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Solar Chimney for Natural Ventilation in Medtrania Climate

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التهوية الطبيعية باستخدام المداخن الشمسية في مناخ البحر الأبيض المتوسط

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Abstract:
The study aims to investigate the possibility of minimizing the heat gain through the outside walls of closed enclosures in order to obtain thermal comfort. Consequently, the enclosure's natural ventilation is achieved by air drains through an attached solar chimney.

A mathematical model was developed to predict the performance of the solar chimney. The geometrical and operational parameters were considered. These parameters include: incident solar radiation, wind speed, ambient temperature and the dimensions of the solar chimney, height, gap and width. Moreover, various chimney cover materials were examined. A computer program was developed to solve the governing energy and conservation equations simultaneously. The model results were compared with the available published data. A good agreement was observed between the developed model results and the published data.

Keywords: Solar chimney, Natural Ventilation, Theoretical Model.

الملخص
تهدف الدراسة للتحقق من امكانية تقليل الحمل او الكسب الحراري خلال الجدران الخارجية للمباني بحيث تتحقق ظروف الراحة الحرارية داخل المباني. بالتزامن، سوف تتم عملية تهوية طبيعية للمبنى من خلال تدفق الهواء الى الخارج خلال المدخنة الشمسية الملحقة بالمبنى.

نموذج رياضي تم استحداثه لغرض التنبؤ بأداء المدخنة الشمسية المرفقة بالمبنى. تم الأخذ في الاعتبار مجموعة من العوامل الهندسية والمناخية الخاصة بالمنطقة المستهدفة بالدراسة. تتلخص هذه العوامل في الآتي: شدة الاشعاع الشمسي، سرعة الرياح، ودرجة الحرارة. بالإضافة الى الابعاد الهندسية للمدخنة: الارتفاع، العرض والحيز الهوائي للمدخنة. تم ايضاً استخدم مواد بديلة للغطاء الزجاجي للمدخنة: الواح الاسمنت، الجبس بورد، الألومنيوم.

برنامج ماتلاب تم انشاؤه لحل منظومة المعدلات الحاكمة لانتقال الحرارة. النتائج اظهرت توافقاً مع بيانات عملية تم نشرها في دراسة سابقة.

الدراسة استهدفت بشكل خاص مدينة طرابلس-ليبيا ومعدلات التهوية فاقت المعايير القياسية للمباني السكنية. بالنسبة للمواد المستخدمة كبدائل للزجاج اظهرت كفاءة اداء عالية اقتصاديا وتشغيلياً اعلى من المتطلبات القياسية.

الكلمات المفتاحية: المدخنة الشمسية، التهوية الطبيعية، النموذج النظري.

Introduction

In recent years, a number of experimental, numerical and theoretical studies have contributed to the current understanding and improve the performance of solar chimneys. Because of many papers that have been published on this subject, that focused on most areas and cities around the world. However, potential of use the solar chimney for the natural ventilation in Tripoli- Libya as a Mediterranean climate will be the objective of the present study. The literature review is intended to survey as a guide in the present study.

Earlier studies were conducted by Bouchair et al (1988) [1] and Bouchair (1994) [2]. They reported results on a full-scale experimental solar chimney with both front and back walls maintained at the same uniform temperature by heating elements. They showed that there is an optimum chimney width (about one tenth of the chimney height) at which a maximum ventilation flow rate can be achieved. Further increase in the chimney gap results in a decrease in the air flow rate due to occurrence of backflow at the outlet of the chimney. Their studies are followed by Joseph Khedari et al (1997) [3] they performed study on four types of roof solar collectors. They used the roof solar collectors as solar chimneys to induce natural ventilation into houses. They found that the measured temperature, velocity and flow rate per area of solar chimney inside the air gap during Sept -Nov were ranged from 30-36˚C, 0.5 - 1.3 m/s and 0.08 - 0.15 m/s, respectively. Moreover, the inclined angle of the roof of 25-30 and the length of air duct less than 1m with collector gap of 14 cm derived a better air flow rate.

Majid H. M. et al [4] conducted numerical simulation of the thermal and fluid dynamic behavior of the solar chimney with ANSYS software which is used resolves the Navier Stokes equations. The software is used to simulate numerically the real sized of 2-D room with solar chimney attached. The room model sized is (1.29x2.5x1.07) m, which has an air inlet in the bottom and air leaving at the top of the chimney. The solar chimney was simulated at 20° for summer. The triangle space at the back of absorb plate area was (0.39x1.29) m and 1.42m height. They concluded that, by using the evaporative cooling and passive cooling, solar chimney decreased the temperature inside the space by 8.5°C lower than ambient temperature experimentally and 5.8°C numerically

Chto A. F. and Armando Oliveira [5] developed a thermal model for simulating solar chimney, tacking into account the wind effect. The model combines the equations for heat transfer processes in the solar chimney with equations for natural ventilation flow. Moreover, they conducted experimental tests with a test cell of 12 m2 floor area (4 × 3 m) and solar chimney has an internal across section of 0.2 × 1 m and height of 2 m. Their experimental results showed that the thickness of chimney did not change significantly the average flow rates, the maximum being obtained at 10 cm. The comparison of computer model results with experimental results showed that the air flow rate due to wind effect is not negligible. The agreement between the calculated chimney temperatures and the measured was better than for ventilation rate.

Khedari et al [6] and Hirunlabh et al [7] implemented different roof solar collector designs. Their results showed that when using the roof solar collectors only, there is a small potential to induce ventilation rates in order to meet the satisfy occupant comfort in the hot climate conditions.

R. Bassiouny, et al [8] conducted an analytical and numerical study. Their study considered some geometrical parameters such as chimney inlet size and width. They used a finite element method to predict flow pattern in side the space as a result of using solar chimney. They found that the maximum absorbed temperature increased by a factor of 2.25 when solar intensity increased by a factor of five. They concluded that the chimney width has more significant effect on room ACH than inlet size, and that increasing the inlet size three times improved the ACH by almost 11%, while increasing the chimney width with same factor improved the ACH by almost 25% keeping inlet size fixed.

Harris. D.J, and Hewing, N., [9] carried out a computer simulation using CFD modeling techniques to assist in the design of solar chimney to induce ventilation in building. The variables that were considered, slope angle, emissivity of absorber surface, and the use of single or double glazing on the cover. They neglected the effect of wind on the flow rates. The conditions used in their study were for Edinburgh in Scotland at latitude 52o. Their computer simulation results indicated that the optimum slope angle for maximum flow rate is 67.5o from the horizontal, giving 11% increase in flow rate in comparing with vertical chimney. They found the best performance was at cavity width of 0.25 m. They observed that including low emissive absorber in the solar chimney gives further 10 % improvement at optimum angle. They stated that including double glazing gave a slight improvement in the performance, but it was insignificant enough to be cost effective.

Gtuseppe B., et al [10] Conducted dynamic simulations performed by coupling TRNSYS and LOOPDA simulation models on an industrial archaeology building placed in Italy – 60 km north from Venice, erected in 1897 and abandoned since 1962, the building has four stories with chimney stack on the roof to exhaust stuffy air from the factory rooms. For rehabilitation the building a double façade glass wall is attached to the out side of building separated by an air gap and provided in both upper and lower parts with automatic louvers to allow and regulate winter and summer ventilation.

For heating period from October 15th to April 15th for the considered climate, the observed result indicates that it is possible to ventilate the building naturally using the double – skin facade and small openings on bottom- side and so 16.7 percent of heating energy may be saved. For cooling period from April 15th to October 15th with top and bottom louver widely opened, the energy saved is about 8 percent for the whole building.

Preeda C, et al [11] investigated experimentally and numerically the thermal performance of double-glazed solar chimney walls (GSCW) under the tropical climatic conditions of Thailand. They use numerical simulation and experimental model of 0.74m height. 0.5m width and 0.1m air gap that was integrated into the southern wall of a small room of 2.8 m3 volume. The GSCW has 0.37m2 surface area. Two openings located at the bottom (room side) and top (ambient side) of double glass panes with size, 0.05 × 0.5m2. Data were collected from 8:00 am to 5 pm during various days in different months. They use the hourly average ambient data from the days of experiment, to validate their study. Their results indicated that the hourly temperature change of the measured inner and outer glazing, air gap and room, compared to the calculated were a reasonable agreement. In addition, they observed that the measured air flow rate varying between 0.13 and 0.28 m3/s and that the simulated by mathematical model varying between 0.1 and 0.26 m3/s these small difference could be negligible. They concluded that the numerical simulation can be used to predict temperature and air flow rate quite accurately.

Sakonidou E. P, et al [12] developed a mathematical model to obtain the maximum ventilation airflow inside the solar chimney as a function of tilt angle and height. They assumed a uniform temperature distribution across the chimney width. In addition, they preformed experiments with chimney of a narrow parallel pipe with dimensions (1 m height, 0.74 m width and 0.11m gap). Black painted aluminum sheet (1.5mm thick) was used for the rear and side walls of the chimney. The front side of the chimney was a commercial glass, 3 mm thick has a south orientation at all times. Their comparison of model prediction the velocity and temperature of air inside the chimney and temperature of glazing and the black painted absorber, as a function of tilt (30 – 90) and height (1-12m) were in satisfactory accord with experimental measurements from 1 m chimney operated at different inclinations.

Raman P, et. al [13] developed and tested passive solar systems based on the incorporation of solar chimney for heating, cooling and ventilation in composite climates on a single room structure in India. The performance of the two developed models was predicted by computation and verified by measurements.

One of the passive models was consisting of a set of two solar chimney, an evaporative cooler (for summer) and added wall insulation, performed well for winter. The second model consisted of a south wall collection and a roof duct cooled from above by a sack cloth evaporative cooling system, through their testing and computing the thermal performance of the models they found that, for model one, at cold season, when the average ambient temperature 11 – 12˚C the passive room temperature was 19 – 20˚C which can be considered as a comfortable for winter and during the summer, the room temperature decreased with 3 – 2˚ C compared with no passive solar system used, model two for summer season the room temperature was 30˚C when the ambient temperature went up to 42˚C , and for winter season, room temperature was around 16˚C when the ambient temperature dropped to nearly 1˚C.

Heras M. R, et. al [14] carried out experiments and specific thermal and energetic saving analysis of a building. The studied building located in the south of Spain and is placed facing Mediterranean Sea, the building with innovative elements based the sawtooth roof concept and with some modifications were added as south orientated openings, thermal insulation, overhangs and solar chimney to improve natural ventilation. Although the winter temperature is near 8˚C and summer temperature at maximum 30˚C, the relative humidity was between 65 % and 70 % due to the closeness of sea. Their results indicated that the thermal evaluation of the patio in winter is very satisfactory, indoor temperature is higher than outdoor and the thermal load needed to obtain same indoor temperature is greater before the refurbishment. For summer time they found that the patio works as a band pass filter moving most cases to arrange between 25˚C and 29˚ C.

Kaneko Y, et al [15] studied the thermal stability and air flow rate in the solar chimney with built in phase change material (sodium sulfate dehydrate) (PCM) for latent heat storage. The ventilation and heat storage in PCM occurred during day time simultaneously, while evening / night ventilation was induced by discharge of the latent heat stored in PCM. The chimney was installed on roof of an eight – story building in Osaka, Japan. The experimental parameters were: heat generation rate, size of the chimney gaps and inclination. They focused on two conditions, part of PCM melted on 14 – 15 Feb, and PCM hardly melted on 23 – 24 Jan. They found experimentally that the flow rate was stable in daytime (from 10:00 AM to 14 PM) and the flow rate in the nighttime was varying, this seem to be caused by the problems in the measurement method of the gas concentration. In addition, they stated that the simulated temperature of solar chimney and air in the solar chimney was in agreement with experimental result from evening to morning (from 17:00 PM to 7:00 AM). However, in daytime, the simulated temperature of chimney layers was higher than the measured values and the simulated air temperature inside the chimney was lower than the measured one. Moreover, the PCM temperature showed a good agreement between the experimental result and the simulated simulated result. between the experimental result and the simulated result.

Theoretical modelling

In order to evaluate the contribution of solar chimney to the natural Ventilation of buildings, a mathematical model is proposed. . In this model the design and performance parameters will be considered. These parameters include incident solar radiation, wind speed, ambient temperature and the dimensions of the chimney and its construction materials.

A schematic diagram of the proposed chimney is shown in the fig (1-A). The solar chimney includes vertical glazed wall, air channel, and thermal storage wall (absorber). The Solar radiation passes through glazing is absorbed at the wall surface. The air in the chimney channel is then heated by convention and radiation from the absorber. The decrease of air density causes it to rise up, whereupon heated air is replaced by air from below, i.e., from the attached room. Fig (1-B and C) demonstrates solar chimney examples [16].

Major parameters in this study are temperature of absorber and glass surface, temperature of air at inlet and outlet, ambient temperature, flow velocity, area of inlet and outlet opening. Writing energy balance equations for absorber surface, glass surface and air column and solving them for Tg, Tw, and Tf to calculate air flow rate have sought a mathematical solution.

The energy balance equations for three parts of the solar chimney namely, the glass cover, the flow channel and the absorber plate are presented in next section. The values of materials thermophysical properties of the solar chimney components for the present study are taken from [17][18].

In order to calculate the temperatures of solar chimney components: glass, absorber and air inside the solar chimney, energy balances are performed first. The energy balance on the glass cover is expressed based on fig. (2) as:

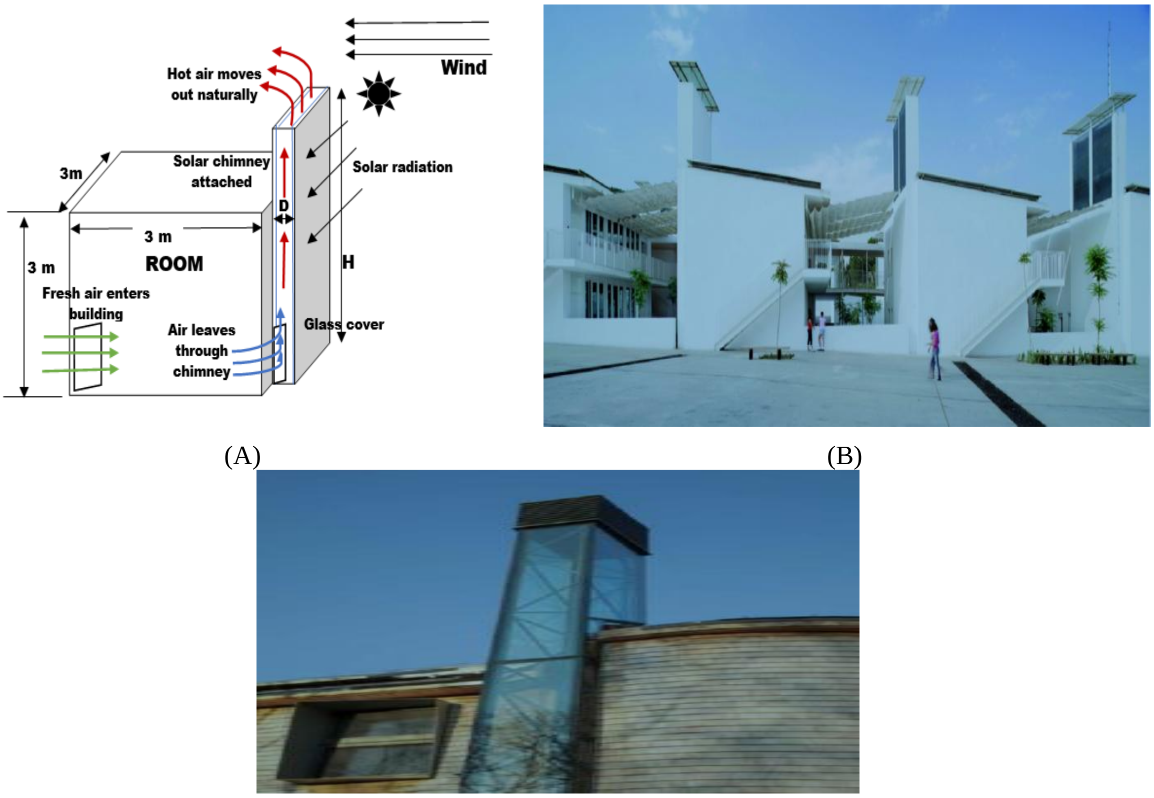

Figure 1: (A) schematic diagram of the proposed room model with solar chimney attached, (B) an office building in Cambridge, USA and (C) a school in Damascus, Syria.[16]

$$[S1\ Ag] + [hrwg\ Aw\ (Tw - Tg)] = [hg\ Ag\ (Tg - Tf)] + [Ut\ Ag\ (Tg - Ta)] \quad (1)$$

The energy balance on the air in the flow channel between glass and absorber walls is conducted based on the heat flows as presented in fig. 2 to be expressed mathematically as:

$$[hw\ Aw\ (Tw - Tf)] + [hg\ Ag\ (Tg - Tf)] = m\ Cf\ (Tfo - Tfi) \quad (2)$$

From equation (2) the difference between outlet air temperature (TF0) and inlet air temperature (TFi) as function of γ is given by:

$$(Tfo - Tfi) = (Tf - Tfi) / \gamma \quad (3)$$

Assuming that Tfi is equal to the room temperature Tr. Therefore, rearranging equation (2) then substituting the value of (TF0 - TFi), we obtain:

$$hg\ Ag\ Tg = hw\ Aw\ Tw - (hw\ Aw + hg\ Ag + (m\ Cf/\gamma))\ Tf = -(m\ Cf\ Tr/\gamma) \quad (4)$$

The absorber wall receives energy in the form of solar radiation while it is losses energy in the form of convection to air in the flow channel, radiation to glass and conduction to the room behind the absorber wall as shown in Fig (2). The energy balance of the absorber wall is expressed as:

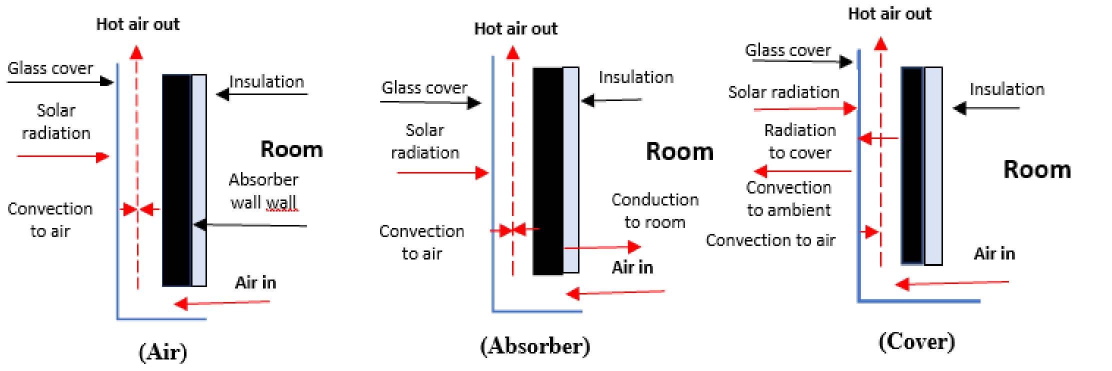

Figure 2: Energy Balance on the solar chimney components, cover and absorber and air inside channel.

$$[S2Aw] = [hwAw\ (Tw\text{-}Tf)] + [hrwg\ Aw\ (Tw\text{-}Tg)] + [Ub\ Aw\ (Tw\ \text{-}Tr)] \quad (5)$$

Equation (5) is re-arranged in the following form:

$$(hw\ Aw + hrwg\ Aw + UbAw)\ Tw - hrwg\ Aw\ Tg - hw\ Aw\ Tf = S2Aw + Ub\ Aw\ Tr \quad (6)$$

Driving the air passively through the chimney is depending on the pressure potential due to the buoyancy as well as the pressure due to the wind. The total pressure potential is given by:

$$\Delta P = \Delta Pb + \Delta Pw \quad (7)$$

The buoyancy term is expressed by the pressure difference between the base and the top of the chimney. For chimney with height of H, buoyancy pressure potential may be expressed as:

$$\Delta Pb = \rho\ g\ \beta\ H\ (Tfo - Tfi) \quad (8)$$

Substituting equation (3) into equation (8) yields:

$$\Delta Pb = \rho\ g\ \beta\ H\ (Tf - Tr) / \gamma \quad (9)$$

Where β is the expansion coefficient of air (β =1/Tm).

Wind flowing across the building may influence the performance of the chimney. The effect of the wind may be detrimental to air flow if a positive pressure is created at the top of the chimney.

The pressure due to wind, ΔPw, at the Surface of a solar chimney is expressed as:

$$\Delta Pw = 0.5\rho CpV2 \quad (10)$$

Where Cp is estimated from literature Chand and Bhragava (1990) [19] and Groso M. (1995) [20], an average value of 0.25 is used in the present study.

The pressure drop due to the chimney resistance to flow based on the pressure drop due to the air friction with internal solar chimney surface and the pressure drop due toinlet and outlet openings, (Hydraulic losses), i. e,

$$\Delta Pr = \Delta Pf + \Delta Ph \quad (11)$$

Friction loss is expressed by Darcy Formulation as follows:

$$\Delta P_f = \left(f\frac{H}{D_h}\right)\left(\rho_f\frac{U^2}{2}\right) \quad (12)$$

The hydraulic diameter of the chimney Dh defined as:

$$D_h = \frac{2WD}{(W + D)} \quad (13)$$

Pressure drop due to hydraulic losses are expressed in term of coefficient Kh of dynamic pressure of flow as:

$$\Delta P_h = \sum K_h\left(\rho U\frac{U^2}{2}\right) = (K_{in} + K_{out})\frac{\rho}{2}U^2 \quad (14)$$

Therefore, the resistance to flow inside the chimney ΔPr is obtained by substituting equations (12) and (14) into equation (11) as:

$$\Delta P_r = \left(f\frac{H}{D_h}\right)\left(\rho\frac{U^2}{2}\right) + (\sum K(\rho\frac{U^2}{2}) \quad (15)$$

The air velocity U through the chimney is obtained by equating the sum of the driving pressure potential in equations (9) and (10) to the sum of the resistance to flow through the chimney equation (14), (i.e ΔPb + ΔPw = ΔPf + ΔPh).

Thus, the velocity of air inside the chimney is given by:

$$U = \sqrt{2g\beta\frac{H}{\gamma}(T_f - T_r) + C_pV_p{}^2}\sqrt{(f\frac{H}{D_h}+)(\sum K)} \quad (16)$$

Thus, the air mass flow rate through the chimney can be written as:

$$\dot{m} = C_d\rho UA_C \quad (17)$$

The value of discharge coefficient Cd was taken as 0.57 as suggested by Anderson (1995) [20].

The number of the air changes per hour which is the ratio of the air volume flow rate to the actual size of the room that is to be ventilated. The mass flow rate obtained from equation (17) is used to calculate the equivalent air changes per hour for ventilated room as:

$$\dot{V} = \left(\frac{\dot{m}}{\rho_f}\right) \tag{18}$$

Where the number of air changes per hour can be calculated from the following expression as defined by ASHRAE [17][21]:

$$ACH = \left(\frac{\dot{V}}{360}\right)/V_r) \tag{19}$$

The numerical procedure is conducted in few steps where the simultaneous equations (1), (2) and (5) which were developed in this study based on energy balance for three components of proposed solar chimney i. e. glass, air, and absorber. These equations are solved using Gauss Seide method for obtaining the temperatures Tg, TF, Tw, these temperatures along with equation (16) are used to obtain the flow velocity in flow channel and subsequence for obtaining the mass flow rate in the flow channel and then air change per hour for the considered room as shown in fig. (1).

In the mentioned equations, Solar radiation, ambient temperature, wind velocity, flow channel dimensions (height, width, bottom opening area, air gap and thickness of insulation), and the thermal and physical properties of flow channel components, all the parameters are the external input besides various factors and constants described previously. computer program has been built in MATHLAP to calculate the temperatures of the main component of the solar chimney (Glass cover, absorber wall and air.), mass flow rate and air change per hour in the room, also their variations

To validate the developed theoretical model, the obtained results were examined as well as the MATHLAB cod. Therefore, the predicted results are compared with published experimental data in Bassiouny and Nader [8] as presented in Table 1.

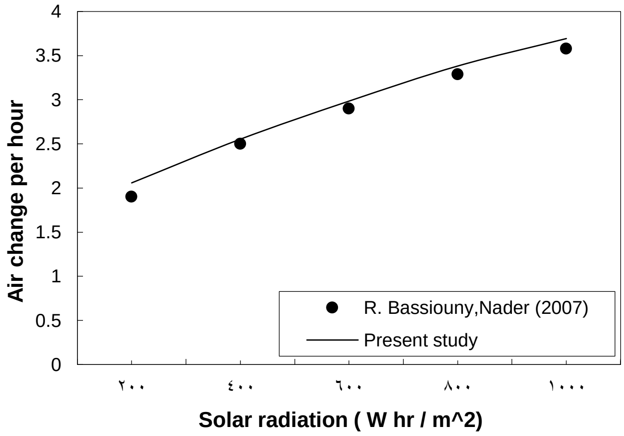

Figure 3: Present results compared with R. Bassiouny and Nader [8].

The comparison concerns the air change rate per hour ACH as shown in fig. (3). The black solid line presents the predicted ACH based on developed model and the dotted line represents the published experimental results of Bassiouny and Nader [8]. The predicted results display the same general trend of the published experimental data. The results in fig. (3) demonstrate a good agreement between the predicted and published results with an acceptable range of error. Finally, the mean percentage error has been calculated for each set of data based on predicted and published data. Well-known formula is used to calculate the mean error as [22]:

$$MPE\ \% = \left\{\left[\sum\left|\frac{(ACH_{pred} - ACH_{pub})}{ACH_{pub}}\right|\right]/n\right\} \times 100 \tag{20}$$

The calculated results of mean percentage error are presented in Table 1. However, the estimated values of the error were found to be within 8 % for the air changes per hour.

Discussion

In the present study the proposed model is validated by comparing the obtained results with published data. Therefore, the calculations can be safely extended to study and discuss the effect of different parameters such as weather condition (solar radiation, wind velocity, and ambient temperature), cover materials and solar chimney dimensions (length, width, and air gap) on the examined parameters such as the flow rates (mass flow rate and air change per hour) and the temperatures of the solar chimney components (cover, air and absorber). In order to analyze the energy performance of solar chimneys, the meteorological information is a critical input.

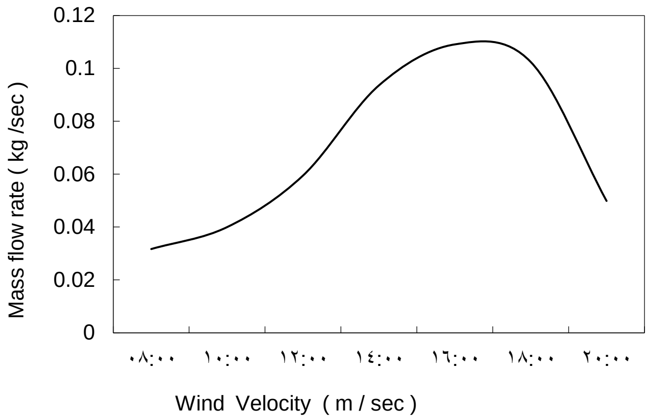

Figure 4: Shows mass flow rate of air as a function of wind velocity for typical day 10th June.

Meteorological data of different complexity are needed at various stages of the design process. The model building used in the present analysis is located in Tripoli –Libya. Tripoli is located in the North of Libya and is placed facing Mediterranean Sea, latitude 32.52 and longitude 13.12. Therefore, its climate is considered Mediterranean. Use of natural ventilation has been increasingly investigated as an energy-saving strategies to provide thermal comfort as well as a fresh and healthy indoor environment. The study investigates the possibility of using the solar. chimney as passive strategy in Mediterranean climate (Tripoli – Libya). The aim was to obtain natural ventilation of enclosers and reduce heat gains through the outside walls and achieve comfort conditions. The effects of several metrological and geometrical parameters on ventilation rates were considered and demonstrated graphically.

Table 1: Error estimation (R Bassiouny, J. Nader [8]).

Solar radiation	Predicted results	Published results	Percentage error
	ACH	ACH	MPEACH %
200	2.05	1.9	7.89
400	2.55	2.5	2.00
600	2.904	2.9	0.14
800	3.18	3.3	3.77
100	3.14	3.5	2.64
The mean error			3.28 %

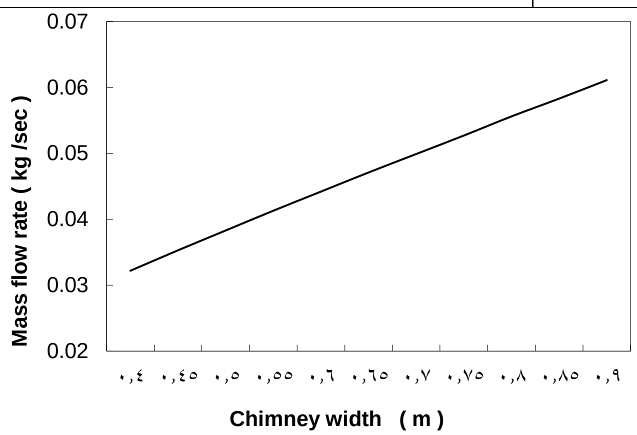

Figure 6: Shows mass flow rate of air as a function of chimney width.

For comparison considerations some digital data were presented in tables. Fig. 1 shows the proposed enclosure of 27 m3 and solar chimney attached. The solar chimney was sketched in fig. 2 to present the energy balances on the solar chimney components. Fig. 3 shows the present results compared with published data from literature [8].

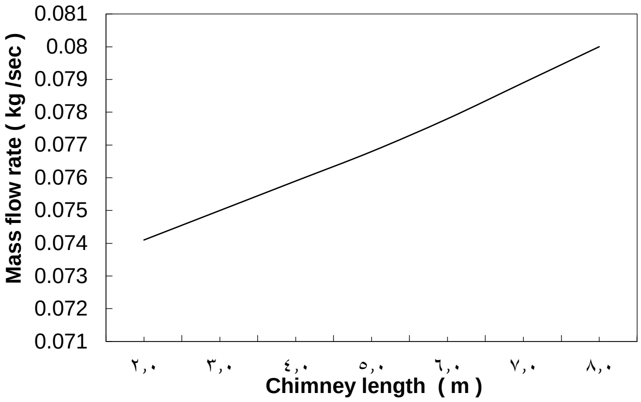

Figure 7 effect of chimney length on mass flow rate of air inside the chimney.

The comparison shows a good agreement between the predicted data and experimental published data with a minimum bar of 8 %. This agreement presents the significance of the proposed theoretical model in the field of solar energy. Effect of metrological data of solar radiation and wind velocity are shown in figs. 4 and 5. The results show a more significant effect of wind velocity on mass flow rate of drained air through the solar chimney over the day. The effect of solar radiation was in the rang of 0.015 m3/s and 0.03 m3/s. The peek value of air flow rates was reported at mid of the day which is three times less than the effect of wind velocity.

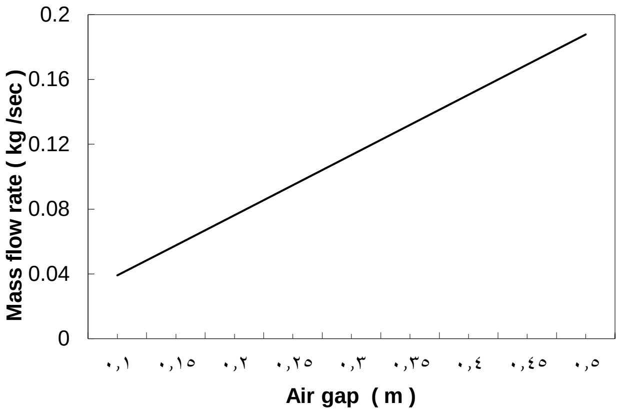

Figure 8 Shows mass flow rate of air as a function of air gap of the chimney.

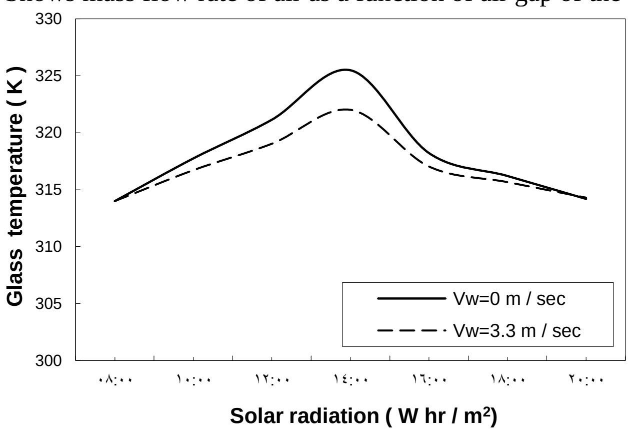

Figure 9 effect of solar radiation on glass temperature at different wend velocities.

The ventilation rates showed proportional with the geometrical dimensions of the chimney as presented in Figures 6 to 8 of chimney width two times led to duplicated mass flow rates of air. The chimney height is not recommended due to the design and cost aspects. The air flow rates were predominated by increase of air gap as result of boundary layer effects.

Figures. 9 to 10 show effect of wind velocity as an important parameter on the temperatures of the solar chimney components, glass cover and the absorber wall. The results demonstrate the predicted temperatures at 0 m/s and 3 m/s.

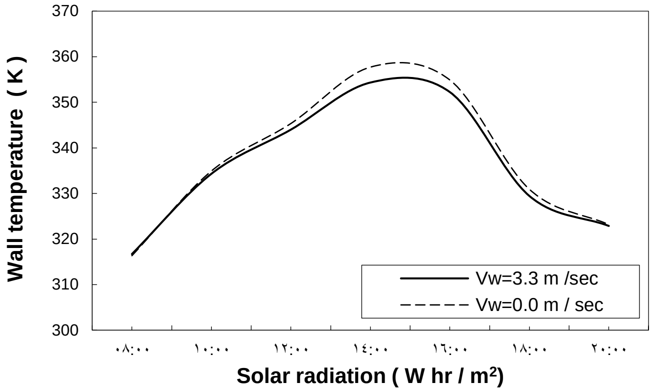

Figure 10 effect of solar radiation on wall temperature at different wend velocities for typical day 10th June.

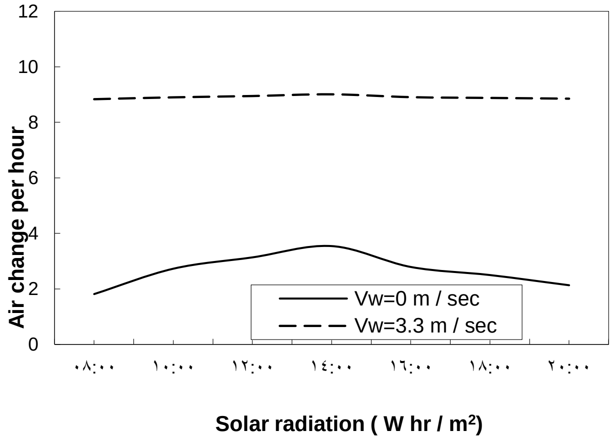

Figure 11 effect of solar radiation and wend velocity on air change per hour for typical day 10th June.

Fig 11 shows effect of solar radiation and wind velocity on ventilation rates ACH. Where wind velocity was increased from zero to 3.3 m/s to show increase by factor of four. The real metrological data of Tripoli air port weather station are used to study the effect of solar radiation and wend velocity on air change per hour for typical day 10th of June, 1993. Fig. 12 shows effect of using a different material as a outer cover for the solar chimney; glass, aluminum. Gypsum and concrete. The glass followed by aluminum showed higher ACH rates.

However, the induced ACH for all cover materials was lied between 5.5 and 6. Based on ASHRE, American Society of Heating and Air Conditioning Engineers [17], the induced ACH with solar chimney attached to the proposed room is higher than ventilation requirements of residential and commercial budlings. The real metrological data for twelve months were presented in fig. 13 to show the monthly variation of ACH through out the year at 14:00p.m. The obtained results of the present study showed an average value of 6 ACH over the year.

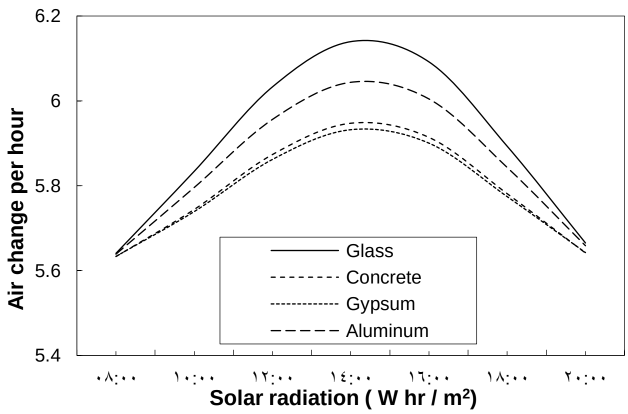

Figure 12 effect of solar radiation on ACH with different chimney covers for typical day 10th June.

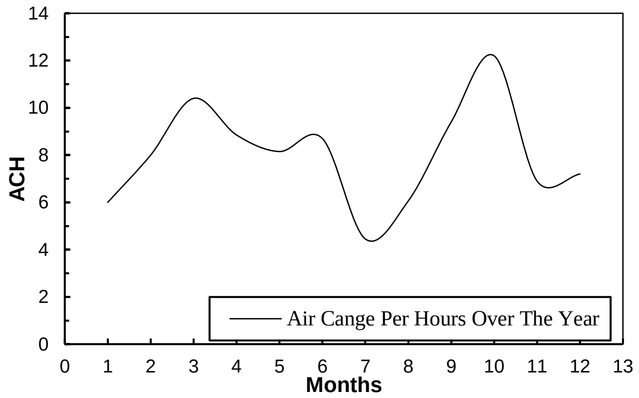

Figure 13 Air change per hour for proposed room of 27 m3 over 12 months of year.

Nomenclature

γ mean temperature approximation
ρf air channel density (kg /m3)
β coefficient of volumetric expansion
ΔP buoyancy pressure drop due to buoyancy
ΔPHydraulic pressure drop due to inlet opening
ACH air change per hour
AC cross sectional area of solar chimney (m2)
Ag area of outer cover (m2)
Aw area of absorber wall (m2)
Cd discharge coefficient
Cf specific heat of air (J/ kg. K)
CP wind pressure coefficient
D gap between absorber and cover (m)
Dh hydraulic diameter (m)
f friction coefficient
G gravitational acceleration (m / s2)
H solar chimney height (m)
hcg conduction coefficient in glass
hg convection coefficient between glass and air channel (W/m2. K)
hi convection coefficient of ambient air (W/m2 . K)
hrs radiative heat transfer coefficient between absorber and air channel (W/m2. K)
hrwg radiation coefficient between absorber and cover (W / m2. K)
hw radiation coefficient between absorber and air channel (W/ m2. K)
I incident solar radiation on vertical surface (W hr /m2)
K pressure loss coefficient
$\dot{m}$ mass flow rate (kg /s)
S1 solar radiation absorbed by glass cover (W/ m2)
S2 solar radiation absorbed by absorber wall (W / m2)
Ta ambient temperature (K)
Tr room temperature (K)
Tf mean temperature of air in channel (K)
Tf.i air temperature at inlet of channel (K)
Tf.o air temperature at outlet of channel (K)
Tg mean glass temperature (K)
Tw mean temperature of absorber wall (K)
U air velocity inside solar chimney (m/s)
Ub over all heat transfer coefficient between absorber wall and room (W/ m2 K)
Ut heat transfer coefficient from top of glass cover (W/ m2.K)
Vw wind velocity (m /s)
W width of solar chimney (m)
Z height of bottom opening (m)

References

[1] A. Bouchair, D. Fitzgerald, The optimum azimuth for a solar chimney in hot climates, Energy and Buildings, Volume 12, Issue 2, 21 September 1988, Pages 135-140https://doi.org/10.1016/0378-7788(88)90075-8.

[2] A. Bouchair, Solar chimney for promoting cooling ventilation in southern, Building Services-Engineering Research and Technology, 15(2) 8 1 -9 3 (1994), Printed in Great Britain.

[3] J. Khedari, J. Hirunlabh, T. Bunnag, Experimental study of a roof solar collector towards the natural ventilation of new houses, Energy and Buildings, Vol. 26, Issue 2, 1997, Pages 159-164. https://doi.org/ 10.1016/S0378-7788(96)01030-4

[4] Majid H. M., and Ali A. M., Natural ventilation in warm climates: The challenges of thermal comfort, heatwave resilience and indoor air quality, International Journal of Current Engineering and Technology, Vol.6, No.6 (Dec 2016)

[5] Chto Afonso, A. Oliveira ,2000. Solar Chimney: Simulation and Experiment. Energy and Building, 32-71-79.

[6] J. Kediri, B. Boonnsri, J. Hirunlabh, 2000, Ventilation Impact of Solar Chimney on Indoor Temperature Fluctuation and in a School Building, Energy and Buildings, 32-89-93

[7] Hirunlabh J., Kongduang W., Namprakai P., Khedari J.,1999, Study of Natural Ventilation of House by Metallic Solar Wall Under Tropical Climate. J. Renewable Energy 18, 109-119.

[8] R. Bassiouny and Nader S., A. Koura, 2007, An analytical and Numerical Study of Solar Chimney Use for Room Natural Ventilation, Energy and Building.

[9] D. J. Harris, N. Hewing ,2007. Solar Chimney and Building Ventilation, Applied energy.

[10][10] Gtuseppe Ballestini, Michele De Carii, Nicola Masiero, Giovanni Tombola, 2005. Possibilities and Limitations of Natural Ventilation in Restored Industrial Archaeology Buildings with a Double - Skin Facade in Mediterranean Climates. Building and environment ,40-983-995.

[11] Chantawong P, Hirunlabh. J, Zeghmati.B, Khidari.J, Teekasap. S, Win. M.M, 2006, 1nvestigation on Thermal Performance of Solar Glazed Solar Chimney Walls, Solar Energy.

[12] Sakonidou E. P., Karapantsiios T. D, D. Chassapis, 2007.Modeling of the optimum tilt of a solar chimney Maximum air flow. Solar Energy.

[13] Raman P., Sanjay Mande and Kishore, 2001, A Passive Solar System for Thermal Comfort Conditioning of Buildings in Composite Climate, Solar Energy, vol70, NO. 4,319-329.

[14] J. Mathur, Sanjay Mathur, Anupma, 2006, Summer - Performance of Induced Roof Solar Chimney for ventilation. Energy and Building, 38-1156-1163.

[15] Y. Kaneko, K. Sagara, T. Yamanaka, H. Kotani, September 2010, Ventilation Performance of Solar Chimney with Built in Latent Heat Storage, CSEM - UAE Innovations Inc.

[16] Tariq A., Prashant K. b., Laetitia M., Natural ventilation in warm climates: The challenges of thermal comfort, heatwave resilience and indoor air quality, Renewable and Sustainable Energy Reviews, 138 (2021) 110669.

[17] ASHRAE Handbook Fundamentals, American Society of Heating and Air Conditioning Engineers, Inc. Atlanta, 1989

[18] Wattmuff, J.H., Charters, W.W.S., Proctor, D., 1977. Solar and wind induced external coefficients for solar collectors. Internationale Revue d'Helio technique 2, 56.

[19] Chand, P. Bhargava, 1990. Studies on Design and Performance of Anon-Conventional system of Natural ventilation in Building. Solar and Wind Technology 7(2/3).

[20] Anderson KT, 1995. Theoretical Considerations on Natural Ventilation by Thermal Buoyancy. Trans. ASHRAE, 101(2):1103-17.

[21] Rakesh Khanal, Chengwang Lei, Solar chimney—A passive strategy for natural ventilation, Energy and Buildings 43 (2011) 1811–1819.

[22] K. Alrbee, Y. Muzychka, X. Duan, Heat Transfer in Gas-Liquid Taylor Flow in Mini-Scale Coiled Tubes, Heat Transfer Engineering: 2024-03-1.