THE STUDY OF 2D THERMAL DISTRIBUTIONS USING FLUENT SIMULATION PROGRAM FOR PASSIVE SOLAR CONCEPT OF LOW RISE BUILDING

By

MOHAMAD FARID MOHAMED HAMDAN

FINAL YEAR RESEARCH PROJECT REPORT

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

MR MOHAMED MUBARAK ABDUL WAHAB
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

July 2008

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.

MOHAMAD FARID MOHAMED HAMDAN

ABSTRACT

This report basically discusses the project research and basic understanding for one of the elements in the chosen topic, which is **The Study of 2D Thermal Distributions Using Fluent Simulation Program for Passive Solar Concept of Low Rise Building**. The general objective is to study the Green Building features for low rise residential building. This lead to the specific objective of the project which is to analyze the temperature distribution inside a low rise terrace house and simulate using Computational Fluid Dynamic (CFD) program in order to compare the temperature distribution pattern. The method established was using the CFD simulation program, named Gambit and Fluent, with all the parameters and conditions set to obtain the temperature distribution in 2D dimension. The Green Building features were proposed into the subject rooms by modifying the window dimension and proposed the air chimney at the room's ceiling. The results indicate that the temperature inside the master and single bedroom was reduced when the window dimension is increased and the proposed air chimney help to ventilate the room better. The study also shown that the simulated data was reliable compare to the measured data with an error less than 1%.

ACKNOWLEDGEMENT

The author wishes to take the opportunity to express his utmost gratitude to the individual that have taken the time and effort to assist the author in completing the project. Without the cooperation of these individuals, no doubt the author would have faced some minor complications throughout the course.

First and foremost the author's utmost gratitude goes to the author's supervisor, Mr Mohamed Mubarak Abdul Wahab. Without his guidance and patience, the author would not be succeeded to complete the project.

Not forgetting to Mohd Nor Akmal Shukor for his sharing moment and team work. To all individuals that has helped the author in any way, but whose name is not mentioned here, the author thank you all.

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CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

Green Building is the term used to define the sustainable building technology that consists of all the life-cycle of the building from the design, construction, and maintenance of the building.

This technology has been widely applied in the European Country, and progressively developed in the United States, Australia, Hong Kong, while Malaysia still has more empty space and gap for the researcher to fill in.

One of the elements in the Green Building is the utilization of the passive solar strategies, to reduce the usage of electricity in the building. The author has narrowed down from the big scope of Green Building to the passive solar elements to undergo the research. One of the strategy to use the passive solar architecture is to design the building so that the daylight can enter certain space in the house thus, reducing the usage of artificial lighting in the house.

There are many elements in the passive solar strategies such as optimization of window design and openings, using the daylight penetration to reduce the artificial lighting which use electricity, and roof design that allows certain amount of sunlight to penetrate into the building spaces. For FYP II, the author had focused on the study of temperature comfort distribution based on Computational Fluid Dynamic (CFD) analysis.

This study however will be depending on the time available to study and learn the CFD software i.e., Gambit and Fluent Analysis to see the temperature characteristic inside the room as in the FYP I.

1.2 Problem Statement

The important principles in the Green Technology are the environment and energy concerns. Indeed there are many who do not give Green Building a high priority. It is surprising how many environmental groups, for instance, appear to attach a low priority to their built environment. Many others see the problem purely in terms of energy efficiency or specifically fuel efficiency and are largely unconcerned about the environmental impacts of the materials which they use to achieve reduction in oil, gas, and electricity bills.

In the Malaysian climate sector, which is the tropical country and surrounded by the sea, the climate condition is greatly influenced by the monsoon wind and naturally received a long hour of sun rays, averagely 6 hours a day. The temperature range is between 27 °C to 32 °C during the day and 21 °C C to 24 °C during the night.

Malaysian situation naturally made in suitable for the passive solar adaptation to the building design. However, high temperature and long hour of daylight received will affects the human comfort level. Therefore, it is important to establish the characteristic of temperature distribution inside an area so that the pattern can be analyzed accordingly.

1.2.1 Problem Identification

Basically the problem is that normally, it is hard see the temperature distribution pattern inside a room or area because the energy flow cannot be seen by a normal eye. Thus, with the help of computer software, the pattern is now available but still depends on certain variables such as the thermal coefficient. The design factor such as window opening and mechanical system will effects the temperature and comfort level inside a house, thus studying these effects will help to improve the design. Moreover, the temperature distribution will determine the thermal comfort itself considering mechanical ventilation is turn off.

1.2.2 Significance of Project

The significance of this project is that in the future, the building designers, engineers, or architect can optimize the passive solar strategy in the future building without deleting the human comfort that occupied the building. This research that study the thermal comfort and temperature distribution in the building can give some comfort level/benchmark for the designers to applied the passive solar strategies for a certain green building.

Furthermore, this study relatively adopts the Malaysian environment as well based on the location at the heart of equatorial region considering long hours of sky light available. Thus, the result could be the reference point of human comfort in Malaysia generally, specifically in the UTP campus.

1.3 Objectives and scope of study

The objectives of this study are to compare the data measured in two or more houses/rooms with same characteristics and using the simulation program under the Computational Fluid Dynamic program, Gambit and Fluent to analyze the temperature distribution inside the rooms. Both, the measured data and the simulated data will be compared to see the distribution pattern and any errors will be predicted.

Besides, the objective of studying the temperature distribution will help the author to understand the principle of Green Technology, in the case of using the daylight to light up the house's spaces without disturbing the comfort inside the house.

The scopes of studies in this FYP II would be on towards the analyzing of temperature data inside the house using the CFD simulation software and compare it with the measured data during the FYP I period. Most of the work will be analyzing work using the simulation program in collaboration with Mechanical Engineering Department.

1.3.1 Relevancy of Project

This project is relevant to the study of civil and building engineering. This project is also relevant to the recent building design and architecture which applies the Green Technology within generally, and specifically for the passive solar practices. Furthermore, the project is also relevant to recent studies and development of existing Green Building in Malaysia so that the designers can improve the existing system. Furthermore, all these data will be use in the FYP II project to design a system that utilizes the passive solar strategies.

1.3.2 Feasibility of Project Within

The project is feasible as it utilizes the Computational Fluid Dynamics simulation program which is available at the Mechanical Engineering Department Laboratory at Block 17. Besides, under the assistant from Dr Hussain Al Kayem, the simulation program can be learned in a progressive way, where a PhD mechanical students will be assisting on how to use the program.

However, the analyzing process duration will be limited due to time constraint and the simulation component is divided into two parts, i.e., the modelling process using Gambit and analyzing process using Fluent. Thus, time management will be important.

CHAPTER 2
LITERITURE REVIEW

2.1 GREEN BUILDING ELEMENT - PASSIVE SOLAR

2.1.1 Visual Comfort

According to Dean Heerwagen (2004), "the environment that surrounds us, whether inside or outside of a building, is composed of assorted light sources and many nonluminous surfaces. In the environment there is likely to be greater range in the brightness of these sources and object. When a person spends time in such an environment, the person visual system will adapt to some specific level of brightness".

2.1.2 Using the sky as a light source

There are two factors in the passive solar elements. First, daylight offers a pervasive source for illuminating the activities of human beings. Thus, means for admitting daylight into buildings should be accommodated during their design and construction. Second, the window, which is essential component through which daylight enters buildings, should be design with care.

Using daylight to illuminate the building interior requires that the building envelope contain windows to admit the light. These windows must be adequately sized and placed to ensure that enough light will enter the building. To establish what indeed are appropriate sizes and location, you will need information about how much daylight is available from sky and data about the extent of variation in the amount of daylight across time.

The daylight that we gain from the hemispherical sky vault over us is solar radiation. Thermal energy from the sun radiates, as this beamed radiation, across space to the upper layers of the atmosphere of the earth. The solar radiation that passes through the atmosphere is composed of ultraviolet, visible, and infrared radiation. Of these three forms, only visible radiation can be seen by human eye. The amount of luminance at a building site is chiefly dependent on three parameters:

1 The climate of the region and microclimate of the specific site;

2 The sky condition above the site;

3 The altitude of the sun in the sky.

2.1.3 Designing for Daylighting

1 Accessibility to the sky vault

The first step is to provide the uninterrupted lines of sight between the building interior and the sky wall. When daylight is used as major illumination source for building interior, unobstructed views of the sky must be accessible from within the future building. Daylight is gained from both direct beam sunlight and diffused light from the sky vault.

2 Use of vegetation for controlling the admission of daylight

Employ vegetation, particularly the deciduous varieties, as means for reducing excessive daylight brightness. The principal point is that the intensity of daylight reaching a window varies widely depending on the time of day and year, the portion of the sky a window faces, whether the daylight consists of direct beam sunlight or diffused radiation from the sky.

3 Reflectance of surface external to a building

External surfaces of a building exercise an important role in the building design. The choices of external surfaces near a building can either enhance or detract from the character of the illumination within building. Surfaces with higher reflectances, commonly those are light colored, can reflect light into a building. Similarly, glossy surfaces, those that provide specular reflections, cam also reflects light into a building. Alternatively, building materials like aluminum and stainless steel can also be highly reflective.

Other factors that affect the daylight admission into the building are the building width, orientation, the use of atria, rooftop openings, and window characteristics.

2.2 HEAT TRANSFER

Heat transfer is a thermal energy in transit due to a special temperature difference. Whenever there exists a temperature difference in medium or between media, heat transfer must occur. When a temperature gradient exists in a moving fluid, or in the author case of study inside the room, the term convection is used to refer to the heat transfer that will occur across the medium, or room's air.

The convection heat transfer mode is comprised of two mechanisms. First is the energy transfer due to random molecular motion and secondly energy is transferred by the bulk, or microscopic motion of the fluid. This fluid motion is associated with a large numbers of molecules are moving collectively or as aggregates in which a temperature gradient will contributes to heat transfer.

The convection heat transfer mode is sustained both by random and bulk motion within the boundary layer. The contribution due to random motion dominates near the surface where the fluid velocity is low while the contribution due to bulk motion originates that the boundary layer grows as the flow progresses in the x direction. In fact, the heat is conducted into this layer is swept downstream and is eventually transferred to the fluid outside the boundary layer.

2.2.1 Computational Fluid Dynamics

Flows related phenomenon can be described as a partially differential equation, and cannot be solved analytically except at certain case. In order to obtain the solution, a discretization method can be used which is approximating the differential equation by an algebraic equation using the computer assistant. The approximation is applied to small domains in space or time so that the numerical solutions provide results at discrete location in space and time.

Once the power of computers had been recognized, interest in numerical techniques increased dramatically. Solution on the equation of fluid mechanics on computers has become so important and has many sub-divisions. Numerical method are always approximate, thus difference in computer results and reality such as error arise from each part process used to produce numerical solutions is normal.

The discrete locations at which the variables are to be calculated are defined by the numerical grid which is essentially a discrete representation of the geometric domain on which the problem is to be solved. It divides the solution domain into a finite number as sub-domains. Some examples of grid are structured grid, block-structured grid, and unstructured grid.

The most fundamental consideration in CFD is how one treats a continuous fluid in a discretized fashion on a computer. One method is to discretize the spatial domain into small cells to form a volume mesh or grid, and then apply a suitable algorithm to solve the equations of motion. In addition, such a mesh can be either irregular for instance consisting of triangles in 2D, or pyramidal solids in 3D or regular; the distinguishing characteristic of the former is that each cell must be stored separately in memory.

CHAPTER 3
METHODOLOGY/TOOLS & EQUIPMENTS

3.0 METHODOLOGY

3.1 Methodology

The methodology in this research project consists of two stages:

i. Stage 1 : Final Year Project I - Data measurement and analysis
ii. Stage 2 : Final Year Project II - Simulation analysis using CFD

The duration of both stages is one year or two semesters, where each research works in each stage will be distributed equally into 1 stage per semester and each stage has their own minor objectives to be achieved which finally leading to the main objectives. The project flow charts are as follows:

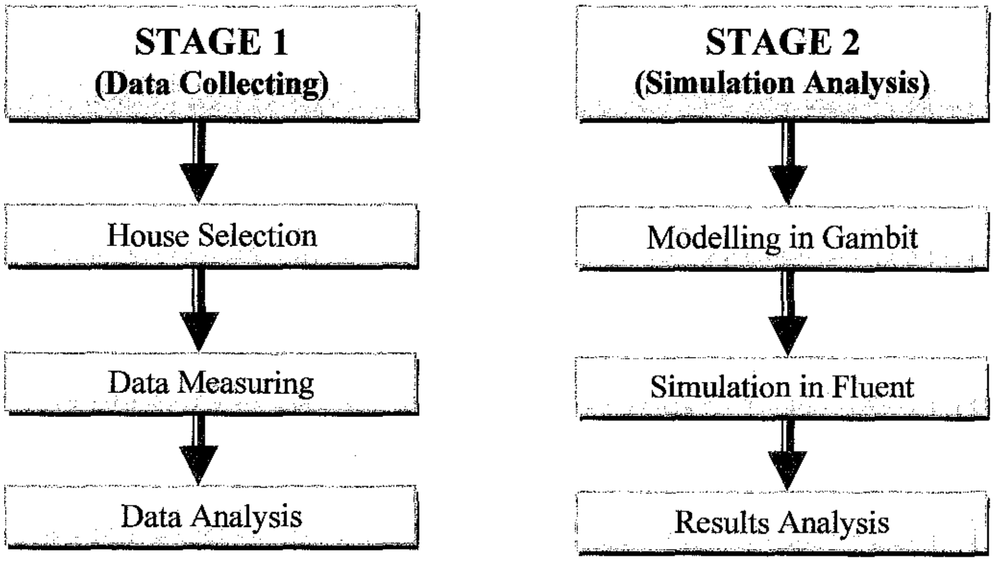


Figure 1: Project Flow Chart

3.1.1 Stage 1 : Final Year Project I – Data Measurement and Analysis

For stage 1 research works, the aim is to establish the fundamentals of research whereby data collecting and analysis by taking an existing house inside the campus as a measurement subject will be the main target to be completed for the first semester. The detail project flow chart for this stage is as follows:

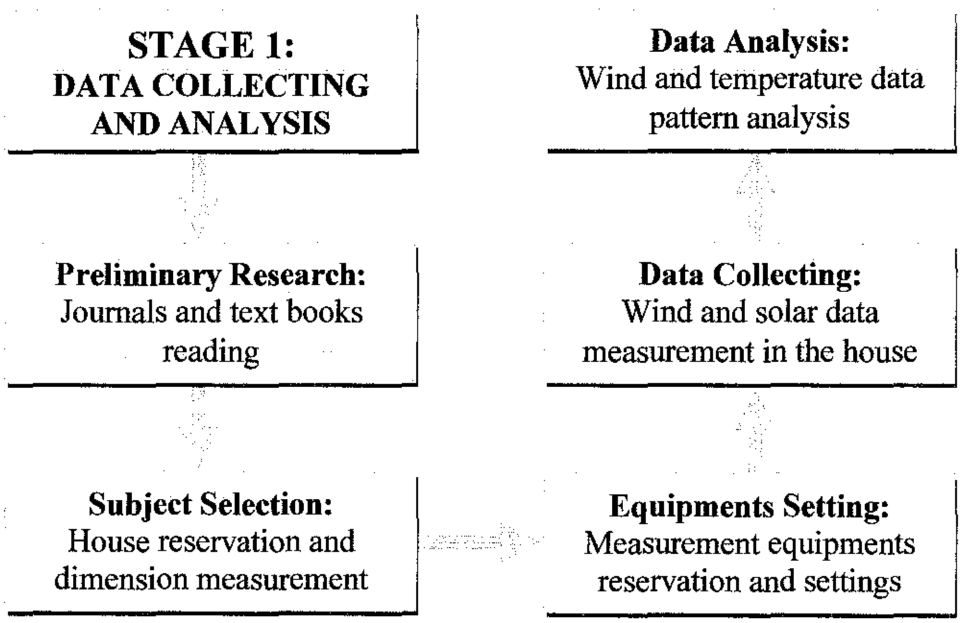


Figure 2: Project Flow Chart: Stage 1

3.1.1.1 Preliminary Research

During the preliminary research stage, the objective is to find what all the researchers around the world have done so far related to the topic selected. Through the journal reading, the author managed to obtain an idea and guidance about his project methodology and analyzed what are the gaps in the research field. However, the time constraint had limited the author studies and only reading material related to the Green Building concept and simulation analysis was chosen as a guide for his project.

3.1.1.2 Subject Selection

The subject is a Guest House located inside the UTP campus. The house is a middle terrace house with 2 rooms; master bedroom and single bedroom. Due to the time and equipments constraint, all the measurement activities were conducted inside the master and single bedroom only, not within all the house area. The house position, layout, and dimension are as follows:

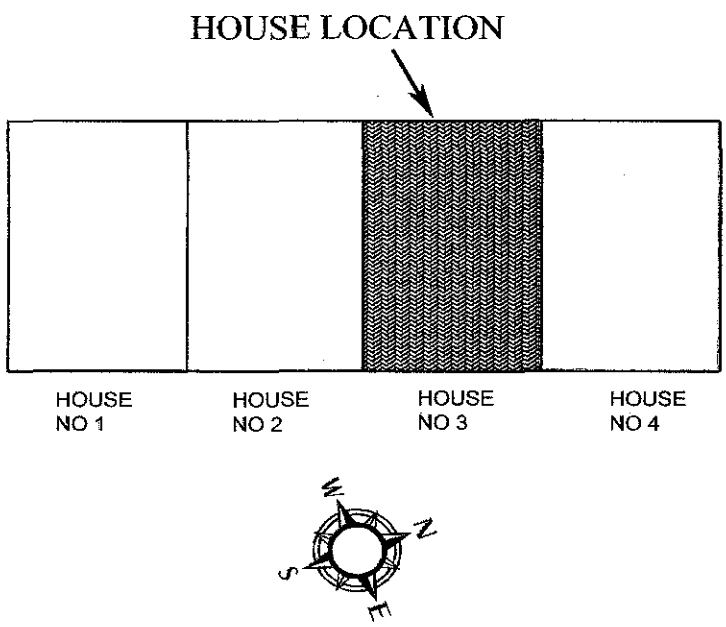


Figure 3: The house position

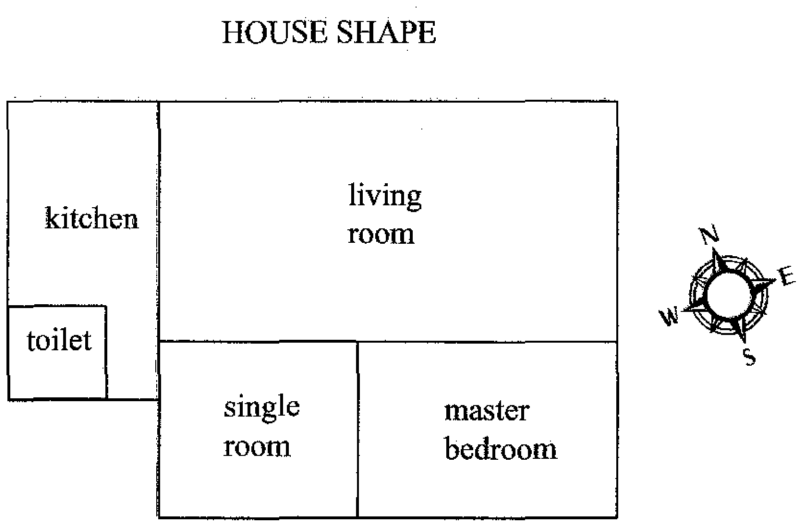


Figure 4: The house layout

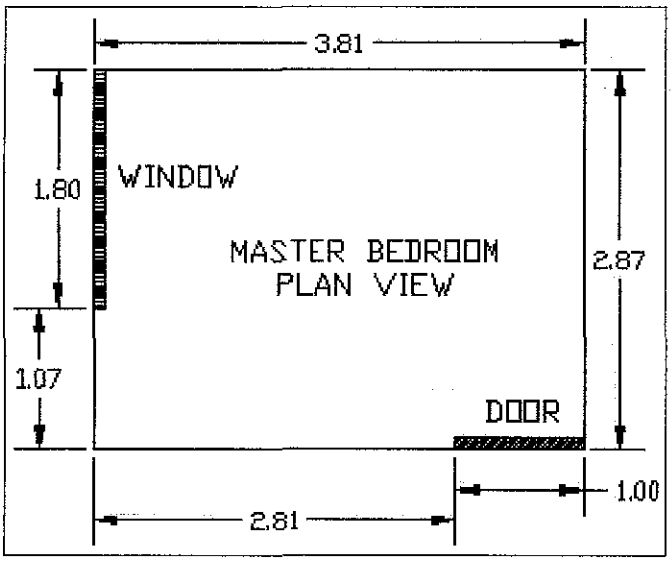


Figure 5: The master bedroom layout

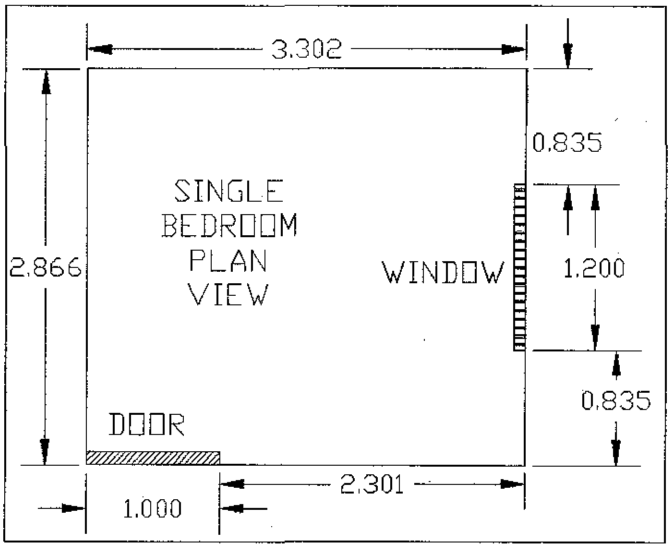


Figure 6: The single bedroom layout

3.1.1.3 Equipments Settings

The types of data to be measured are the wind and temperature data, based on the equipments availability at the UTP Mechanical Engineering Laboratory (refer to **section 3.2** for details). All the equipments were set and calibrated accordingly with an assistant from the laboratory technician.

3.1.1.4 Data Collecting

The data was measured for two days only, considering the time constraint to borrow the equipments and the Guest House occupation. The author has teamed up with another student, Mohd Nor Akmal who is conducting a research on Green Building too but focused on the natural ventilation scope to collect all the data. The details are:

DATE	:	19 and 20 April 2008
TIME	:	8.00 am – 4.00 pm
TYPES OF DATA	:	Temperature at five different points, wind direction and velocity, relative humidity. (see **Section 4.1.1** for the results)
WEATHER	:	Dry, hot, windy day


Figure 7: Measuring and taking data

3.1.1.5 Data Analysis

All the data was compiled and tabled together into a table form. The data that are relevant to the author research scope on passive solar strategies is the temperature data only. In order to analyze the data, the most critical temperature data was selected and this data will be used for simulation using CFD to compare the measured and simulate temperature distribution inside the rooms.

3.1.2 Stage 2: Final Year Project II – Simulation Analysis Using CFD

In this stage, all the results and selected data from Stage 1 will be used in the Computational Fluid Dynamic (CFD) simulation program to simulate the temperature distribution inside both rooms. The minor objectives are to compare the measured and simulate data (see **4.0** for results) and to modify the room's features (see **Section 3.1.2.2** for modification details) as part of the passive solar strategies and see the differences. The project flow chart for this stage is as follows:

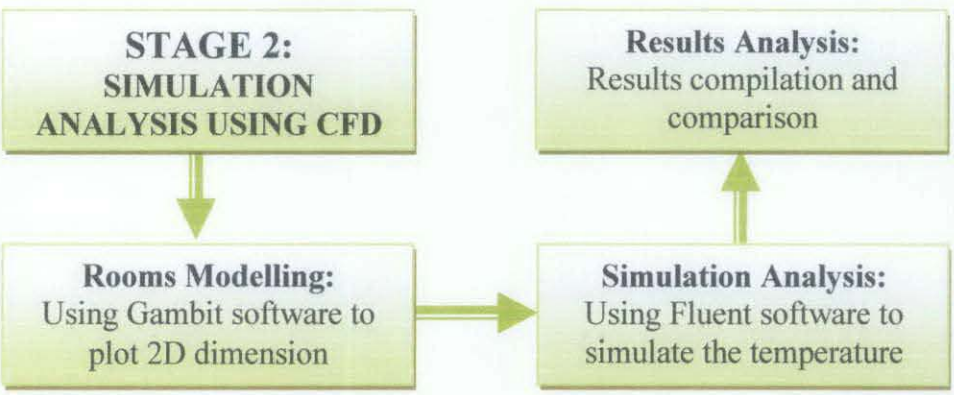


Figure 8: Project Flow Chart: Stage 2

3.1.2.1 Rooms Modelling

The rooms modelling process is where each master and single bedroom will be plotted in a computer program. The software used called Gambit is part of simulation package specialized in model building. The author chooses to conduct the simulation in 2D environment only considering the time limit to learn the software. The two rooms are assumed without any electrical devices are turn on. The steps in Gambit are as follows taking single bedroom as example:

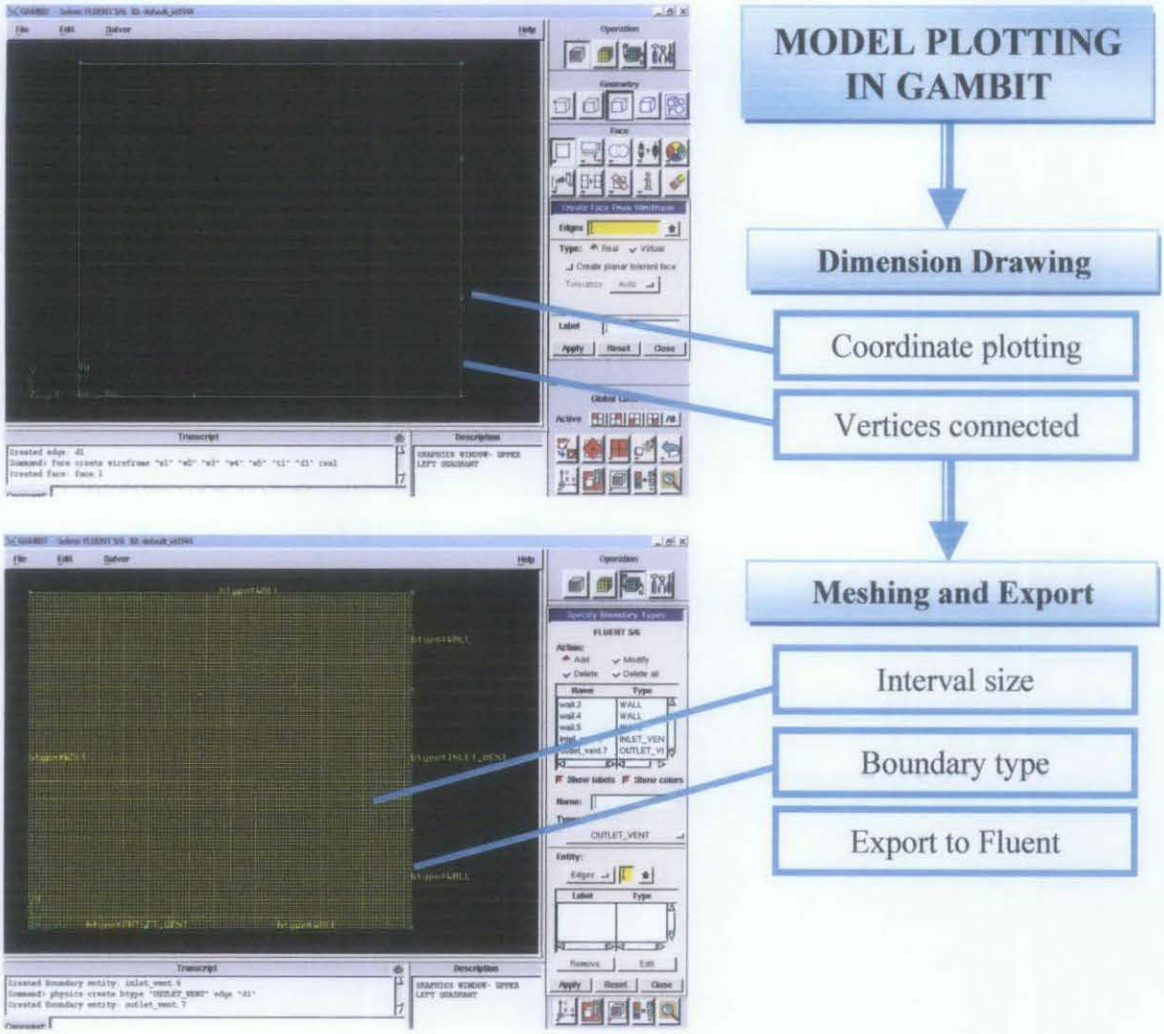


Figure 9: Model Plotting

All the steps taken in these stages will be recycled for other rooms and modified room plotting with same setting and boundary type.

3.1.2.2 Simulation Analysis

After the model plotted in Gambit completed and exported, the model will be opened using the Fluent software for simulation. The 2D simulation consists of the plan view and side view of each room together with a modified room. All the relevant data are taken from Stage 1 and other conditions are taken as a default value in Fluent as follows:

Air Properties

Density	: 1.225 kg/m^3
Specific Heat	: 1006.43 j/kg-k
Thermal Conductivity	: 0.0242 w/m-k
Viscosity	: 1.7894 x 10^{-5} kg/m-s

Masonry Wall Properties

Density	: 1800 kg/m^3
Specific Heat	: 840 j/kg-k
Thermal Conductivity	: 1 w/m-k

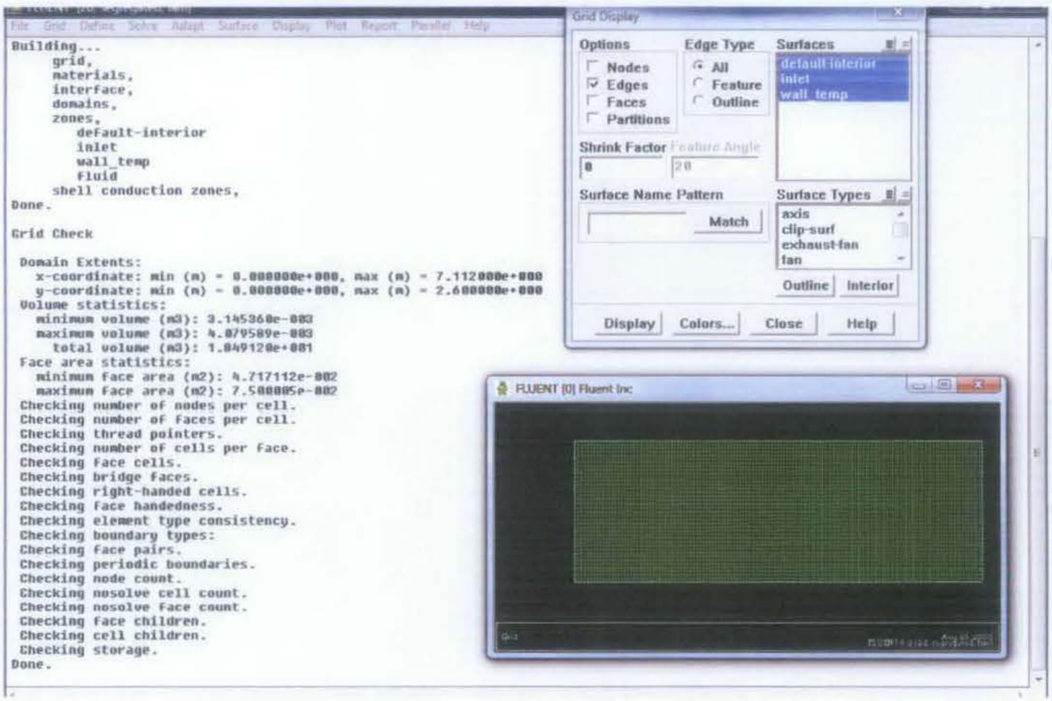


Figure 10: Simulation in Fluent

The temperature distribution is then simulated and the results are compared with the measured temperature during the Stage 1 period. After that, the room is modified by expand the window length by 2 feet and the height by 1 feet and then simulated again. Furthermore, an imaginary ventilation hole 1 meter length is created at the ceiling and simulated as part of the passive solar strategies (see **Figure 3.1.22** for the modified model).

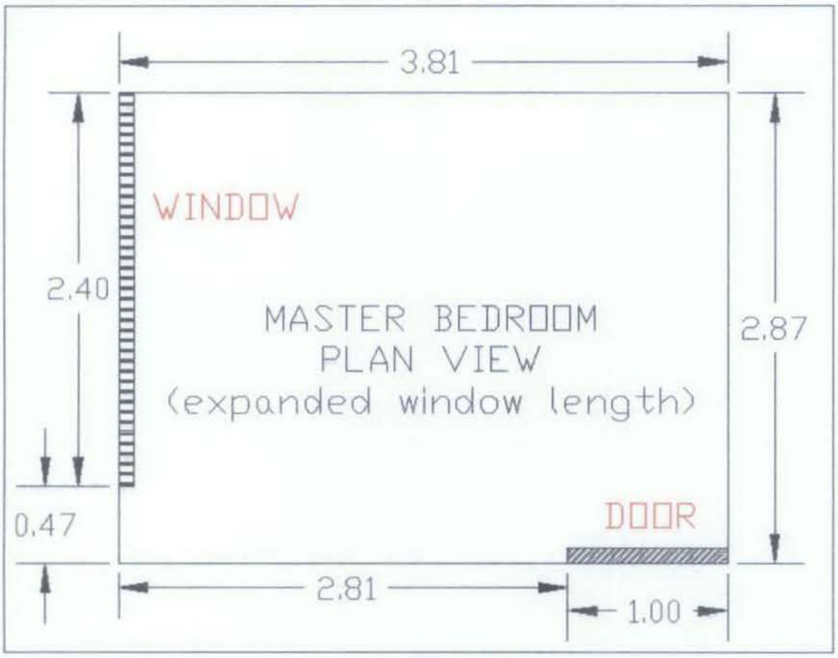


Figure 11: Modification in master bedroom

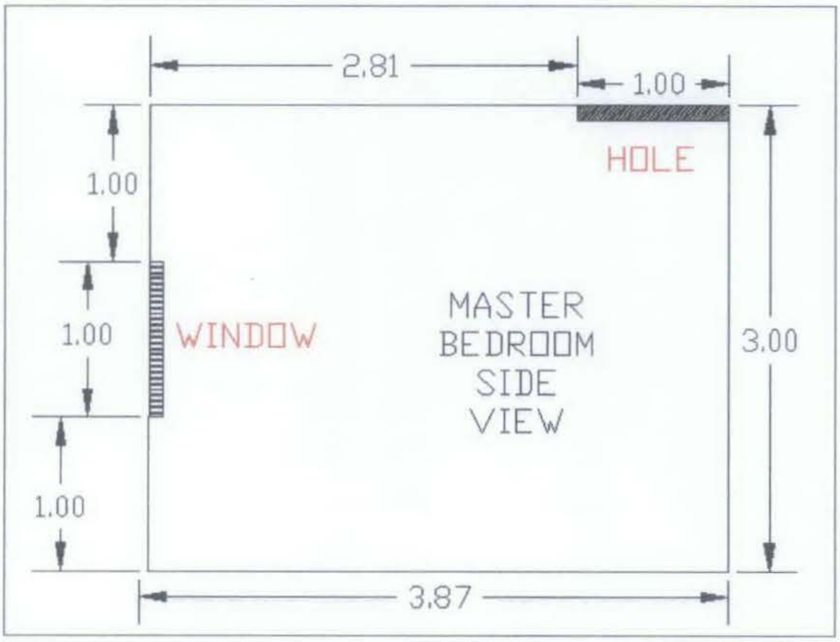


Figure 12: Master Bedroom side view

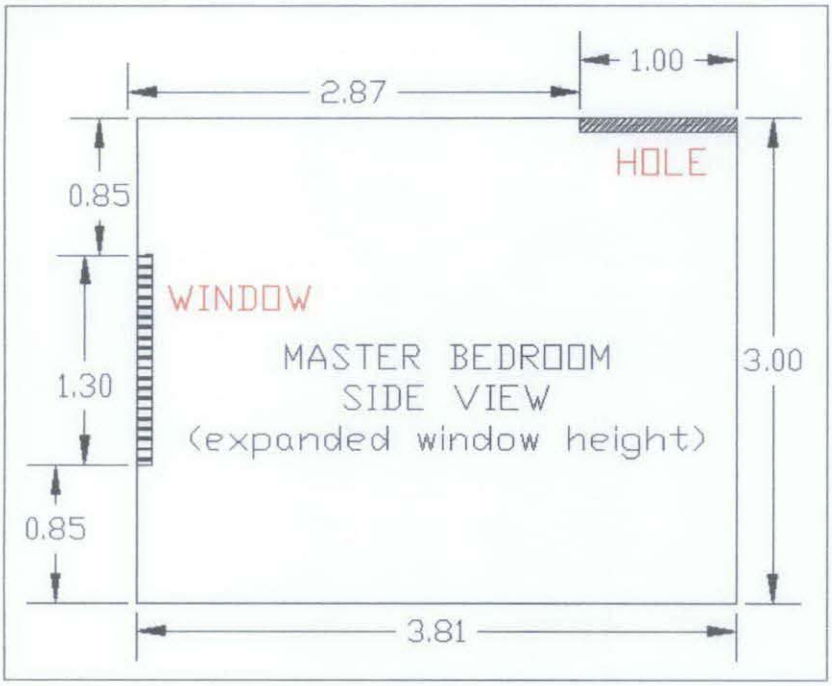


Figure 13: Modification in master bedroom side view

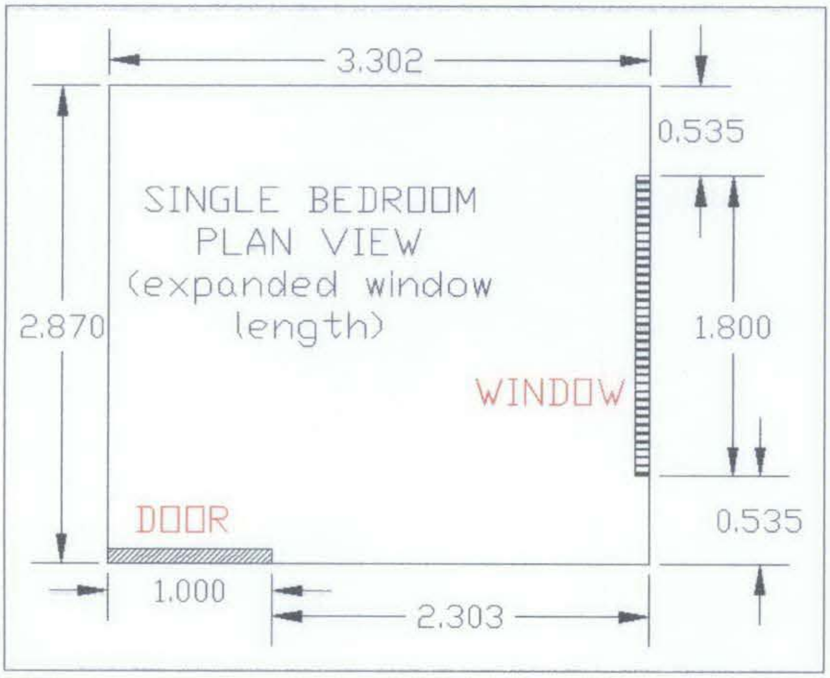


Figure 14: Modification in single bedroom

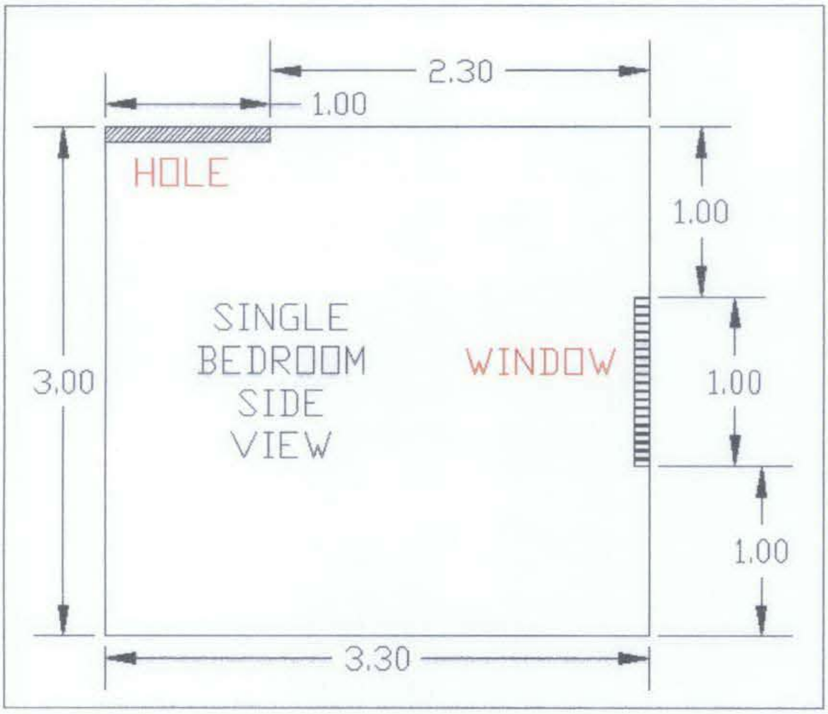


Figure 15: Single bedroom side view

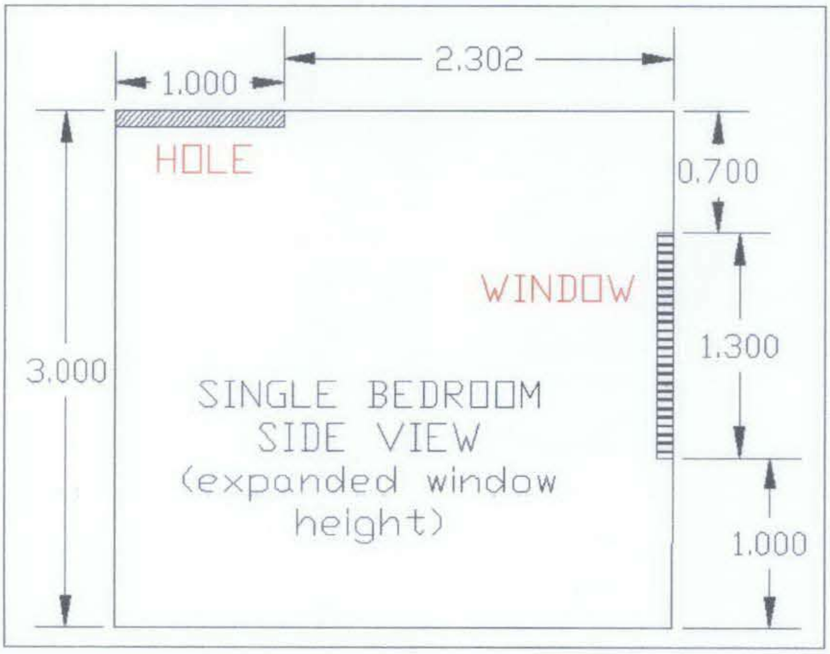


Figure 16: Modification in single bedroom side view

3.1.2.3 Results Analysis

After all the temperature distribution had been compiled, the results will be analyzed by comparing the temperature distribution between the original layout with the modified layout and the ventilation added layout. All the results are then compared and discuss (see **Section 4.0** for discussion).

3.2 Tools and Equipments

The equipments used during this project consist of tools for data measurement and the simulation software. For the data measurement, the equipments were borrowed from the Mechanical Engineering Laboratory consist of:

i.	Temperature	: Temperature Probes
		: Data Logger
ii.	Wind Velocity	: Anemometer with wind gauge
Iii.	Humidity	: Anemometer with humidity sensor

The temperature probes were placed at five different locations per room to measure the temperature at the respective points for an interval of one hour. The points were named A and B for the point in the middle of the room, C for the point at the door, and D and E for the points at the window (see **Figure 17** below). All the collected data were recorded as per table in the results section.

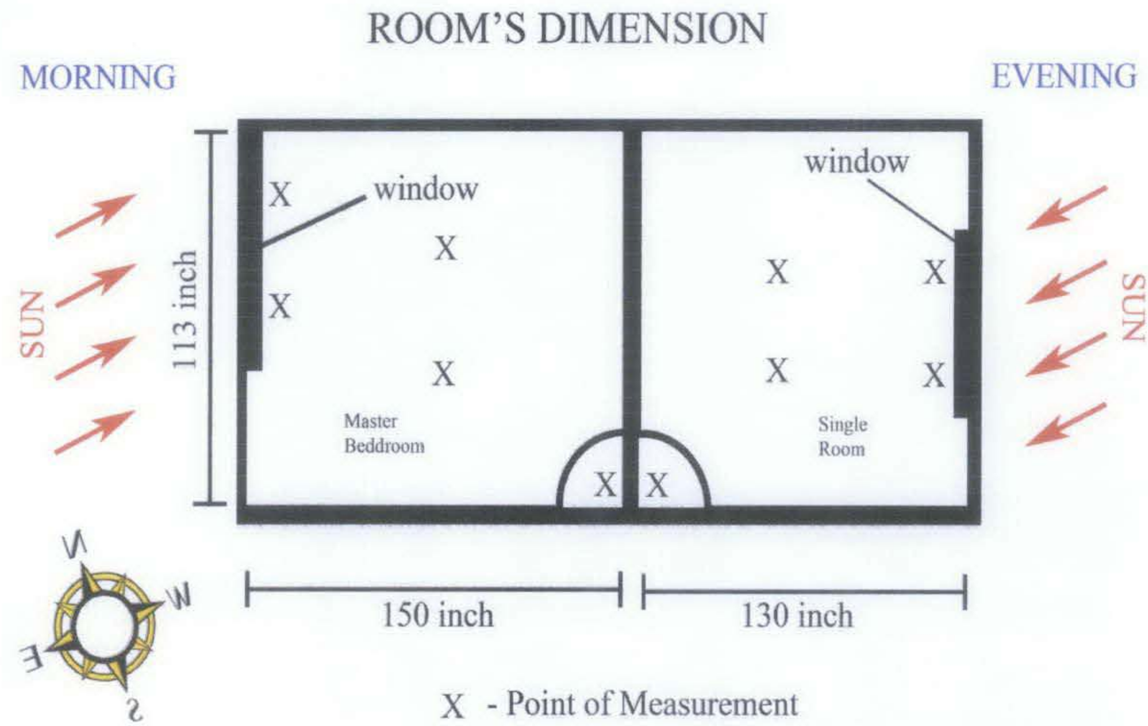


Figure 17: Points of measurement

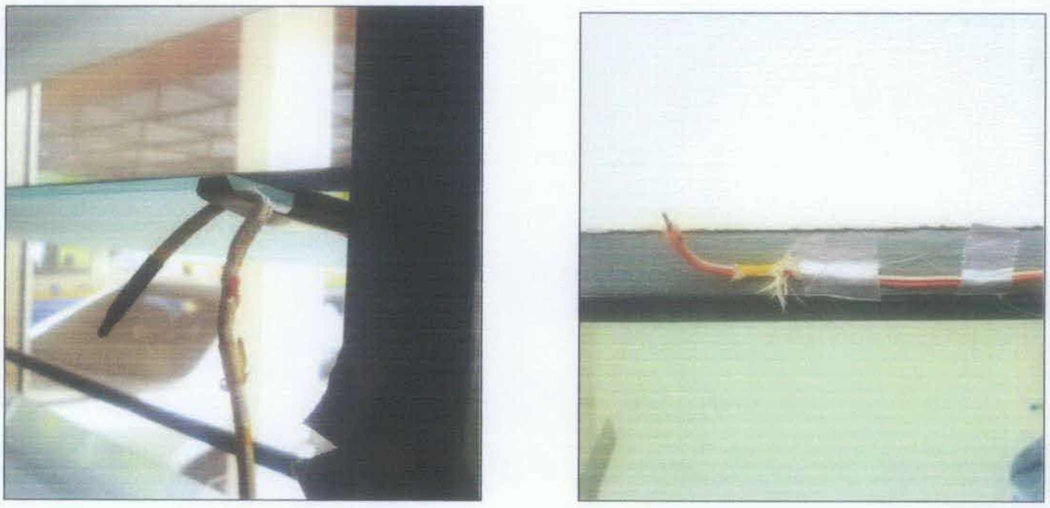


Figure 18: Temperature probe placed at the windows

Figure 19: Data logger and anemometer set

CHAPTER 4
RESULTS AND DISCUSSION

4.0 RESULTS

4.1 Results from Stage 1: Data Collecting

The results for the data measurement are tabulated in the table below, and the critical temperature was taken and plotted as follows:

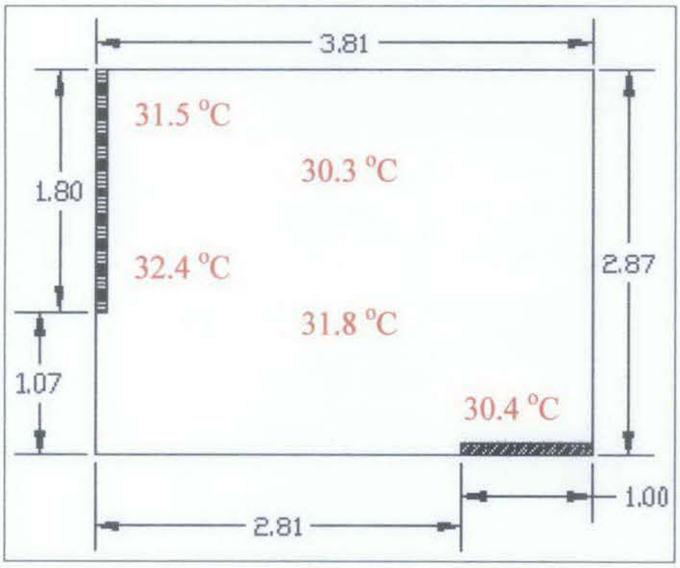


Figure 20: The temperature distribution in master bedroom

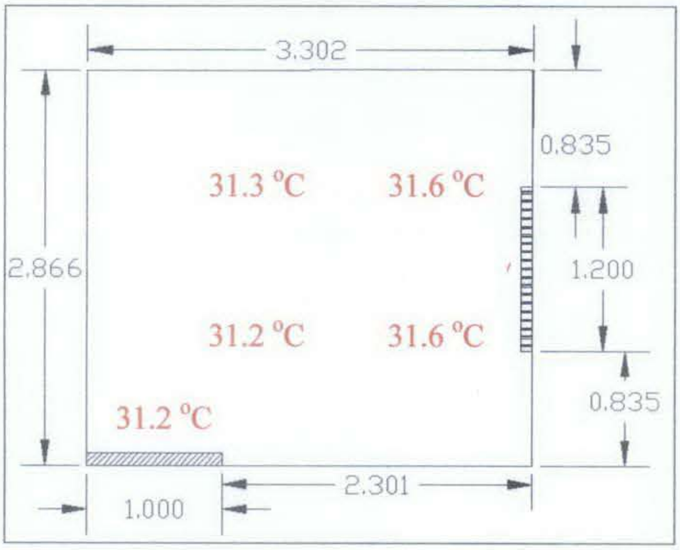


Figure 21: The temperature distribution in single bedroom

4.1.1 DATA FOR : SATURDAY, 19 APRIL 2008

<u>MEASURED DATA FOR THE SINGLE BEDROOM</u>

TIME	TEMPERATURE AT THE ALLOCATED POINTS* (°C)					WIND DIRECTION		WIND VELOCITY (m/s)		Relative Humidity (%)
	A1	B1	C1	D1	E1	Inside the Room	Backyard	Inside the Room	Backyard	
0800	27.0	27.2	27.4	27.5	27.6	-	-	-	-	87.1
0900	28.1	27.9	28.1	28.1	28.0	-	E 60°	-	0.5	86.9
1000	28.7	28.4	28.5	28.6	28.3	-	N 20°	-	0.1	72.0
1100	29.5	29.3	29.4	29.3	29.4	E 10°	N70°	0.3	0.2	78.7
1200	30.3	30.1	30.2	30.3	30.3	E 80°	N 20°	0.5	0.5	81.0
1300	30.4	30.6	30.4	30.7	30.6	N 50°	N 10°	0.8	0.2	76.0
1400	31.4	31.4	31.4	31.9	31.8	E 10°	E 30°	0.5	0.7	75.0
1500	31.1	31.0	31.0	31.2	31.3	E 45°	W 80°	0.2	0.8	75.9
1600	31.7	31.6	31.7	32.0	32.1	N 46°	E 45°	0.6	1.1	76.5

<u>MEASURED DATA FOR THE MASTER BEDROOM</u>

TIME	TEMPERATURE AT THE ALLOCATED POINTS* (°C)					WIND DIRECTION		WIND VELOCITY (m/s)		Relative Humidity (%)
	A2	B2	C2	D2	E2	Inside the Room	Porch	Inside the Room	Porch	
0800	26.2	26.6	26.6	26.8	26.8	-	-	-	-	87.1
0900	28.5	29.0	28.8	29.1	28.9	-	E 60°	-	0.3	87.0
1000	29.2	29.2	29.1	30.9	29.5	-	N 50°	-	0.2	73.4
1100	30.0	29.9	29.3	31.1	30.1	-	N 45°	-	1.0	79.1
1200	30.7	30.7	29.7	31.5	30.7	-	W 80°	-	0.6	80.8
1300	31.0	30.6	30.4	30.7	30.6	-	W 60°	-	0.5	75.1
1400	30.3	31.8	30.4	32.4	31.5	-	E 45°	-	0.5	74.1
1500	31.4	31.4	30.4	31.7	31.5	-	W 20°	-	0.3	76.5
1600	30.8	31.8	30.8	32.2	31.6	-	E 70°	-	0.3	77.0

4.1.2 DATA FOR : SUNDAY, 20 APRIL 2008

MEASURED DATA FOR THE SINGLE BEDROOM

TIME	TEMPERATURE AT THE ALLOCATED POINTS*(°C)					WIND DIRECTION		WIND VELOCITY (m/s)		Relative Humidity (%)
	A1	B1	C1	D1	E1	Inside the Room	Backyard	Inside the Room	Backyard	
0800	28.4	27.8	28.0	27.8	28.2	-	-	-	-	85.0
0900	28.9	28.3	28.5	28.3	28.5	-	-	-	-	84.3
1000	29.5	29.3	29.3	29.4	29.4	-	-	-	-	84.4
1100	29.6	30.2	30.1	30.3	30.2	-	-	-	-	76.2
1200	31.2	31.2	31.2	31.2	31.3	-	N10°	-	0.3	75.3
1300	31.3	31.2	31.2	31.6	31.6	N30°	N20°	0.1	0.3	73.3
1400	31.2	31.0	31.2	31.2	31.4	E10°	W30°	0.1	0.3	74.5
1500	30.7	21.4	31.5	31.7	31.8	-	N15°	-	0.3	75.2
1600	30.8	31.5	31.6	31.7	31.7	-	E20°	-	0.2	73.8

MEASURED DATA FOR THE MASTER BEDROOM

TIME	TEMPERATURE AT THE ALLOCATED POINTS* (°C)					WIND DIRECTION		WIND VELOCITY (m/s)		Relative Humidity (%)
	A2	B2	C2	D2	E2	Inside the Room	Porch	Inside the Room	Porch	
0800	28.9	29.0	28.7	29.6	29.3	-	-	-	-	85.0
0900	29.4	29.5	29.4	31.4	29.9	-	-	-	-	84.7
1000	29.9	30.1	29.7	32.1	30.5	-	S30°	-	0.2	84.4
1100	30.4	30.6	29.9	31.1	30.7	-	N20°	-	0.1	76.5
1200	31.8	31.6	30.3	32.5	31.4	-	N20°	-	0.4	74.5
1300	31.6	31.5	30.5	32.2	31.6	-	W45°	-	0.3	72.9
1400	31.7	31.5	30.6	32.0	31.5	-	N20°	-	0.1	74.9
1500	31.7	31.7	30.7	32.1	31.6	-	E20°	-	0.1	75.6
1600	31.7	31.8	31.0	31.8	31.6	-	W45°	-	0.1	73.1

4.2 Results from Stage 2: CFD Simulation Analysis

Figure 21: MASTER BEDROOM – Plan View

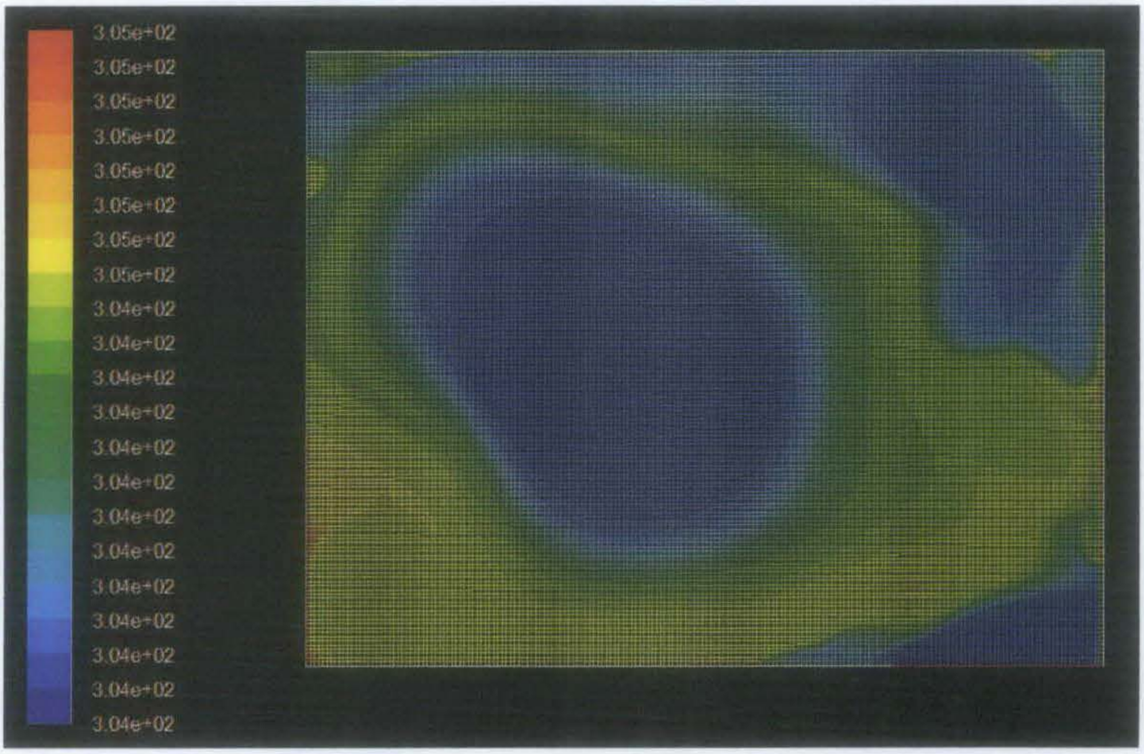


Figure 22: MASTER BEDROOM – Plan View with an Expansion of Window by 2 feet

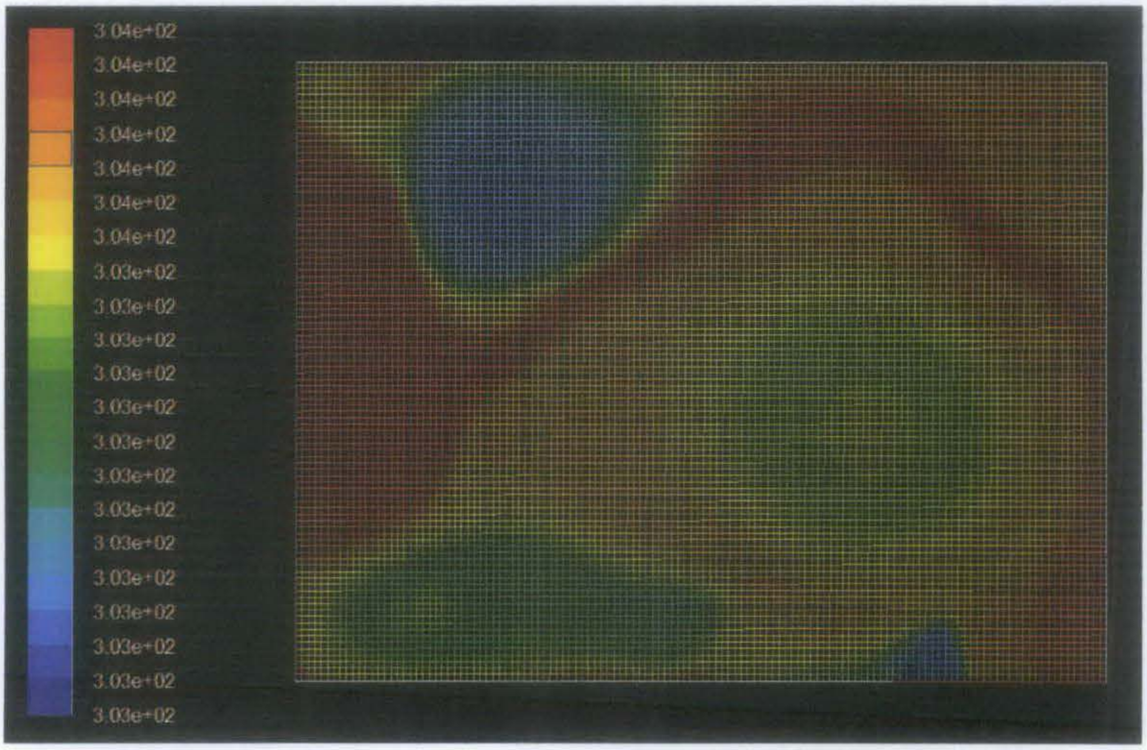


Figure 23: MASTER BEDROOM – Side View

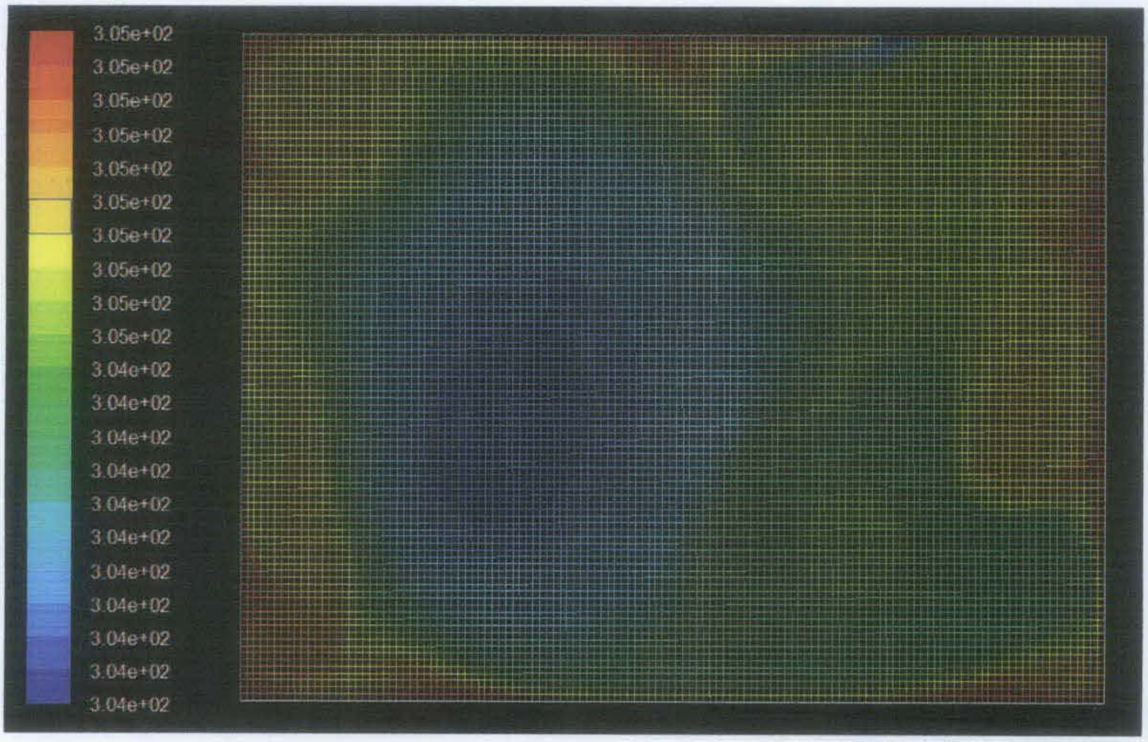


Figure 24: MASTER BEDROOM – Side View with an Expansion of Window by 1 feet

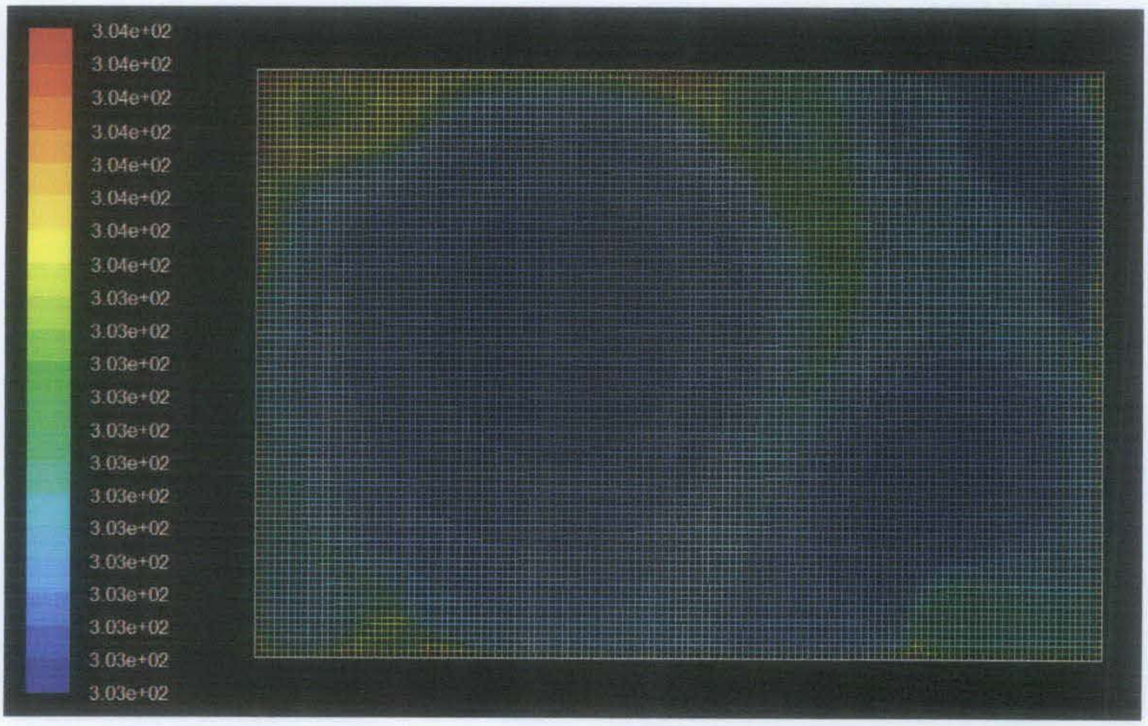


Figure 25: SINGLE BEDROOM – Plan View

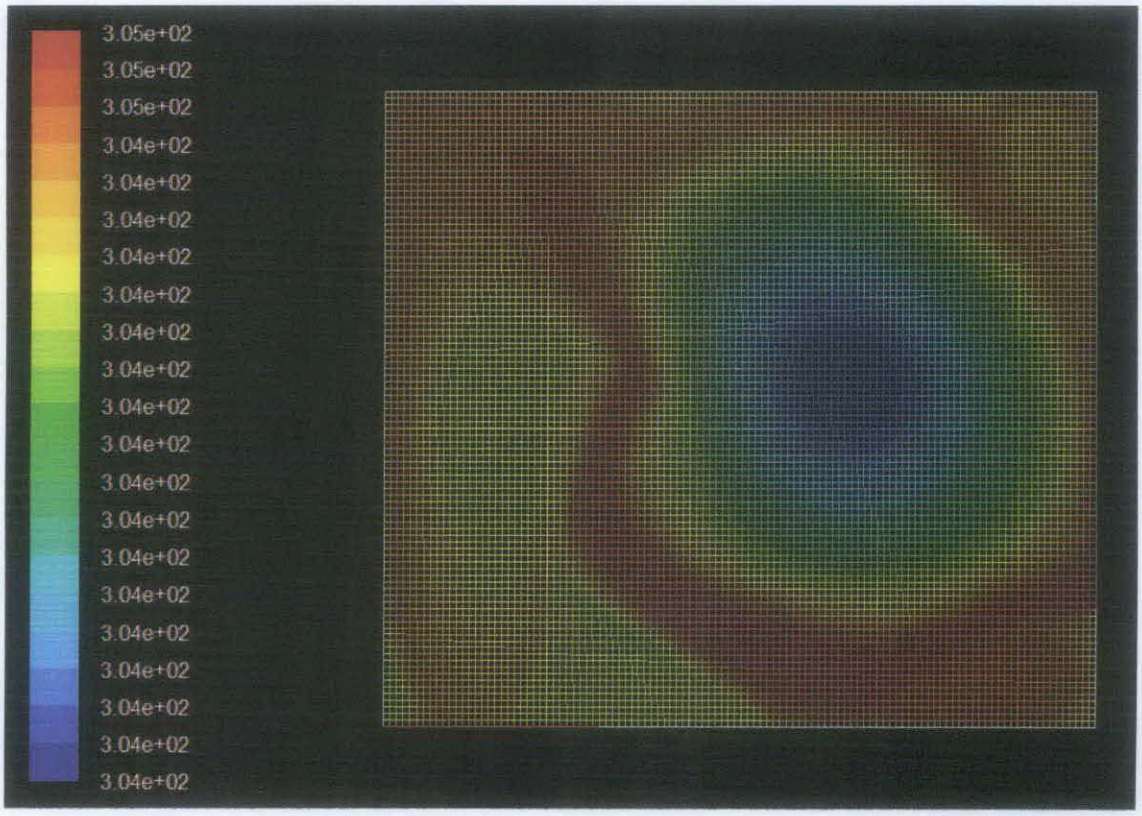


Figure 26: SINGLE BEDROOM – Plan View with an Expansion of Window by 2 feet

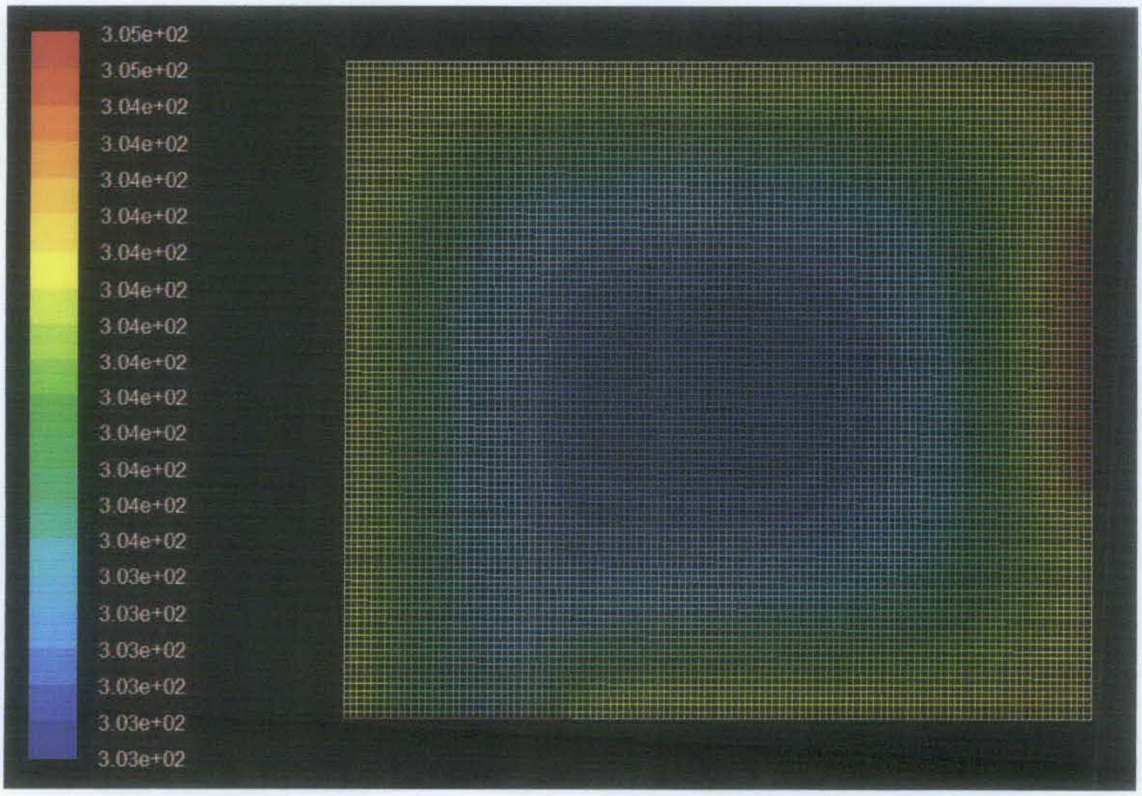


Figure 27: SINGLE BEDROOM – Side View

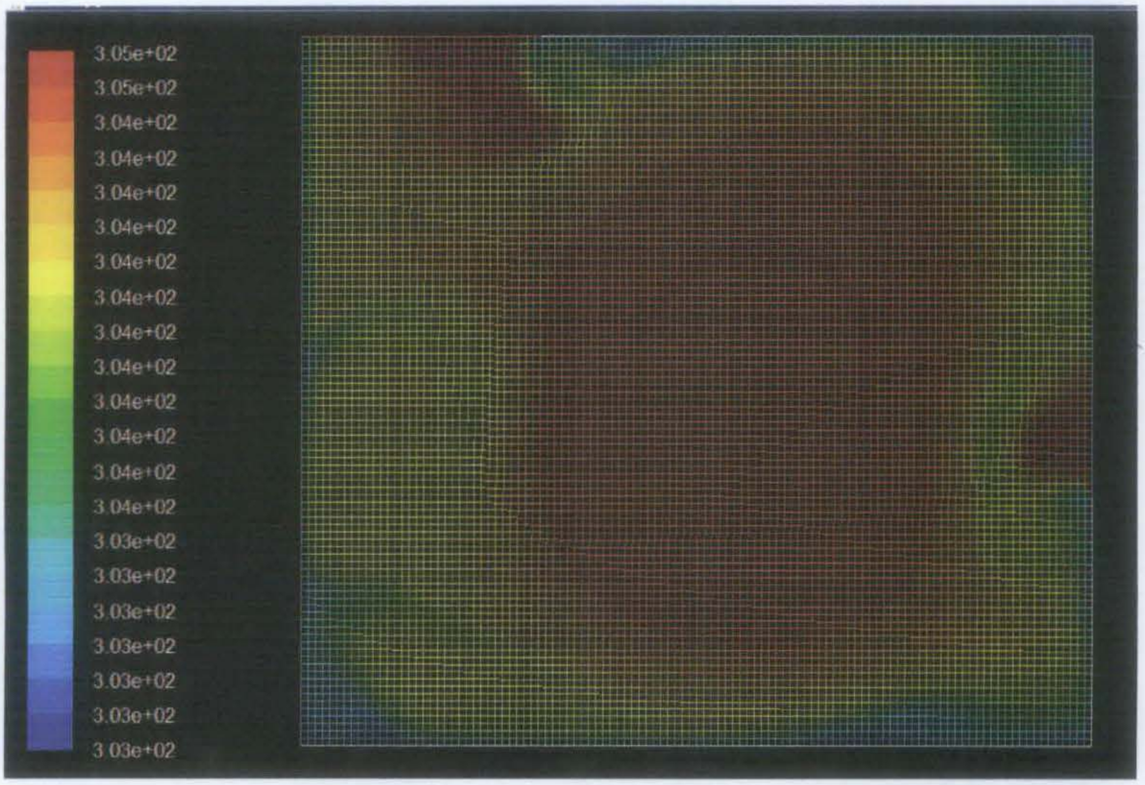
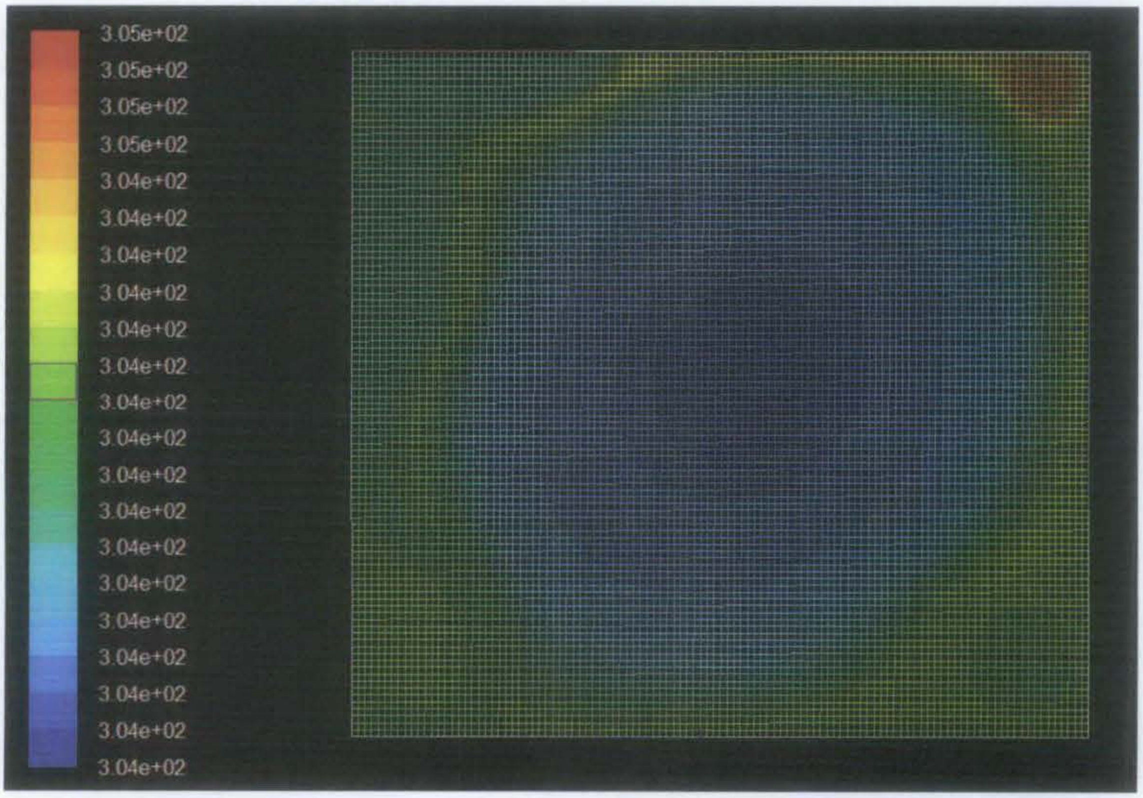


Figure 28: SINGLE BEDROOM – Side View with an Expansion of Window by 1 feet



4.3 Results Discussion

The results tabulated in Section 4.1 refer to the critical temperature tabulation picked up from the table data. The critical means the temperature is the highest in average and taken from the afternoon reading where at this time, the sunlight is maximum and penetrated direct towards the master bedroom. The graphical temperature plot will be compared with the simulation analysis results.

4.3.1 Comparison between the Measured Data and Simulation Analysis

From the graphical comparison, the measured temperature all five points can be considered exactly equal with the simulation temperature with an error range just between only 0.1 to 0.3 ^{o}C only. Thus the simulation analysis result can be precise tools to plot the temperature distribution.

From the simulation results, the highest temperature plotted is 305 K and the lowest temperature is 304 K. Then the simulation continues with a modification by expanding the window length by 2 feet to see the effect to the temperature distribution.

4.3.2 Comparison between the Original and Modified Room

From the graphical plot comparison, the highest temperature plotted by the simulation program is 304 K and the lowest temperature is 303 K for the modified window master bedroom. Compare this temperature range with the original master bedroom simulation plot, the temperature is going down by 1 Kelvin probably because as the window length is expand, more natural ventilation penetrate the room and lowered the temperature.

4.3.3 Comparison between the Side View Temperature Distributions

The side view design was made in order to study the effects of providing a ventilation hole at the ceiling similar like the air chimney function. A one meter length air hole was designed and plotted to be simulated. From the simulation plot, the highest temperature is 305 K and the lowest is 304 K for master bedroom. Then another model was plotted by modifying the window height by expand a 1 feet height and being simulated again. The highest temperature is 304 K and the lowest temperature is 303 K.

This showed the temperature was lowered by 1 Kelvin after the modification was made. This is due to the natural ventilation system was created from the window to the air hole at the ceiling. This Green Building effect can help to ventilate the house naturally and reduced the temperature. However, the master bedroom temperature of 32 ^{o}C is still high compare to human comfort temperature of 24 – 26 ^{o}C due to direct sun light that penetrate the house without shading or other control measures.

4.3.4 Comparison of Temperature Distribution for Single Bedroom

The explanation for the effects in single bedroom is same with the explanation for master bedroom above.

4.3.5 Results Accuracy and Error

Comparing the measured data with the simulated data, the error was calculated to obtain the percentage. For all the results, the error range was less that 1% and this is significant to ensure that the simulation program is reliable and produce the similar trend with the real situation.

Although the simulation program is very precise, there are still some other factors that can effects the results such as:

i. The boundary condition is hard to measures
ii. The time limit factor that effect the duration of measurement
iii. The equipments limit factor that limit the types of data measurement
iv. The accuracy of the equipments used and human error factor
v. The Malaysian climate condition which change over certain period

4.3.6 Recommendation for Future Research

There are a lot of improvements can be made to this experiments, in the point of view for the modification features made to the model and the equipments usage. For the model modification, these recommendations are suggested:

i. More variety dimension of window can be design
ii. Natural ventilation devices and control can be implement
iii. More accurate boundary condition can be obtain by right equipment
iv. A 3D model can be simulate which produce more accurate results compare to 2D
v. A multi storey model can be analyzed using the simulation program

For the equipments side, the improvements that can be made are:

i. More accurate and precise equipment can be used
ii. Special equipments that measures the human comfort level can be used
iii. Spending more time with the equipments will yield more accurate results
iv. A lot more data can be measured such as radiation and light brightness

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

5.1 Conclusion from the Simulation Analysis

From the simulation results, the Computational Fluid Dynamic Simulation Program can be good tools for designers to conduct a design of building during the preliminary design stage where the effects of each element in the building can be studied before the decision being made. The objective to compare the relevant data was achieved where the differences of each element were observed and several suggestions on why the data are different were made.

Some conclusion of making the Guest House as a subject was made. From the survey, the orientation and the shading system for windows is very important. For the window facing directly towards the sun without any shading system, a good comfort condition is hard to be achieved. The temperature range between 30 – 32 ^{o}C is quite uncomfortable if the air condition and the electric fan is totally off. The natural ventilation within the house also is not very good as there are only windows and door to circulate air.

The house location, which is in between other neighboring houses, is not a suitable subject because the wind blows is not totally optimized. If the house is a corner house, the wind can penetrate into the building and will contribute something to the comfort factor. The orientation factor is very important where good orientation will give a passive solar to replace the electrical lighting usage and in the same time did not disturb the comfort level.

5.2 Conclusion from the Project Research

The Green Building element approach, which is to implement passive solar strategies by modifying a window and provide an air opening into the building can be studied through a simulation modelling and analysis. This is relevance to the project objective. Although the scope of study is very small compare to huge scope of Green Building technology, still it is very effective method to conduct a research on this topic considering the time limit.

There are a lot of factor that affects human comfort inside a building such as orientation, passive devices, roof design, and more. Combining all these elements together, a comprehensive Green Building can be achieved precisely but it will take some cost in terms of money and time. But in the long term, this technology will save more compare to conventional technology.

5.3 Suggestion of Future Work for Continuation

Although there are a lot of researches are in this field, still there are a lot of improvements can be made for this scope of research. For example:

i. 3D modelling simulation

   A 3D modelling and analysis is a good step towards more accuracy results compare to 2D analysis because the simulation will consider the volume compare to area. The inlet and outlet air intake can be design with more precise dimension. However, this will take longer time compare to 2D simulation.

ii. Multi storey simulation

This type of simulation is very complicated and time consuming as a lot of aspect and detailing must be considered, but the result will be very useful to study the effect of certain number of building storey to the passive aspect.

iii. Solar Radiation and penetration simulation

This scope of research is a bit different but related to the passive solar strategies and human comfort aspect closely. A special radiation and light simulation program can be used which are available in the market but some of them is a freeware program. Using the program, the shape of sun light inside a space can be projected and analyzed accordingly.

iv. Other usage of Green Building software

There are a lot of third party software developers selling a good product for Green design in the market, and each of them has their own advantages. This third party program can be utilized for research work for a variety of aspect.

v. A prototype modelling

A prototype modelling is a good example of extensive research works, combined with a computer powered simulation program, will produce an excellent result. A scale model can be constructed with a variety of design elements and analyzed simultaneously with the simulation program.

5.4 Suggestions for the University

After going through all these project experience, the author would like to suggest some recommendation to the University, especially the Civil Engineering Department:

i. Establish a Green Building Design Laboratory

   A special design laboratory can be allocated for students and lecturer's accommodation to conduct a research with the aid of computer program.

ii. Provide a facilities for prototype modelling

   A place similar to concrete works site could be allocated for model building, section moulding, and fabrication works for wide purposes of other field which can benefit all students.

iii. Implement a Green Building aspect into a lecture syllabus

   Considering this technology and knowledge is not widely implemented in Malaysia environment, a student with an engineering minor in Green Building Technology could attract the industries attention.

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