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## **Simulation Study of Trombe Wall for Passive Solar Technique of buildings in Egypt**

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**Abstract.** The studies aimed to evaluate a Trombe wall, a solar wall, which is a critical component of passive solar strategies in energy usage. It is a very compact wall and can be south-facing or north-facing, which is painted black and made of exclusive material that absorbs a lot of heat. The main advantage of the Trombe wall is that they are often easily built from locally obtainable materials, very dependable, and having less repair, maintenance, and operation costs. In this study, a BASECASE model were simulate with “Design Builder” software based on “Energy Plus” with the passive solar technique of Trombe wall in Egypt of a model of residential building with two façade alternative base case. The research has shown that Trombe wall has the possibility of providing acceptable internal thermal comfort through "Mixed-Mode" ventilation strategy in hot climate, this is important in determining the possibility of Trombe wall in incorporating "Mixed-Mode" ventilation reducing energy usage in cooling demands. The conclusion of this research that Trombe walls can reduce the cooling load by 75% compared to the base case with annual energy savings.

**Keywords:** Trombe wall; Passive solar cooling; Energy efficiency; Thermal comfort.

### **1. Introduction**

In Egypt, approximately 90% of the electricity produced depends on fossil fuel sources [1]. Similar to the elevated responsiveness of climate change in Egypt, the energy demand in buildings has also developed an increasing alarm in the challenge of the new power failure [2]. In 2015, residential electricity consumes the largest amount of the nationalized consumption of energy, nearly 52% (see Fig. 1) compared with 44.2% in 2014 [3].

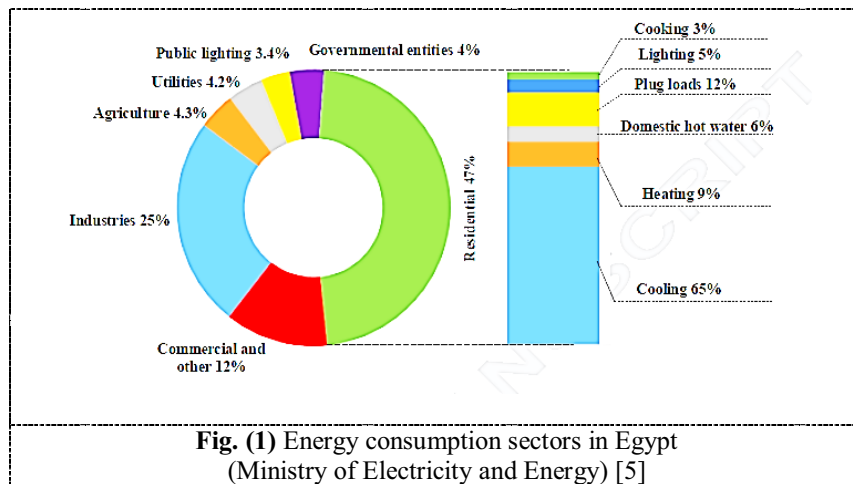
### **2. Problem definition**

Operation hours of air conditioners is rapidly increasing inside the residential homes sector through summer season, this is consequently responsible for a higher demand for heating and cooling, which already bills for 50% of power intake in Egypt [4]. The main problem in the design process is the lack of understanding of the passive solar techniques inside the space in the initial design stages.

### **3. Research aim**

The aim of the research to achieve the standard Comfort Conditions under operation condition and decrease energy consumption as long as possible by adapting passive solar technique.





#### 4. Passive Solar Techniques

##### 4.1 Passive Solar Design Strategies Package

Passive Solar Architecture is a way of designing buildings that takes advantage of the benefits of the resident environment (for example sunlight) while reducing the unfavourable effects of the climate (for instance cold night-time temperatures) on the comfort level of the building.

The idea of passive solar is straightforward but applying it efficiently does need data and consideration to the details of design and construction. passive solar techniques are simple and low-budget and need only little modifications in a builder's standard preparation. A passive solar system can exactly remove a house's need [6].

##### 4.2 Advantages of Passive Solar technique

The Advantages of Passive Solar technique can summarize in:

- **Energy performance:** Minimize energy bills all year-round.
- **Smart living environment:** huge windows and visions. Sunny interiors, open floor plans
- **Comfort:** noiseless, hard structure, cooler in summer, warmer in winter.
- **Value:** extraordinary owner approval, as customers buy more digital works, resale rights will become a bigger issue
- **Low Maintenance:** strong, reduced controlling and maintenances
- **Investment:** independence from future increases in fuel costs, will remain to keep money long after any initial costs have been improved
- **Environmental Concerns:** fresh, renewable energy to prevent growing alarms over global warming, acid rain and ozone reduction [7].

Passive solar technique provides a method of decreasing the amount of energy required to cool buildings to a suitable comfort level, by changing some of the heat resulting from biomass or fossil fuels with heat resulting from sunlight. Sunlight is permitted and has none of the negative economic, environmental or health properties of biomass and fossil fuel use [8].

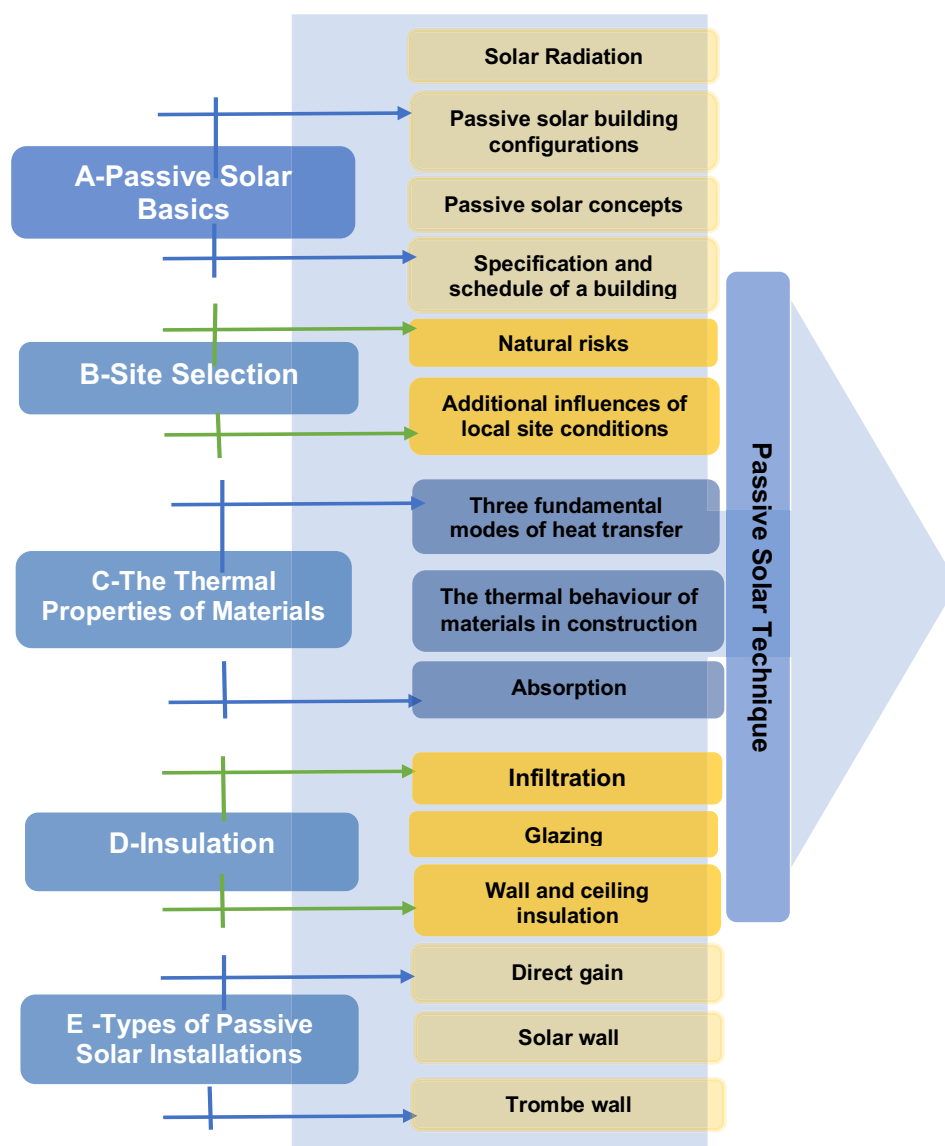
#### 4.3 Passive Solar Building Configurations

Passive Solar Design Strategies can be classified in five basic parts as shown in Fig 2. [9].

##### 4.3.1 Passive Solar Concepts

There are four interconnected elements in passive solar buildings, which operate at the same time to build the structures well-organized of energy efficiency:

1. Assembly and absorption of the maximum amount of solar radiation during the day
2. Packing of the heat collected from the sun's radiation during the day
3. Emission of this heat into the internal spaces of the building during the night [10].
4. Insulation of the full construction to keep as much of the heat as imaginable in the building [11].



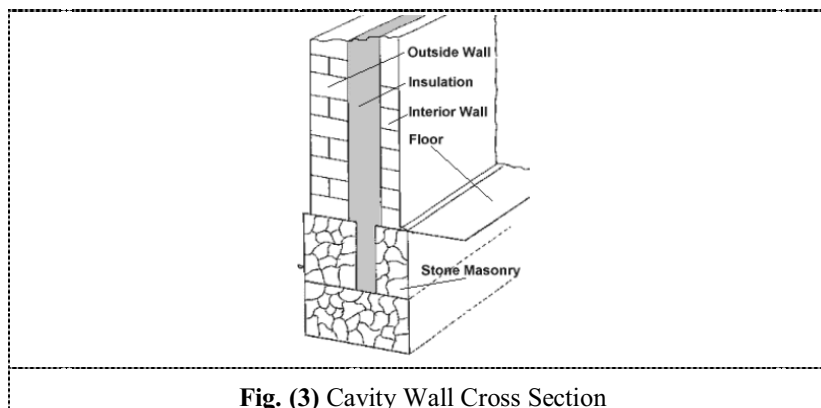
**Fig. (2)** Classification of Passive Solar Technique.

#### 4.4 Wall Insulation

There are several different types of walls:

- **Partition Walls:** The closest area is a buffer zone where the temperature level is much greater than the outside temperature level. Minimal insulation is essential.
- **The wall is buried partially underground:** The ground is usually at a higher temperature than the outside air, so less insulation is required
- **The wall is external and east, west or south-oriented:** In this case, the wall must be carefully insulated [12].
- **Wall Design:** An insulated wall is consisting of three layers:
  - 1-An external wall to keep insulation from animals and rain
  - 2-Insulation layers
  - 3-An internal wall for thermal storage

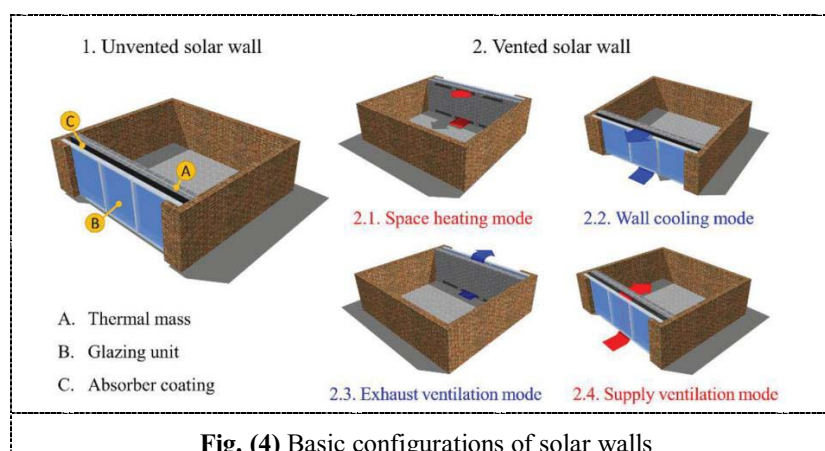
This type of wall is identified as a cavity wall, and it is occupied with insulating materials. The external wall is the supporting wall and protects the insulation layer from moisture and animals [13].



**Fig. (3)** Cavity Wall Cross Section

#### 4.5 Solar Wall

**Solar Wall:** A sun wall is south oriented black painted a glazed wall. The black painted wall catches the solar radiation and by using the glass covering, the wall stays insulated from the weather outdoor so the heat is saved and migrates slowly to the inside [14]. A conceptual example of a few basic solar wall configurations is shown in Fig. 5.



**Fig. (4)** Basic configurations of solar walls

A solar wall includes four major elements: (1) thermal storage mass, i.e. wall; (2) absorber coating on the exterior face of the wall; (3) glazing element installed in the external face of the wall; and (4) air gap between the internal wall and the external layer of the wall.

#### 4.6 Trombe Wall

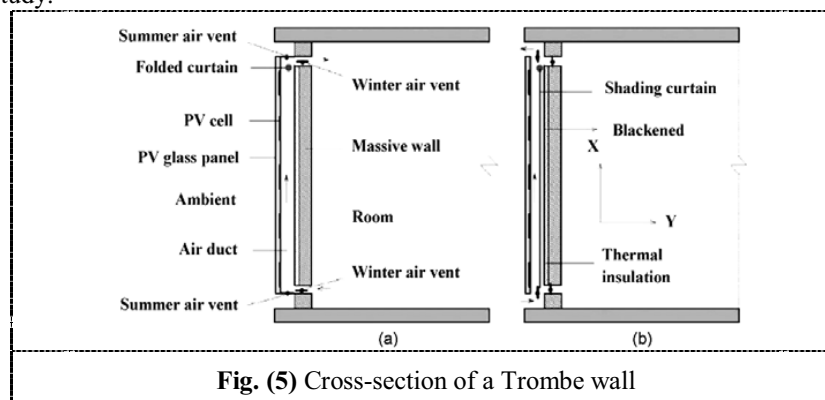
Trombe Wall: A Trombe wall is a ventilated solar wall. There is a vent in the upper and lowest of the wall. During the day, the airflow trapped between the external layer and the internal of the wall heats up and rises (warm air tends to go up) [15].

Practical Features of Trombe Wall: A familiar Trombe wall contains the following features/technical aspects:

- 10 – 41 cm thick masonry wall is painted with a dark, heat-absorbing color that is typically black in color.
- Covered with insulated glass (double glazing) or low emissivity glass (Low e-glass).
- The glass is laid at 2 – 5cm distant from the masonry wall that allows you to construct small air space.
- It must be South facing.
- For residential buildings in the southern facade, Trombe walls should be installed in the south- certain orientation for highest efficiency and extreme usefulness, as that is the side that will be exposed to the sunlight rays.
- Extraordinary transmission glass increases solar gains to the masonry wall.
- The glass layer avoids the leakage of radiant heat from the warm facade of the storage wall.
- The air gap prevents the heat radiated by the wall, controlling to additional heating of the wall surface [16].

## 5. Methodology

In this study, a BASE CASE model was simulated with Environmental simulation software (Design-Builder for thermal and energy) [17]. with the application of Trombe wall Techniques as a part of achieving sustainable buildings and increasing demands for energy in buildings. The results proved that the application of Trombe wall in Egypt had the main impact on enhancing performance and as a result, a reduction in energy usage. Moreover, a comparison between the base case and the final improved proposals in the two levels of technology will show the helpfulness and implantation of each case study.



**Fig. (5)** Cross-section of a Trombe wall

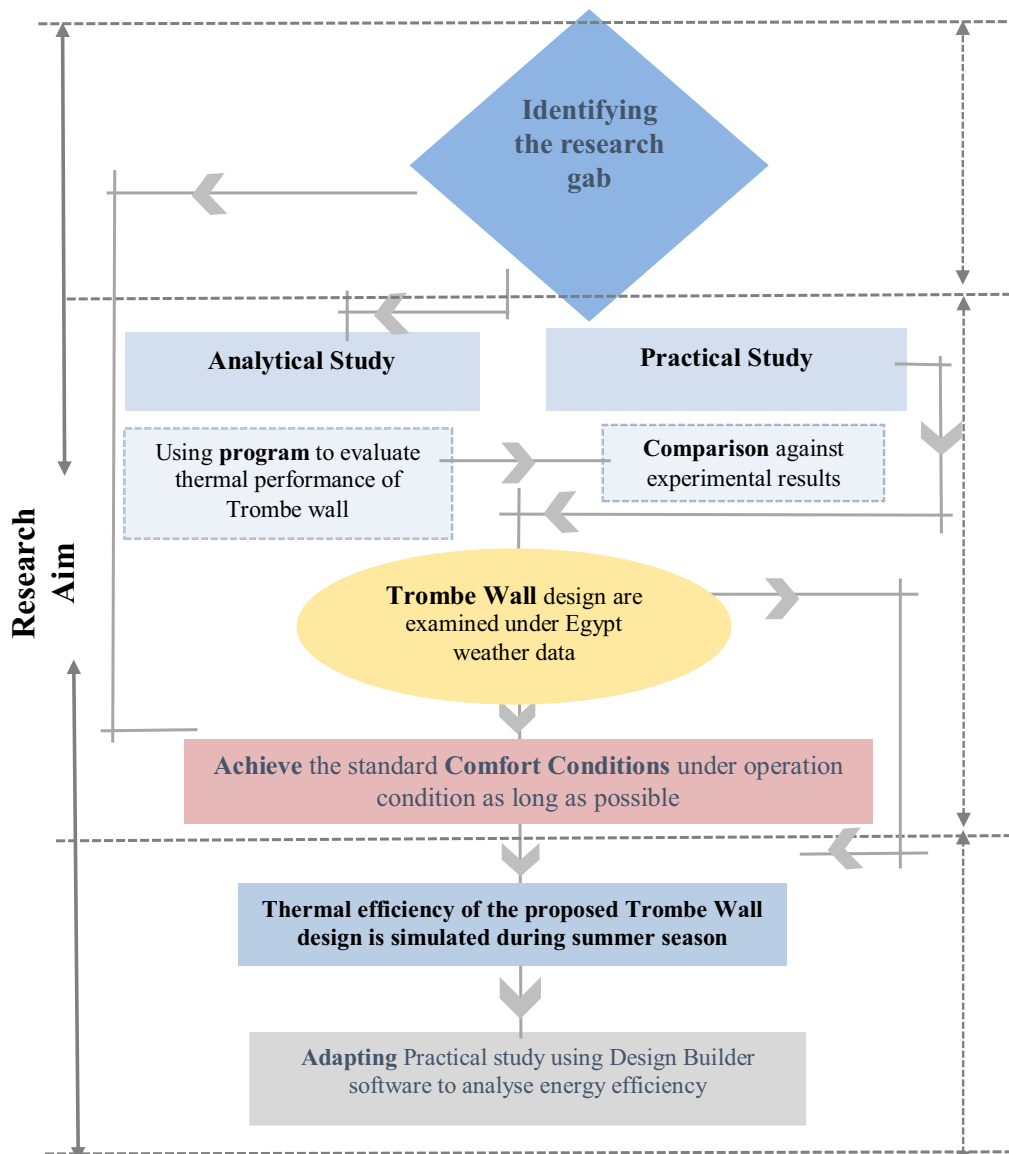
### 5.1 Study Models design & Office Building model description

General villa building design data (see Table 1):

**Table 1.** Residential Building Architectural Data

<b>Building type</b>	Residential Buildings.
<b>Building floors numbers</b>	Ground floor + first floors 4.0 m (slab to slab), 3.70 m ~ 3.0 m (clear height)
<b>Typical office floor</b>	(4.0 m * 2 floors) + 2.0 m parapet of façade= 10.0m
<b>Ventilation system</b>	For "Base-Case" building: Artificial Mechanical ventilation (Full HVAC) system. For a Trombe wall case study: 'Mixed-Mode' (Hybrid) system all of the year.

A methodology with the flow chart short the investigation is proven in Fig.1



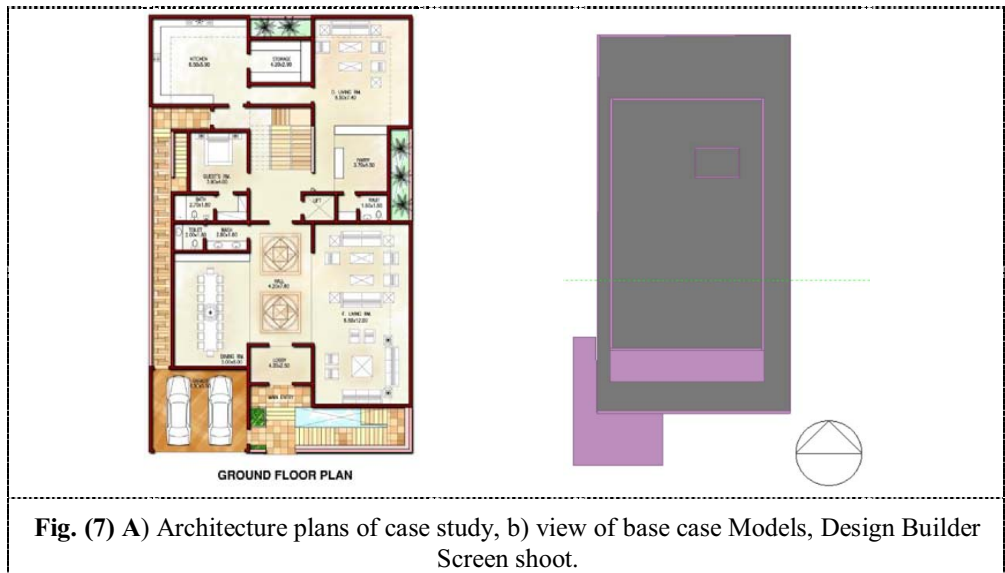
**Fig. (6)** The framework of Analytical & practical of research

5.2 Weather data file

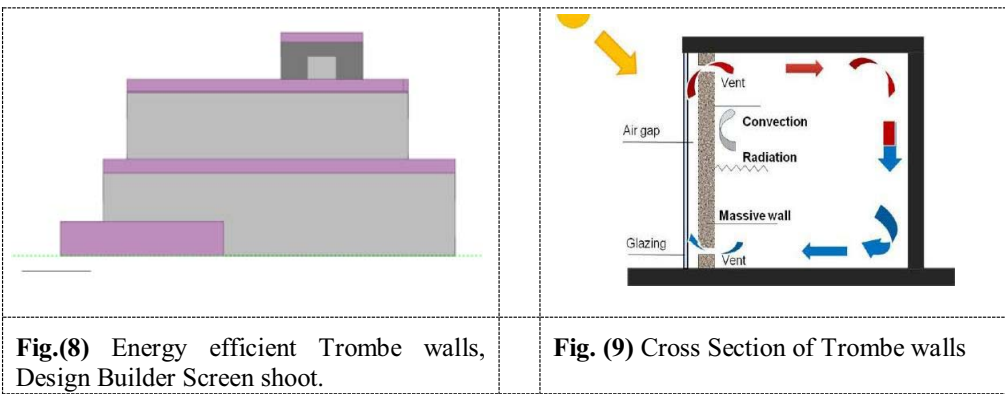
The Egyptian Typical Meteorological Year (ETMY), the International Weather for Energy Calculations (IWEC) and Köppen categorized Cairo climate as a warm semi-arid climate with a hot to extremely warm dry summer and moderate to warm moist winter [18].

5.3 Standard Model Definition

The “standard model” was defined considering a one-story isolated room, with regular geometry 27 x 7 m (94.5 m<sup>2</sup>), a ceiling height of 3.5 m, and a total dimension of 15 x 3.5 m (52.5 m<sup>2</sup>) & 12 x 3.5 m (42 m<sup>2</sup>) for the façade glazing building block composition (Figure 8,9&10). For the Trombe wall module, the use of double glazing with a high shading coefficient was measured. The double glazing had two panes built of 6mm and 13mm Argon air space as shown in Fig 11. [19].



**Fig. (7)** A) Architecture plans of case study, b) view of base case Models, Design Builder Screen shoot.



**Fig.(8)** Energy efficient Trombe walls, Design Builder Screen shoot.

**Fig. (9)** Cross Section of Trombe walls



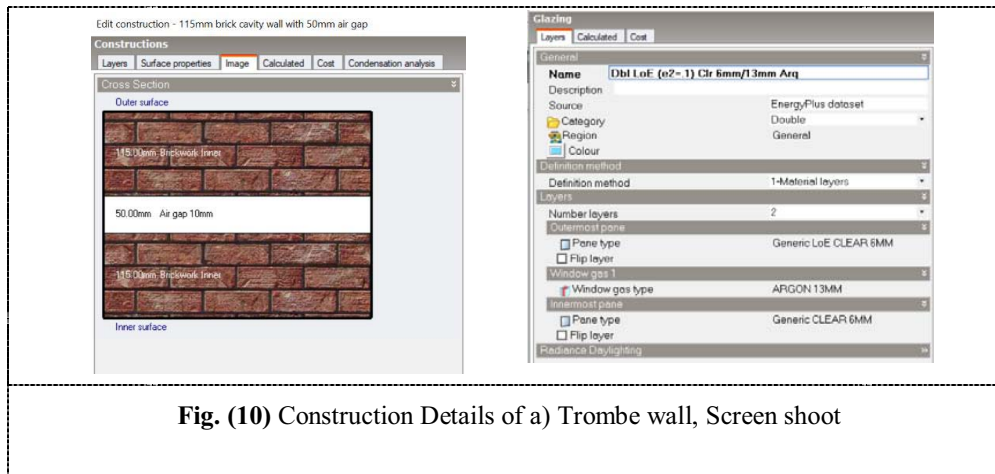


Fig. (10) Construction Details of a) Trombe wall, Screen shoot

### 6. Results and discussion

Figure 12 &13 shows the Zone sensible cooling for Hybrid Ventilation modes with the base case (without Trombe Wall) with Full (HVAC) Mechanical Ventilation (Fully Air-conditioned). This clearly shows that the best ventilation mode was the hybrid case (with Trombe Wall) which made a reduction in zone sensible cooling more than 50%. Figure. 12 &13 Shows the Effect of applying the Trombe Wall Strategy on annual sensible cooling with 247565 kWh compared to the base case 325947 kWh.

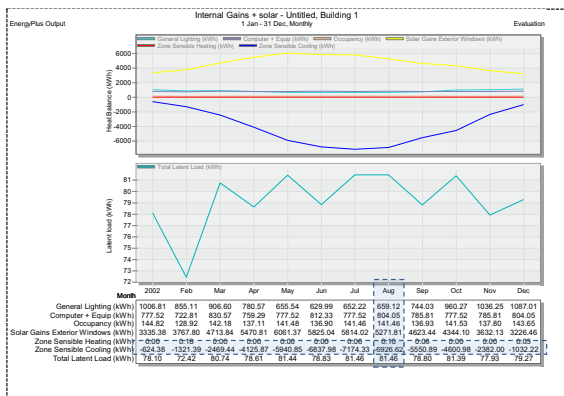


Fig. (11) Monthly results of Zone Sensible Cooling (kWh) for Trombe Wall case studies.

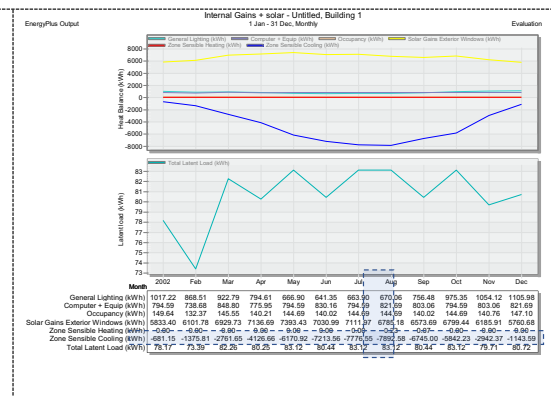


Fig. (12) Monthly results of Zone Sensible Cooling (kWh) for base case (without Trombe Wall).

Figures 14&15, In applying the Fanger PMV on the Trombe wall case study, it is clear that all lay between arranging of (-1 to 1), whereas the base case never reached above 4, but still the most effective was the base case without Trombe Wall.

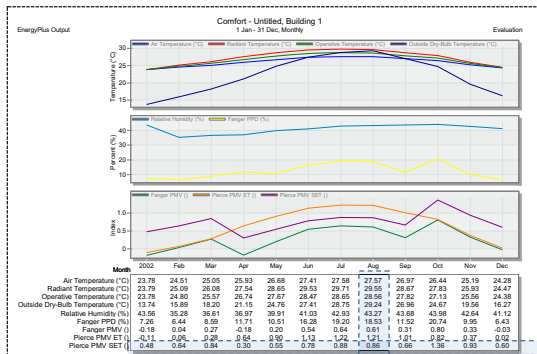


Fig. (13) Monthly results of PMV for Trombe Wall case studies.

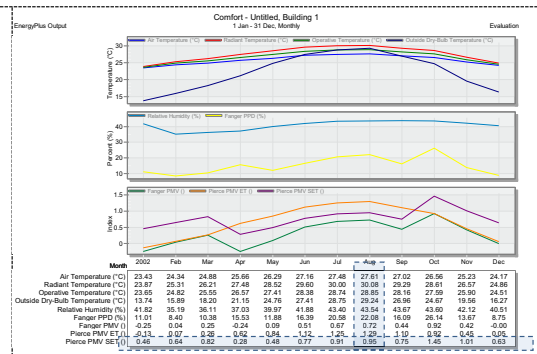


Fig. (14) Monthly results of PMV for base case (without Trombe Wall).

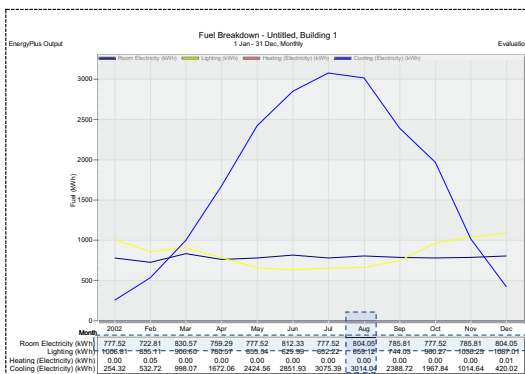


Fig. (15) Monthly results of Building Electricity (kWh) for Trombe Wall case studies.

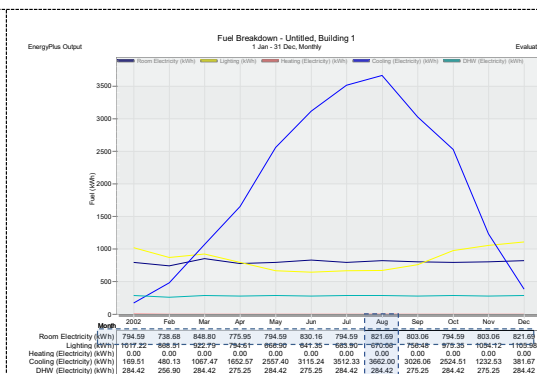


Fig. (16) Monthly results of Building Electricity (kWh) for Trombe Wall case studies.

Figure. 16 Shows the Effect of applying the Trombe Wall Strategy on room electricity with 284 kWh compared to the base case 3014 kWh.

7. Summary and conclusion

Obviously, the planned Trombe wall was presented to passively supply sensible comfort conditions in Egyptian residential buildings. The Trombe wall shows higher saving in total energy consumption compared with a conventional Trombe wall. The results, according to simulations, showed that the as-built base-case consumes 2730 kWh, which is greater with 75% than the modified-case that adopts passive design concepts. The Trombe wall can be observed as high energy conservation, improve thermal comfort, reduction in CO2 emissions and producing ventilation in subfloor spaces. A Trombe wall can reduce more than 75% of zone sensible cooling. The economics of Trombe wall is dependent on many variable factors such as climatic condition, cost of materials, cost of power, cost of energy and type of construction.

11.References

- [1] Ahmed M A (2012) Natural Ventilation Techniques as a Base for Environmental Passive Architecture With Special Reference to Residential Buildings in Greater Cairo. Cairo: Ain Shams University
- [2] Egyptian Electricity Holding Company-Annual Report 2015/2016, Ministry of Electricity & Renewable Energy, Egypt, n.d
- [3] Certain elements of the text have been extracted and modified from the CD-Rom Solar Bioclimatic Architecture, Lior Environmental, Charlierlaan 78, B1560 Hoelilaart, Belgium.
- [4] NREA (New & Renewable Energy Authority), (2013). Ministry of Electricity & Renewable Energy Annual Report 2012/2013, Cairo.
- [5] Ministry of Electricity and Energy , [online]. Available from: <http://www.moee.gov.eg/english/efrmain.htm>
- [6] Jaber, S., Ajib, S., 2011. Optimum design of Trombe wall system in mediterranean region. *Sol. Energy* 85, 1891–1898. <http://dx.doi.org/10.1016/j.solener.2011.04.025>.
- [7] Abdallah, A., Yoshino, H., Goto, T., Enteria, N., Radwan, M., Eid, M., 2013. Integration of evaporative cooling technique with a solar chimney to improve indoor thermal environment in the New Assiut City, Egypt. *Int. J. Energy Environ. Eng.* 4, 1–15. <http://dx.doi.org/10.1186/2251-6832-4-45>
- [8] A.A. Saleem, A.K. Abel-Rahman, A.H.H. Ali, Experimental Study on Thermal Comfort Conditions in Existing Public Primary Schools Buildings in Upper Egypt, in *Sustain. Energy Build. Res. Adv.*, Future Technology Press, Cardiff, Wales, UK, 2014: p. 6. <http://nimbusvault.net/publications/koala/sebr>
- [9] W. Weiss Editor “Solar Heating Systems for Houses - A design handbook for solar combi system” -James and James 2003.
- [10] Norbert Lechner - Heating, Cooling, Lighting: Sustainable Design Methods for Architects, Wiley Publishers, 2015.
- [11] MC Munari Probst, C Roecker, Architectural integration and design of solar thermal systems, PPUR -Routledge, Taylor&Francis, 2011
- [11] B. Kundakci Koyunbaba, Z. Yilmaz, The comparison of Trombe wall systems with single glass, double glass and PV panels, *Renew. Energy.* 45 (2012) 111–118. doi:10.1016/j.renene.2012.02.026
- [12] Z. Yilmaz, A. Basak Kundakci, An approach for energy-conscious renovation of residential buildings in Istanbul by Trombe wall system, *Build. Environ.* 43 (2008) 508– 517. doi:10.1016/j.buildenv.2006.11.033
- [13] Marwa Dabaieha and Ahmed Elbablyb - Ventilated Trombe wall as a passive solar heating and cooling retrofitting approach; a low-tech design for off-grid settlements in semi-arid climates, *Solar Energy*, Volume 122, December 2015, Pages 820–833.
- [14] Kreider, J.F., Kreith, F., 1982. *Solar Heating and Cooling: Active and Passive Design*. Hemisphere Pub. Corp., Washington.
- [15] Chen, B., Chen, X., Ding, Y.H., Jia, X., 2006. Shading effects on the winter thermal performance of the Trombe wall air gap: an experimental study in Dalian. *Renew. Energy* 31, 1961–1971. <http://dx.doi.org/10.1016/j.renene.2005.07.014>
- [16] Dowson, M., Harrison, D. & Dehouche, Z., Trombe walls with nanoporous aerogel insulation applied to UK housing refurbishments. *International Journal of Smart and Nano Materials*, 5(4), pp. 283–303, 2014.
- [17] Design Builder 2018. Design Builder [Online], Available: <http://www.designbuilder.co.uk/>. Accessed 15/2/2020
- [18] EMA (Egyptian Meteorological Authority), 2014. *Meteorological Annual Report 2014*. Egyptian Meteorological Authority, Cairo.
- [19] Design Builder 2019. Design Builder Software [Online] (Gas glow Scotland: Design Builder Software Ltd).