Study of Performance Enhancement of a Building in Tropical Climate

By

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11807

Dissertation submitted in partial fulfilment of the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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In partial fulfilment of the requirement for the
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Approved by,

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(Dr. Khariul Habib)

UNIVERSITI TEKNOLOGI PETRONAS
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MAY 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken nor done unspecified sources or persons.

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Anas Elrayah Ahmed Elmahdi

ABSTRACT

The application of Trombe wall in hot climate is problematic due to undesired heat gains and overheating resulting from the solar radiation incident on the building. Heating and cooling in commercial and residential buildings consume a lot of energy generated mostly from fossil fuels and steam plants. Studies and researches are made to come up with better solutions to save the cost of energy, and the new types of energy are called renewable energies like solar energy, wind energy and biomass energy. They are introduced to compensate the degradation of fossil fuels and reduce the electricity bills. Using the solar energy principles, Trombe wall- a passive solar system- is becoming widely used to establish heat energy transfer from the solar radiation to moderate the ambient temperature of a building. In this project the concept of Trombe wall will be studied and applied to suite the Malaysian climatic conditions. At the end of the project the effect of double glazing filled with argon was justified and found to reduce the temperature inside the building.

ACKNOWLEDGEMENT

First and foremost, I pray to God the Almighty for his love and blessings, giving me all the strength to complete the final year project.

I am indebted to many individuals who had directly or indirectly involved in helping me for this project. Hence, I would like to express my greatest gratitude to my respected supervisor Dr. Khairul Habib. Without his guidance and patience, I would not succeed to complete the project. His advices were of valuable and priceless.

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ABBREVIATIONS

PV Photovoltaic

PV-TW Photovoltaic Trombe wall

NOMENCLATURE

A_{int} Air duct convective Area (m^2)

A_{pv} PV model aperture Area (m^2)

C_p Specific heat capacity of Air (J kg^{-1} K^{-1})

G In-plane solar radiation (W m^{-2})

h_c Convection heat transfer between the surface (W K^{-1} m^{-2})

$h_{f,pv-g}$ Radiation heat transfer between PV and glass cover (W K^{-1} m^{-2})

$h_{f,pv-w}$ Radiation heat transfer to back wall (W K^{-1} m^{-2})

h_w Wind convection heat transfer coefficient (W K^{-1} m^{-2})

h_f Radiative heat transfer in the air channel (W K^{-1} m^{-2})

$\dot{m}$ Mass flow rate (Kg/s)

Nu Nusselt number

Pr Prandtl number

T_e Environmental air temperature (˚C)

T_s Sky temperature (˚C)

T_a Ambient temperature (˚C)

T_f Mean air temperature (˚C)

T_g Glass temperature (˚C)

T_{in} Inlet air temperature (˚C)

T_{out} Outlet air temperature (˚C)

T_{pv} PV temperature (˚C)

T_w Back wall temperature (˚C)

U_b Back heat loss (W K^{-1} m^{-2})

U_l Overall heat loss coefficient (W K^{-1} m^{-2})

U_t Top heat loss coefficient (W K^{-1} m^{-2})

I_r Incident solar radiation (W m^{-2})

E Electric power generated by the PV panel (W m^{-2})

CHAPTER 1:

INTRODUCTION

1.1 Project Background

Most of the energy generated in the world is coming from fossil fuels, which basically have certain concerns including the rise of the world's population, the depleting of the amount of fossil fuels and the effects these fuels cause to the environment. And since the buildings consume around 33% of the total energy used in the world, it is of high significance to find alternative ways to generate the energy in those buildings to comply with the new changes and requirements to accomplish the need of thermal comfort inside the building [1].

Solar energy is used as an alternative way to produce electrical energy by using the incident solar radiation on a photovoltaic panel. From pervious researches, it was found that it is very beneficial to use this photovoltaic technology in buildings, in a system that is called Trombe wall which its basic aim is to reduce the energy consumption in a building. The basic function of the Trombe wall is to make use of the solar energy to cool, heat, ventilate and supply the thermal calm inside the building. The Trombe wall is considered a green technology that assists reducing the energy in a building by installing a photovoltaic panel in the south wall to absorb the solar energy and convert it into useful energy, which can be used for heating and cooling [1-2].

Sun Energy or in other word solar radiation is considered as the ultimate source of energy, and investing this energy coming from the Sun is significantly important because it is cheap and available in abundant. Many applications use the solar radiation either for heating or cooling or for direct electric energy generation. In this project the study of the thermal behavior of thermal wall known as Trombe wall is reviewed. Trombe wall system was first developed by American named Edward Morse in 1881, and then was revived by the French inventor Felix Trombe.

The heat will be transferred to the building by convection between the absorbing wall and the inside area, and by radiation in the air gap. In this project a study of the building energy behavior will be carried out and it will be simulated using software called TRNSYS to get some ideas about its performance [5].

1.2 Problem Statement

The concern of this project is to enhance the performance of building in tropical climate; Malaysia is the domain of the project. Trombe wall that will be used has been built in many different climate regions of the world; most of these cases were for heating purposes. For cooling purposes it is really challenging, since cooling the surrounding when it is actually hot outside requires a lot of energy load which will eventually requires a lot of energy consumption, and the main aim of this project is to change the possible variables that can affect the behavior of Trombe wall in hot climate and that would lead for the air cooling. In this project we incorporate photovoltaic cell with the support of a DC fan to regulate the temperature inside the building.

1.3 Objectives

- To Study the effect of Photovoltaic Trombe wall on thermal load.
- To Study the effect of Photovoltaic Trombe wall on thermal comfort.
- To evaluate economic performance of Trombe wall for different vent configuration and glazing type.

1.4 Relevancy of topic

If the Trombe wall is used in buildings under Malaysian climate, it will save a lot of energy used in the country for cooling. If the results are approved to be valid and satisfactory it will help in increasing the usage of Trombe wall more effectively.

1.5 Feasibility of project within timeframe:

This project is divided into two parts namely (FYP I & FYP II), to be done in the final year semesters. In the first part (FYP I), literature review, background of the project is studied, to come up with the design of the wall required for the conditions of Malaysia. In the second part, (FYP II), simulation of the building using TRNSYS software is done, and then it is validated and analyzed with compare with other cases. Writing of the Final report, the project can be easily done during this time border.

CHAPTER 2:

LITERATURE REVIEW

This chapter gives a literature review of selected Trombe Wall models in different parts of the world in their summer behavior. In addition, some researches regarding the use of a DC-fan Trombe wall will be reviewed.

K.Sopian et al. [1] explain that the basic function of a Trombe wall is to use the solar radiation coming from the sun to heat, ventilate and to provide the maximum thermal comfort inside a building taking into account the applications in different climatic areas. The basic working principle behind the Trombe wall is that it absorbs the solar radiation and converts it into useful electrical energy. Studying this principle had lead to the innovation of different types of Trombe walls like classic Trombe wall, Zigzag Trombe wall, Water Trombe wall, solar transwall, solar hybrid wall, Trombe wall with phase change material, composite Trombe wall, fluidized Trombe wall and finally Photovoltaic Trombe wall (PV-TW) which is the focus in this project. In PV-TW front side of the glazing is composed of photovoltaic panels that simultaneously convert solar radiation into heat. With the PV-Trombe wall, the cool air of the room is drawn in from the lower vent, absorbs the PV heat, becomes hot and travels inside the room before exiting through the upper vent. Absorbing PV heat increases the efficiency of PV panels because the panels function better when they are cool.

In the study of M. Alzyood et al. [3] it focuses on the behavior of Trombe wall in Jordan, since it is one of the countries that has got an abundance in solar energy, since the annual daily average solar irradiance varies between 5-7 KWh/m^2 and the average sunshine days are around 300 days per year and 10 hours per day. The main aim of this study was to inspect the thermal and economical impact of installing passive or active solar system in a typical Jordanian residence. The aim is to reduce the cost of energy bill as well as to reduce the CO_2 emissions. In this study, a typical Jordanian house was put under experiment. They included different types of layers used in Jordan to build the house, and that will include the thermal insulation for the

Trombe wall system. A specific percentage of the window areas with respect to the wall under the study was varied with respect to the wall position wither it is facing East, West, North or South. Since the temperature differs from the winter to the summer, and thus the building requirement of heat energy will be different. From the study, it was found that façade facing the south is a better energy saving.

Menelaos Xenakis [4] reflected about the main purposes of using a passive solar system in a building, and that is to provide a thermal comfort, make use of the local climate to reduce the energy consumption. For a system of passive solar energy, it is highly important to design the energy behavior of the building and that is for increasing the solar gains accumulation, increasing thermal storage and reducing heat losses. There are different types of energy transfer mechanism:

1) **Direct gain:** It is the simplest way of energy transferred to the building, where the solar radiation strikes the window facing the south, figure 2-1; and that will cause a heat up in the building directly by the glazing or by absorptance of the wall and then transfer it sometime later [4].

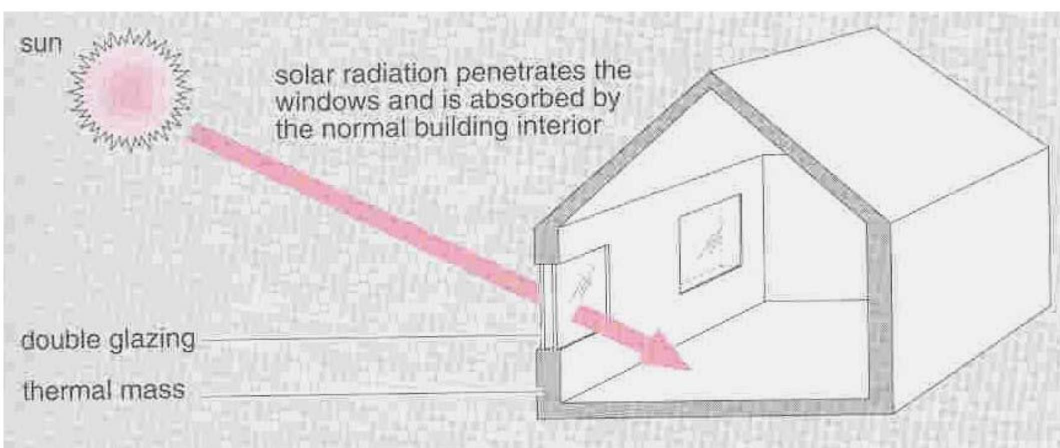

Figure 2-1 Direct Gain

2) **Indirect gain:** It is indirectly making use of the solar radiation for heating the building. This system absorbs the radiation by the building and then transfer it to the inside place, the thermal mass – Trombe wall as an example- Figure.2-2; plays a

major role in this process and it works like a regulator between the sunspace and the inside of the building.

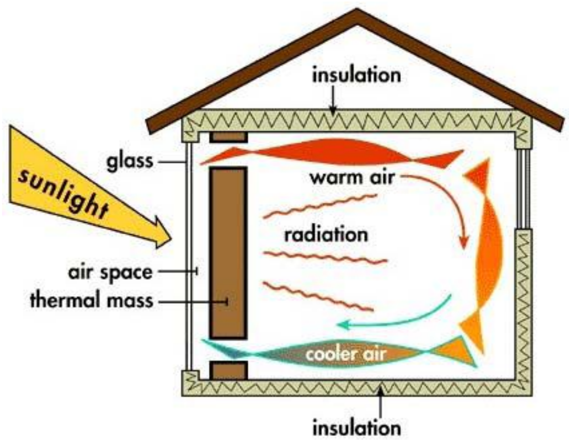

Figure 2-2 Indirect Gain

3) Isolated gains: In this system, the solar collection surface is isolated from the thermal storage space. The energy (heat) is transferred to the inside of the building using a forced mechanism like a fan, figure 2-3. Unlike the true passive solar system, it only uses the effects of natural buoyancy, radiation and convection without any use of any mechanical means [4].

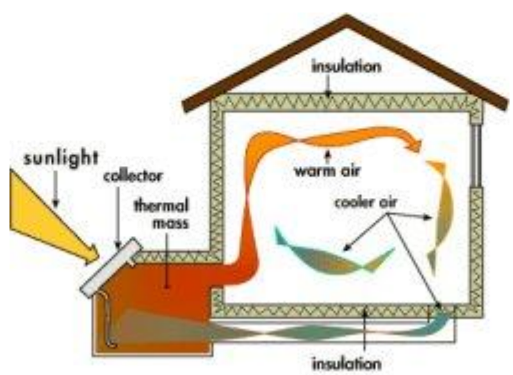

Figure 2-3 Isolated Gains

In another study by Samar Jaber and Salman Ajib [5] they were concerned about the optimum and economic design of Trombe wall and their main focus was the Mediterranean region. Trombe wall is usually made of materials that can absorb heat like concrete or masonry and it is farther painted black to increase the absorptivity of the wall. Moreover, it is made facing south to increase the thermal mass and thus increase the solar gain. The design of the wall will control the thermal loads and air circulation inside the building envelops, it has two opening at the top and at the bottom, glazing and a gap between the wall and the glazing. During the day time, heat is radiated and convected into the space for heating. Then the heating air will be circulating by the effect of buoyancy with colder air inside the building through the vents. This process is happening naturally, it can be further improved by forcing the air using a fan, and then it will become a forced convection heat transfer. A lot of calculation involved in this type of walls, to determine the heat supported to the house by either convection which happens between the absorbing wall and moving air or by radiation in the gap between the glazing and the wall [5].

To simplify the calculation and study the thermal behavior the TRNSYS software is used. It is complete simulation software for building environments including multi zone buildings. The study be Shen et al. that compares between two construction that are classic and composite walls shows that the composite wall perform better in heating the building by using the solar energy. In this study of passive solar system there is a potential problem of overheating the building during the summer. As an approach to solve this problem the overhang shading is installed to reduce the amount of insolation affecting the building. Using the method of Life Cycle Cost (LCC) was investigated by Jaber and Ajib, and it is an approach to design the most economical building, and the results shows that 28% of the annual energy consumption can be saved by defining the best façade, and increasing the windows size as well as the thickness of the thermal insulation [5].

In the review by Francesca Stazi et al. [6] they studied the performance of the building in summer conditions (Mediterranean climate); they have examined ways to reduce heat gains by thermal wall in summer. In this experiment they have examined a classical Trombe wall in Italy, which is made up of a south facing massive wall and painted black on the external surface, and there is an air gap between the external and internal walls with two vents at top and bottom, glazing is placed in the external side of the wall.

In their research, they have studied some actions that can improve the performance of the building in summer climate by controlling the flow of the undesired energy transfer and overheating phenomena. They have grouped the actions in the following categories [6]:

1) Ventilation: it was studied by Gan, he used CFD numerical analysis and he found that ventilation rate was stimulated by the buoyancy effect and it is induced by the wall temperature, solar heat gain, thickness and insulation, distance between wall and glazing.
2) Solar shading of Trombe wall: it is an approach recommended by Tasdemiroglu et al. There are many different types proposed, like overhangs, shutters and blinds. In an experiment where the overhangs were used in summer condition it showed that the walls experienced an additional cooling load.
3) Insulation: Some experiments have examined the effect of the insulation on the building behavior; Jaber and Ajib have recommended the roller shutters and an insulation curtain between the glass and the masonry layer. It is recommended to insulate the internal surface of the Trombe wall and double glazing. Using a composite wall will also work as an insulation as it would have a higher convectivity coefficient which will have its impact on the thermal behavior.

Experiments have been carried out for this particular building in Italy, and they have studied the performances of it in many different summers with changing the conditions like ventilation, insulation, screening, roller shutters and shading for each experiment. With studying the behavior using the analytical approach using the software of “EnergyPlus”, Trombe walls were modeled to all the conditions mentioned above. From the experiment and with acceptance with the analytical approach, it shows that the roller shutters have a relevant influence in reducing the surface temperature of the Trombe Wall by1.4^{o}C and the daily heat gain was further reduced to 0.5 MJ/m^2. They have found that combining overhangs; roller shutters and cross ventilation it gave a reduction of cooling energy need up to 72.9% for the Trombe wall comparing it with the normal ventilation building without solar protections [6].

In another study by Rakesh Khanal et al. [7] they have discussed the natural ventilation of a building, and they compare it with the mechanical ventilation in terms of productivity, cost and their effects on the environment.

Mechanical ventilation has impact on the environment where the emission of CO_2 is higher due to the use of some machines which requires some fuel burning. It is also considered as costly because of the electricity it consumes to function. In the other hand natural ventilation is consider as energy saving mean and it also produce quality air with adequate thermal comfort.

Natural ventilation is mainly induced by thermal buoyancy or air. Ventilation with the effect of buoyancy depends on the temperature difference between the inside and the outside of the building, this process is also referred to as stack ventilation. Studying these effects are very important since this research is concerning about the enhancement of buoyancy effect to achieve the desired air flow. Solar chimney is an excellent example which is designed to increase the ventilation by increasing the solar gain, therefore there will be a temperature variation between the inside and outside to move and improve the air flow. The solar chimney can be affected by several factors like location, climate, orientation, size of the place to be ventilated and the internal heat gains. To analytically study the performance and the effect of the solar chimney, CFD software is used to find the flow patterns inside the chimney and inside the building as well [7].

There are two factors affecting the thermal performance of the building namely the effect of geometry and the effect of tilt angle, figure 2-4 [7].

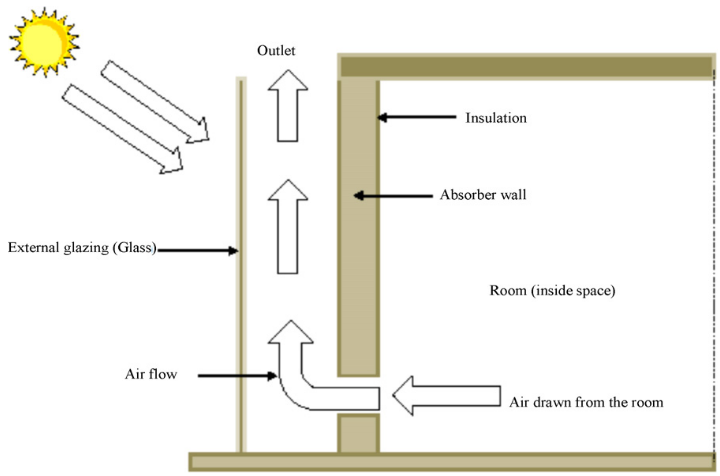

Figure 2-4 Schematic of Solar Chimney with Vertical Absorber Geometry

The study of the Trombe wall characteristics has been a very important topic for the last few decades where it has been tested both experimentally and theoretically in different part of the world , and in each part like, America, China, Tunisia, Jordan, Syria and Turkey it has different weather requirements for improving the climatic calm inside the building in different seasons for these countries, because of different temperature variation between summer and winter, the effect of the sun angle also have been studied as shown in figure 2-5, because the sun has different angles of incident between the summer and the winter [8-9].

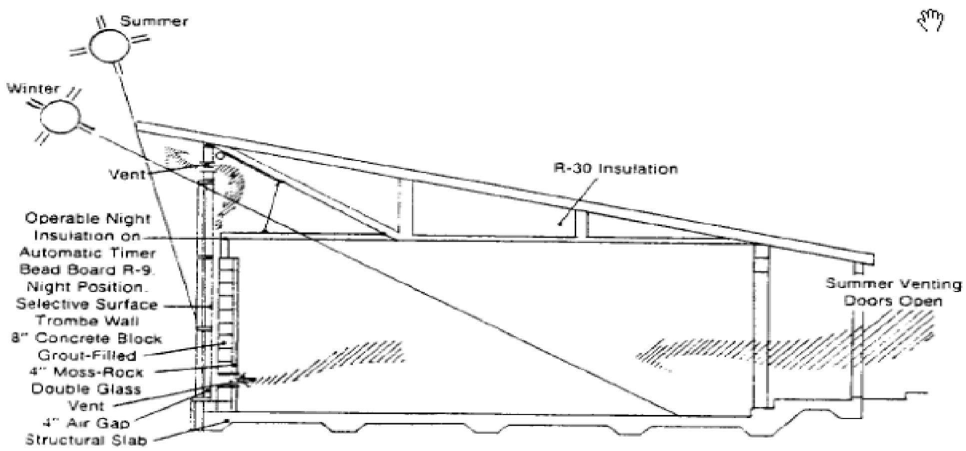

Figure 2-5 Sun Angles between Summer And Winter

In other studies, the effect of Trombe wall is examined with and without the help of a DC fan, using both simulations with some software called TRNSYS and other software, and field exams on both conditions. The results of these tests are found to be in good conformity after the comparisons. A fan that is placed in the air duct as shown in figure 2-6 and is driven by solar radiation can play an important role in cooling. It has not been widely examined, but in some places like Thailand where the weather is hot and humid. It is important to continue the studies for cooling the building using the Trombe wall for better solutions for high energy consumption [9].

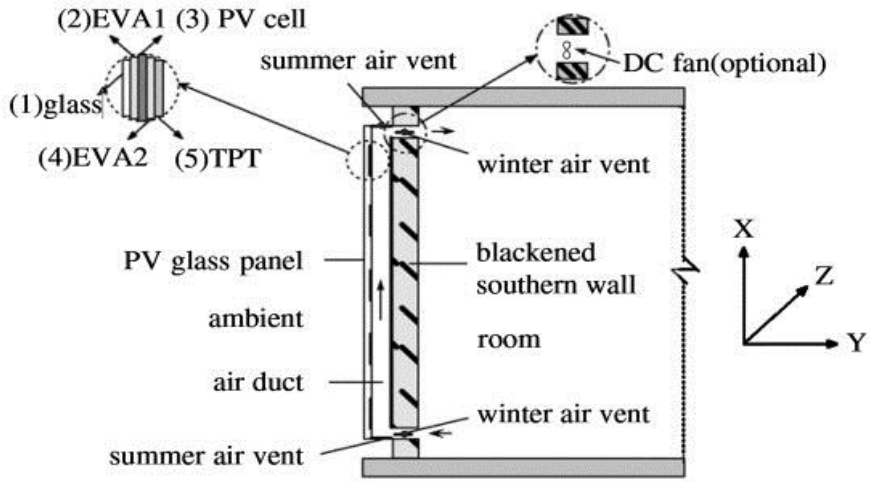

Figure 2-6 Diagram of PV-TW with DC Fan for Winter Heating

In the design of buildings with green technology purposes, it is very important to select the most appropriate type of glazing because it will affect the performance of the PV-TW. Gan et al. [11] suggested that insulating the internal surface of Trombe wall and double glazing prevent overheating. For glazing type, not only the material used is important but also the thickness and the number of layers are very important which will have huge impact on the performance. Mostly, the glazing types used are either single or double glazing. As studied by Stazi et al [6] they found that double glazing improves the performance and the efficiency of Trombe wall .New type of glazing that was studied by Richman and Pressnail [12] is considered very effective on the performance. They used a low-e coating film sprayed over spandrel glass. The glazing increases the efficiency of Trombe walls by reducing radiation. Another factor is that the longitudinal and latitudinal location of the wall will have an effect on the efficiency of the PV-TW [13].

In the study by Koyunbaba et al. [14] they have examined the effect of implementing different number and types of glazing, from that they concluded that the double glass has higher insulation character during night time and the evening; however, single glass provides higher solar radiation gain for the thermal wall during day time due to having higher solar radiation transmissivity. Thus, the use of single glass with a shutter for the night time and the evening will provide more thermal gain for winter heating. As the PV module part has a lower solar radiation transmissivity, the air temperature in the air duct of the PV module part is less than the double and single glass parts which is necessary for providing higher electrical efficiency. The results show that the heat stored in the wall during the day is transferred into the room during night time when there is no radiation.

The Photovoltaic Trombe wall is a system that consists of photovoltaic panel, single, double or triple glazing, two vents for air ventilation and a fan in the case of air forced ventilation. These components are placed in a normal masonry wall usually chosen to be facing the south, to maximize the solar radiation incident on the wall. This system was mainly used in the cold climate zones to remove the cold air from the building and thus reducing the energy bill. However, with some techniques it can be even applied in the hot countries – Malaysia for example- to reduce the hot air inside the building and reduce the bill of cooling. It is a good solution to assist reaching for climatic comfort temperature inside the buildings.

Cheng et al. developed a correlation between the optimum angle of the BIPV/T system and the latitude of the ground. Thus, they concluded that to get maximum solar radiation in northern hemisphere, the system should face south and the angle of the panel should be equal to the latitude of the ground [14].

Mathematical Modeling

A PV wall structure consists of a massive wall, a PV array on the massive wall, an air gap between the PV panels and the wall, and an air inlet and an air outlet of the air gap. These are considered the basic outfit of the Trombe wall integrated with Photovoltaic panel. It is assumed that the indoor air temperature and the thermal–physical properties of the wall materials are constant, one dimensional steady state heat transfer. The massive wall is entirely covered by the PV panels [15]. The energy balance equations of figure 2-7 are given as:

Photovoltaic:

$$A_{pv}\,\tau\alpha(1-\eta_e)I_r = A_{pv}U_t\left(T_{pv}-T_a\right) + A_{pv}h_c(T_{pv}-T_f)A_{pv}h_{r,pv-w}(T_{pv}-T_w) \quad (1)$$

Fluid:

$$\dot{m}C_p(T_{out}-T_{in}) = A_{pv}h_c(T_{pv}-T_f)A_{int}h_c(T_w-T_f) \quad (2)$$

Back wall:

$$A_{pv}h_{r,pv-w}\left(T_{pv}-T_w\right) = A_{pv}U_b(T_w-T_a)A_{int}h_c(T_w-T_f) \quad (3)$$

Glass Cover:

$$A_{pv}\left(h_{r,pv-g}+h_c\right)\left(T_{pv}-T_g\right) = A_{pv}\left(h_{r,g-a}+h_w\right)(T_g-T_a) \quad (4)$$

Electrical Power generation:

$$G = E + h_w\left(T_{pv}-T_e\right) + h_c(T_{pv}-T_f) \quad (5)$$

The maximum power output decreases linearly with increasing cell temperature and is proportional to the absorbed incident solar radiation as is given as:

$$E = (T_{pv}+\beta)I_r \quad (6)$$

The channel air temperature is assumed to vary linearly in the flow direction so that the mean temperature T_f required to fix air properties is calculated as:

$$T_f = (T_{out} + T_{int})/2 \quad (7)$$

The average convective heat transfer coefficient due to wind on the outside surface of the PV glazing cover is given by:

$$h_w = 5.7+3.8V \quad (8)$$

The equations for laminar and turbulent boundary layer from Tsuji and Nagano are used:

$$N_{ux} = 0.387(G_{rx}\mathrm{Pr})^{1/4} \quad \text{(Laminar boundary layer)} \quad (9)$$

$$N_{ux} = 0.120(G_{rx}\mathrm{Pr})^{1/3} \quad \text{(Turbulent boundary layer)} \quad (10)$$

The heat transfer coefficient is calculated from:

$$h_c(X) = (N_{ux}\lambda_a)X \quad (11)$$

The overall heat loss coefficient U_L combines the losses from the top (front) U_t, bottom U_b and sometimes edges U_e but normally the edge losses is assumed to be negligible or included in the back loss:

$$U_L = U_t + U_b \tag{12}$$

The top heat loss coefficient U_t is evaluated by considering the wind convection h_W and the radiation heat exchange with sky $h_{r,g-a}$ from the glass cover of PV module:

$$U_t = h_W + h_{r,g-a} \tag{13}$$

$$h_{r,g-a} = \sigma\epsilon_{py}\,(T_\sigma^4 - T_S^4)/(T_g - T_a) \tag{14}$$

The sky temperature T_S is calculated from:

$$T_s = 0.0552\,T_a^{1.5} \tag{15}$$

The bottom loss coefficient U_b accounts for the conduction losses through the back insulation are given by:

$$U_b = K_{ins} / \partial_{ins} \tag{16}$$

Radiation heat-transfer coefficient $h_{r,1\text{-}2}$ is determined using the linearized coefficient from Stefan–Boltzmann equation:

$$h_{r,1-2} = \sigma(T_1 + T_2)(T_1^2 + T_2^2)\left(\frac{1}{\epsilon} + \frac{1}{\epsilon} - 1\right) \tag{17}$$

Where the subscripts 1 and 2 represent any two surfaces that are facing each other.

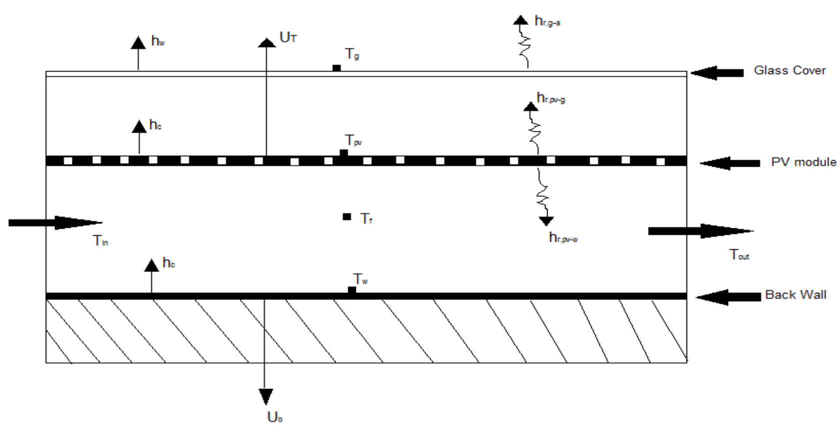

Figure 2-7 Temperature Nodes and Heat Transfer Coefficient in PV-TW

To improve the function of Trombe wall and provide the highest level of thermal comfort inside the building envelope the use of the fenestration is extremely vital because it provides an optimum illumination level. In modern years, there have been major advances in glazing technologies. These technologies include solar control glasses, insulating glass units, low emissivity coatings, evacuated glazing, aerogels and gas cavity fills along with improvements in frame and spacer designs. [16]

In some studies that were carried out in 5 different places in India with different climate conditions, the effect of using 10 different types of glazing was observed, and it was found that the annual energy saving by windows is not only dependant on thermal conductivity (U-Value), but it also depends on the heat gain solar coefficient, orientation, climatic condition, and other building specification such as insulation level, floor area and the materials used in the walls [16].

CHAPTER 3:

METHODOLOGY

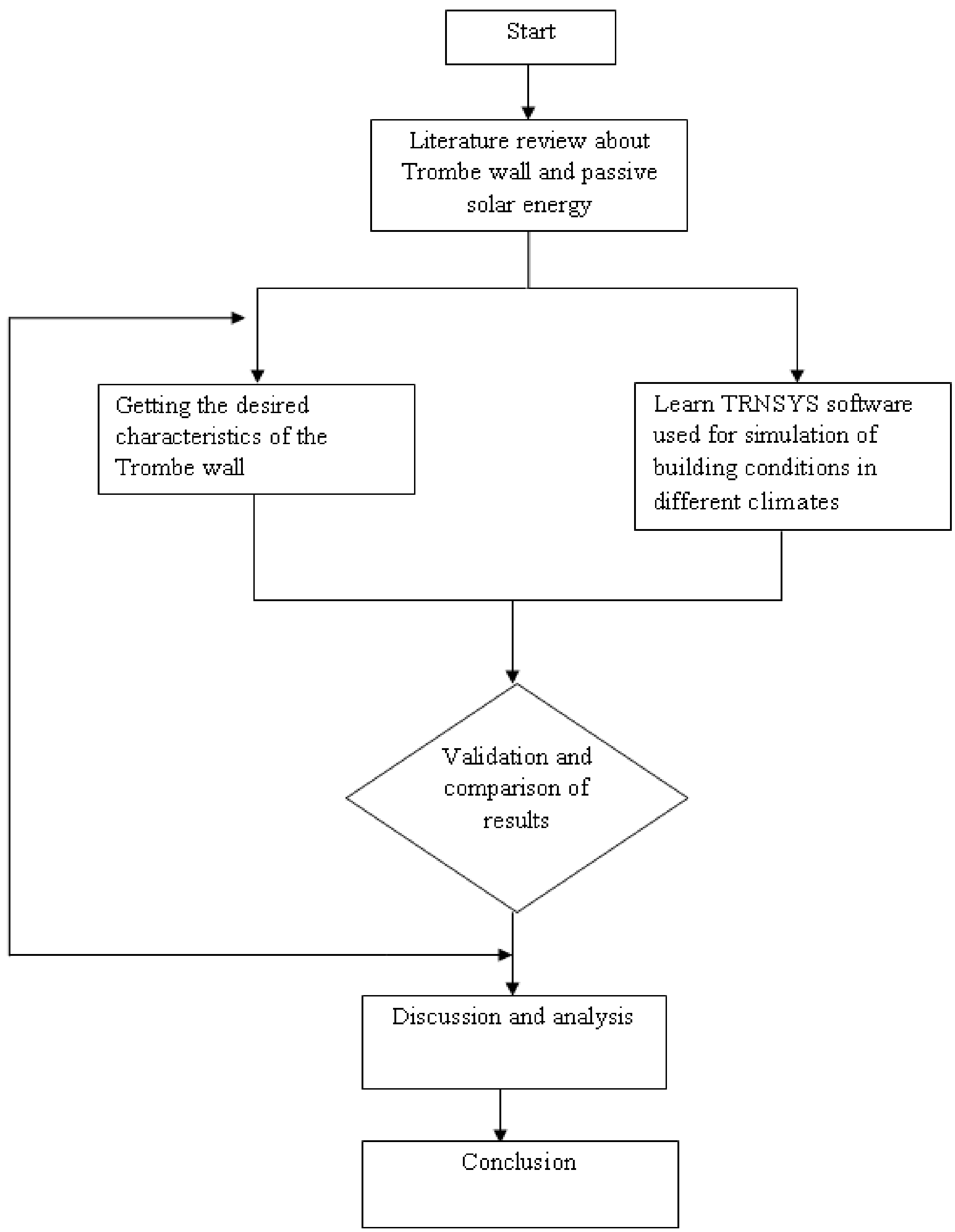

Figure 3-1 Project Flow Chart

3.1 Project Activities

- **Literature review:**

In this project extensive knowledge about the photovoltaic cells, the passive and active solar systems and Trombe wall is of high importance. Many research papers, journals and reviews are to be reviewed for knowledge and data validation at the result phase of the project.

- **Modifying independent variables and simulation of the Trombe wall using the software (TRNSYS):**

TRNSYS is very flexible graphical software where the environment conditions are used to simulate the behavior of transient system. This software is used mainly in renewable energy engineering and buildings with passive or active solar applications. After reading and understanding the requirements of the Malaysian climate, and understanding how is it possible for making a building that can be passively cooled, it is then brought further to be tested for results using the software.

- **Validation and Comparison of results:**

The performance of the new wall for the Malaysian climate is to be compared after obtaining the results from the software with other similar conditions.

3.2 Project timeline (Gantt chart)

Project Title: Study of performance enhancement of a building in Tropical climate											
Project Tasks	**Project**										
	2013										
	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*
Project Title Selection											
Research phase and Data collection											
Literature review and collecting of data											
Design and simulation phase											
Proposing criteria conditions, simulating and analyzing											
Optimization and Validation of results											
Conducting simulation on different types of glazing											
Presentation phase											
Submission of Progress Report											
Pre-EDX											
Submission of Draft Report											
Submission of Dissertation											
Submission of Technical Paper											
Oral Presentation											
Submission of Project Dissertation											

3.3 Milestone:

The important key milestones of this project are submission of progress report, Poster presentation and Pre-EDX and preparation of the final dissertation. The most important step is getting the results from the software to compare the different conditions used and further the project activities.

3.4 Tools and Software

The basic software that is used in this project is TRNSYS (Transient system simulation tool).

CHAPTER 4:

RESULTS AND DISCUSSION

- **Project preliminary results and outputs**

4.1 Description of the test cell

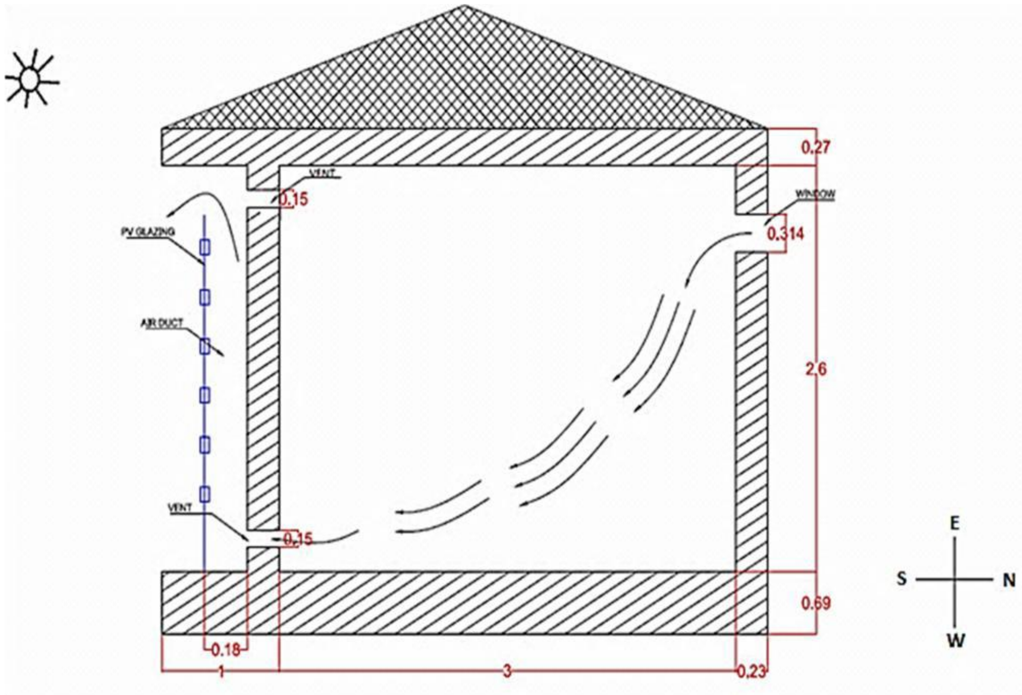

Figure 4-1 Schematic Diagram of the Test Room

At this stage of the project, the focus was only on the south wall of the building orientation. Dimensions have been accepted to be X 3.0 m (width, X) Y 3.0 m (depth, Y) Z 2.6 m (height, Z).

After setting the dimensions, other parameters of the cell is justified according to the conditions that suits Malaysian climate, like introducing the Attic roof on top of the cell, selecting the best materials for the layers of the cell. On the cell we have got a firmly small vent on the south side (Trombe Wall) and a small window on the north wall to help for air circulation.

4.2 Simulation of the cell in TRNSYS software

After sitting all the parameters of the cell, the project can be proceeded to use the simulation face in order to check some results with respect to the data supported.

The elements used in the software were:

1) Building [Type36]: which is a normal building using the arrangements mentioned above.
2) Trombe Wall [Type36d]: Which is the Trombe wall attached to the building's South-wall.
3) Photovoltaic module [Type567-2]: a photovoltaic cell with single glazing attached to the Trombe wall.

After introducing all the necessary elements and provide the software with Malaysia climate condition we can run the Software and get the desired output.

4.3 Outputs selected to be shown in the results

In this stage only few outputs are wished for-which are given as options in the software-which are:

a) Air Temperature of the room.(TAIR)
b) Total convection to Air from all surfaces within air node. (QCSURF)
c) Inside surface temperature of South wall. (TSI)
d) Sensible heat in the room (QSENS).

Here the effected of photovoltaic cell with single glazing, is accounted for, to know how it can affect the temperature inside the building.

4.4 Graphs of the obtained results

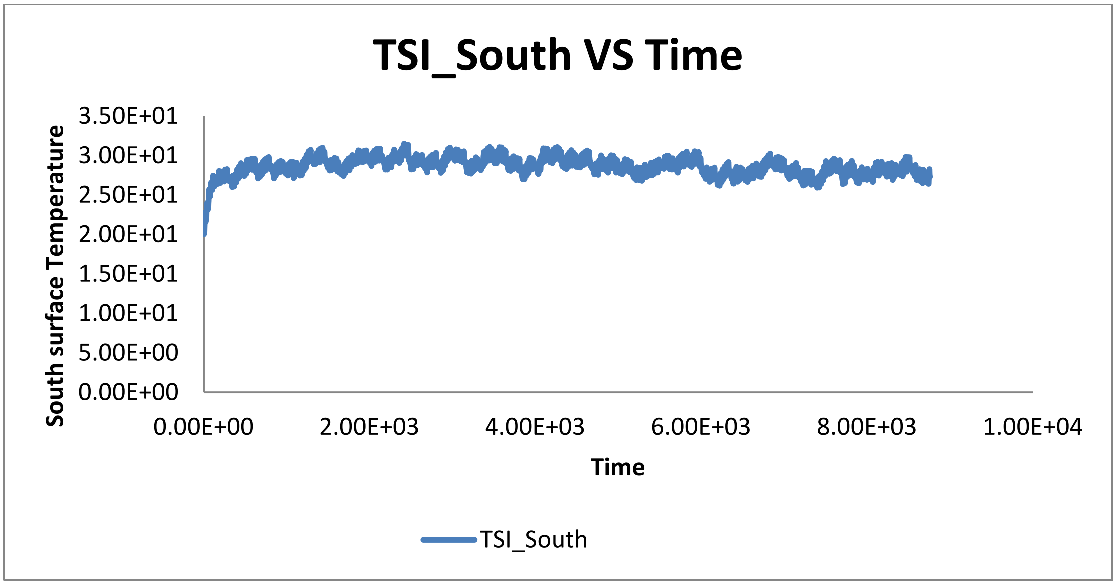

Figure 4-2 South Wall Inner Temperature vs. Time

From figure 4-2, it can be shown that the inside temperature varies slightly through this period of time, and the temperature is minimum at 20 ºC and highest at 33 ºC.

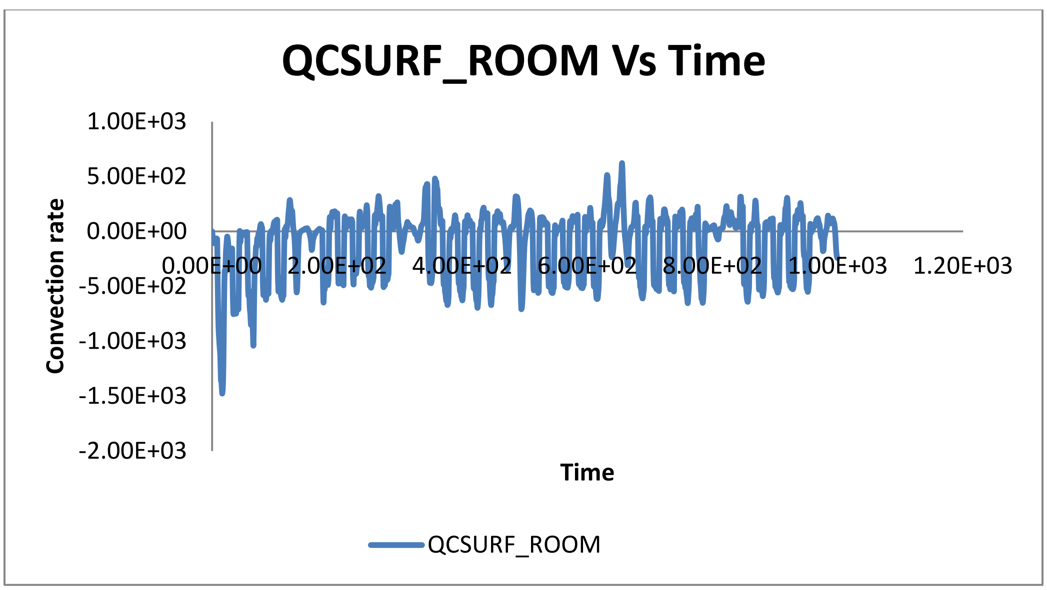

Figure 4-3 Convection Rate vs. Time

From figure 4-3, it can be shown that the convection is varied between negative and positive values which will clearly validate the heat lost during the night period and heat gained during the day period and that is because of the solar radiation.

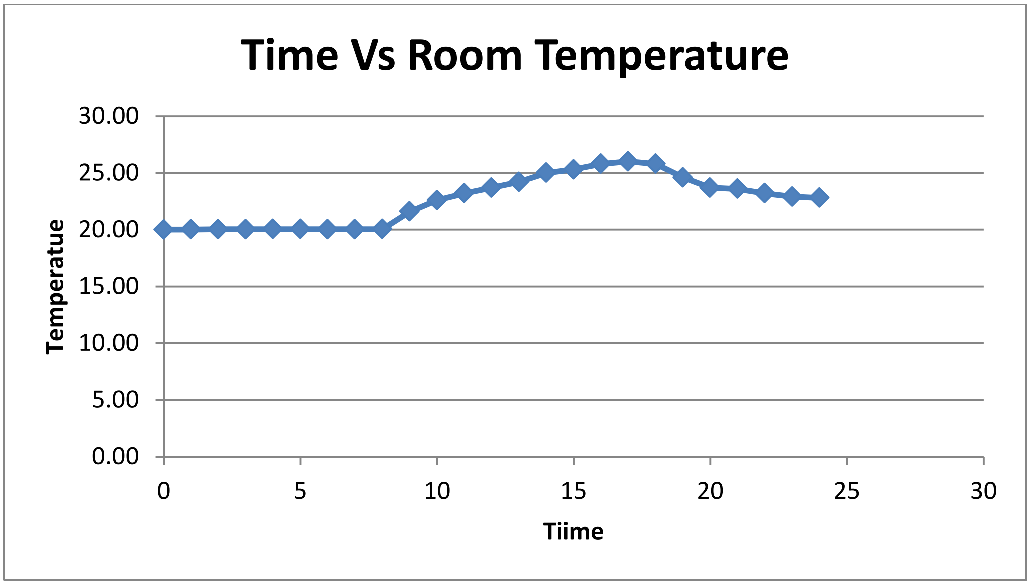

Figure 4-4 Room Air Temperature vs. Time (Without PV-TW)

From figure 4-4, it can be seen that room temperature is fluctuating between 20 ºC and 26 ºC, this shows the normal profile of a temperature inside a building under Malaysian climate without any introduction of the Trombe wall. The temperature is just cooled by natural ventilation.

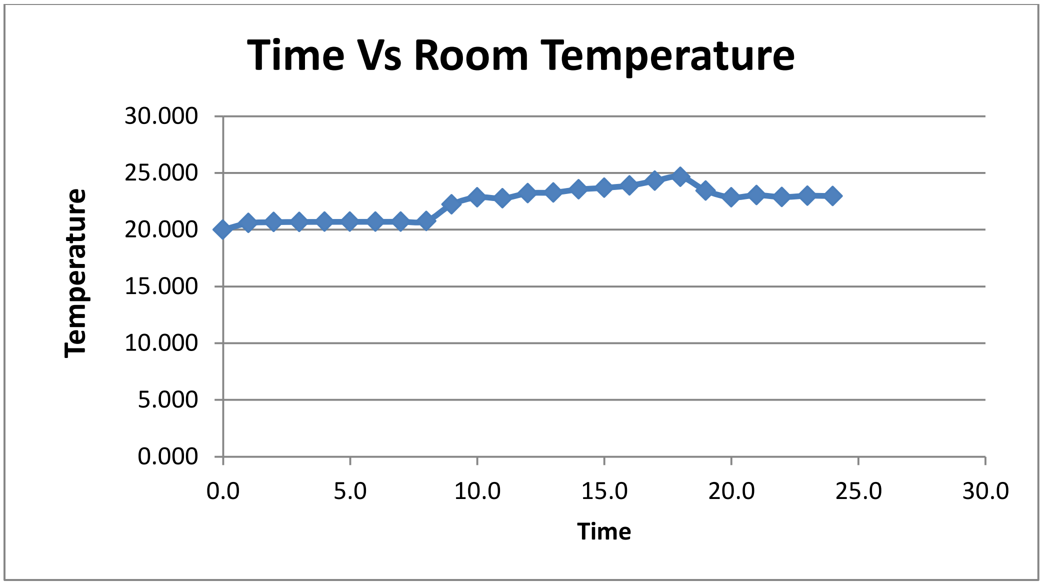

Figure 5 Room Air Temperature vs. Time (With PV-TW)

From figure 4-5, it shows slight change in the temperature ranges throughout the day especially during the time of peak which is about 6:00 PM. It is started to show the effect of introducing the Trombe wall and its noticeable change on temperature of the room.

- **Following Results obtained from different glazing types e.g. single glazing, double glazing and double glazing filled with argon**.

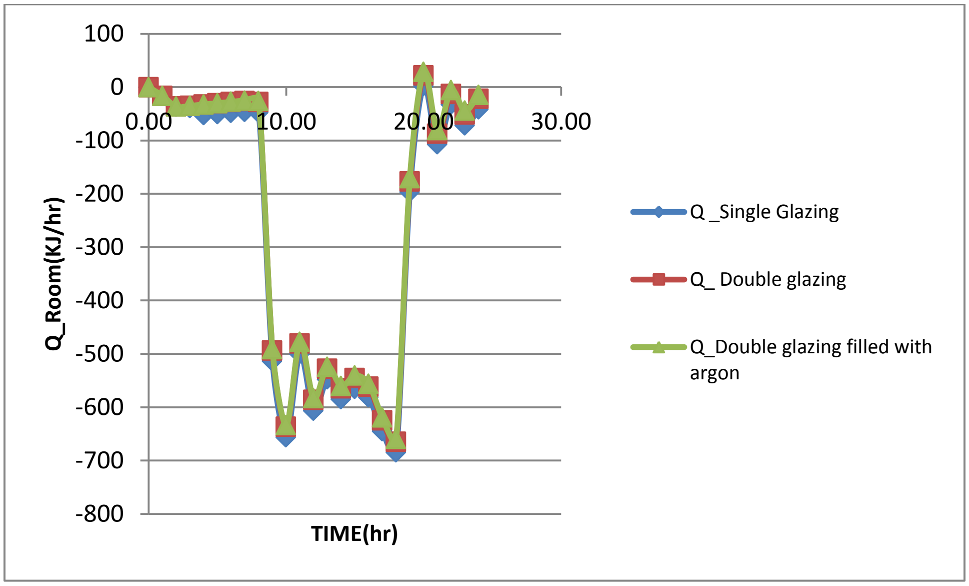

Figure 4-6 Sensible Heat Profile of Room at Different PV Glazing

From figure 4-6, the difference of sensible heat profile in a room for 3 different type of glazing is shown. It is clear that the sensible heat Q in all the types of glazing is negative, and that proves that the heat is flowing outward. It is clear that single glazing has the highest amount of heat transferred, although it was expected the double glazing will have higher transferred rate, it shows that they act like a resistance or as insulation to reduce the heat lost which some part of it will be trapped inside the building similar to the effect of greenhouse gasses. Proper ventilation should be done to avoid overheating.

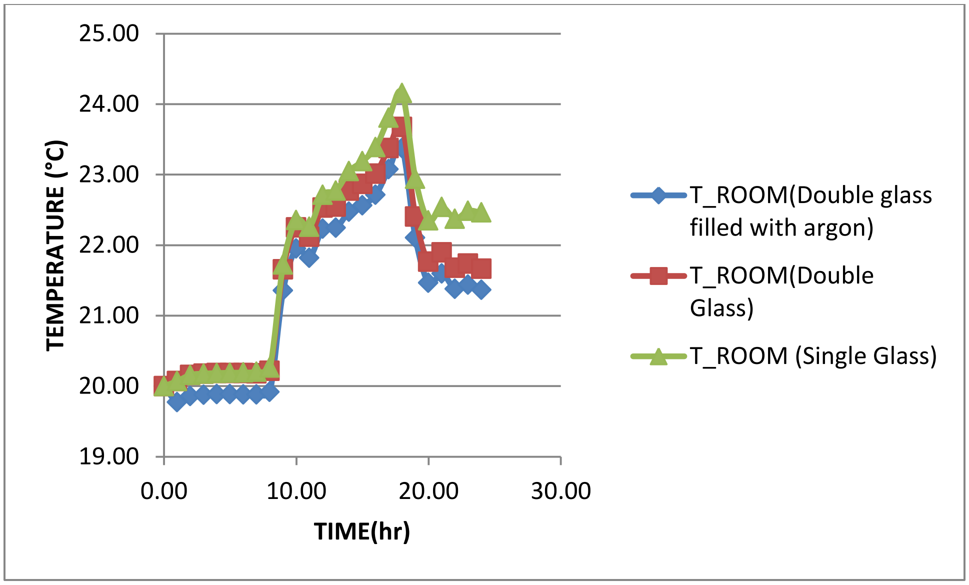

Figure 4-7 Room Temperature at Different PV Glazing

From figure 4-7, the effect of the time of the day can be easily noticed, that during the day and when there is more solar radiation falling on the 3 different types of glazing, It can be noticed that single glazing is having higher temperature values than in the case of double glazing and double glazing filled with argon. This effect is due to the nature of higher transmissivity of the single glazing. The double glazing, and double glazing filled with argon will reduce the transmissivity rate and thus the temperature inside the room will be reduced up to 2.36 ºC. The solar radiation that falls on the massive PV-TW is transmitted to the room by radiation and convection, so when the transmissivity reduce the radiation captured will be reduced as well. In this case double glazing filled with argon is showing significant temperature reduction up to 23% as compared to the double glazing which is desired.

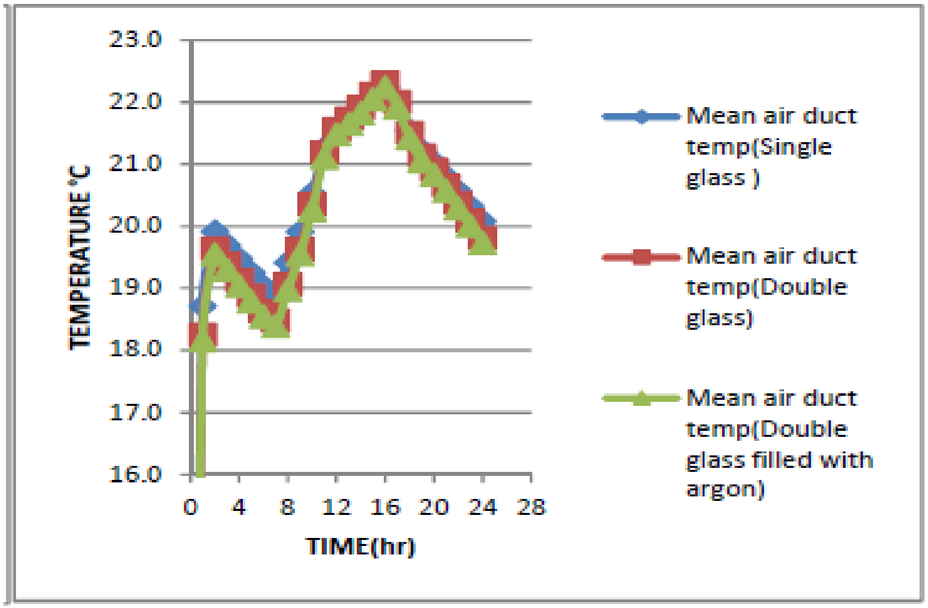

Figure 4-8 Average Air Duct Profile for Different PV Glazing

From figure 4-8, the variation of the average air temperature in the duct with respect to time and with different types of glazing e.g. single glazing, double glazing and double glazing filled with argon is shown. Since the PV glazing absorbs around 90-95% of the incident solar radiation, and 5-20% is converted into electrical energy. Thus the remaining energy will be in form of heat which has to be taken away by the air in the duct. Simulation results shows that average air duct temperature for double glass filled with argon is 1.83ºC less if compared to single glazing, and 0.64ºC less if compared to double glazing less as compared to single glazing PV-TW and. The explanation of these results is that when the number of glass increases from single to double glass transmissivity of solar radiation reduces which will further be reduced by using double glass filled with argon.

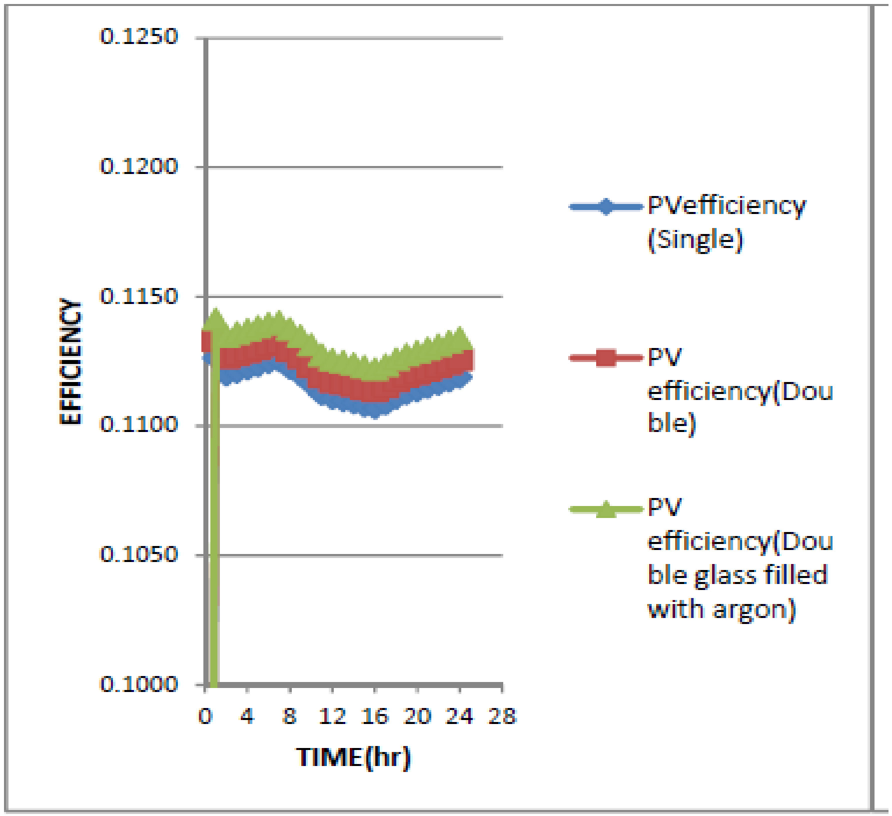

Figure 4-9 Effect of Different PV Glazing Type on PV Efficiency

From figure 4-9, it is shown that the efficiency of the double glazing filled with argon is higher than efficiencies of single glazing and double glazing respectively, it is resulted from the average temperature inside the duct in the double glazing filled with argon is lesser than the other two, and thus it proves the effect of higher temperature on reducing the efficiency of PV panels.

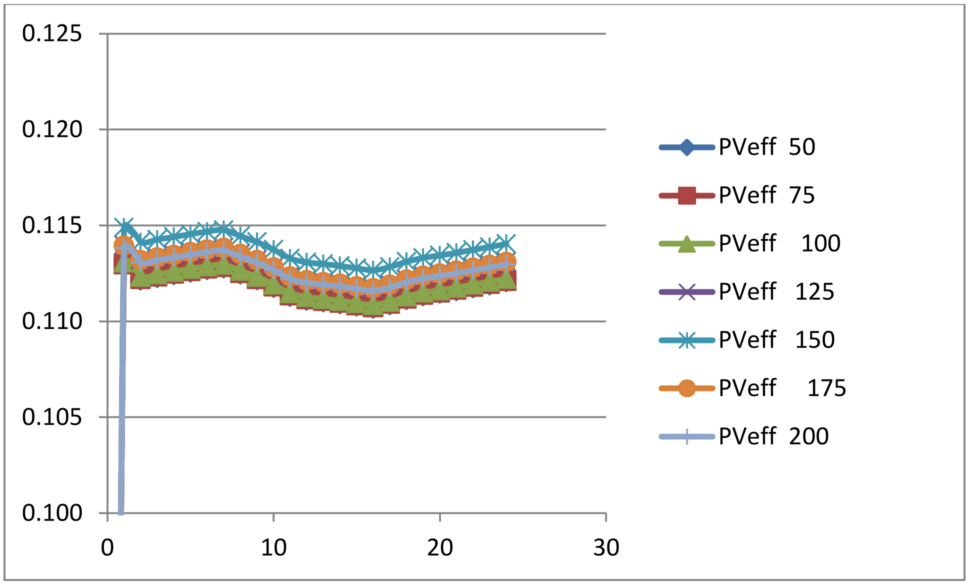

Figure 4-10 PV Efficiency at Different Flow Rate (Double Glazing Filled with Argon)

From figure 4-10, another effect of air flow rate is shown. The efficiency of PV panel using only one type which is double glazing filled with argon is found to be increasing as the air flow rate increases and that proves that the air moving providing cooler air which will cool the PV panel as well, since the PV functions better when the temperature is lower.

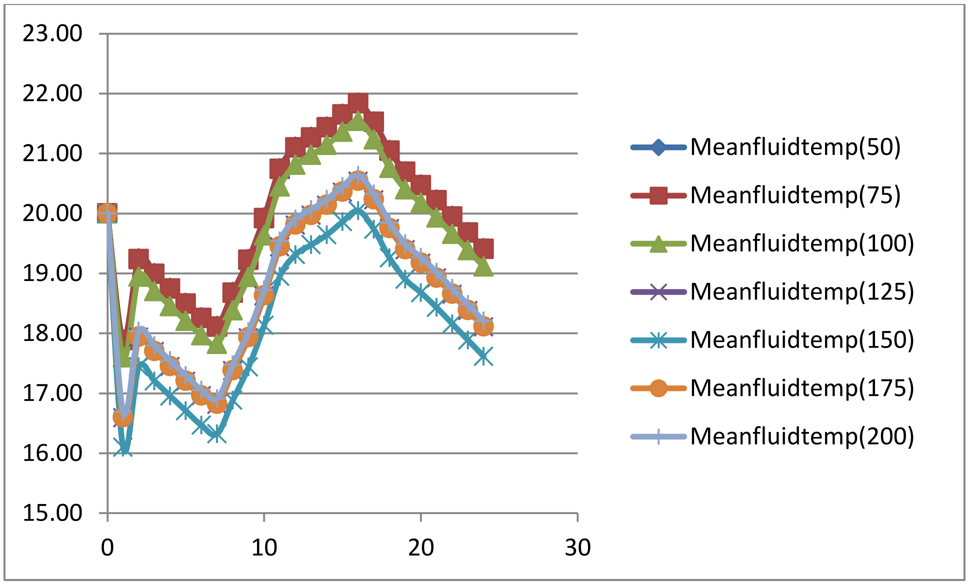

Figure 4-11 Mean Fluid Temperature vs. Time at Different Flow Rate

From figure 4-11, the effect of varying the flow rate of the air movement is vital and it changes the temperature inside the building significantly. It is seen that when the flow rate of the air is 200 kg/hour it has the lowest mean fluid temperature with about 2 degrees less than the flow rate of 50. This will comply with the effect of ventilation and the speed of air studied in the literature.

CHAPTER 5:

CONCLUSION AND RECOMMEDNATION

In conclusion, improving a building performance is possible by applying different types of glazing like single glazing, double glazing and double glazing filled with argon. Using the TRNSYS software the results are achieved, and it is found that the results are in compliance with the studies, that using the double glazing filled with argon will have significant change on the climatic condition inside the building which will eventually improves the thermal comfort inside the building. Also it was approved that this type of PV-TW will reduce the thermal load and increases the production of the electrical energy by the PV wall, which will eventually reduce the cost of energy. All in all, the double glazing filled with argon is considered the best option that will make the buildings under Malaysian climate go green and reduce the dependency on fossil fuels which is considered harmful to the environment and depleting rapidly. It is recommended that farther studies on this type to be carried out for experimental purposes, so that it can be applied throughout the country to save the cost of energy.

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APPENDICES

Material	Density (kg/m^3)	Specific heat (kJ kg^{-1} K^{-1})	Thermal conductivity (W m^{-1} K^{-1})
Brick tile	1892	0.88	0.798
Mud brick	1731	0.88	0.750
Mud phuska	1622	0.88	0.519
Cement plaster	1762	0.84	0.721
Cement mortar	1648	0.92	0.719
Limestone tile	2420	0.84	1.800
Sand grave	2240	0.84	1.740
GI sheet	7520	0.50	61.060
Plywood	640	1.76	0.174

Table 1: Thermo physical properties of building materials

				Average High/Low Temperature - Peark, Malaysia								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High °C	27	28	28	29	31	31	30	30	30	28	30	27
Low °C	22	23	24	25	24	24	24	24	24	24	23	22

Table 2: Average High/Low Temperature of Tronoh-Perak

				Average Daily Sunshine Hours - Peark, Malaysia								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	7	9	8	8	8	8	8	8	8	7	6	6

Table 3: Average daily sunshine hours of Tronoh-Perak

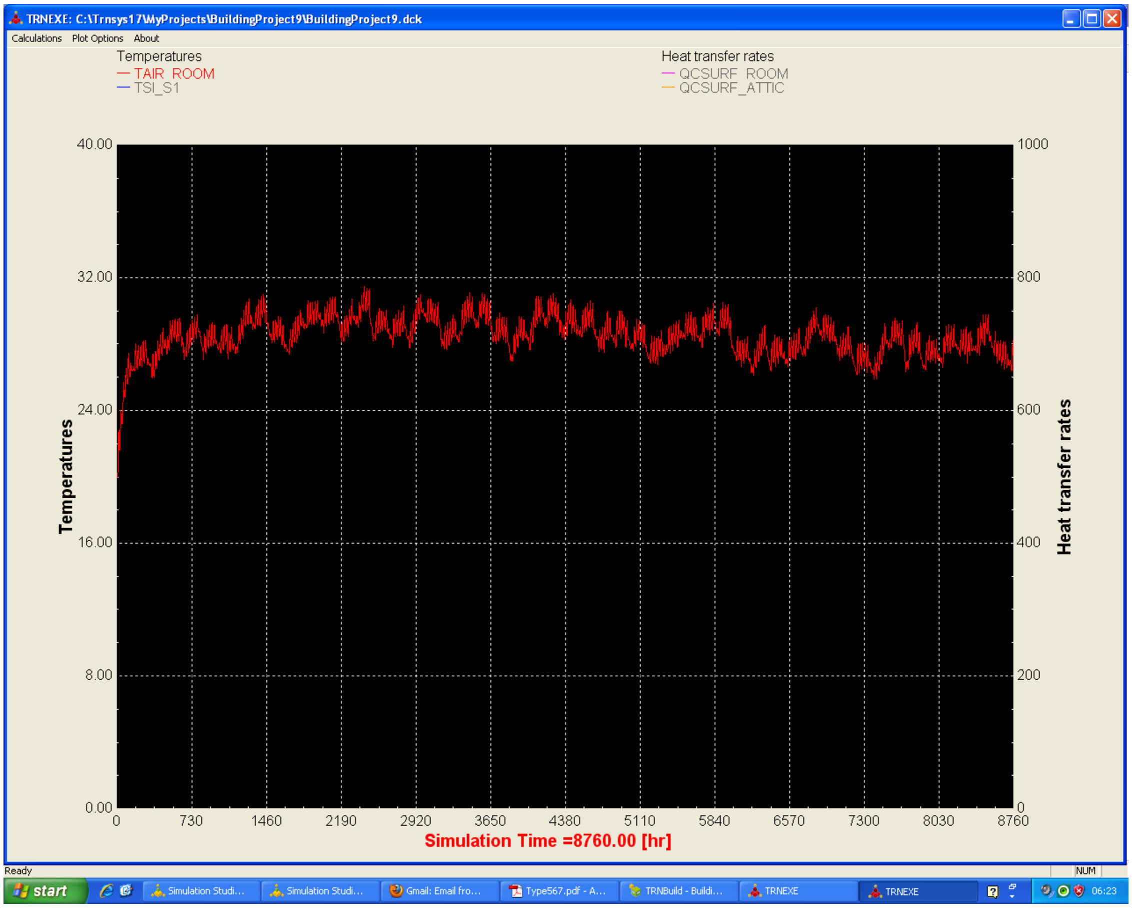

Figure A: Plot for Room Air Temperature VS time cycle (One year)

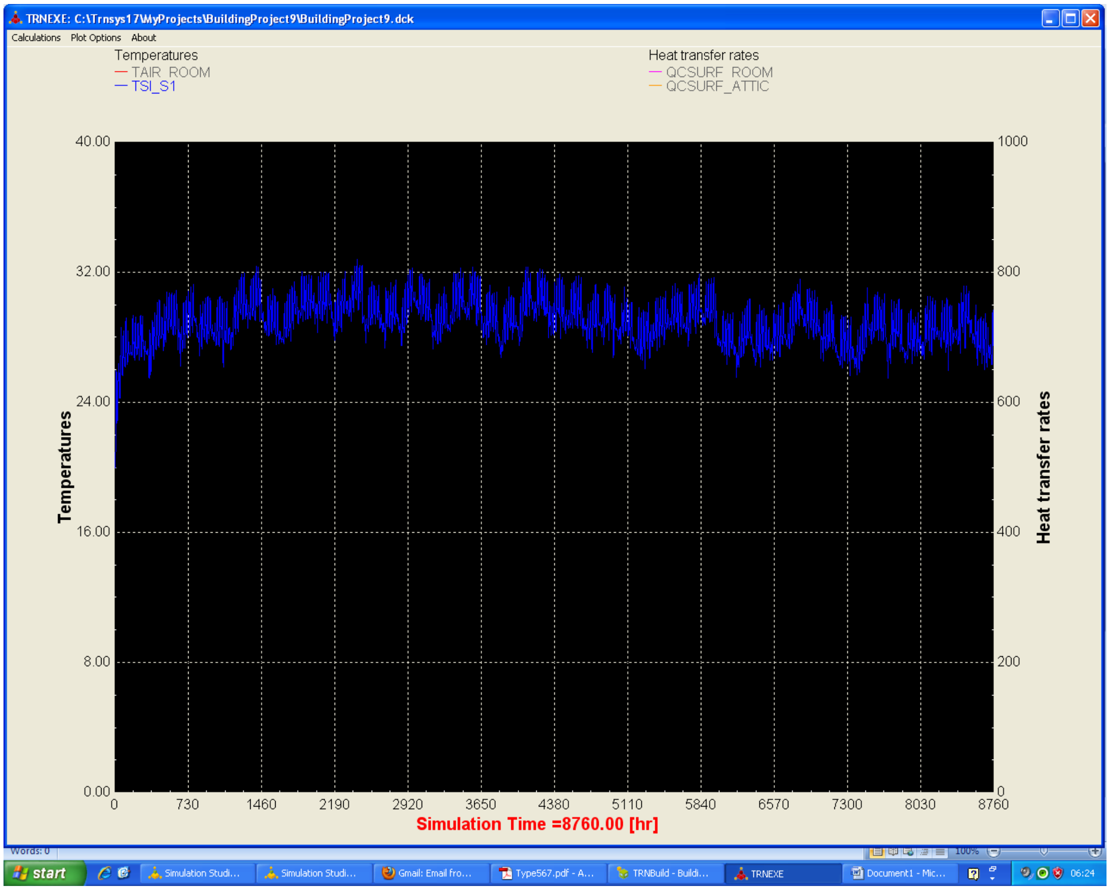

Figure B: Plot for south-wall inner Temperature VS time cycle (One year)

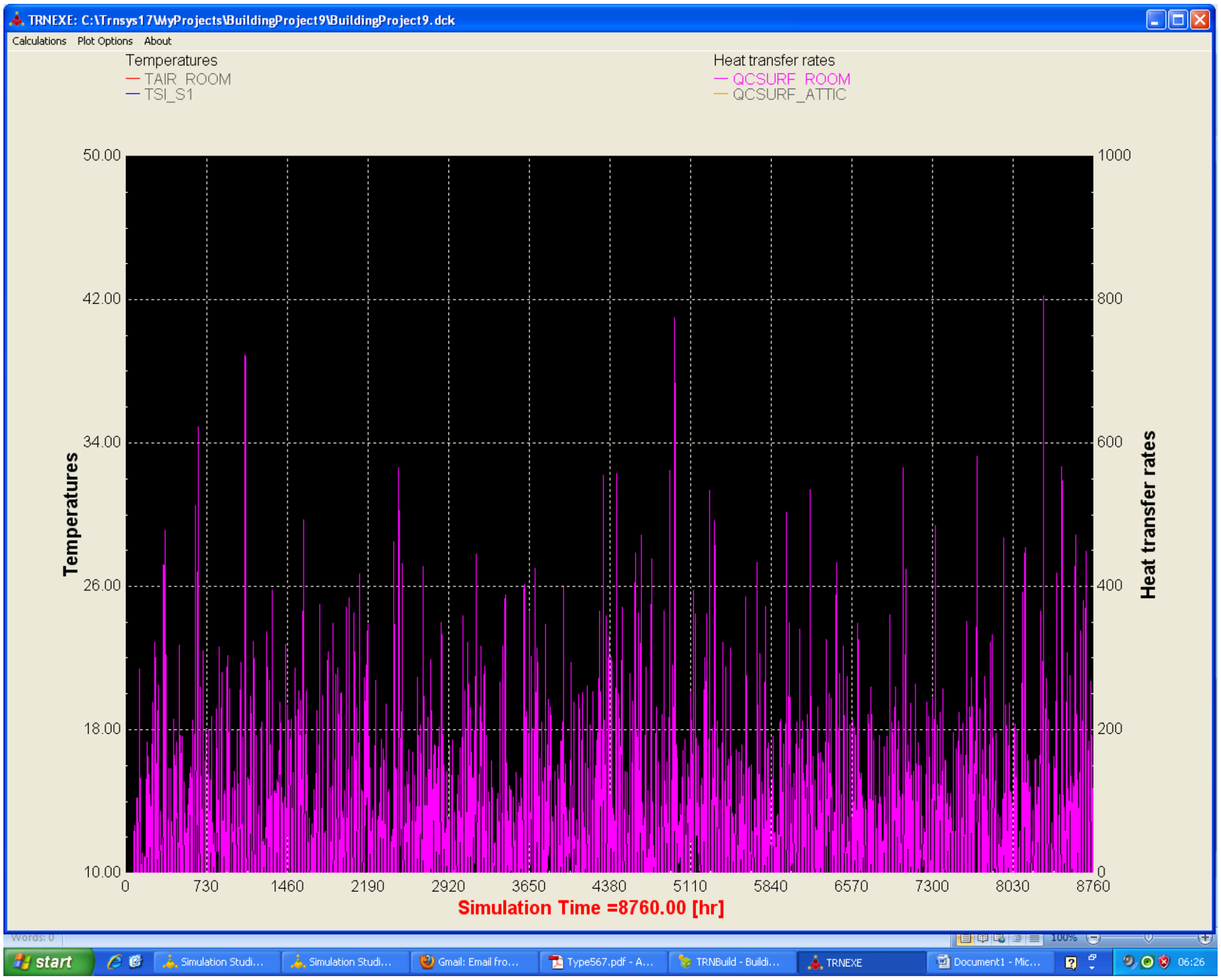

Figure c: Plot for convection of heat of the room VS time cycle (One year)

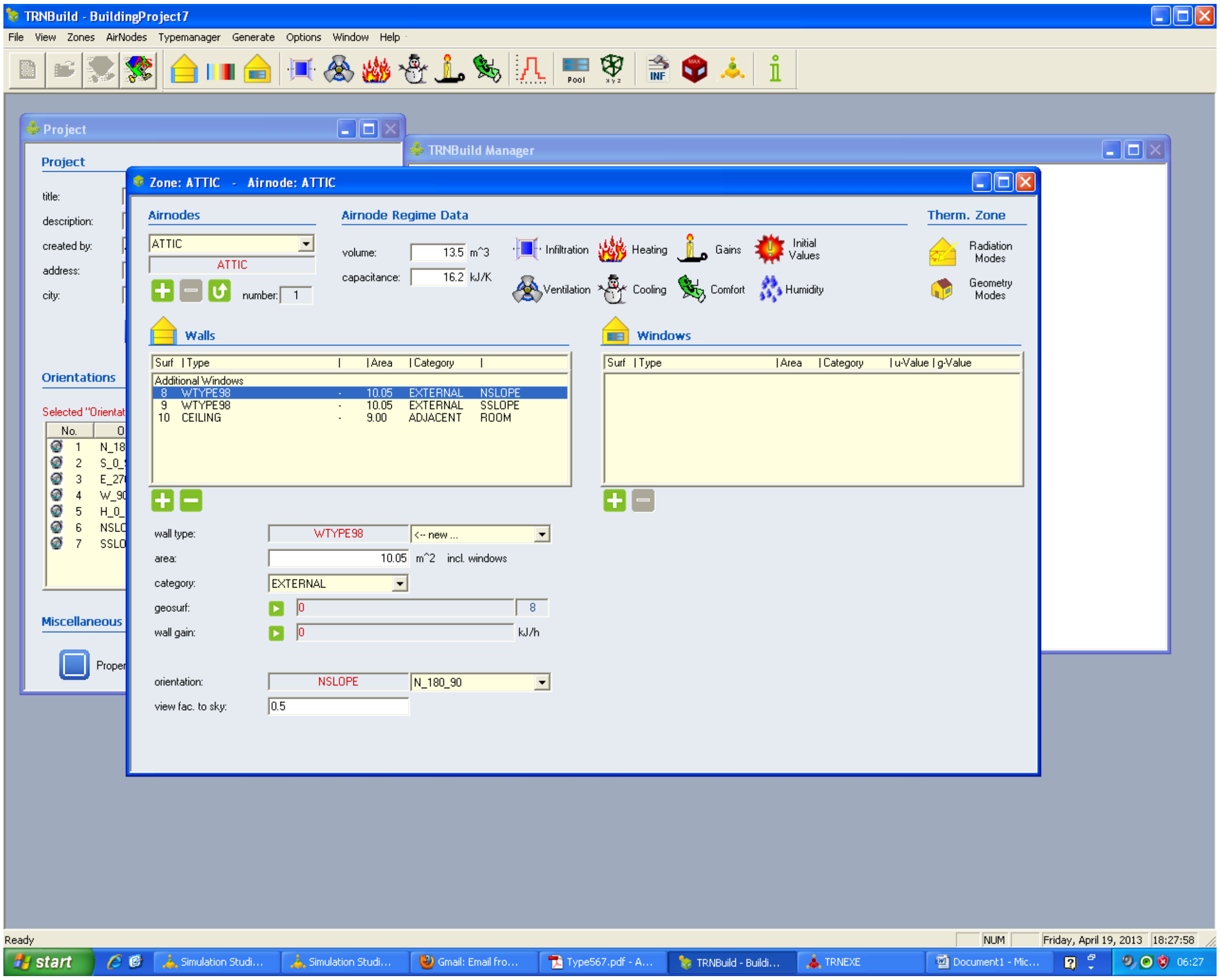

Figure D: Building setup in the TRNSYS Software

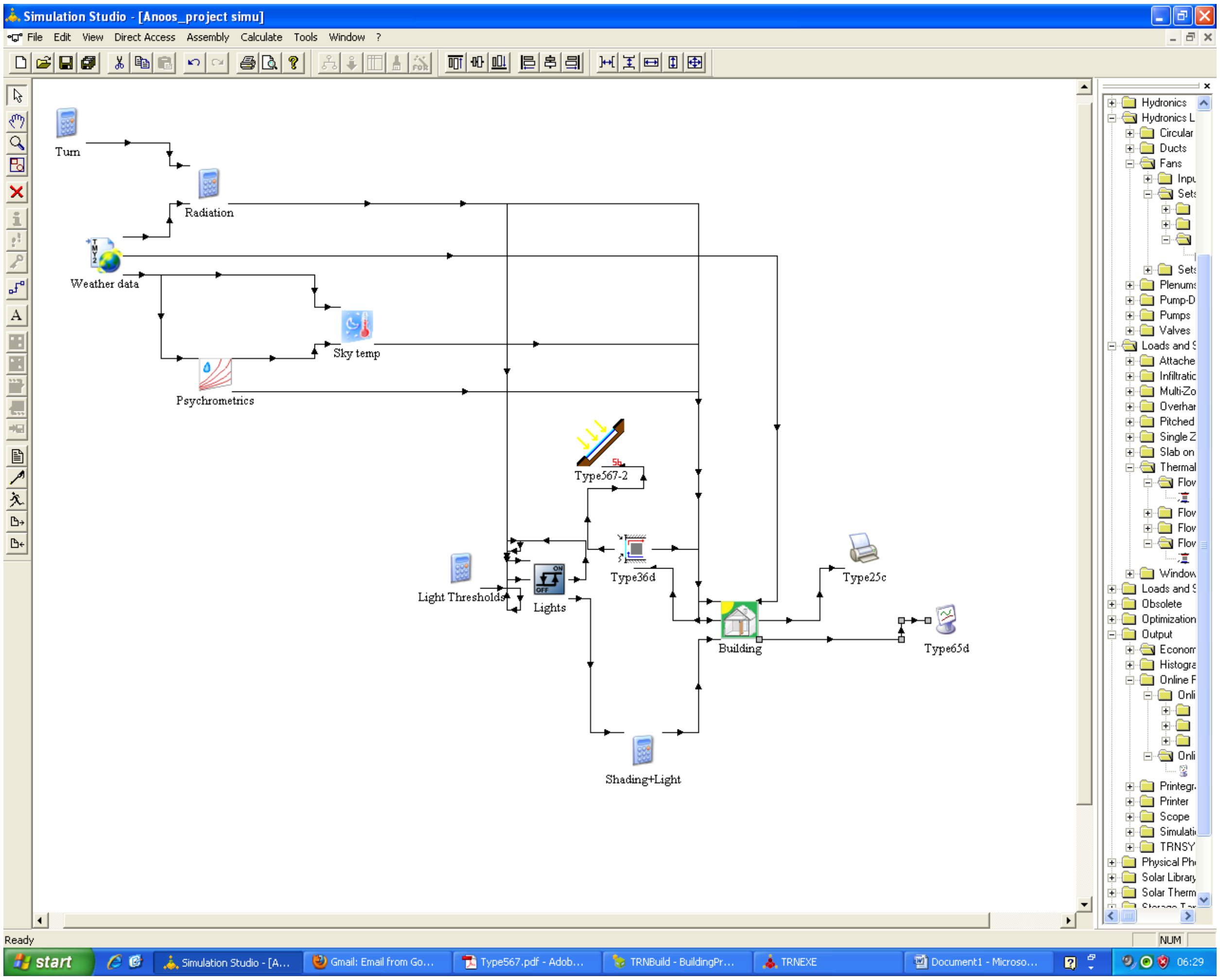

Figure E: Connection and elements setup in TRNSYS Software for simulation

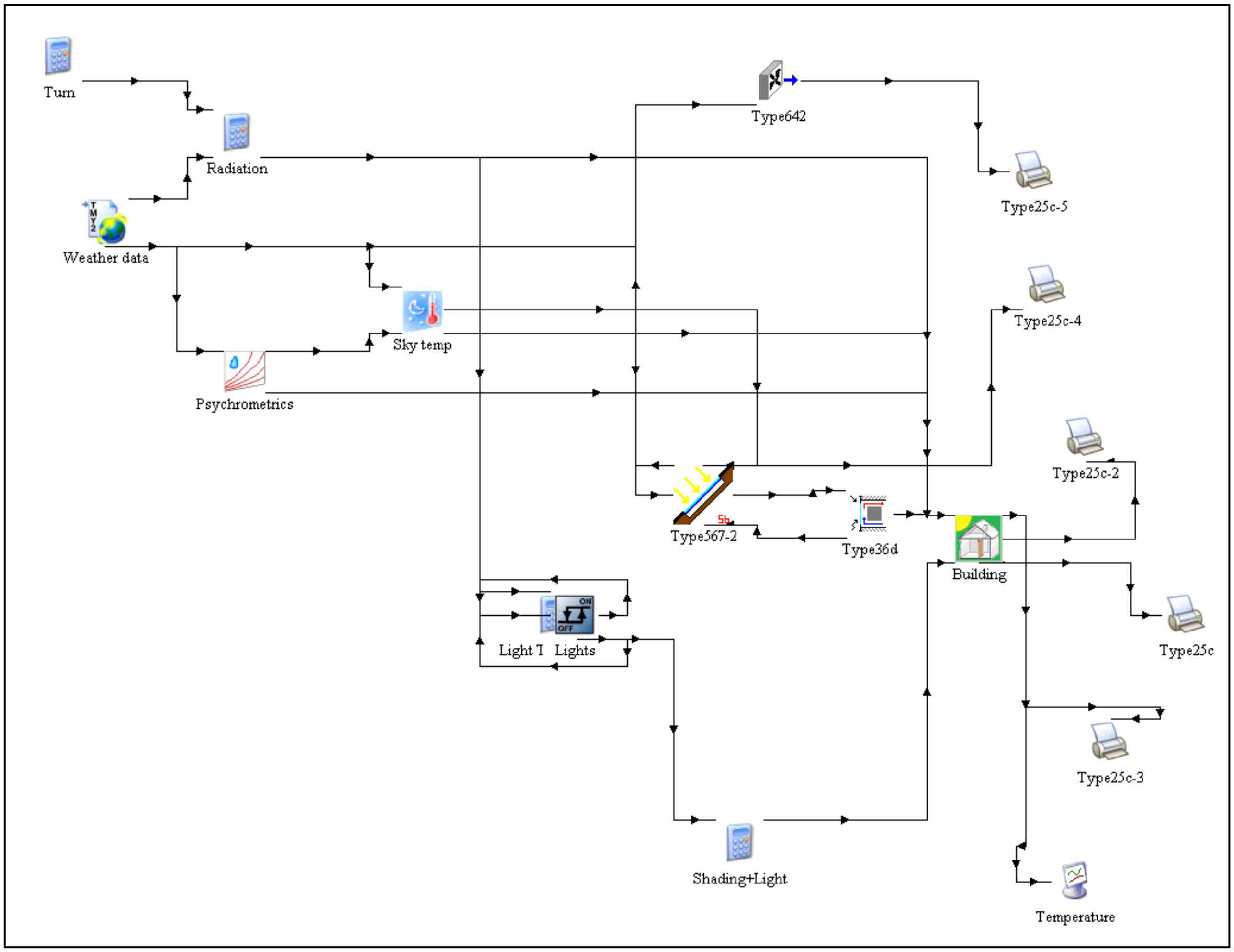

Figure F: Connection and elements setup in TRNSYS Software for simulation With Fan