Design and Fabrication of on Roof Solar Chimney

by

Mohd Haziq Bin Ahzahar

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

JUNE 2009

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Design and Fabrication of on Roof Solar Chimney

by

Mohd Haziq Bin Ahzahar

A project dissertation submitted to the

Mechanical Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(MECHANICAL ENGINEERING)

Approved by,

____

(A.P Dr Hussain H. Al- Kayiem)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2009

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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

MOHD HAZIQ BIN AHZAHAR

ABSTRACT

Integration the air ventilation by the solar chimney and the wind rotor is the innovation to generate power for normal house at rural area. In this research the design analysis and fabrication of the model is execute to find the best design to have the optimum power generation. The design basis of this model is to have the high velocity of the air flow, so that can turn the wind rotor to generate power. The model is expected to capable to generate power for usage of household. The power generation by the solar chimney can be the alternative for the rural area and cheap especially country with tropical climate.

ACKNOWLEDGEMENT

Alhamdullilah, I have come to the completion of my Final Year Project signaling the nearing of the end of my journey at UTP.

First and foremost, this is a great opportunity to express my deepest appreciation for my supervisor, AP Dr Hussain Al-Kayiem whom has given me continuous support throughout my time under his supervision. I am truly fortunate to have his guidance through the tough time.

A big thank you to my family for their prayer and moral support, that have kept me strong until the end.

Special recognition also to all my Mechanical Engineering colleagues and also my housemates for their support and idea throughout this project.

To the technicians at the lab and workshop that have given me advice and assistance in their respective arenas

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLE

CHAPTER 1

INTRODUCTION

This chapter is dedicated to introduction and explanation of the project titled, "*Design and Fabrication of on Roof Solar Chimney*". A background about this FYP project is given followed by statement of the problem addressed and lastly the objective and scope of the work in this project.

1.1 Background

From the research have been done, the solar chimney have been proven improve the ventilation of the house. The movement of air by the ventilation may turn the wind rotor hence can generate electricity and resulting a new alternative to generate electricity. Big scale updraft tower which using the concept of movement of air by ventilation have been developed in Manzanares, Spain and have been proven to generate electricity. The updraft tower also has been use in many other countries to generate electricity.

Figure 1.1 Solar Updraft Tower in Spain

1.2 Problem Statement

The inclination of world oil prices now leads the global to find the alternative way to generate electricity. The alternative energy such as solar, hydroelectric, biomass has been widely use and application of this alternative energy is developed rapidly to increase its feasibility. The concern about the global warming because of the green house effect also leads the research and development work to find the alternative way to generate electricity. The green house effect which is caused by the emission of CO_2,, where the biggest contributor is by the electricity generation sector.

The awareness of this matter, leads to develop the electricity generation by utilizing the solar energy. The successful of development of electricity generation by utilize solar updraft tower leads the development of the electricity generation by using the same concept for small scale as example for house at rural area. The idea is to develop the on the roof solar chimney for the house. The on roof solar chimney has been analyzed analytically, but still the experimental model is still required to conduct a series of measurement to prove the feasibility.

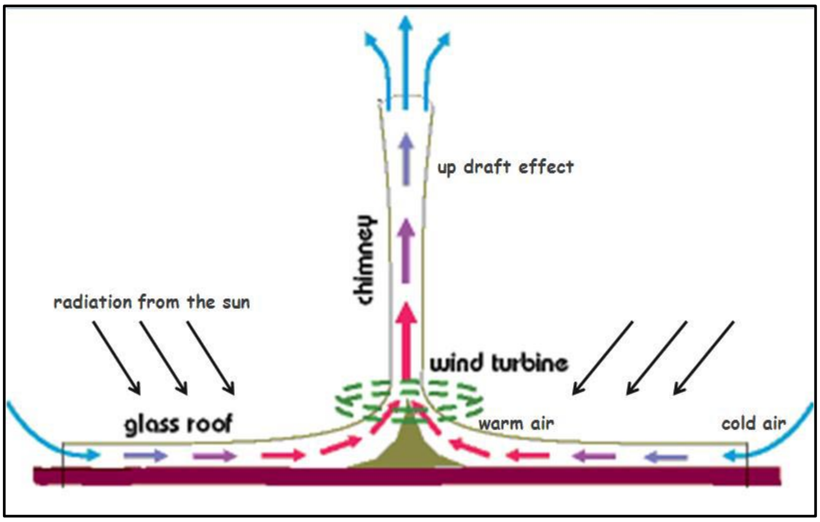


Figure 1.2 Schematic Diagram of Solar Updraft Tower

1.3 Objective

The objective of this project is to design and fabricate an on roof solar chimney model to be used in Mechanical Engineering Department for further investigation.

1.4 Scope of work

Scope of work of this project includes:

1. Design analysis, investigation and selection of the most suitable design, geometry and material for the on the roof solar chimney.
2. Fabricating the solar chimney.

1.5 Significant of work

Significant of this project is to prove the concept of on the roof solar chimney by executing the experiment using real experimental model.

CHAPTER 2

LITERATURE REVIEW

Lot of research and study has been done before this, all this research have been review and the finding is the basis for the design and concept of the project.

2.1 Inclination Angle

Kotani et al, 2005, Development of Solar Chimney with Built-In Latent Heat Storage Material for Natural Ventilation

A proto type of solar chimney with built-in latent heat storage system for prolongation of the ventilation system operation until evening / night or even 24 hours was designed and developed. The prototype is to evaluate the thermal performance of solar chimney with the effect of parameters such as gap spacing (100 mm - 300 mm) between the absorber plate and glass cover, air mass flow rate, inclination angle (45, 60 and 75) under different atmospheric conditions like ambient air temperature, solar radiation.

The prototype of the solar chimney with built-in latent heat storage was fabricated and installed on the roof of a Department of Architectural Engineering, Osaka University for testing thermal performance. A sectional view and photograph of the prototype solar chimney using PCM are shown in **Figure 2.1.** The dimensional size for tested solar chimney was 1.3 m length x 0.85 m wide x 0.01 - 0.03 m channel gap. The chimney could be tilted with different angles from the horizontal. The air gap could be set at pre-adjusted values of 0.1 m, 0.2 m and 0.3 m for air flow over the absorbing plate and inside the chimney. The chimney was covered with 6 mm thick transparent glass glazing for trapping the heat.

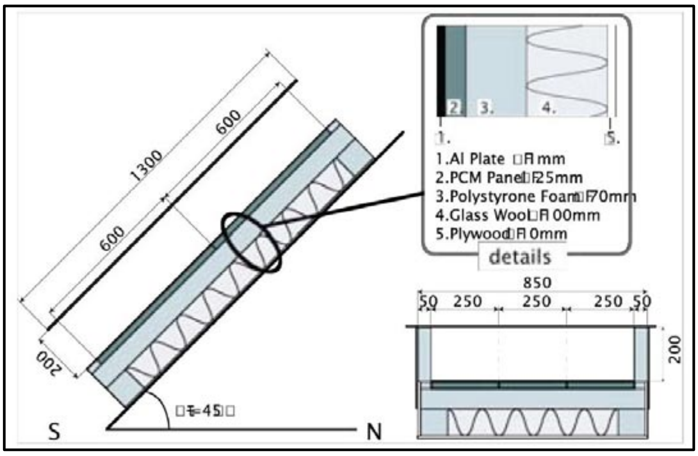


Figure 2.1Prototype of Solar Chimney Using PCM

As a conclusion it was observed that from the simulated and experimental results that integration of PCM storage inside the solar chimney is positive and it can supply the nearly constant highest average airflow rate of 155 m3/h (air gap = 0.20 m, inclination angle =45 degree) in evening and night if PCM completely melted in the day. The prototype solar chimney is capable to provide the average airflow rate of nearly 200 m3/h (air gap = 0.20 m, and inclination angle =45 degree) in daytime.

Mathur et al, 2006, Experimental Investigation on Four Different Types of Solar Chimneys

The paper objective is to compare for different configuration of solar chimney for ventilation in the residential building. The configuration is vertical solar chimney, inclined solar chimney, cylindrical chimney and cylindrical chimney with transparent cover.

The reading parameters for this experimental work are the average radiation and the mass flow rate of the air, to find the relationship between the average radiation and the mass flow rate, a graph is plotted. The graph is plotted for the vertical and inclined solar chimney, a graph also plotted to show the relationship between the cylindrical bare solar chimney and cylindrical chimney with transparent cover.

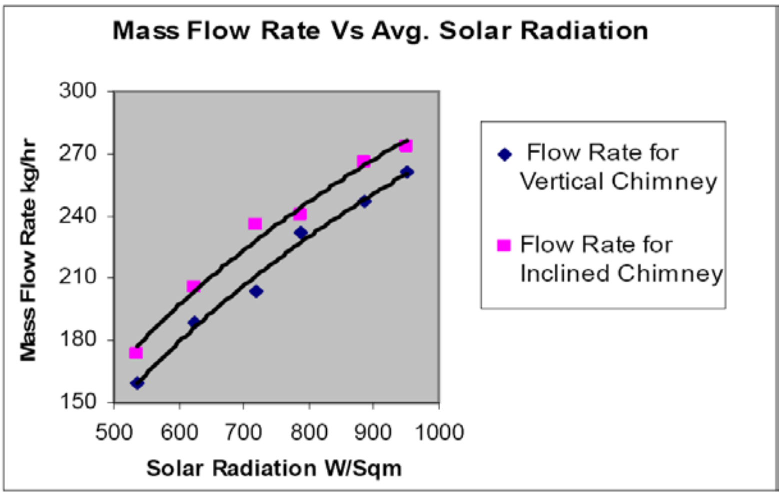


Figure 2.2 Mass Flow Rate vs Average Solar Radiation for Vertical Chimney and Inclined Chimney

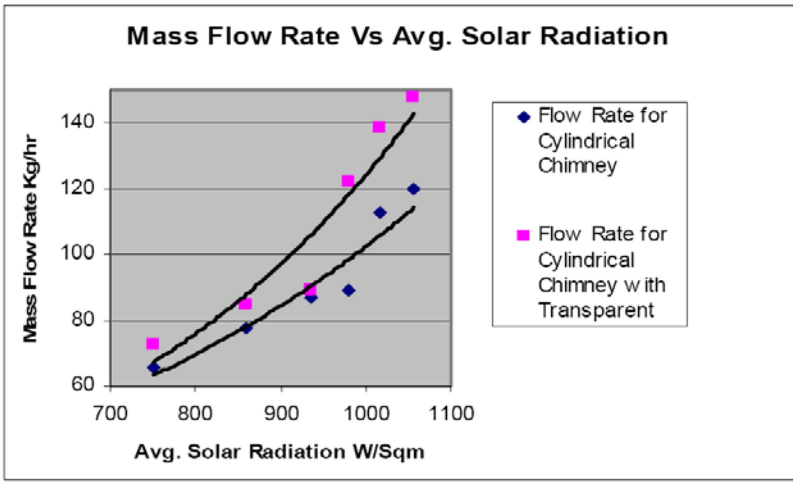


Figure 2.3 Mass Flow Rate vs Average Solar Radiation for Cylindrical Chimney and Cylindrical Chimney with Transparent Cover

As a conclusion four different configuration of solar chimney has been studied experimentally. Comparison of Vertical and Inclined absorber chimneys shows that by inclining 45^{o} the absorber, ventilation rate can be increased by about 15.94 %. Experiments on cylindrical chimneys show that this concept of using small industry like solar chimneys can also be used for ventilation in residential buildings. Further, results show that by covering the metallic absorber, ventilation rate increases by about 36.85 %.

2.2 Air Gap

Thong et al, 2007, Simulation of Flow in Solar Roof Collector Driven by Natural Convection

The solar roof collector is modelled as a two dimensional air gap with one heated wall. The Boussinesq approximation is used to model the density variation. Four different air gap heights were simulated, namely 0.07m, 0.014m, 0,21m and 0.28m for a 2m long solar roof collector.

Simulations were performed using the commercial software Fluent. The flow is assumed to be two dimensional, steady and laminar. These assumptions are based on the low air speeds in the air gap and the living space shields the inlet stream from atmospheric disturbances. The Boussinesq approximation is used to estimate the effect of density variation with temperature. This is valid for this study because the temperature variation is typically less than 20°K. The “surface to surface” radiation model is used to account for heat transfer between the top and bottom plate and between the plates and the inlet and outlet openings.

The results show that a high inclination angle improves ventilation. This can be explained by buoyancy effects being stronger when the gap is closer to vertical.

As a conclusion results show that the amount of ventilation can be increased with increasing inclination angles. Except for the highest inclination angle, the simulations have shown that air gap heights past 0.14m actually reduce the mass flow rate. This is caused by the hot jet close to the top wall in the air gap drawing air from the outlet. The reverse flow near the outlet reduces the mass flow rate through the air gap.

2.3 Ventilation

Agung et al, Possibility to Use Solar Induced Ventilation Strategies in Tropical Conditions by Computational Fluid Dynamic Simulation

The study of this paper is to evaluate the stack induced ventilation strategies performance on experimental room model in Malaysian condition. The climatic conditions of the tropical regions are characterized by high air temperatures, high relative humidity and very low wind speeds, which make the environmental conditions uncomfortable. The use of solar roof chimneys in buildings is one way to increase natural ventilation and, as a consequence, improve indoor air quality.

The use of solar induced ventilation strategies in building was investigated using CFD FloVent technique. Validation of CFD Flovent was done by comparing the pilot testing. Where an experiment is been done using the pilot testing model and then compare it with the FloVent software to check the validity. Validation of the program was performed by comparing the measurement of pilot testing with the CFD simulation. The result shows that the agreement between the measurement and simulation is generally good. The average difference between the measurement and simulation for ambient temperature was 0%; for black bottom was about 3%; the maximum difference was 8% for the cavity. This gives confidence in using the computer code to study the air flow and temperature.

After validating the software, the solar induced ventilation simulations were performed on selected model of trombe wall, solar chimney and solar roof using FloVent. The simulation is done to simulate the air velocity and temperature profile of the selected model.

As a conclusion, results showed that the solar chimney can increase air velocity in the room but also increase heat gain in the room. The results also indicated that solar roof reduced the heat gain but resulted in low air velocity. Use of solar wall can increase air velocity in the room depending on the orientation of the solar wall. Modification with combine solar chimney and solar roof will be use to improve the induced ventilation have been suggested.

CHAPTER 3

THEORY

3.1 Concept

The concept is to use solar as the heater to heat the cold air, T_{air} at the roof inlet. Hence the warm air T_m at end of the roof will go up because of the low density of warm air and the up draft effect. The movement of the air will turn the wind turbine, resulting the power generation by the rotation of the wind turbine.

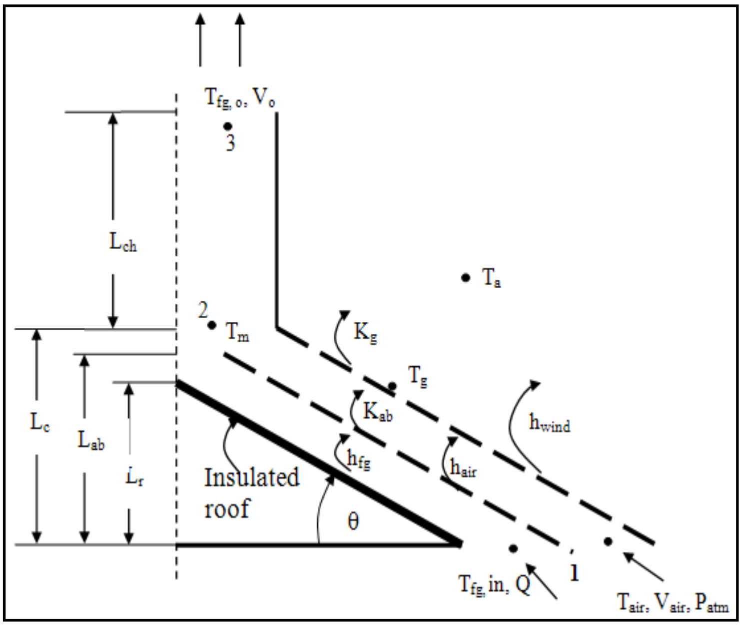


Figure 3.1 Schematic Diagram of On Roof Solar Chimney

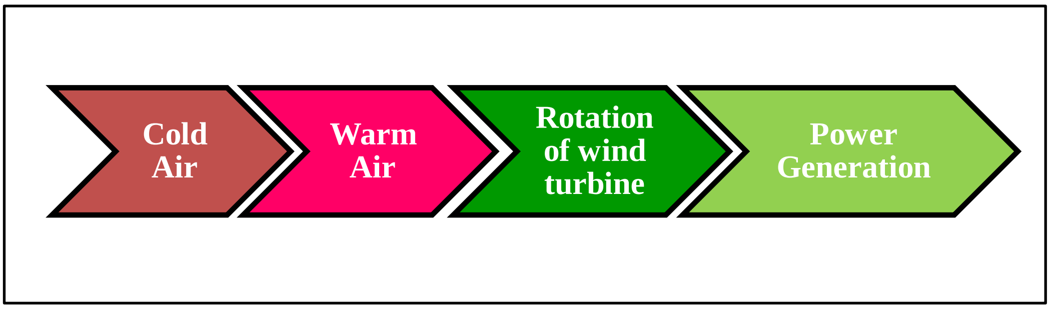


Figure 3.2 Flow of Power Generation

3.2 Stack Effect

The pressure difference of the stack effect can be calculated using equation:

$$\Delta \boldsymbol{P} = \boldsymbol{C}\ \boldsymbol{a}\ \boldsymbol{h}\left(\frac{\mathbf{1}}{\boldsymbol{T}_\circ} - \frac{\mathbf{1}}{\boldsymbol{T}_i}\right)$$

Where:

$\Delta \boldsymbol{P}$ = available pressure difference, in Pa

$\boldsymbol{C}$ = 0.0342

$\boldsymbol{a}$ = atmospheric pressure, in Pa

$\boldsymbol{h}$ = high or distance, in m

$\boldsymbol{T}_\circ$ = absolute outside temperature, in K

$\boldsymbol{T}_i$ = absolute inside temperature, in K

Base on the equation of the stack effect, the $\Delta \boldsymbol{P}$ related to the h and the difference of the temperature.

Referring to Figure 3.3, the pressure difference between the inside air and outside air of the building is cause by the temperature difference. The pressure difference can be representing by the difference reading of absolute air pressure by the gauges

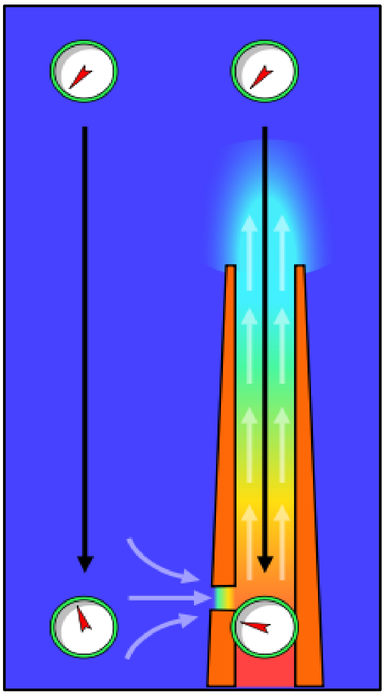


Figure 3.3 Illustration of Stack Effect

CHAPTER 4

METHODOLOGY

This chapter explains works done in this project and the methods used at various stages. Firstly step taken and schedule used for the completion of the project is explained and illustrated. Then each of the project works are described in separate sections.

4.1 Research Methodology

To achieve the objective of this project, there are some steps required to be executed base on the engineering knowledge. There steps are:

i. Design Analysis
   - To do the design analysis on the design, geometry and the material of the chimney.

ii. Fabrication
   - To decide the fabrication method of the chimney.

4.2 Project Completion

In order to successfully complete this project, various steps were taken. Each step had its own importance and effect on the overall progress of the project. Care was taken to perform each step as good as possible to prevent problems and delay in other part of the project. The methodology and steps used in this project is illustrated in Figure 4.1.

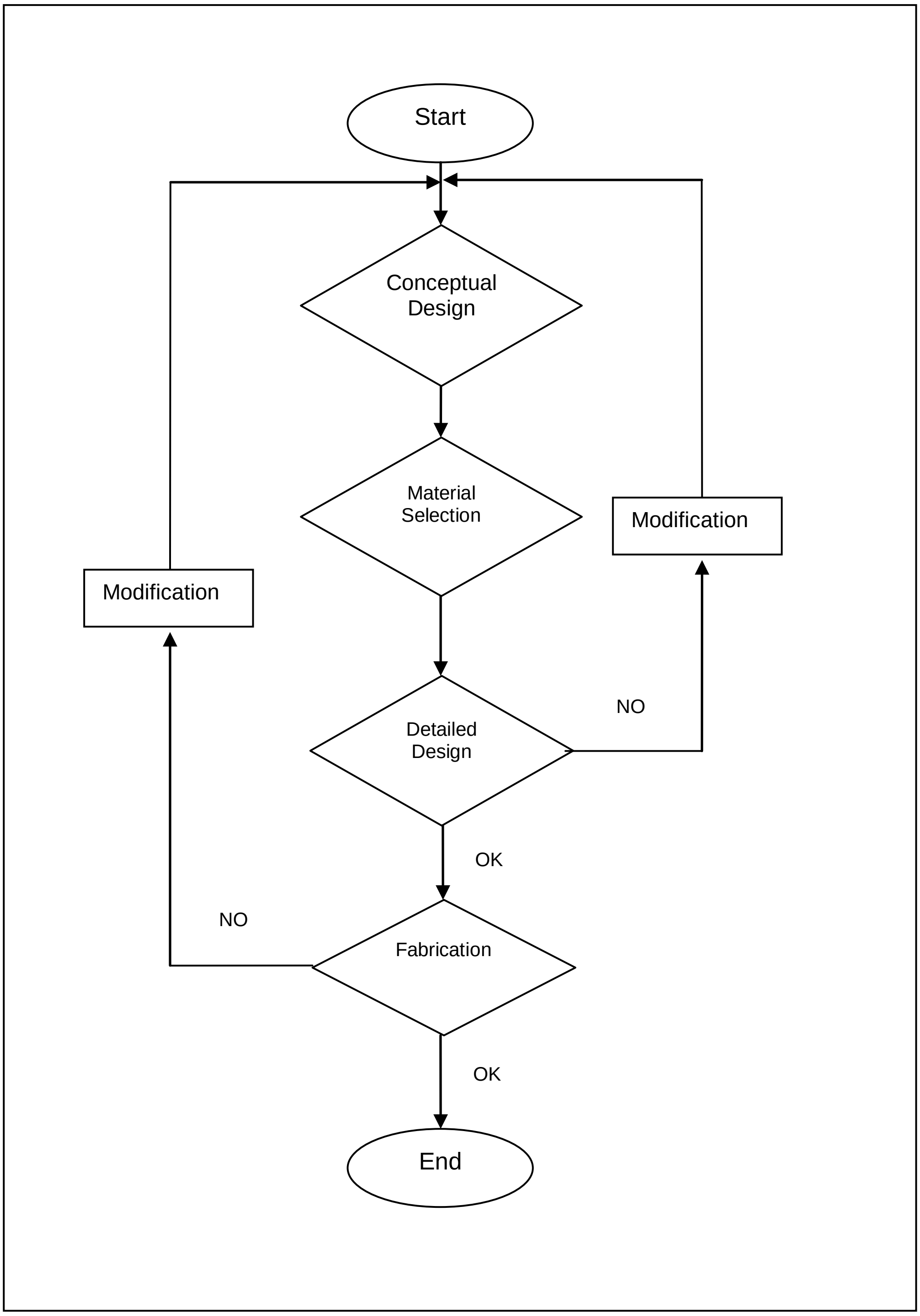


Figure 4.1 Flow Chart of the Project Works

Project works were planned to be completed in two semesters. Tables shows the schedule used for completion and the milestone for the project

Table 4.1 Milestones for FYP 1

PROJECT FLOW/TASK	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TITLE SELECTION AND PROPOSAL										MID SEM BREAK				
PRELIMINARY RESEARCH WORK														
DESIGN CONCEPT														
PROGRESS REPORT														
DETAIL DESIGN														
MATERIAL SELECTION														
INTERIM REPORT														
ORAL PRESENTATION														

Table 4.2 Milestones for FYP 2

PROJECT FLOW/TASK	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
MODIFICATION DETAIL DESIGN										MID SEM BREAK				
FABRICATION														
PROGRESS REPORT 1														
PROGRESS REPORT 2														
SEMINAR														
SUBMISSION OF POSTER														
ORAL PRESENTATION														
HARDBOUND DISSERTATION														

4.3 Design and Fabrication of the model

In order to achieve the objective, there was a need to fabricate an experimental prototype or physical model. The model will be installed at the open air at the UTP to simulate the real situation.

Figure 4.2 shows the design of the model and the main part of the model. Detail designs of various parts were attached in the appendix of this report.

The model consists of :

i. Chimney
ii. Chimney Cover
iii. Collector
iv. House

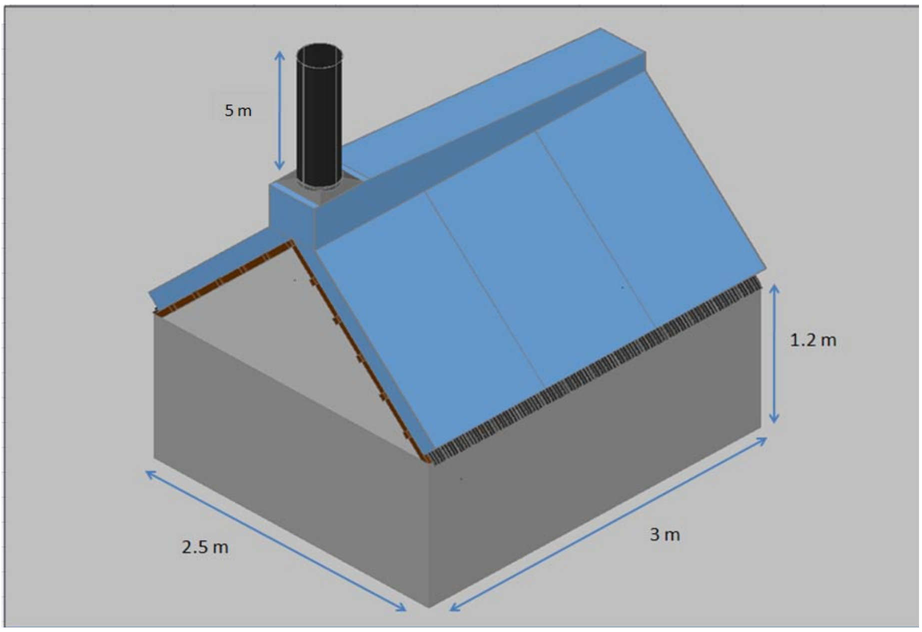


Figure 4.2 The Model of On Roof Solar Chimney House

4.3.1 Structure

The structure of the model was built using metal bars, cut to designed dimension. Each part was fabricated separately and they were assembled later. Special attention was paid during the detail design and fabrication itself to make sure the structure is very rigid and can sustained the load of the collector. The structure has been set to 4 feet from the ground. The relevance is for ease of the installation of the model at the site, especially to lift the collector onto the structure.

Figure 4.3 The Metal Structure of the House

4.3.2 Collector

For the collector, corrugated zinc plate was used to increase the effective collector area and also increase the heat transfer to adjacent air. The use of zinc plate is to simulating the use of zinc plate in the most house in the rural area. The corrugated plate was painted black to maximize the absorptivity.

Figure 4.4 Black Painted Corrugated Plate

4.3.3 Insulation

To prevent heat loss from the back of the collector, heavy insulation was used behind the corrugated plate. Two layers of 1 cm-thick glass wool were glued to the back side of the plates and were fixed between the plates and collector structure.

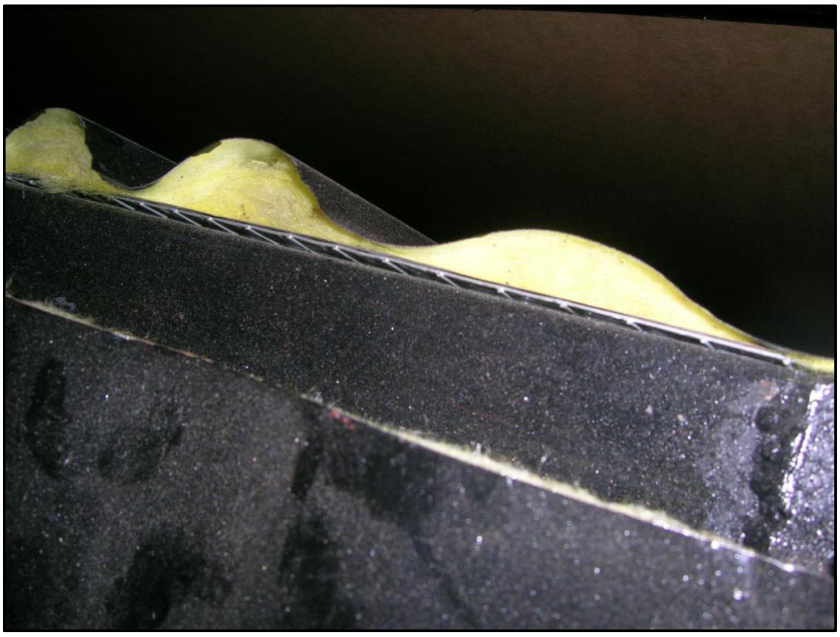


Figure 4.5 Glass Wool was used as the Insulator

4.3.4 Cover Plate

For the transparent cover plate, 5 mm-thick acrylic glass (Perspex) was used. It is preferred on account of its moderate properties and easy handling than the glass. It has less than half the density of glass and has good impact strength higher than glass. It also transmits up to 98% of visible light (depending of quality).

As mentioned and discussed in the literature review, the used of cover can increase the mass flow rate of air. Hence in this project, to optimize the mass flow rate of the air, transparent cover plate was installed to the collector.

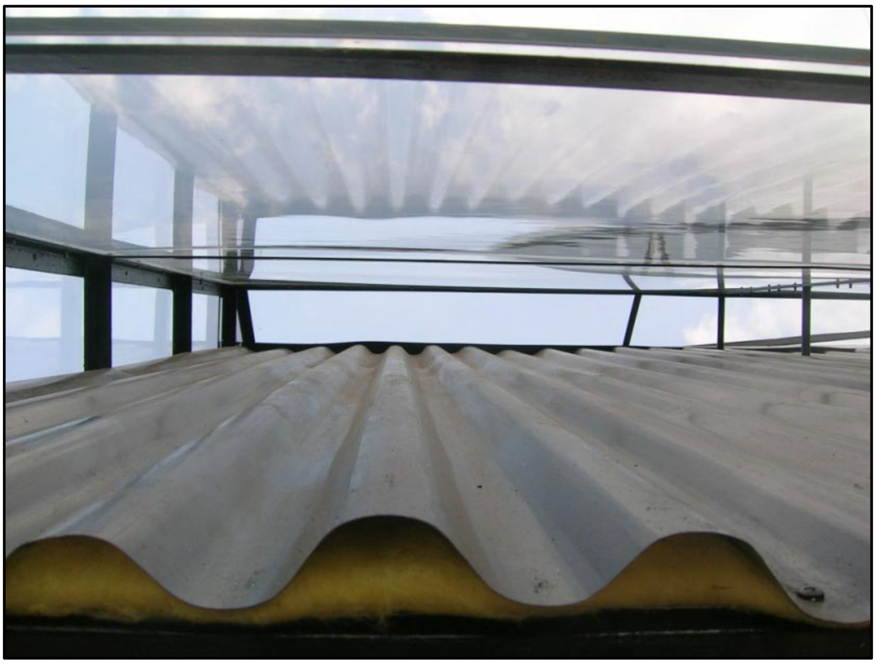


Figure 4.6 Used of Perspex as the Cover Plate

4.3.5 Chimney

For the chimney, standard PVC pipe was used. The PVC pipe was chosen because of the availability in the market. The pipe was used are standard pipe diameter 6 inch and 4 inch.

Figure 4.7 PVC Pipe Functioned as the Chimney

CHAPTER 5

RESULTS AND DISCUSSION

This section results, findings and outcome of the project work are presented. Result from the research of previous work or paper is presented and discussed. The problem encountered and solutions are also been discussed and justified.

5.1 Wind Rotor

From the research have been done evaluating the traditional wind rotor and the Savonius wind rotor, the traditional wind rotor have been proved to have higher power coefficient, C_P rather than Savonius wind rotor. Hence the traditional wind rotor was used for this model.

The selection of traditional wind rotor instead of Savonius wind rotor resulted, the modification of design the model need to suit the traditional wind rotor.

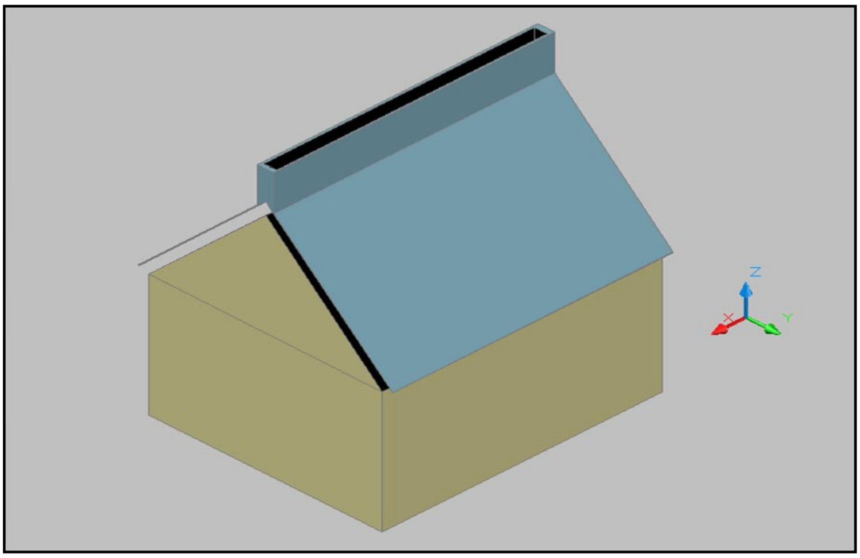


Figure 5.1 Initial Design of the Model

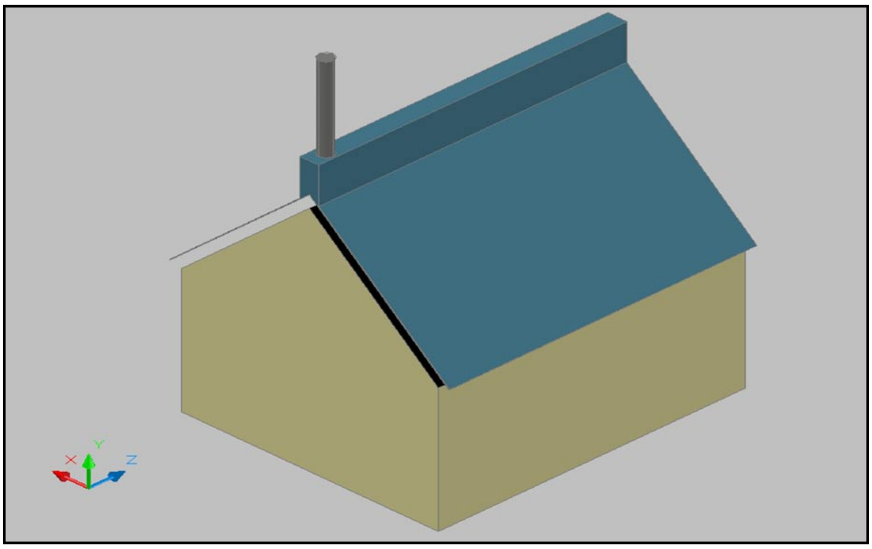


Figure 5.2 Modified Design of the Model

1.2 Geometry of the collector

The collector is the most essential part in this model, so the collector in this model was designed to optimize the mass flow rate of the air.

5.2.1 Inclination of the Collector

Inclination of the collector is set to 45 degree to optimize the flow rate of the air. From the research have been done in the work previously in the literature review, the inclination of 45 degree is has been prove to generate the highest flow rate. To make sure that the wind rotor is moving at the maximum speed to generate power so we need the maximum flow rate.

Figure 5.3 Inclination of the Collector

5.2.2 Chimney

The 5 meter long chimney has been installed at the end of the collector. From the discussion in the theory part, the chimney was installed to create the stack effect. The stack effect is generated because of the temperature and pressure different of the inlet and outlet of the chimney. The stack effect will give external forced to the air flow and can increase to flow rate of the air.

The high of the chimney was set to 5 meter for the ease of the installation at the site. Beside the availability of the PVC pipe at the market which normally the standard size about 5 meters long, the constraint of the rigidity of the chimney also considered.

Extra support using metal bar has been put to strengthen the chimney. Beside the metal bar, three cable also was installed to the chimney to strengthen and adding rigidity to the chimney.

Figure 5.4 Chimney of the House

5.2.3 Chimney cover

To make sure the air flow is not flowing into lower part (collector) and to guide the air flow into the inlet of the chimney, the chimney cover is designated inclined. This is very important to utilize all the flow and no lost while the process.

Figure 5.5 Inclined Chimney Cover

5.2.4 Air Gap

As suggested in the literature review, to make sure no backflow in the collector the air gap between the collector and cover plate is set to 140 mm.

Figure 5.6 Air Gap in the Collector

5.3 Installation of the Model

5.3.1 Part by Part

To meet the design criteria for this model which was need to ease for mobility, the model is designed to part by part. The model is designed so that it can be dismantle and assemble easily. Every part was fixed by screw of nut for the ease of the assemble process. Every main part also can be dismantled to small pieces for the ease of the transportation and can be lifted by human. The model was divided into few main parts:

i. Collector
ii. Chimney
iii. Chimney Cover
iv. Structure
v. Base

Figure 5.7 The Base and the Structure of the House

Figure 5.8 Smaller Pieces of the Collector

Figure 5.9 The Chimney

5.3.2 Position

The model was installed under the sunshine in E-W direction. This orientation was chosen to optimize the sun ray so it can cover the whole collector. The chimney was installed to face the west to prevent the shadow from the chimney hence to maximize the sun ray.

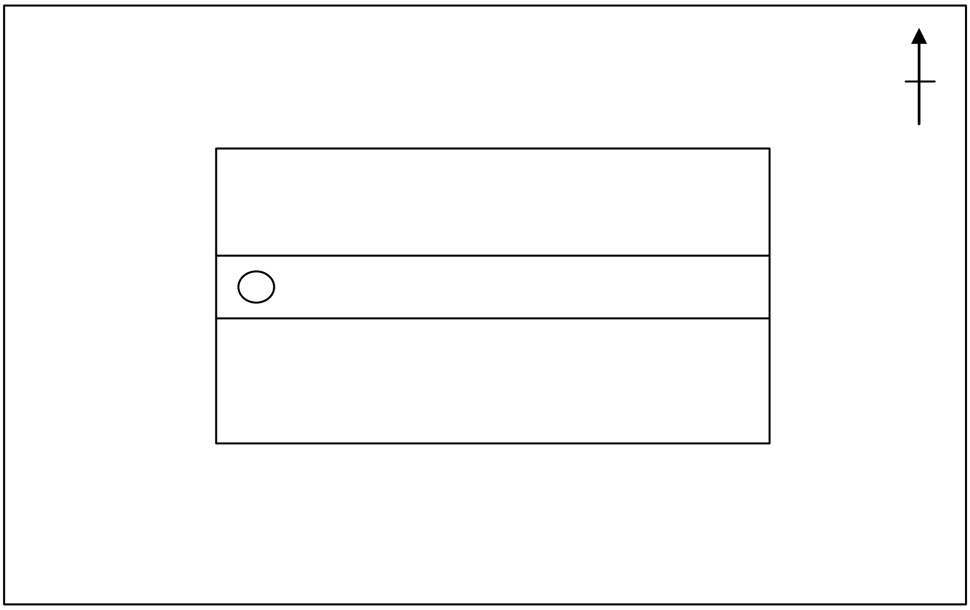


Figure 5.10 Layout of the House

Figure 5.11 Installed and Fabricated on Roof Solar Chimney

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The on roof solar chimney has been fabricated to meet the design criteria to optimize the mass flow rate of the air. The model also has been installed at the site already been proved at the University Technology of PETRONAS. The model was ready for to be used by the Mechanical Engineering Department for further investigation.

6.2 Recommendation

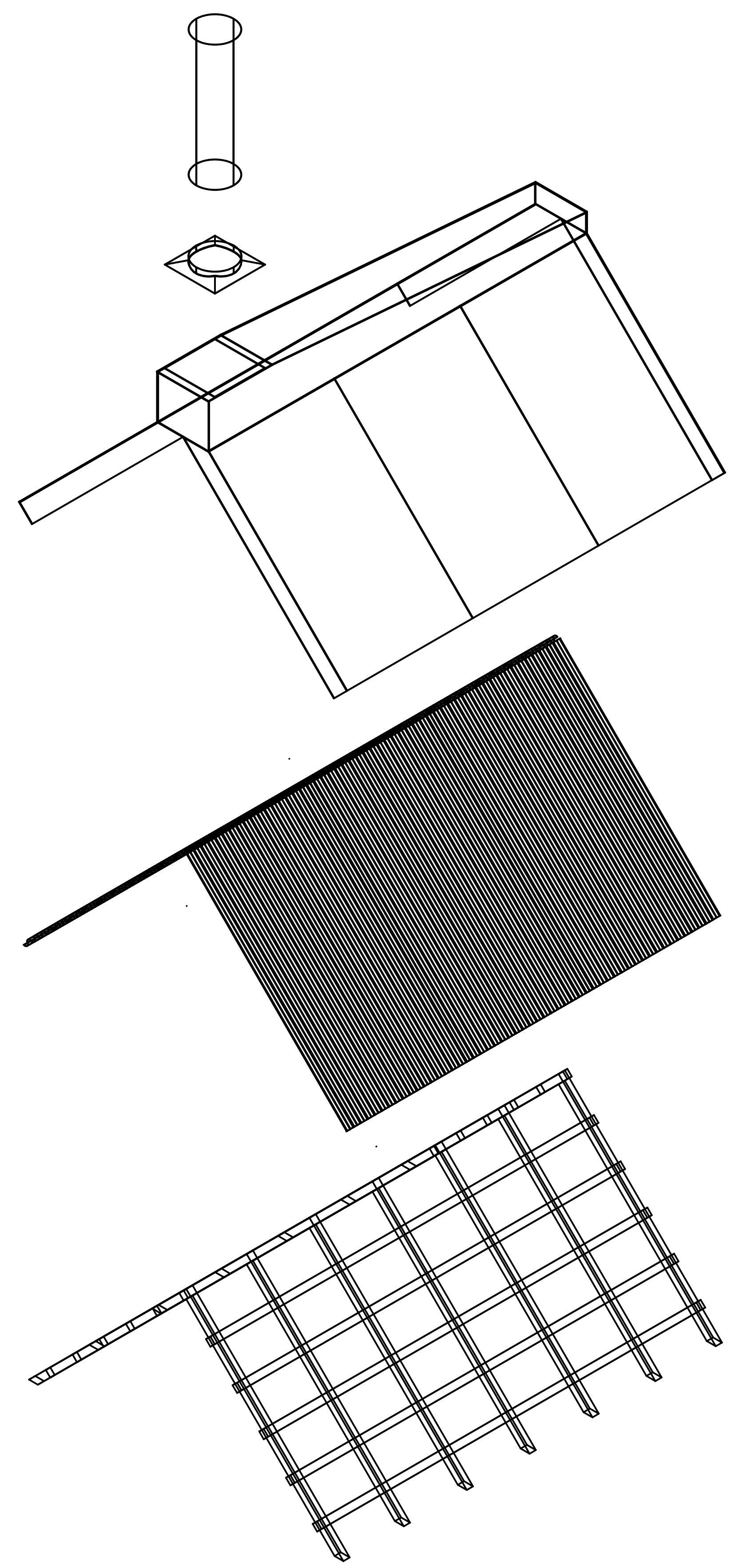
Throughout this project, there are some suggestion and recommendation to improve the model:

i. To investigate the effect of several design of wind rotor for the model.
ii. To find the alternative for usage at night and cloudy day.

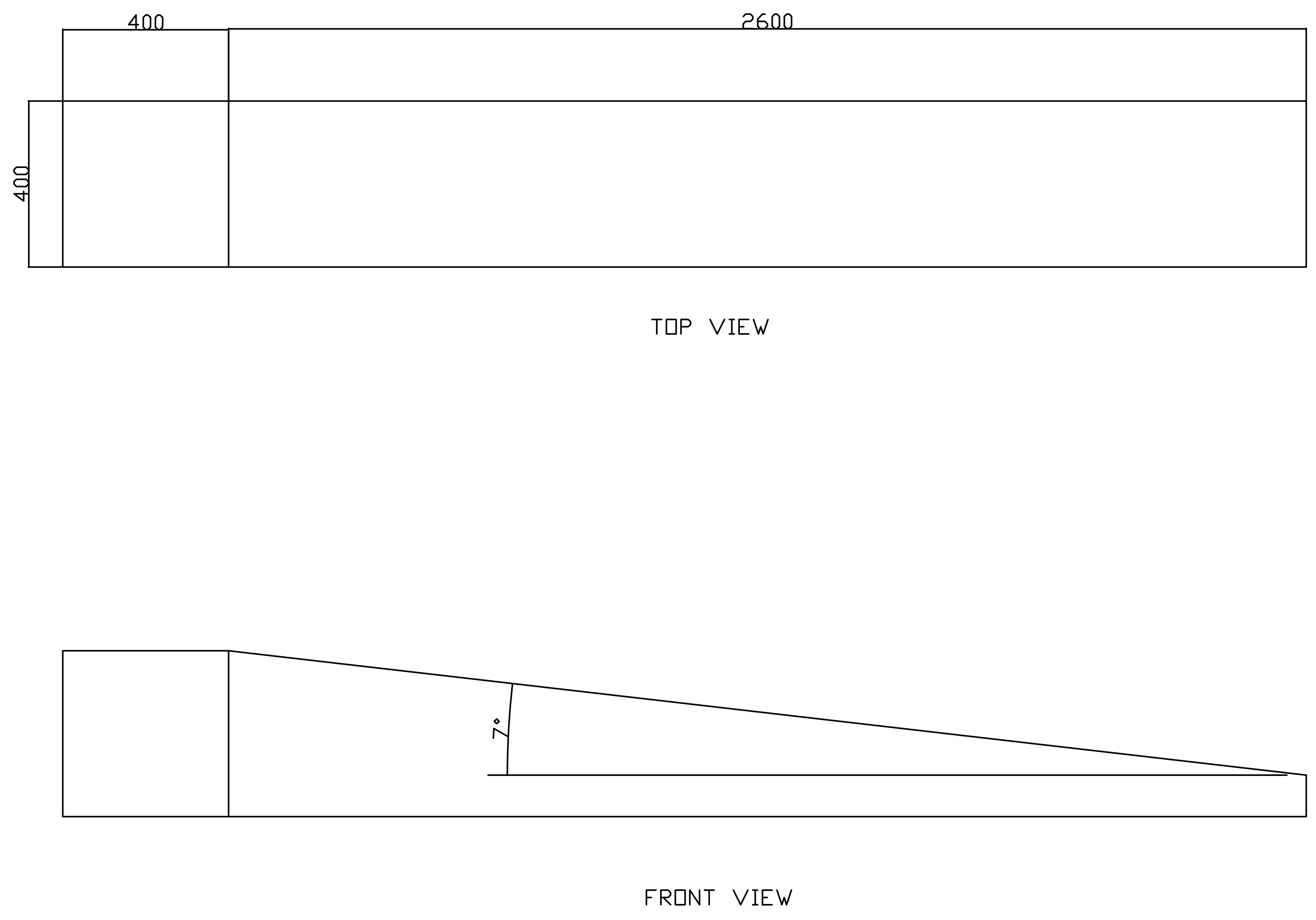
REFERENCES

1. H. Kotani, S.D.Sharma, Y. Kaneko, T. Yamanaka, K. Sagara, Development of Solar Chimney with Built-In Latent Heat Storage Material for Natural Ventilation, 2005
2. Mathur Jyotirmay, Anupma and Mathur Sanjay, Experimental Investigation On Four Different Types Of Solar Chimneys, 2006
3. Tan Boon Thong, Lew Mai Quaan and Ong Kok Seng, Simulations of Flow in a Solar Roof Collector Driven by Natural Convection, 2007
4. Ong, K. S., Performance of a natural convection solar air heater. J. Energy, Heat and Mass Transfer, 2005
5. Ong, K. S., Tan, B. T., Joe, R. and Tan, K. S., Feasibility of solar passive cooling, 2006
6. Agung Murti Nugroho, Mohd Hamdan bin Ahmad, Possibility to Use Solar Induced Ventilation Strategies in Tropical Conditions by Computational Fluid Dynamic Simulation
7. Agung Murti Nugroho, Mohd Hamdan Ahmad, Then Jit Hiung, Evaluation of Parametrics for the Development of Vertical Solar Chimney Ventilation in Hot and Humid Climate, 2006
8. Ali,Practical Investigation of the Proposed Solar Chimney, FYP Project (Mechanical Engineering)

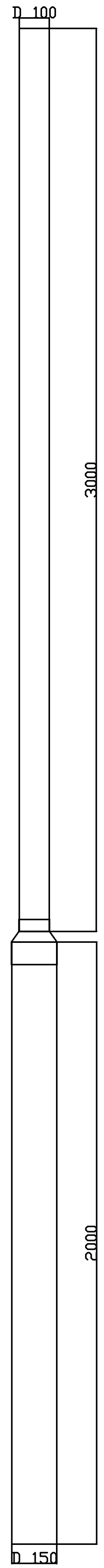
APPENDIX



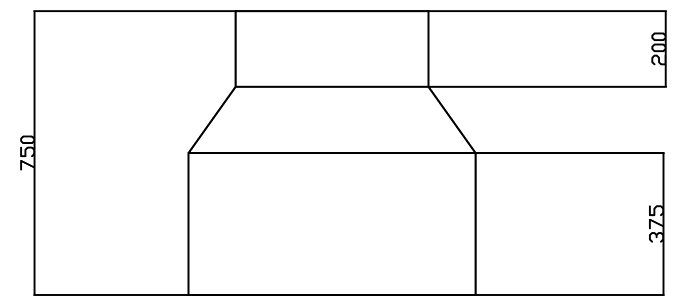
Designed by MOHD HAZIQ AHZAHAR	APPROVE BY DR HUSSAIN AL-KAYIEM	File name FYP - 1000	Date 00/00/00	Scale 1:1
UNIVERSITY TECHNOLOGY OF PETRONAS	DESIGN AND FABRICATION OF ON THE ROOF SOLAR CHIMNEY			
	ASSEMBLY DRAWING		REV 0	SHEET 1/1



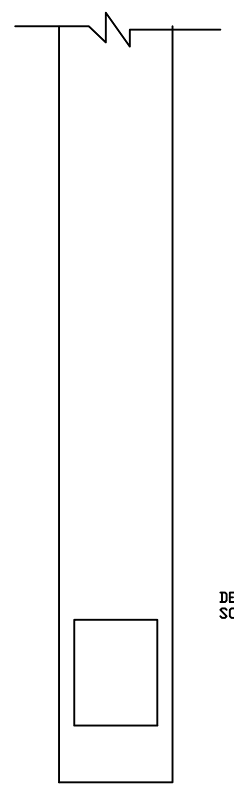
Designed by MOHD HAZIQ AHZAHAR	APPROVE BY DR HUSSAIN AL-KAYIEM	File name FYP - 1000	Date 00/00/00	Scale 1:15
UNIVERSITY TECHNOLOGY OF PETRONAS	DESIGN AND FABRICATION OF ON THE ROOF SOLAR CHIMNEY			
	CHIMNEY COVER		REV 0	SHEET 1/1



SCALE 1:20

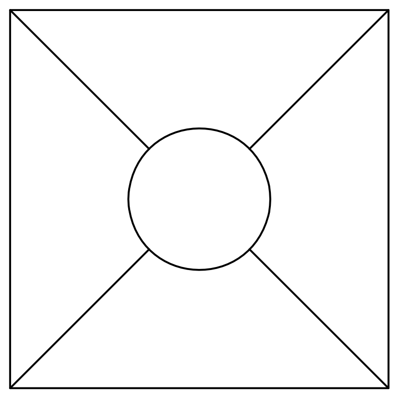


REDUCER
SCALE 1:4

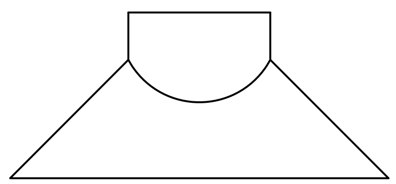


DETAIL DESIGN OF TH DOOR
SCALE 1:4

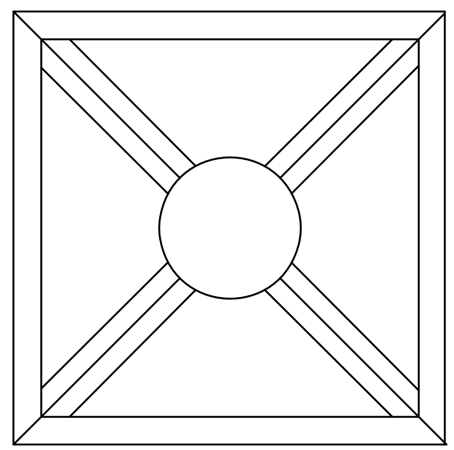
Designed by MOHD HAZIQ AHZAHAR	APPROVE BY DR HUSSAIN AL-KAYIEM	File name FYP - 1000	Date 00/00/00	Scale 1:1
UNIVERSITY TECHNOLOGY OF PETRONAS		DESIGN AND FABRICATION OF ON THE ROOF SOLAR CHIMNEY		
		CHIMNEY DETAIL DRAWING	REV 0	SHEET 1/1



TOP
VIEW

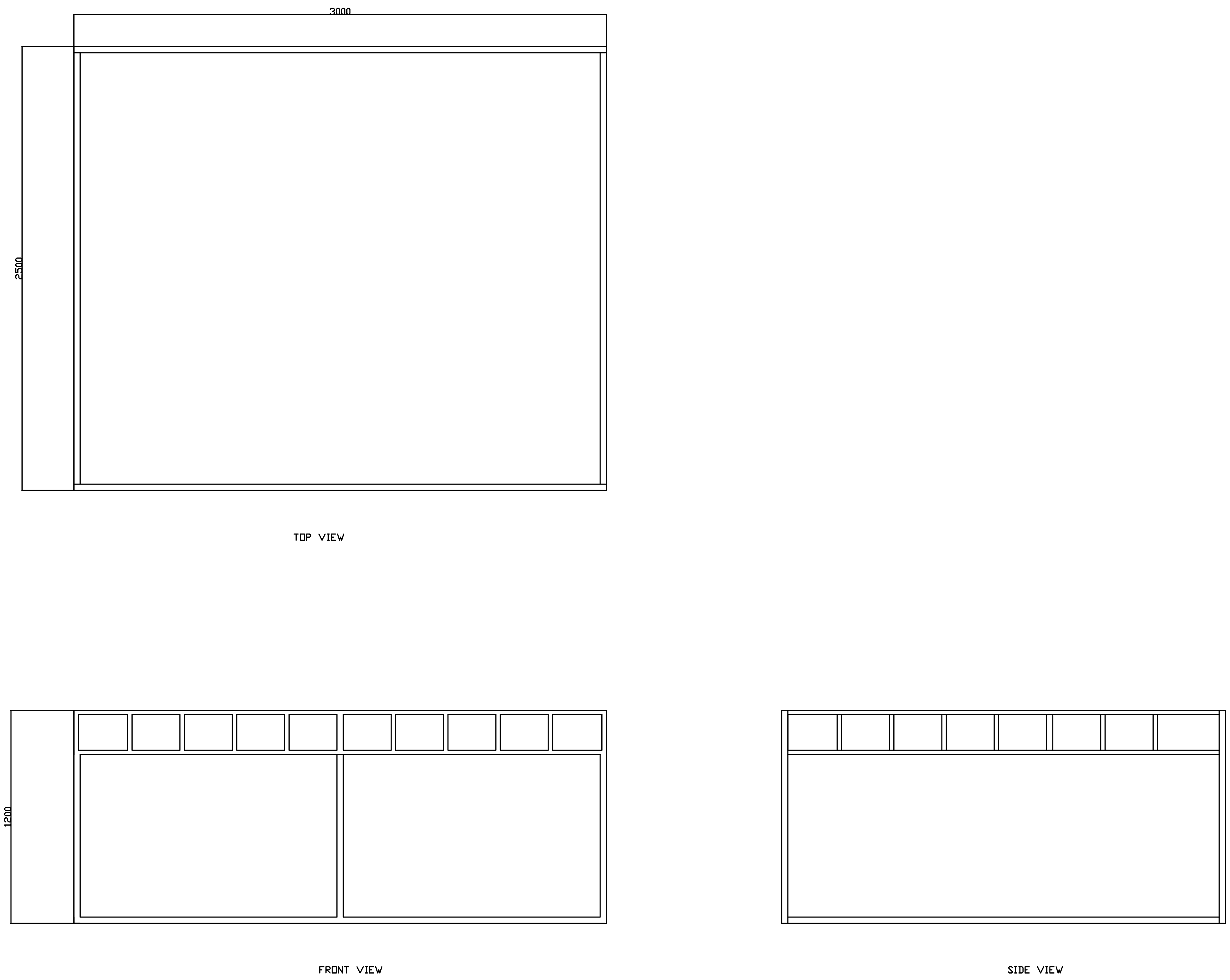


FRONT
VIEW



METAL FRAME
SUPPORT

Designed by MOHD HAZIQ AHZAHAR	APPROVE BY DR HUSSAIN AL-KAYIEM	File name FYP - 1000	Date 00/00/00	Scale 1:8
UNIVERSITY TECHNOLOGY OF PETRONAS		DESIGN AND FABRICATION OF ON THE ROOF SOLAR CHIMNEY		
		DUCTING	REV 0	SHEET 1/1



Designed by MOHD HAZIQ AHZAHAR	APPROVE BY DR HUSSAIN AL-KAYIEM	File name FYP - 1000	Date 00/00/00	Scale 1:15
UNIVERSITY TECHNOLOGY OF PETRONAS		DESIGN AND FABRICATION OF ON THE ROOF SOLAR CHIMNEY		
		HOUSE STRUCTURE	REV 0	SHEET 1/1