m. The chimney giving the best performance (0.20 m × 0.80 m, single glazing, low emissivity, 45-degree angle is studied in more detail with regard to the dimensions of the hole connected to the chimney and the vacuum due to the velocity of air flow, performance varies throughout the day depending on the intensity of the radiation. Solar and the speed of Air flow inside the vacuum. The width of the opening between the solar chimney and the vacuum along the chimney line in the studied case gives less than optimal conditions. On average, the performance at 0.20 × 0.80 m is better, but it is 10% lower than the performance when open, and the flow is lower 25% in its dimensions 0.40 m x 1.20 m, and 30% less than a solar chimney is considered clogged. The increase in heat loss from the roof more than compensates for the increase in solar radiation received, (at least during the summer months, when ventilated cooling is often required of times). When reductions in construction costs are taken into account, it may also be beneficial to construct a chimney along the slope of the roof. This study shows that the reduced flow is due to air entering from western windows only, but is much less in the absence of a chimney., and (Figure 26) shows the speed of the air A inside the classroom, where we see that the air velocity increases at the smaller chimney compared to the 160 × 40 cm and the closed chimney.

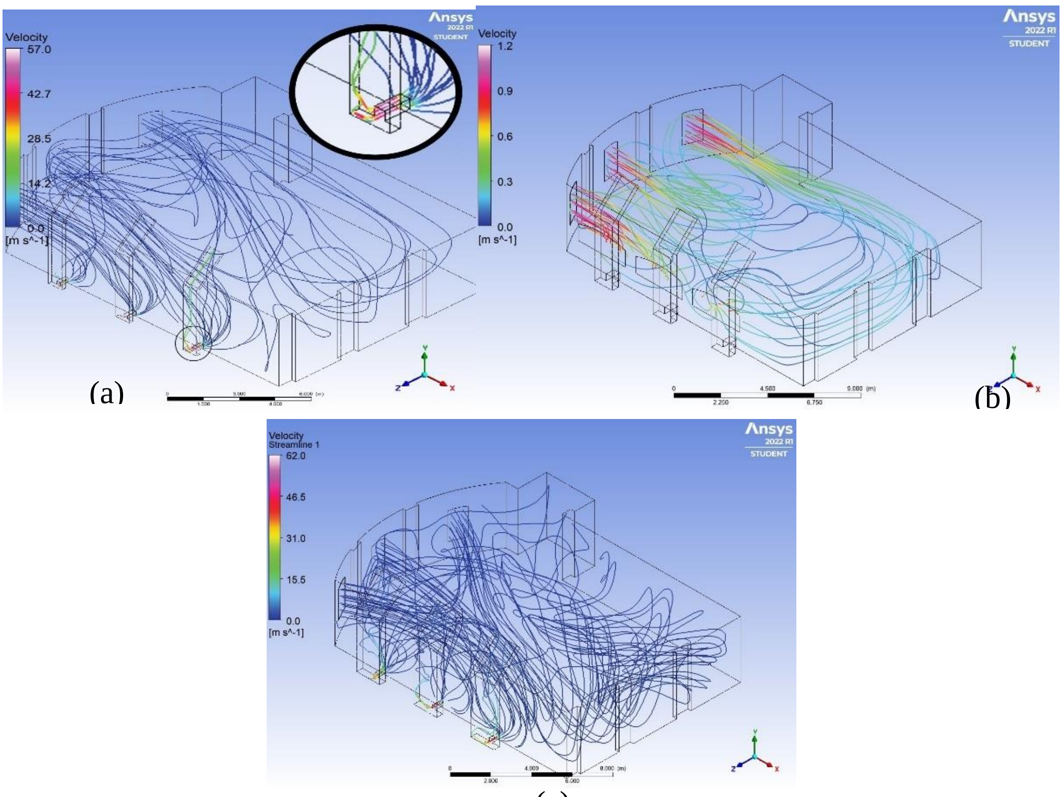



Fig 26: velocity of air in solar chimney (a)model 20×80, (b)model 40X160 & (c)chimney closed.

Planned additional studies will include empirical confirmation of this, and trials to determine whether the use of more effective north windows with west windows already in the hall on nature, even with poor performance of west windows, can improve lifelong thermal comfort. Year-round performance should also be investigated. By comparing the temperature results for the three cases and knowing the comfortable temperature limits in the range (295-300 K), it becomes clear that the lower the temperature, the closer we get to the thermal comfort limits, and therefore the efficiency from the chimney with a slot (20 × 20)cm is higher than the slot) (40 × 40) cm which will be discussed in another research paper and by reviewing the total chimney temperature drop z 80 × 20 during the five months of the study, during 35 hours, 84.6 degrees were found, with an average decrease of 84.6 / 35 = 2.4 degrees. In the case of the chimney 160×40, 21.14 is found. With an average of 21.14 / 35 = 0.6 degrees, we find the efficiency of the chimney 80 ×20 compared to other proposed alternatives

= 84.6 / 21.14 = 4 times.

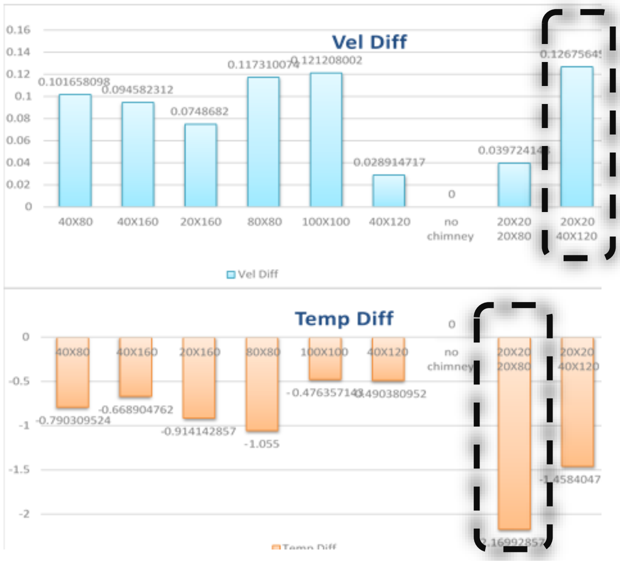



Fig 27: Average differences in indoor air velocity and temperatures in 9 different chimneys over a period of five months.

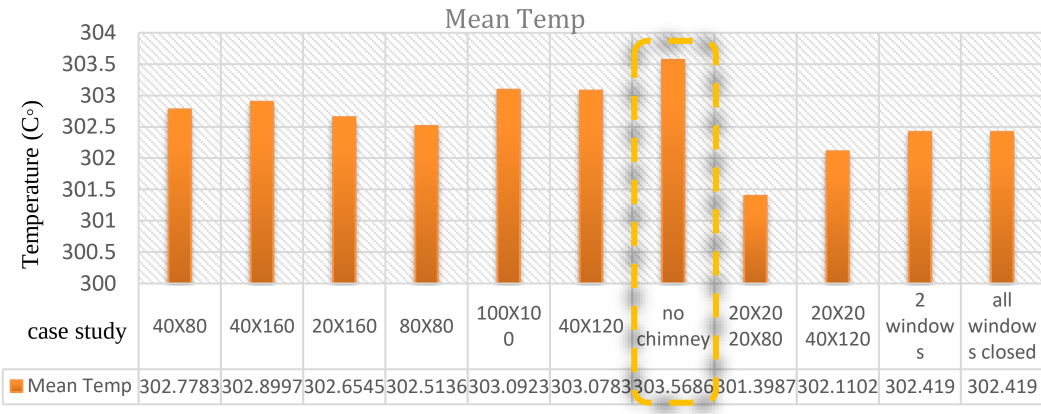



Fig 28: shows a comparison between the Average temperature among the nine cases.

The results can be shown in Figure No. 26 also that the internal wind speed of the chimney with dimensions of 80 cm x 20 cm increases from the internal wind speed, more than others in the proposed chimneys were studied on 9 cases, we also notice in (Figure 27) that the air speed in the closed chimney was 0.17 m s^-1 and in the chimney 40 × 120 m is 0.298 = 0.3 m s ^-1, which is the highest speed that was achieved in the proposed alternatives.

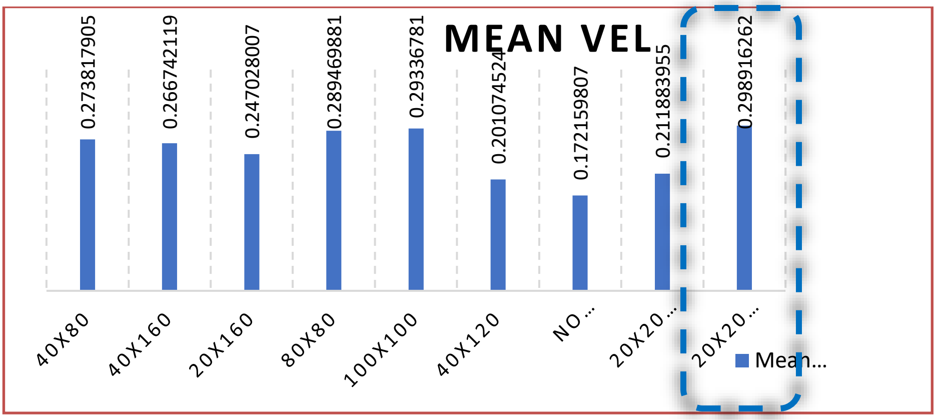



Fig 29: shows a comparison between the Average in air speed among the nine studied cases.

the chimney was 20 × 80 cm = 0.211 m s^-1 and in (Figure 28), the highest average temperature difference was a closed chimney = 303.5 K, and the lowest average temperature was a chimney of 20 × 80 cm was = 301.39 K, and in (Figure 29) it shows the average wind speed of a mill 120 × 40 cm =. 298 m s ^-1 It is the highest air velocity among the 9 cases, and thus we conclude that the smaller the chimney size, the more it can make a difference in temperatures, while the higher the chimney size, the higher the indoor air velocity.

## 6. Conclusions

The performance of a solar chimney operating in a room is investigated using Computational Fluid Dynamics (CFD), and different dimensions of the chimney are considered. It is found that changing the air outlet opening connected between the hall space and the chimney led to changes in performance, as measured by the air flow rate through the chimney. The optimal opening dimensions for maximum flow are 20 cm x 20 cm - for a chimney dimension of 20 cm x 80 cm, gives an average benefit of 11% more flow compared to a chimney with larger dimensions of 40 cm x 120 cm, which improves the solar chimney performance in cooling and ventilation of the building, and reduces the risk of overheating. Besides, it is found that the air inlet direction to the hall space improves the chimney performance, giving approximately 25% additional improvement to that chimney. Angling the chimney led to a slight improvement in performance, but it wasn't large enough to be cost-effective. With different solar flue dimensions, the effect of wind is always to increase flue suction pressure. With roof angles greater than that, the wind direction plays a role in determining whether the chimney pressure increases or decreases (Sharples et al.). Hence, it is recommended to open northern windows and study its effect on increasing the flow and movement of air in the hall space.

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