Heating and Cooling Loading Processes and Optimizes Material Properties for the Best Thermal Performances using CES

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Abstract

This study examines the issues as regards the development of the Built Environment and discusses the thermal performance of Trombe Wall with respect to heating and cooling load profile. The scope of this research is limited to Trombe Wall designs that are suitable for a common building structure facilitate the comparison and reduce the time taken. Therefore, a good solar building performance will provide good selection material by using Cambridge Engineering Selector (CES) software and go through the process of selecting a candidate material (or a range of materials), hence only a few materials able to pass the requirements. The result shows that the best materials for Trombe that meets the requirements of the CES software are found on Titanium alloys, Stone, Concrete, Silica glass, Soda-lime glass, Brick, Silicon, and Borosilicate glass. The research concludes that solar energy produces different energy performances which resulted from different building techniques that affected the environment in various ways.

Keywords
Trombe Wall, Solar Thermal, Solar Photovoltaics, Energy and Buildings

Introducation

Solar energy delivers total solar radiation, which is absorbed by the earth and its atmosphere at 3 x 1024 J per year. This is more than enough energy to meet global demand, even allowing for the conversion, storage and transmission losses required when putting this resource to human use. It is believed that solar energy has been used in buildings since 2500 years ago when the heat is used to warm the people through solar collection and storage in thermal properties of the buildings they constructed. Over the last few decades, solar architecture, which used this solar energy, has started to become popular again because of energy conservation issues and nowadays, considerable progress has been made promoting solar renewable energy. Several programmers are still being developed to tap the power of the sun. In relation to the influence of solar energy in people's lives, it noted that since ancient times, people have used thick walls of adobe or stone to trap the sun's heat during the day and release it slowly and evenly at night to heat their buildings. Today's low-energy buildings often improve on this ancient technique by incorporating thermal storage and delivery system called a Trombe wall. Named after French inventor Felix Trombe in the late 1950s, the Trombe wall continues to serve as an effective feature of passive solar design (Torcellini and Pless, 2007). Thus, there is a close relationship between the building's performances and energy consumption with several environmental issues such as global warming, the implication of greenhouse gases and carbon intensity of energy supply, carbon dioxide emissions and depletion of the ozone layer. Solar energy comprises namely Passive Solar Design (PSD), Photovoltaic System (PV), Active Solar Heating and some photoconversion processes. Therefore, this thesis is undertaken to pay attention to good solar building performance.

Background of Study

In a recent study done by Ji Jie et al. (2007b), the PV-Trombe wall (PV-TW) assisted with DC fan is examined. Their research was based on the original PV-TW model, theoretical simulations have been conducted for PV-TW with and without assisted DC fan. At the same time, field tests for these two cases have been performed to validate the model, and then the simulated and experimental results are found in considerably good agreement after their comparisons. It is reported that a significant temperature increase of indoor temperature with a maximum of 14.42 °C, if compared with the reference room, can be obtained by the PV-TW assisted with a relatively small DC fan by testing. Meanwhile, the experimental average electrical efficiency of the PV-TW assisted with DC fan can reach 10–11%, due to the glass cover. Furthermore, the testing results for PV-TW assisted with DC fan show that the average (during 7:00–17:00) temperature of PV cells reduces by 1.28 °C and the average indoor temperature increases by 0.50 °C if compared with the original PV-TW with similar solar radiation, and more than one degree lower ambient temperature. It indicates that the assisted DC fan can help to improve the indoor temperature and cooling the PV cells in some measure and the potential of PV-TW can be exerted by the assisted DC fan. Furthermore, the energy efficiency of new buildings is critical to a sustainable future and in the context of accelerating climate change, it is essential that the right choices are made (Sorrell, 2003). This research is to seek these potential and right choices before the building is constructed to achieve the human thermal comfort and further clean energy scenario.

Research on thermal performance of a building to suit human comfort can be achieved by differentiating and analyzing the load assessment of the chosen building. Load assessment is directly related to the assessment of sensible and latent heat gain and losses which affected the room air temperature and the moisture content of the room air (Webb, 1999) which will impact on human thermal comfort. Different data will be gathered from Trombe Wall specific changes to the building. However, typical values, especially in comfort factor and climate envelope, will be picked and applied to both buildings in order to maintain the same condition and then a different result of heating and cooling load die to different materials applications will be collected.

Purpose of Study

This paper examines the issues as regards the development of Built Environment. The typical Trombe wall, which can form part of the building envelope and may incorporate thermal mass principles, will be further studied. As Trombe walls save energy by complementing conventional heating, the advances selection material that can be used for the advances design solar Trombe wall system will be further studied.

- Evaluate the progress on solar Trombe wall systems
- Study the different designs of solar Trombe wall system
- Using the software Cambridge Engineering Selector (CES)
- Maximize thermal energy stored per unit material cost
- Wall thickness W
- Choice of materials

The scope of this study will be limited to Trombe Wall designs, which is suitable for a common building structure as this facilitates the comparison and reduces the time taken. Hence, the different materials for passive solar heating that will be selected by using Cambridge Engineering Selector (CES) software and go through the process of selecting a candidate material (or a range of materials) will be adjusted to the climate change in Athens that has a Mediterranean type climate with mild winters and hot summers. In addition to this, the following parameters are the only ones to be considered; thermal performances, energy cost efficiencies and energy, and carbon saving. The justification of these will be discussed in more detail and the results will then be compared.

Tromble Wall material and analysis

New materials advanced engineering design in Epictetus' time. Today, with more materials than ever before, the opportunities for innovation are immense. But advanced is possible only if a procedure exists for making a rational choice. This study develops a systematic procedure for selecting materials and processes using CES software, leading to the subset which best matches the requirements of a Trombe Wall (TW) design. This section uses an approach that emphasizes design with the materials rather than materials 'science', although the underlying science is used, whenever possible, to help with the structuring of criteria for selection.

First Materials can be divided into categories of permanent and non-permanent. Materials, which are in our culture perceived to be non-permanent, such as timber, lifespan can be prolonged through the correct treatment and maintenance. The use of such materials in buildings helps users to perceive the building as living in the urban context. The permanent materials should be of a very durable and robust nature, requiring little maintenance. Preferably most of the permanent materials used for the structure should be able to serve a dual function such as structural functions and mass insulation.
The construction methods, materials, and techniques should be selected for the following reasons explained as follows (Human, 2007):

- Social and economic sustainability
- Locally produced materials
- The complexity of construction methods
- Speed of construction (reduced time period equals reduced cost

Next provide the product specification for passive solar heating and its function. In this section, the different materials for passive solar heating will be selected by using Cambridge Engineering Selector (CES) software and go through the process of selecting a candidate material (or a range of materials) and will be adjusted to the climate change in Athens that has a Mediterranean type climate with mild winters and hot summers.

Using CES Software

Before using CES software, some of the material can be eliminated in the beginning stage since we know the good and suitable candidates of material. To select the best materials, 2 stages are performing referring to the constraint of the Trombe Wall.

1. Process in (Stage 1)

The heat content Q, per unit, are of the wall, when heated through a temperature interval ΔT gives the objective function, where w is the wall thickness, and Cρ is the volumetric specific heat (the density ρ times the specific heat Cρ). The 12-hour time constant is a constraint. It is adequately estimated by the approximation. Wall thickness, w. M is a material index, α is thermal expansion,λ is thermal conductivity, t is the time, T temperature, a is the thermal diffusivity.

$$a = \frac{\lambda}{\rho \, Cp} \tag{1}$$

$$Q = \omega\rho \;\, Cp \;\, \Delta \, T \tag{2}$$

$$\omega = \sqrt{2\,t} \;\; a^{1}_{2} \tag{3}$$

Where a is the thermal diffusivity .eliminating the free variable w gives

$$= \sqrt{2t}\ \Delta Ta^{\frac{1}{2}}\ \rho CP \qquad (4)$$

$$= \sqrt{2t}\ \Delta\ T\ \frac{\lambda^{\frac{1}{2}}}{(\rho\ Cp\ )^{\frac{1}{2}}(\rho\ Cp\ )^{-1}}$$

$$= \sqrt{2t}\ \Delta T\ \frac{\lambda^{\frac{1}{2}}}{(\rho Cp\ )^{\frac{1}{2}}(\rho Cp\ )^{-1}}$$

$$= \sqrt{2t}\Delta T\ \frac{\lambda^{\frac{1}{2}}}{(\rho Cp\ )-\frac{1}{2}} \qquad (5)$$

The heat capacity of the wall is maximized by choosing material with a high value of

$$M_1 = \frac{\lambda^{\frac{1}{2}}}{(Cp\ ) - \frac{1}{2}}$$

$$\log\ M_1 = \log(\ \lambda)^{\frac{1}{2}} - \log(\ Cp\ ) - \tfrac{1}{2}$$

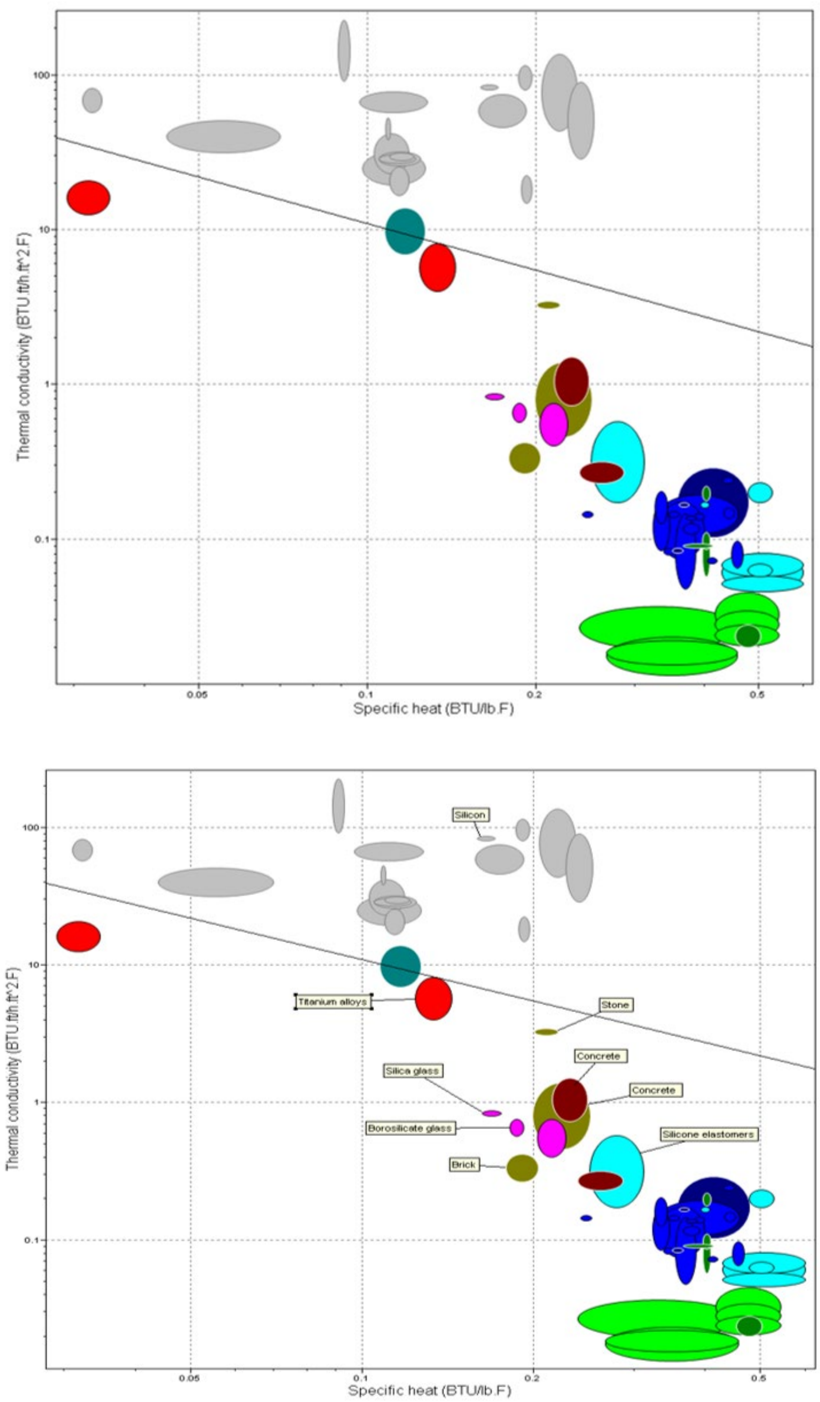
$$\log\ M_1 = \tfrac{1}{2}\ \log\ \lambda - \tfrac{1}{2}\ \log(\ Cp\ )$$

$$\frac{1}{2}\log\ \lambda = -\tfrac{1}{2}\ \log(\ C\rho) + \log\ M_1$$

$$\log\ \lambda = -\ \log\ C\rho\ +\ 2\ \log\ M_1$$

$$M_1 = -1 \qquad (6)$$

The selection Figure 1. on the left shows thermal conductivity plotted against specific heat. *a* with M and the limit on *a* plotted on it. Identifies the group of materials, listed in appendix B. They maximize M_1 while meeting the constraint on wall thickness. Solids are good; porous materials foams (often used in walls) are not.



(Figure 1 on the left) A chart of thermal conductivity and specific heat using. The Generic filter & on the (Figure 1 on the right) Stage 1 selection chart for thermal conductivity and specific heat using The Generic filter

The material passing stage 1 is shown in (Figure 1. on the right). It identifies some classes of material, there are 47of 64 types of material are passing from 64, such as Titanium alloys, Stone, Concrete, Silica glass, Soda-lime glass, Brick, Silicon, Borosilicate glass.

2. Process in (Stage 2)

After passing through the selection process in stage 1 and defining the thermal conductivity and specific heat, thermal conductivity is plotted on y-axis and Density on x-axis ,

$$Q = \sqrt{2t}\ \Delta T \frac{\lambda^{\frac{1}{2}}}{(\rho Cp)^{-\frac{1}{2}}} \tag{7}$$

$$M_2 = \frac{\lambda^{\frac{1}{2}}}{\rho^{-\frac{1}{2}}}$$

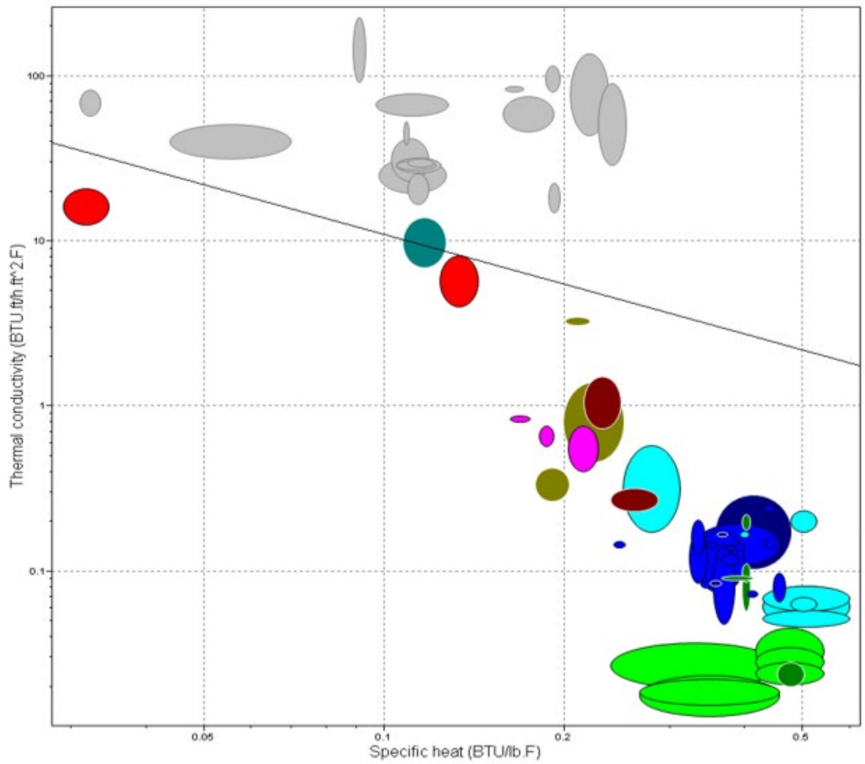
$$\log M_2 = \log(\lambda)^{\frac{1}{2}} - \log \rho^{-\frac{1}{2}}$$

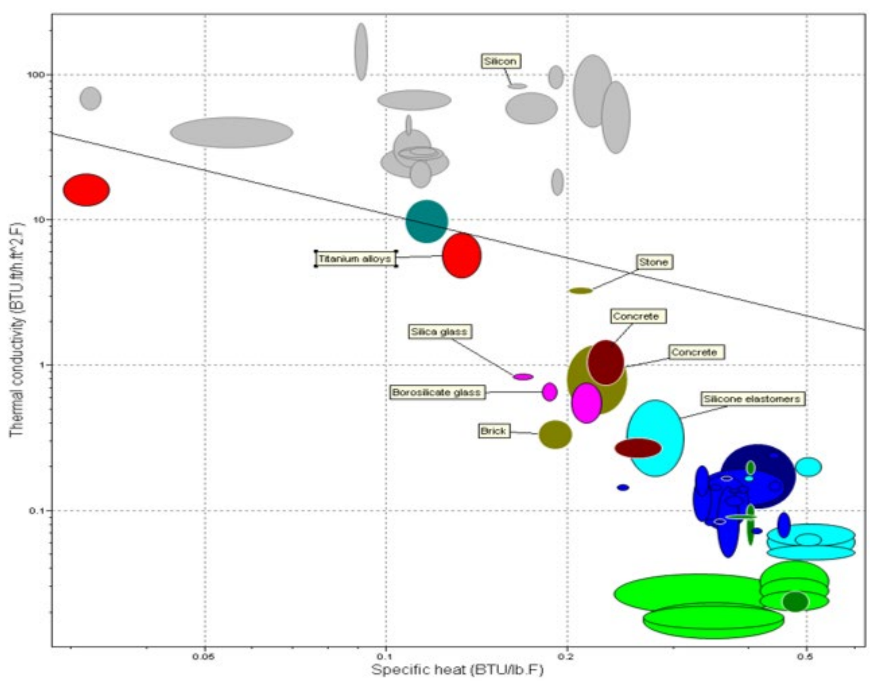
$$\log M_2 = \frac{1}{2}\log \lambda + \frac{1}{2}\log \rho$$

$$\frac{1}{2}\log \lambda = -\frac{1}{2}\log \rho + \log M_2$$

$$\log \lambda = -\log \rho + 2\log M_2$$

$$M_2 = -1 \tag{8}$$





(Figure 2. on the left) Selection materials thermal conductivity and specific heat & (Figure 2 on the right). The second selection process: A chart of thermal conductivity & Density using the Generic filter

The material passing the (Stage 2) are shown in the (Figure 2 on the left & right) It identifies some classes of material, there are 31of 47 types of material are passing from 47.

Escription

In this unit, I will choose the best materials for the Trombe Wall After all two stages are superimposed; there are only 31 materials able to pass the requirements. And the final selection will be a compromise between technical competence and economic factors. In specifying a material, the task usually requires two stages:

- Listing the requirements
- Selecting and evaluating the candidate material
- Choosing the most economical material

The materials' selection process is also influenced by the fact that the materials are either considered for the construction of a new system, or for the modification or repairs in an existing facility. For the construction of new equipment, the selection procedure should begin as soon as possible and before the design is finalized.

Analysis data from CES chart

After all stages are superimposed, only few material able to pass the requirements. There are eight types of materials in stage I saw that is in the (Stage 2).

- Titanium alloys
- Stone
- Concrete
- Silica glass
- Soda-lime glass
- Brick
- Silicon
- Borosilicate glass

Discussion on the suitability of the materials passed the selection criteria by eliminating some materials before using CES software and analyzing the data from CES chart in the section above. All the materials above are fine, but what about cost? If this scheme is not be used for housing, cost is an important consideration. The approximate costs per unit volume, are listed in Table 1, it compares and points out the selection of concrete, with stone and brick as alternatives.

Table 1 Material for Passive Solar Heat-Storage

Material	**$M_1= \lambda/a^{1/2}$ ($W.s^{1/2}/m^2.K$)**	**approx cost $/m³**	**Comment**
Concrete	2.2×10^3	200	The best choice – good performance at minimum cost.
Stone	3.5×10^3	1400	Better performance than concrete because specific heat is greater, less good than concrete, but more expensive.
Brick	10^3	1400	Less good than concrete.
Glass	1.6×10^3	10,000	Useful- part of the wall could be glass.
Titanium	4.6×10^3	200,000	An unexpected, but valid, selection. Expensive.

Lastly, the actual location of thermal mass materials in the home requires attention to solar architectural as well as heat flow engineering details. The three most popular types of passive solar systems are Direct Gain, Trombe Wall, and Sunspace. A rule of thumb for designing a comfortable Direct Gain system, which lets the sun shine directly into rooms, is to distribute the thermal mass materials over a large area of walls and floor, about nine or ten times the area of south glass and about 4-6 inches thick (for earth materials). For a Trombe Wall design, 12-inch concrete wall is placed directly behind the south glass. For a Sunspace design, this same wall is moved back several feet from the glass to create a greenhouse area that is allowed to swing in temperature more than the house interiors. The solar rays heat one side of the wall and this heat begins to show up on the interior side in the evening time. From an economic point of view, the added building cost for deploying quantities of thermal mass materials can be compared to the future life cycle cost savings of the fossil fuels not used.

Inside Design Condition

A typical value of comfort factors for an educational building are gathered from BSRIA, Rules of Thumb (2003),CIBSE Guide A(1986) and O´Callaghan (1980).the data are as established below:

Table 2. Inside Design Condition Comfort Factor

DESCRIPTION	COMFORT FACTOR
Temperature upper limit	24°
Temperature lower limit	20°C
Humidity upper limit	60%
Humidity lower limit	40%
Plant maximum outside temperature	24°C
Infiltration	2ac/h
Ventilation fresh air	3 l/s/person
Heating load	100W/m2
Central air conditioning cooling load	125W/m2
Maximum cooling	5KW
Maximum heating	140 kW
Lighting heat gain	25.5 W/m2
Equipment sensible gain	14.38W/m2
Equipment latent gain	3 W/m2
Population of people	117 (10m2/ person)
Occupancy sensible gain	90W/m2
Occupancy latent gain	50W/m2

The general information concerning the load for the building will need to determine Table 3. This is needed to estimate the daily operation of each load and daily load requirement Table 4.4 for the building.

Table 3 Electrical Load for the Building

	Electric Loads	KW
	Heating system	140
	Cooling system	5
	Lighting Type A	30
	Lighting Type B	10
	Telephone lines and UPS	3
	Carlifting jacks	3
Total	116	

Table 4. Daily load requirements for the building

ELECTRIC LOAD	POWER (KW)	CURRENT (Amp)	DAILY OPERATION HOURS	LOAD REQUIREMENT KWh/day	Ah/day
Heating System	140	184	10	1400	1840
Cooling System	5	65	10	50	650
Lighting A	30	79	10	300	790
Lighting B	10	26	24	240	624
Telephone & UPS	3	8	24	72	192
Car-lifting Jacks	3	8	24	72	192
TOTAL	191			2092	4176

Passive Solar designe with Trombe Wall

The first solar material to be applied to the building is the Trombe wall (TW) which is masonry or concrete wall covered externally with a glass skin spaced in front to leave a small air space. The mass is heated during the day and then releases its warmth to the interior during the evening and night hours. Vents can be placed in the wall to make use of convection currents to directive heat the room during the day. A typical TW consists of 200-400 mm thick masonry wall coated with dark heat-absorbing materials and faced with a single or double layer of glass. The glass is placed between 20-15 mm away from the masonry wall to create small airspace. The heat from sunlight passing through the glass is absorbed by the dark surface, stored in the wall, and conducted slowly inward through the masonry. Table 5 below shows the value of the parameter for the glass skin façade which placed at the outer layer of the exterior wall at the main entrance of the building.

Table 5 Glass Skin Properties

Masonry Wall Description	Typical Values
Solar Transmittance	0.498
External surface	0.173
Internal surface	0.135
Internal surface	0.227
External surface	0.097
Light transmittance	0.742
External Emmisivity	0.845
Internal Emmisivity	0.845
Conductance	2.60 W/m^2C

The case studies of this section illustrate how the choice of material is narrowed from the initial, broad, menu to a small subset that can be tried, tested, and examined further. Most designs make certain non-negotiable demands on a material. However, the final choice between these will depend on more detailed information on their properties, considerations of manufacture, economics, and aesthetics.

Conclusion

A Trombe wall can enable a building envelope to go from a net-loss feature to a net-gain feature. The Trombe wall provides passive solar heating without introducing light and glare into these commercial spaces. Overhangs are necessary to minimize the summer gains; however, additional means would be helpful to minimize summer cooling impacts. TW does not give many influences to the internal temperature. Therefore, it is proved that both materials are suitable to be applied in building in terms of comfort internal temperatures. As this study evaluates the progress of solar Trombe wall system-wide and the possibility for further use, the analysis shows the different designs of solar Trombe wall system that requires elements of passive solar design, the passive solar design principles, the potentials, the difficulties, also main environmental and thermal performance strategies of Trombe wall. In this way, the good performance of the solar Trombe wall system will be accomplished. Trombe walls save energy by complementing conventional heating. In an efficient building, Trombe walls may even replace the need for conventional heating. The innovation of the Trombe wall not widely used in victoria and integration with existing facilities not widely performed. Application of Trombe walls can be used wherever building heating is required providing that a suitable north-facing wall is available. Consideration must be given to hot summer months. To avoid overheating it is important to provide shade over the glass collector and close both the upper and lower vents. Therefore, a good building will provide good selection material by using Cambridge Engineering Selector (CES) software and go through the process of selecting a candidate material (or a range of materials) that find the best candidates for TW selection of concrete, with stone and brick as alternatives because from the comparison.

Recommenidation for Future work

Future studies should incorporate theoretical, experimental evaluation and mathematical simulation for the design work. Once the theory has been established. It is possible to investigate all the parameters affecting the performance so that an optimum size Trombe wall system of the reasonable cost could be established. Future research could also be made on the design of the Trombe wall system in Libya, which is a large country in North Africa. Libya has a long coastline on the Mediterranean but the greater part consists of the central Sahara desert which is boiling hot. This research is regarding its winter system using the annual temperature in North Africa - Libya that can be seen as follows.

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Biography

Dr. Ahmad Yame earned his Bachelor degree in Engineering Technology from the Lawrence Technological University in 2010, Mr. Yame has three master degree, the latest was in 2015 in Industrial Engineering from Lawrence Technological University, second MSc was in Engineering Management 2011 from the Lawrence Technological University and his first MSc was in Mechanical Engineering back in 2007 from the National University of Malaysia. He earned his Associate's degree in Mechanical Engineering 2004 from the Libyan Higher Professional Center for Comprehensive Professions. He primarily develops engineers but also has experience with software and testing. Dr.Yame has tested many enterprise applications for automotive MAHLE Laboratories in 2013, he working with Panasonic automotive in North America since 2016 to test vehicles for AHU/Sync and diagnostic functionalities of engine control systems. He has organized several simulations, in order to test the engine control software and the diagnostic functionality on a CANlog, respectively, through non-regression and diagnostic tests.