THE STUDY OF AIR FLOW MOVEMENT USING GAMBIT AND FLUENT SIMULATION (2D) PROGRAM FOR PASSIVE VENTILATION DESIGN CONCEPT OF LOW RISE BUILDING IN MALAYSIA

By

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FINAL YEAR RESEARCH PROJECT REPORT

Submitted to the Civil Engineering Programme
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for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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TRONOH, PERAK

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ABSTRACT

Providing adequate natural ventilation would reduce the building cooling load in tropical areas. This regarded as a design moving towards green or sustainable building concept. Driving forces for natural ventilation in those hot and humid countries are basically wind induced actions. This effect depends on the surrounding environment in a dense urban area, where buildings are closely built together. This project is to adapt the green building design concept in Malaysia. Further investigation is to be done especially on air flow movement. The Green Building features were adapted by modifying the window dimension and proposed the air chimney at the room's ceiling. Some simulations using CFD software (Gambit and Fluent) was done in order to analyze data and to come out with a proper system .The results show that the wind velocity inside the master and single bedroom has increased when the window dimension is increased and the proposed air chimney is provided. Results are useful to provide better ventilation system.

Keywords: Energy, ventilation, CFD software, Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Green building practices the techniques to reduce and finally eliminate the impacts of buildings on the environment and human health. But effective green buildings are more than just environmental friendly technologies. it requires careful, complete attention to all the life cycle impacts of the resource consumed and pollution emission over the building's complete life cycle.

1.2 Problems statement

Since Malaysia is located in the tropical region, it is natural that we are facing problems regarding sun and wind. The weather here (hot most of the time) cause to gain excessive heat. The climate here is influenced by four monsoon wind that is north east monsoon , north west monsoon and two short term transition monsoon period that comes from different directions; generally from 4 primary directions, North, South, East (November to March), and West (May to September). With reference to Malaysia meteorological website, the average daily temperature is 27 °C to 32 °C during the day and 21 °C to 24 °C during the night.

A study conducted by W.K Chow (2004) on wind induced indoor-air flow in a high rise building; he stated that orientation of the building and ventilation openings must be designed with respect to the geological features and statistical data on wind movement to give enough natural indoor air-flow to give adequate natural indoor air-flow.

1.3 Significance of study

The significance of this study is that in the future, organization that involve in construction of low rise buildings would be able to refer to this study as a guide and be able to design their buildings with better understanding of environmental factors.

Failure to design building with good ventilation system will not help the occupant to live in comfort without the help of mechanical system such as air condition that eventually will lead to high consumption of energy and pollute the environment.

As we aware, we are now facing environmental crisis such as green house gases impact, which has significantly increasing the global temperature that eventually will lead to disaster. We are also having energy crisis due to excessive demand and less supply because our energy resources are decreasing. If this situation continuous, we will be facing great economy catastrophe.

As concern to the problem above, most advanced countries especially in Europe and US have started making movement to green concept. However, the green awareness still at low level among Asian countries except for some likes Singapore, Hong Kong and Japan.

The data from this study will help in the future as a reference and guideline and at the same time may give awareness to Malaysian about the importance of green building though the data provided here specifically for ventilation system of low rise building.

1.4 Objective and scope of study

The study aims to provide better ventilation system to those low rise buildings relying on mechanical air-conditioning in tropical region like Malaysia.

Basically it is difficult to determine the human comfort level with regard to temperature since it is because of different nature of human being. However generally people are comfortable under the condition of a good air movement

The experiment on data collection has been done, the data collected will be analyzed and further research will be done in order to increase the accuracy of results. Finally simulation using CFD software will be made and the result will be compared with the data from experiment in order to find the best condition where the air movement can result a comfortable temperature.

Since the ventilation system plays an important part in maintaining the temperature in certain space or room, therefore the right design for the air flow movement system must be provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Green Building or sustainable building design is the idea of designing a building that is in-fitting with the natural features and resources surrounding the site. There are several focuses in designing Green Buildings such as, reducing loads, optimizing systems, and generating on-site renewable energy.

Construction materials normally considered to be Green must include renewable materials such as recycled stone, recycled metal, and other products that are non-toxic, reusable, and renewable.

In order to minimize the energy loads on the building, it is important to set the orientation of the building to get the benefit of wind and sunlight. The sufficient day lighting will reduce the need to turn on electric lights during the day and also it will provide good view of outside. However, for the country like Malaysia, sun light most of the time will produce excessive heat. Good shading system is needed in order to prevent overheating. Well insulated windows, doors, and ceilings and walls help in reducing energy loss; as a result it will reduce energy usage.

Green building also should have to reduce waste of energy, water and materials. For example during the construction period, the amount of material going to landfills should be reduced. Well-designed buildings also help in reducing the amount of waste generated by people by providing onsite solutions such as compost bins to reduce material going to landfills.

Finally, renewable energy using solar power, wind power, hydro power, or biomass can extensively reduce the environmental impact of the building. It is because; power generator is the most expensive element to add into a building.

2.2 Natural ventilation simulation

Wang Liping and Wong Nyuk Hien (2006) conducted study on Natural ventilation simulation with coupling program between building simulation (BS) and computational fluid dynamics (CFD) simulation program for accurate prediction of indoor thermal environment. They stated that passive cooling of houses using natural ventilation has become an attractive alternative to alleviate problems associated with air-conditioning such as energy shortage, global warming and sick building syndromes. Various mechanical systems including heating, ventilation and air-conditioning (HVAC) systems in residential and office buildings contribute substantially to the energy consumption. In the United States, building services use more than one third of the primary energy consumption and two thirds of all electricity (U.S. Energy Information Administration 1995).

As the benefits of natural ventilation, including reducing operation cost, improving indoor air quality and providing satisfactory thermal comfort in certain climates, are being acknowledged, there is a growing interest in the natural ventilation of buildings. The concept of natural ventilation is well accepted and welcomed by people and designers in the world. Even in hot-humid climates, where air-conditioners are common in both residential and commercial buildings, HDB (Housing Developing Board) residential buildings, where about 86% people in Singapore live, are designed to be naturally ventilated.

However, natural ventilation is difficult to design and control although the principle itself s simple. Furthermore, because of the excessive amount of moisture in the air and intensive olar radiation, many passive cooling design strategies are difficult to be realized in hot and umid regions. The success of a naturally ventilated building is decided by a good indoor limate, which influences its sustainability. For this reason, naturally ventilated building design n hot-humid climates need to pay more attention to orientations, shading devices, material elections, window sizes and positions. Therefore, the optimization and evaluation of the facade ystem in naturally ventilated buildings are significant in natural ventilation designs. Because of ime and budget constraints, only few cases could be measured on site or modeled in wind tunnel xperiment. Large amount of parametric study on facade can only depend on simulations.

However, there are no available tools which could accurately predict natural ventilation for various facade designs.

Currently, simulation methods for natural ventilation could be divided into two types: Computational fluid dynamics method (CFD) and building simulation method (BS). CFD simulation could provide detailed air temperature, air velocity, contaminant concentration within the building or outdoor spaces. It has become a reliable tool for the evaluation of thermal environment and contaminant information. However, the application of CFD for natural ventilation prediction has been limited due to long computational time and excessive computer resource requirements. On the other hand, building simulation (BS) tools could greatly facilitate energy efficient sustainable building design by providing rapid prediction of facade thermal behaviors, indoor air flow of the building and better understanding of the consequences of various design decisions, through solving the heat and mass transfer and airflow network in the building systems. However, BS programs assume the indoor air is completely mixed and uniform; so BS results could only provide the uniform results for targeted spaces, which normally does not meet our requirements for detailed indoor environment evaluation. The airflow network method for airflow estimation in building simulation can not accurately predict indoor airflow. Therefore, the integration of the BS and CFD simulation could provide a quick and more accurate way to assess the performance of natural ventilation in whole buildings, as well as detailed thermal environmental information in some particular spaces. There is urgent need to provide an efficient coupling program between BS and CFD to predict natural ventilation efficiently and accurately.

2.3 Temperature impact on ventilation

Agung Murti Nugroho Mohd Hamdan bin Ahmad (2005) conducted study about Possibility to Use Solar Induced Ventilation Strategies in Tropical Conditions by Computational Fluid Dynamic Simulation. In the study, they stated that in tropical climatic regions passive cooling is one of the most difficult problems to solve. The simplest and the most effective solution for active cooling is to introduce air conditioning. However, such equipment involves high initial and operational costs for installation, energy and maintenance. Therefore air conditioners are unlikely to be applied widely, in particular, for residential building. Thus, a passive cooling system is more desirable. Although in Malaysia, passive cooling method is a popular cooling strategy adopted in residential building, researches (Pan, 1997; Tan, 1997; Jones, 1993; Zulkifli, 1991; Hui, 1998; Abdul Razak, 2004) have shown that its natural ventilation performance could not provide internal thermal comfort. Climate conscious design in the equatorial tropic assumes that air movement is one of the main cures for thermal comfort ills. According to Hui (1998), the indoor air velocity in low rise building range between 0.04m/s – 0.47 m/s. The reasons may be due to inappropriate design solutions for indoor air movement or low outdoor air velocity remains to be determined. However, recent data from the Malaysian Meteorogical Service Department showed that mean outdoor air velocity is between 1 m/s to 1.5 m/s.

In theory, there are two natural ventilation mechanisms (ASHRAE, 1997). First is by wind pressure and the second is by temperature difference or stack effect. Both mechanisms have the same aim, which is to act as an aid to create air movement and consequently control the indoor air temperature (Abdul Razak, 2004). Natural ventilation may result from air penetration through a variety of unintentional openings in the building envelope, but it also occurs as a result of manual control of building's openings doors and windows. Air is driven in and out of the building as a result of pressure differences across the openings, which are due to combined action of wind and buoyancy-driven forces. Today, natural ventilation is not only regarded as a simple measure to provide fresh air for the occupants, necessary to maintain acceptable air-quality levels, but also as an excellent energy-saving way to reduce the internal cooling load of housing located in the tropics. Depending on ambient conditions, natural ventilation may lead to indoor thermal comfort without mechanical cooling being required.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.0 METHODOLOGY/ PROJECT WORK

3.1 Methodology

The goal is to do simulation using CFD software (Gambit and Fluent) and to compare the result between experimental and simulation. The scope has been narrowed down to the research on the natural ventilation in low rise building, finding the accuracy data between experimental and simulation and understanding the relation of air movement with the thermal comfort in particular space in the building will be the primary objective in this study.

The subjective measurement will be done if there is enough time to do the more experiments and simulations with different parameters.

The methodologies are as follow:

Firstly, collect and summarize all data regarding to the air movement (velocity and direction) outside and inside the particular house (low rise building) in UTP. Two different rooms with near similar characteristics such as occupancy level, size and internal design but with different orientation is been observed. It is to make sure the data collected are precise, comparable and to minimize error. Secondly, collect all the data regarding the air flow. The data collection activity has been done for two days. Thirdly, reduce the number of parameters that are being considered so that the analysis will not be too complicated. Fourthly, compare the relation of air movement with the temperature. Fifthly, doing the simulation using CFD software (Gambit and Fluent) and compare the result between theory and experiment .Finally find the best condition where the air movement can result a comfortable temperature and draw the conclusion.

3.2 Project Flow Chart

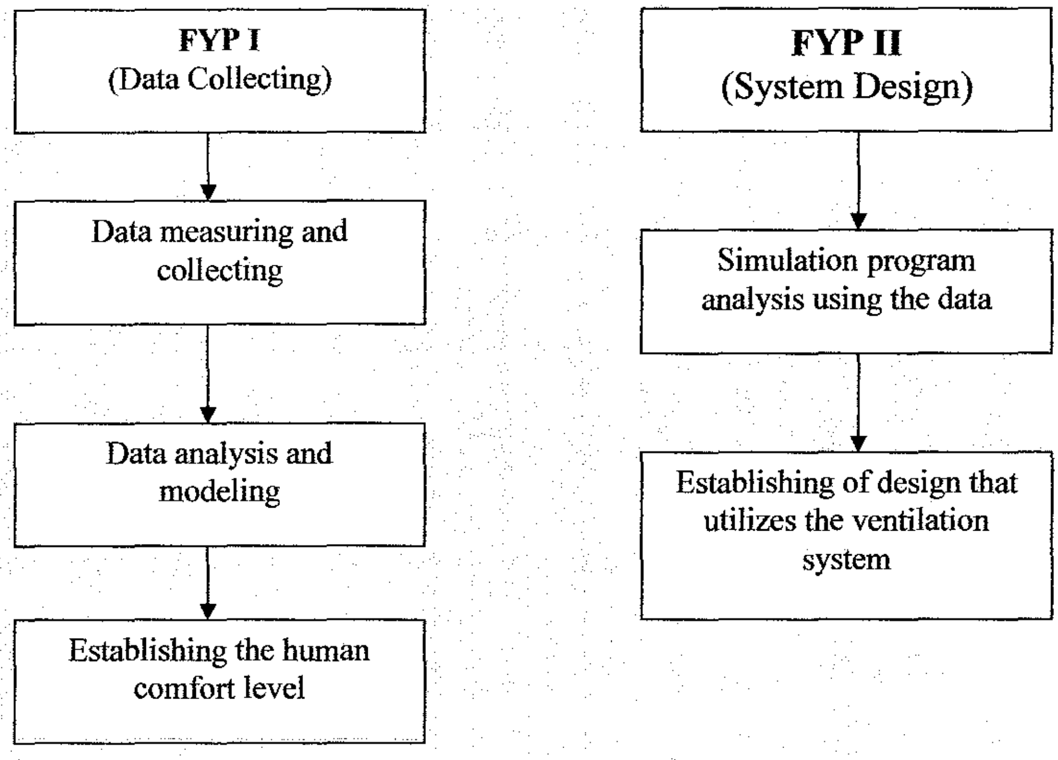

Figure 1: Project Flow Chart

3.3 Tools/Equipment Required

The tools and equipments required in this study were thermal sensors, wind gauge, data logger and Windows based PC together with the CFD software programs that are Gambit and Fluent to do simulation and other programs such as Microsoft Office and excel which is to analyze and compare the data obtained from the experiment and simulations. The thermal sensor was used to measure the temperature for the particular time while the data logger collects the data (temperature) automatically and put it into memory. Wind gauge was used to determine the wind direction and velocity for the particular day. Gambit was used to sketch the building dimension while the Fluent was used to the simulation of the wind flow and temperature in the particular space in the building. Microsoft Office programs include Microsoft Word used to type reports, Microsoft Excel to draw graphs and rearranging of data.

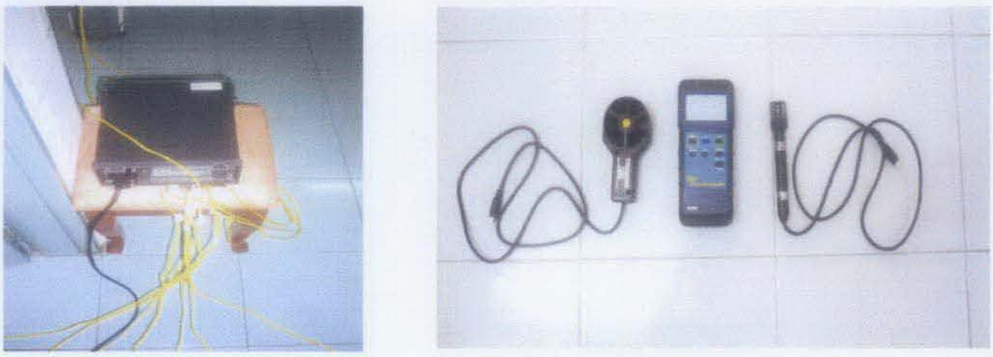

Figure 2: The data logger and anemometer

3.4 Hazard Analysis (HSE)

Hazard is defined as something that can cause harm to us. Since this experiment doesn't include any laboratories activities and also does not use any chemicals properties, so the biological and chemical hazard will not be put into account. Anyway there are still physical hazard that need to be considered.

3.4.1 Physical Hazard

There are several physical hazards that included in this study.

1. **Electrical equipments.**

   The electrical equipments that will be used are lap top and laboratory computer. Therefore safety precaution must be taken when using the equipments. The safety step must be taken for all at the site. All the system must be carefully arranged in order to avoid any accident risk.

2. **Traffic roads.**

   Since the activities require me to do lot of travels, so generally I will expose to the road traffics. So in order to reduce the risk during travel on the road, all the road safety precaution must be taken. All the travels must be well planned in order to reduce any risk.

CHAPTER 4

RESULTS AND DISCUSSION

The results obtained from the experiment and the simulation progresses and result were shown in below. However the data collected are limited due to limited time of experiment. In this study the simulation was done in 2D and limited to certain condition of room. In order to get more precise and comparable data, the experiment on collecting data need to be done at least for a week and the simulation also need to be done in 3D with several condition and factor count.

The pictures below show some activities during the experiment session.

Picture 3: Room humidity test

Picture 4: Data taking from data logger

Picture 5: Wind velocity tes

4.1 House location and layout

The house for the experimental purpose located at house no 3 as shown below. It was chosen due to availability.

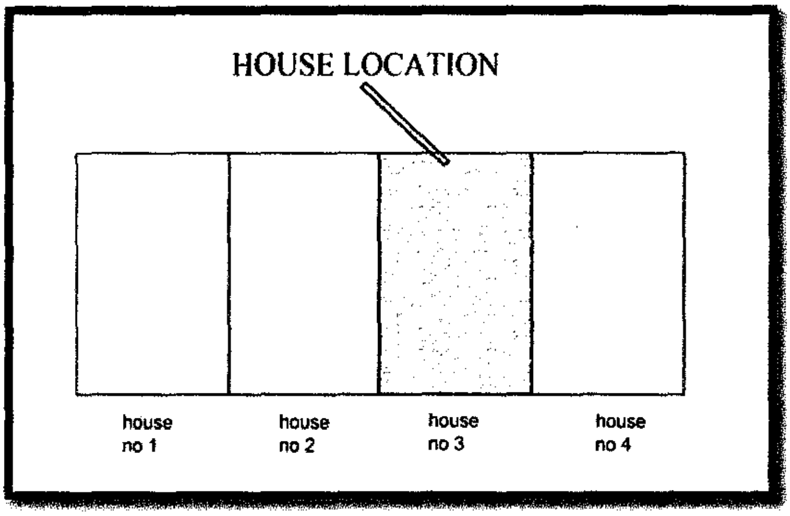

Figure 6: The house location

The house contains 2 rooms, 1 kitchen, and 1 toilet. The master bedroom's window facing the east direction and the single bedroom's window facing the west direction. The house layout is as follows:

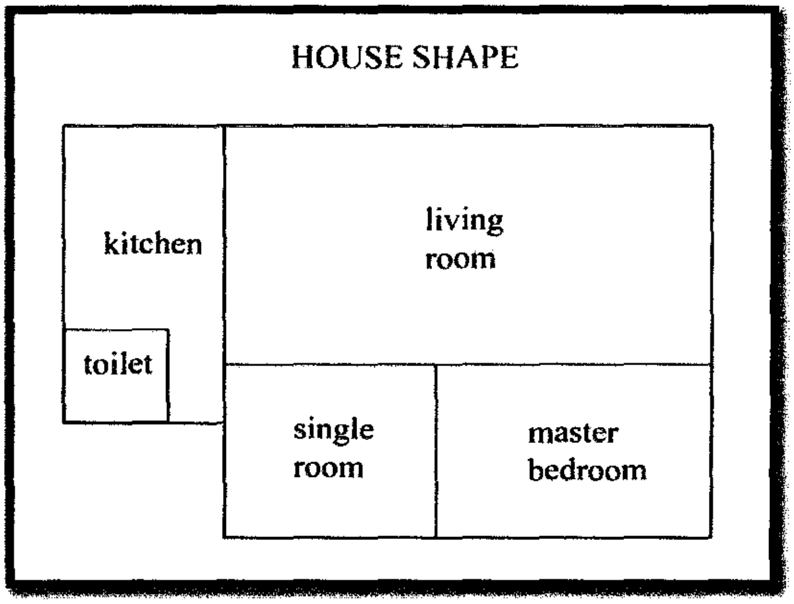

Figure 7: The house layout

For every room, we placed 5 sensors probe at different location as shown in the picture below. All the fan and air condition were shut off. The wind data was taken in front of the house (at the porch), in the middle of each room and at the back of the house (backyard). The humidity data was taken in every room. The details are as follows:

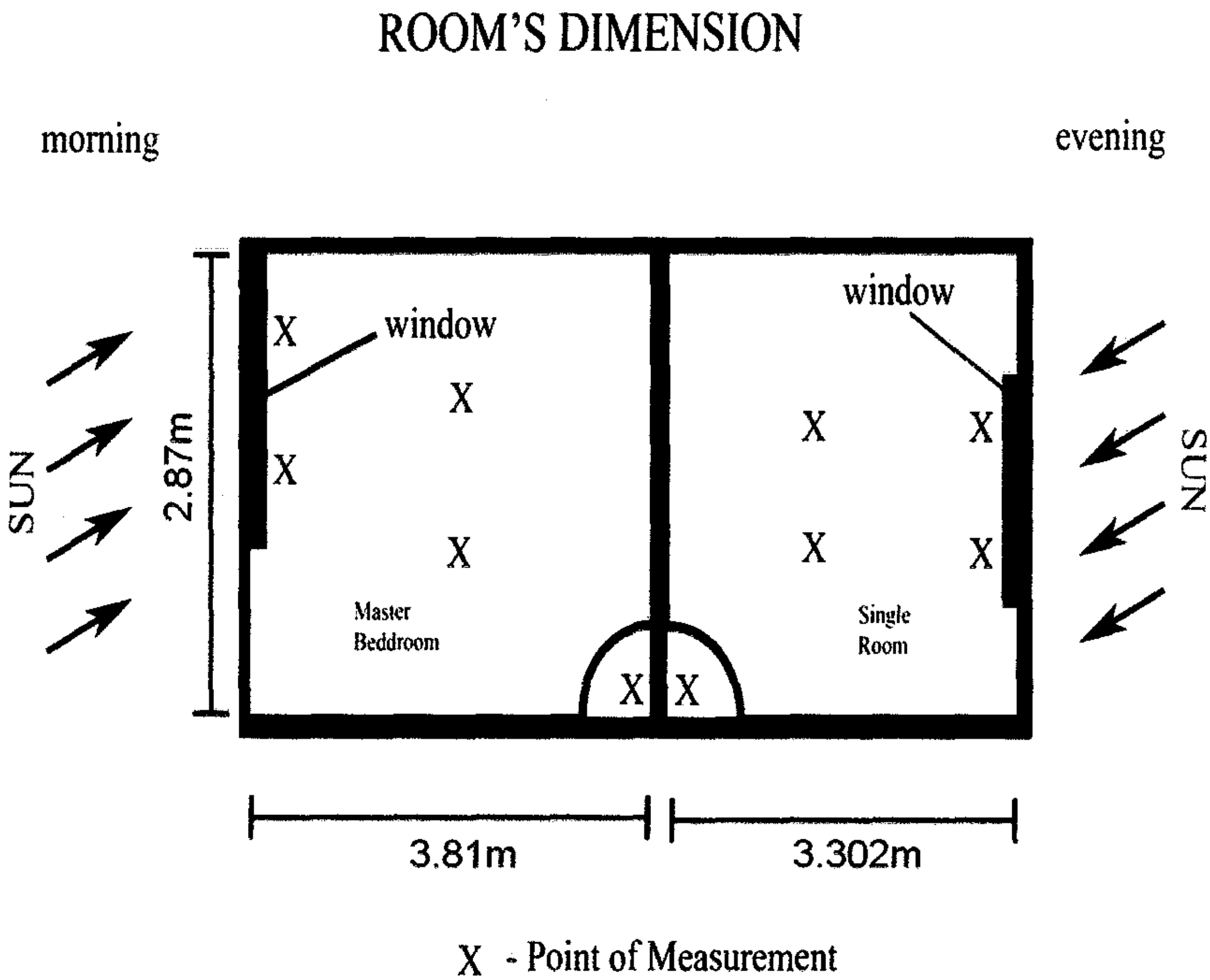

Figure 8: The room's details

4.2 DATA FOR: SATURDAY, 19 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	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

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	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 25°	E 45°	0.3	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

*** Please refer the house layout to see the allocated points**

4.3 DATA FOR : SUNDAY, 20 APRIL 2008

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°	-	0.5	75.3
1300	31.3	31.2	31.2	31.9	32.0	N30°	N20°	0.5	0.7	73.3
1400	31.2	31.0	31.2	31.2	31.4	E10°	W30°	0.1	0.4	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

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

*** Please refer the house layout to see the allocated points**

4.4 Discussion for the Experiment result.

The data shows a difference of temperature and wind data. For the temperature difference, the temperature in the morning was recorded between 27 – 28 °C, at 8.00a.m. The temperature increase as the time moves, showing that both rooms received the sun light. However, the temperature inside the master bedroom is higher in the morning, since the master bedroom orientation is towards the east direction (sun rise direction).

Generally the wind direction is from north to south, which is opposite the house opening. As a result, there is no wind recorded for master bedroom, but for single bedroom, the wind able to go through into the room as there is a wall (kitchen's wall) perpendicular to the wind direction. This wall reflects the wind into the single bedroom's window.

The humidity on the rooms is measured using the anemometer. Generally both rooms have slightly equal humidity records, and this value is lower in the afternoon, as warm air enters the house. The single room is more comfort compare with the master bedroom because the temperature is lower compared to master bedroom (heat from the sun and the wind factor).

4.5 Room's sketching for simulation.

The room was sketched using Gambit software the simulation for thermal condition can be done using Fluent software. For this case we choose to use 2D rather than 3D analysis due to time constrain and less expertise in CFD software. 3D simulation will be done later in order to increase the accuracy of the result.

The room sketching is as follows:

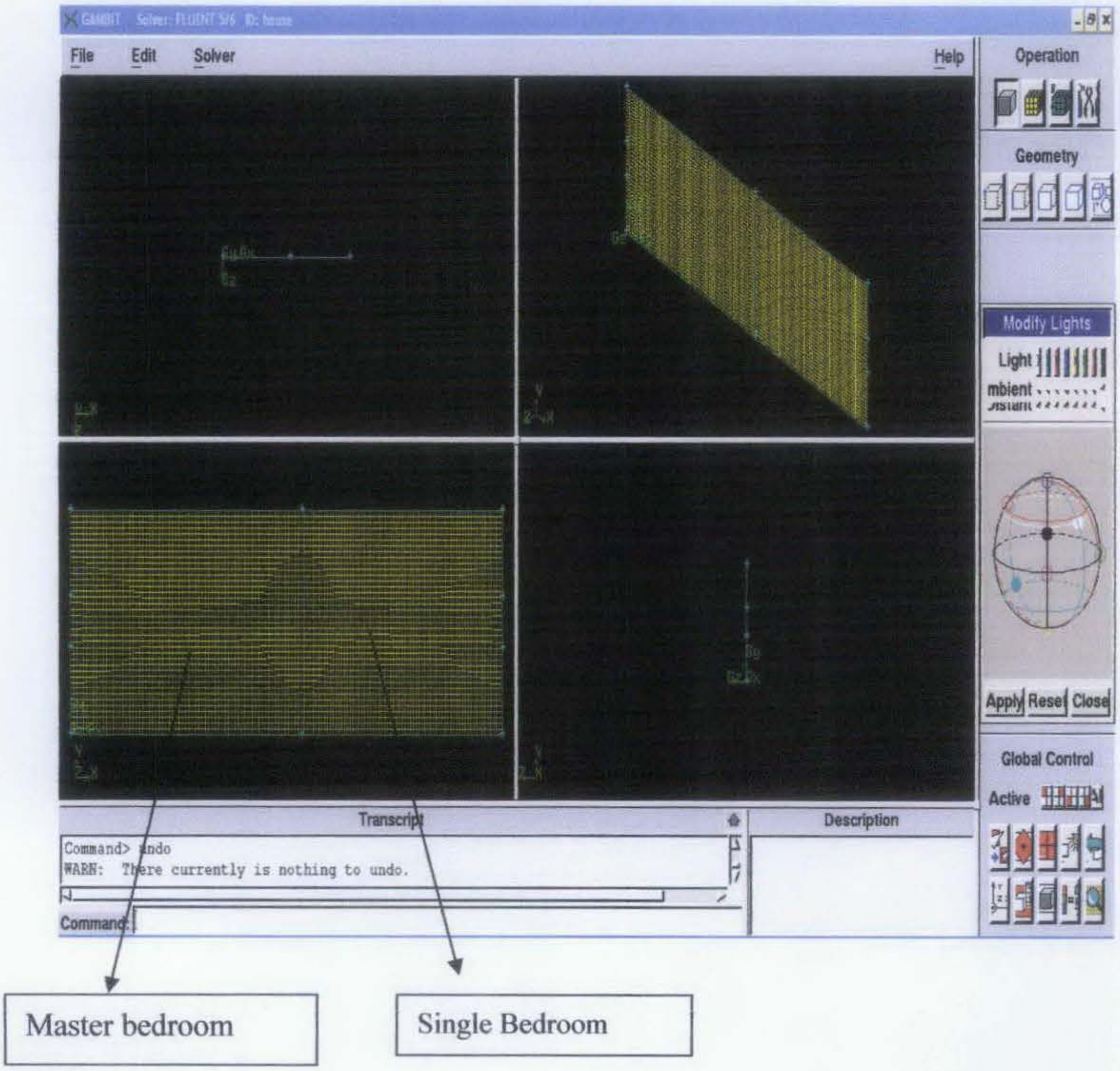

Figure 9: The room's sketch in Gambit software

After the sketching work in Gambit software, we import the file to Fluent software for further analysis that is to simulate the thermal condition in the sketched area.

The importing file progresses are as follow:

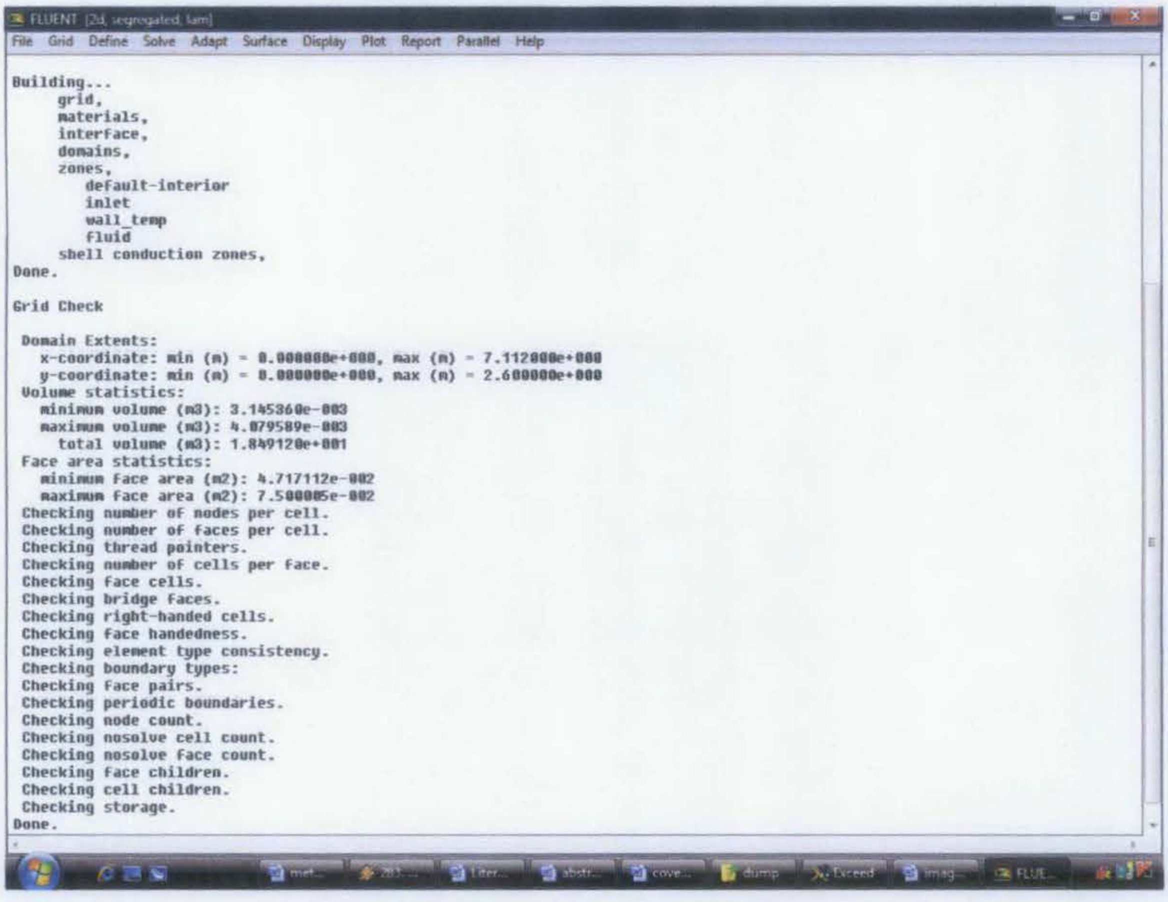

Figure 10: Checking the file format.

After import the file, pre simulation is done to make sure it is work before key in the required parameters for further analysis.

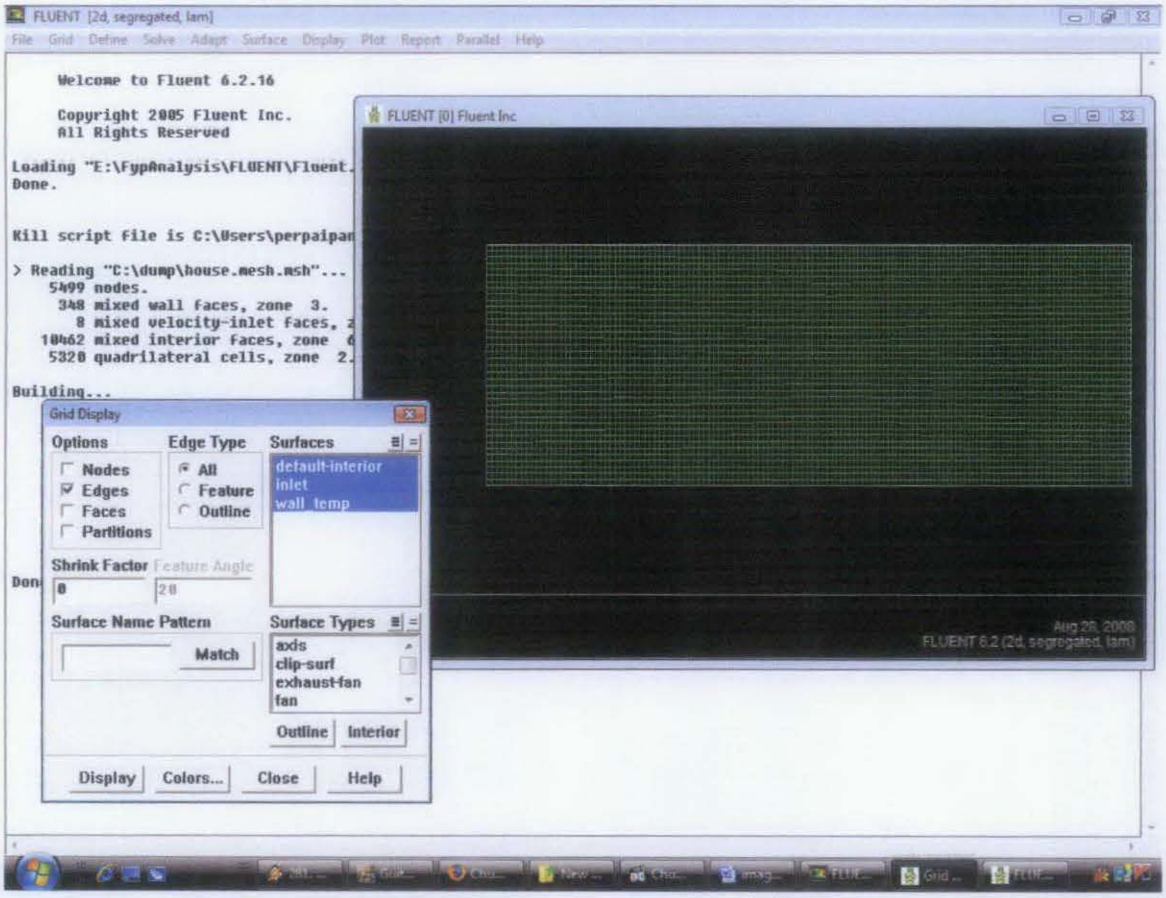

Figure 11: pre simulation before inserting the parameters.

Bedroom properties

BEDROOM PROPERTIES

- Weather : Dry sunny day
- Wind Velocity (master bedroom) : 0.3 m/s
- Wind Velocity (Single bedroom) : 0.5 m/s
- Wall Thickness : 0.1 m
- Humidity (master bedroom): 74.1%
- Humidity (Single bedroom) : 73.3%

AIR PROPERTIES

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

MASONRY WALL PROPERTIES

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

4.6 Simulation Result

4.6.1 Master Bedroom (Plan View)

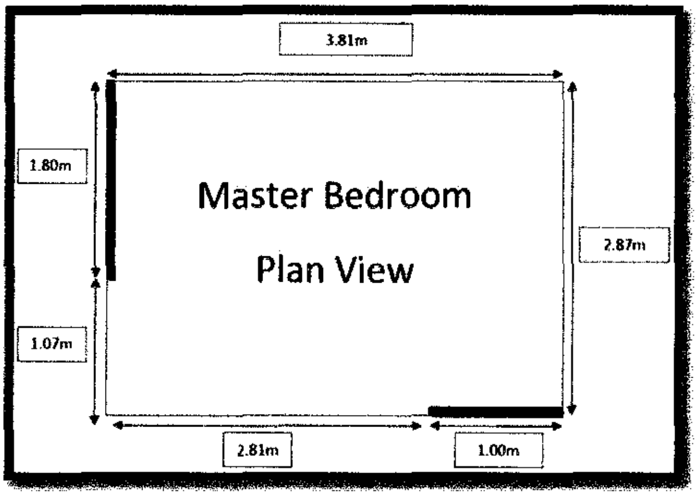

Figure 12: Master bedroom's original plan view and dimension.

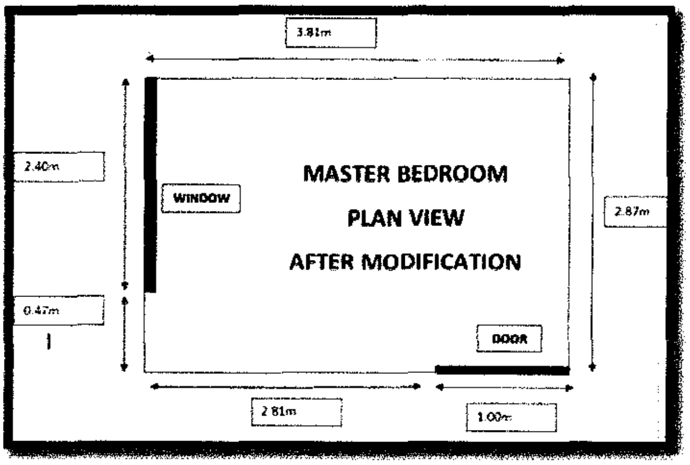

Figure 13: Master bedroom's plan view and dimension after modification (Increase window's width)

i. Air velocity (ventilation) – Without modification

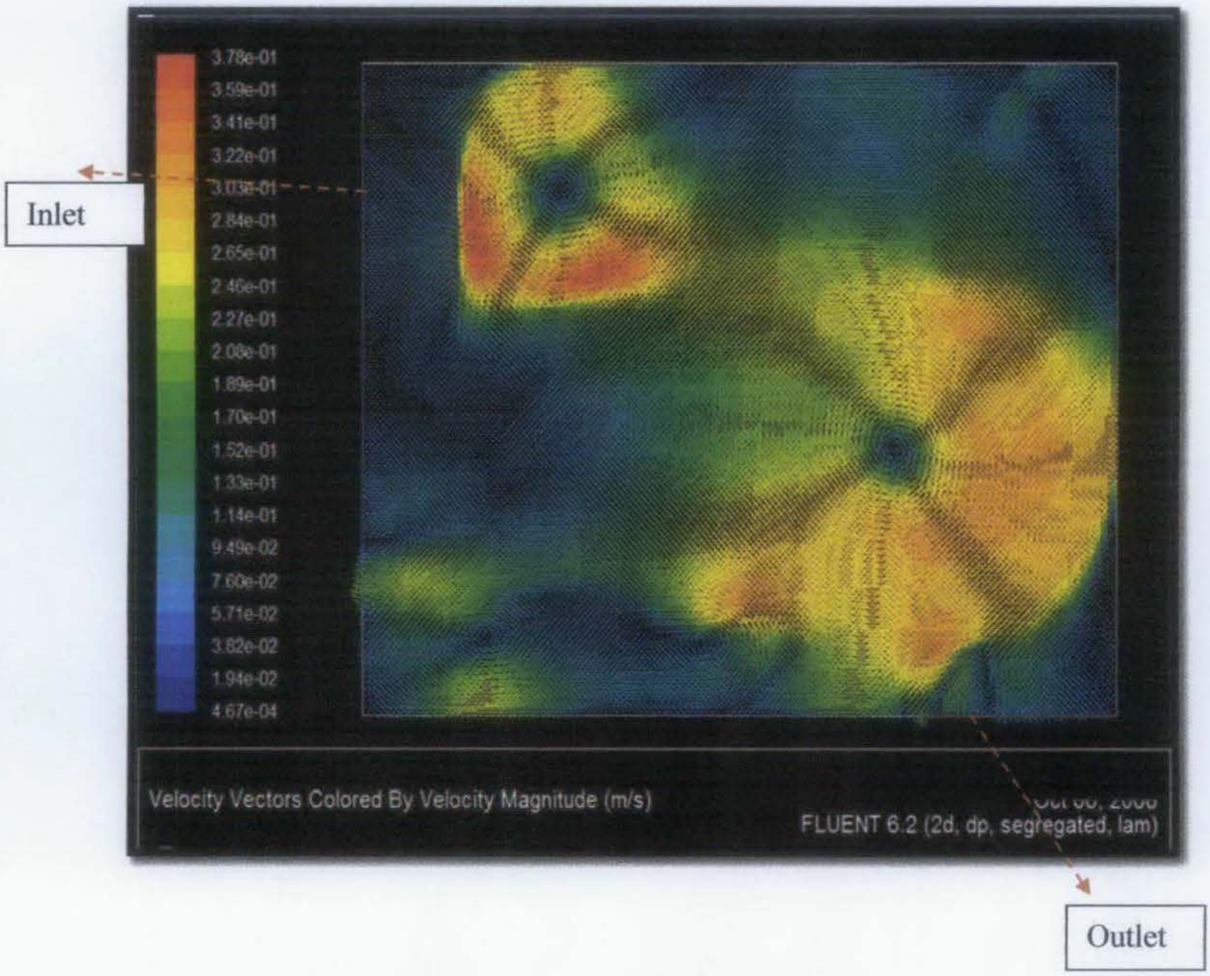

Figure 14: Simulation result of air velocity without modification

- The velocity range is from 4.67x10-4m/s – 3.78x10-1m/s
- From the experimental data, the velocity in the room is 0.30m/s.
- The simulation result is almost same with the experimental result.

ii. Air velocity (ventilation)- After modification

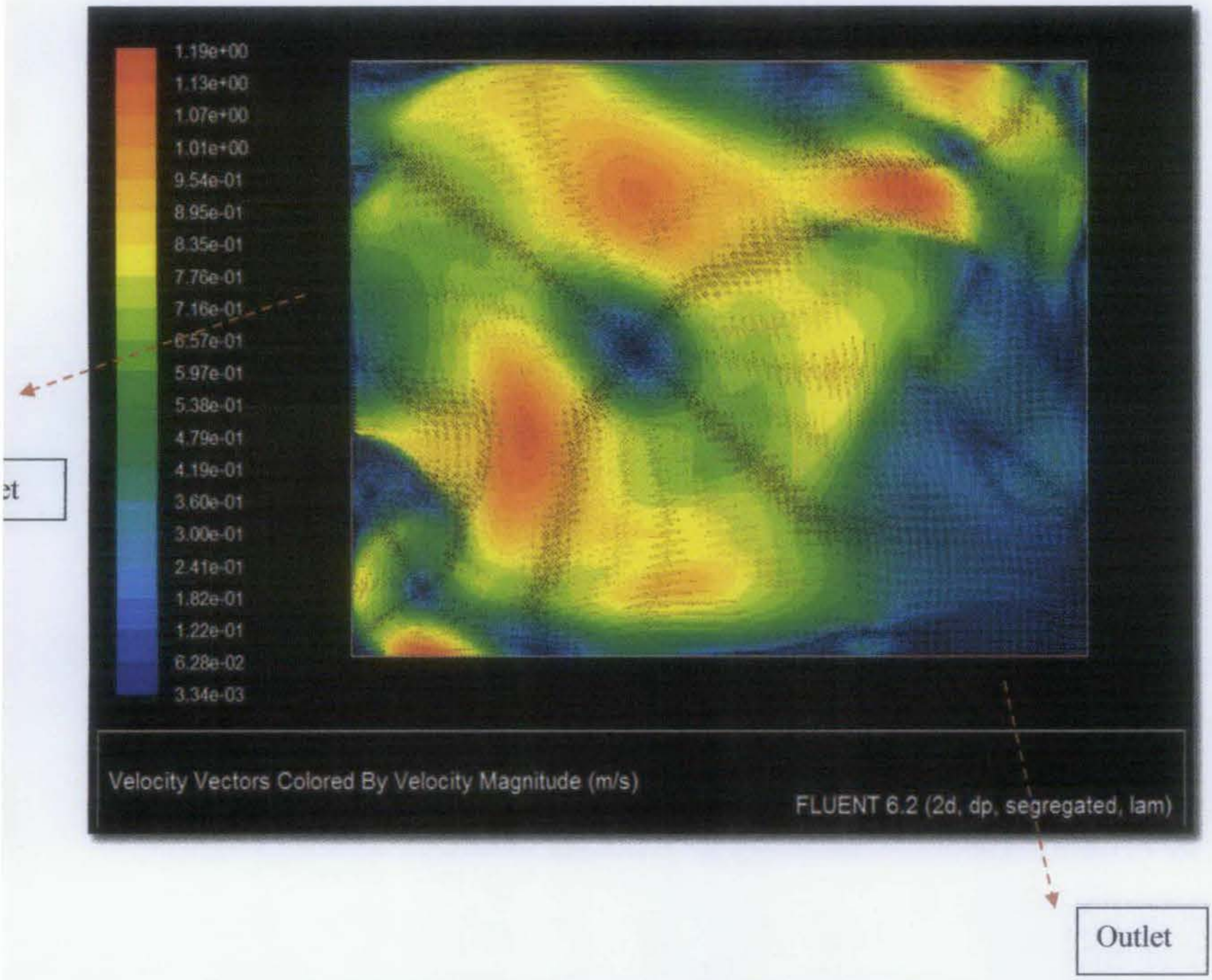

Figure 15: Simulation result of air velocity after modification

- The velocity range is from 3.34x10-3m/s – 1.19m/s
- From the experimental data, the velocity in the room is 0.30m/s.
- After the modification the air velocity has increase to 1.19m/s at maximum spot which higher than the air velocity without modification.

iii. Temperature – Without modification

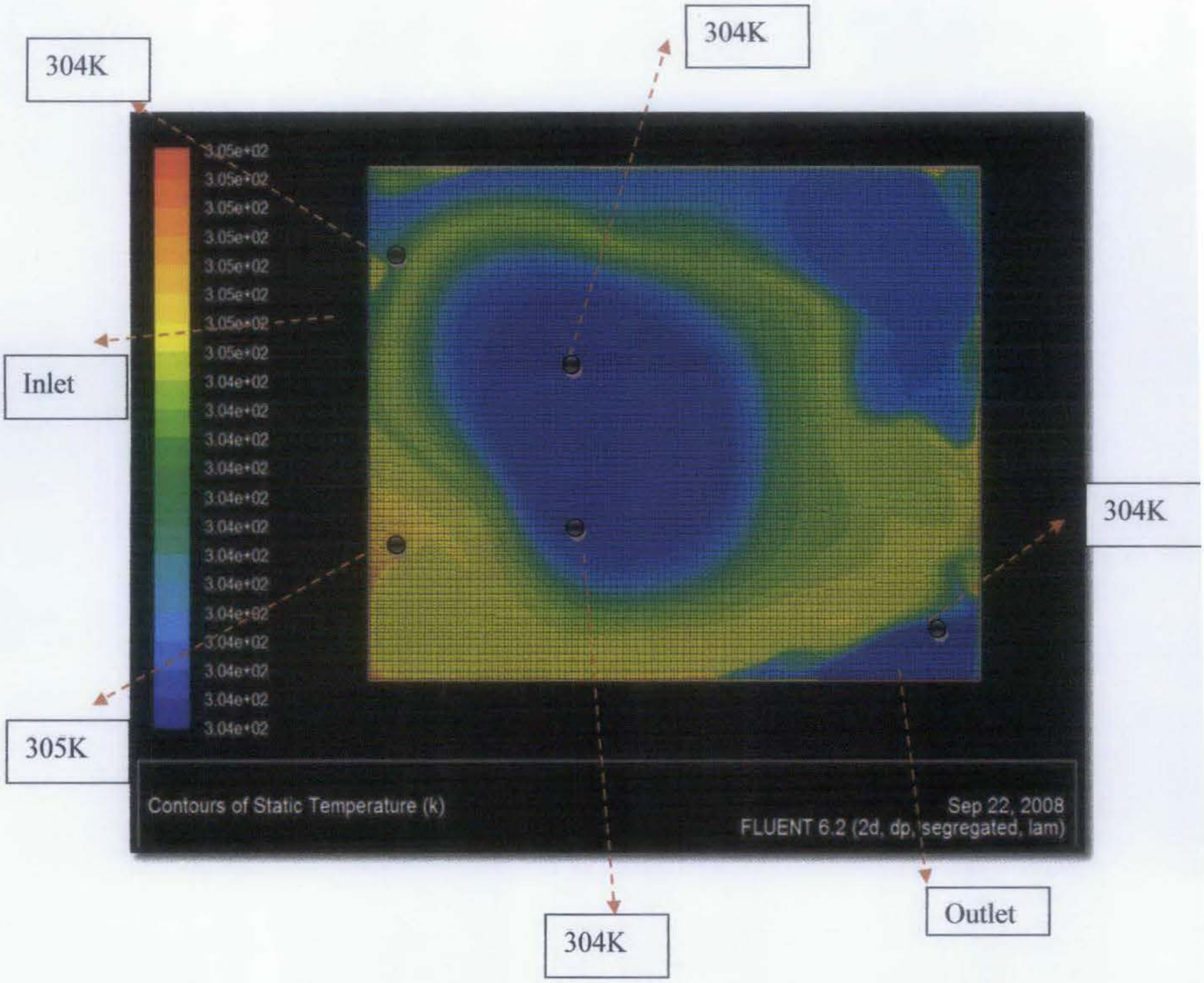

Figure16: Simulation result of room temperature without modification

- The temperature range is from 304K – 305k
- From the experimental data, the temperature in the room is 303.4K – 305.4K (Refer figure 14)
- The simulation result is almost same with the experimental result.

iv. Temperature – After modification

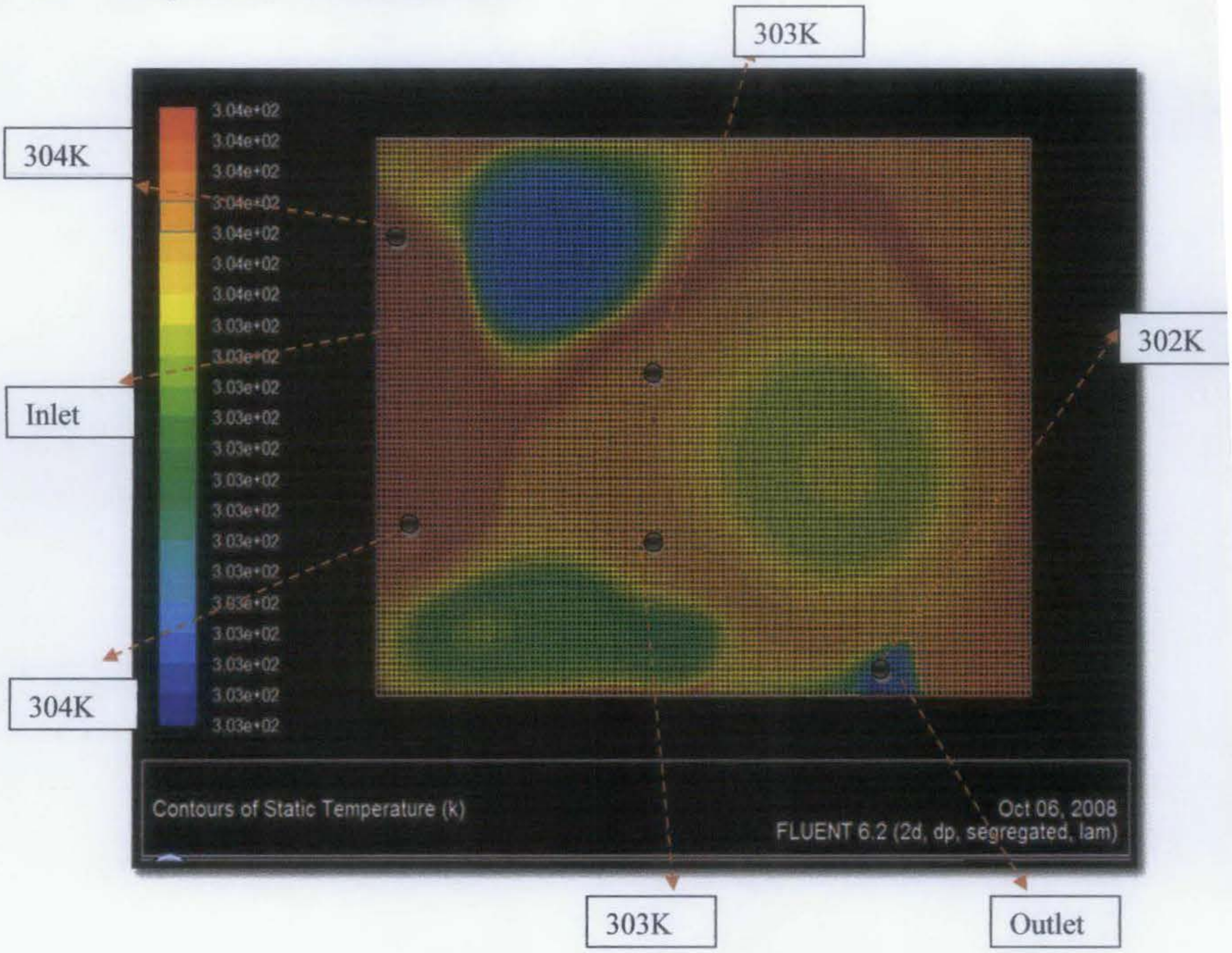

Figure 17: Simulation result of room temperature without modification

- The temperature range is from 302K – 304K
- From the experimental data, the temperature in the room is 303.4K – 305.4K (Refer figure 14)
- After the modification the temperature has decrease to the range 302K – 304K which is lower than room temperature before modification.

4.6.2 Master Bedroom (Side View)

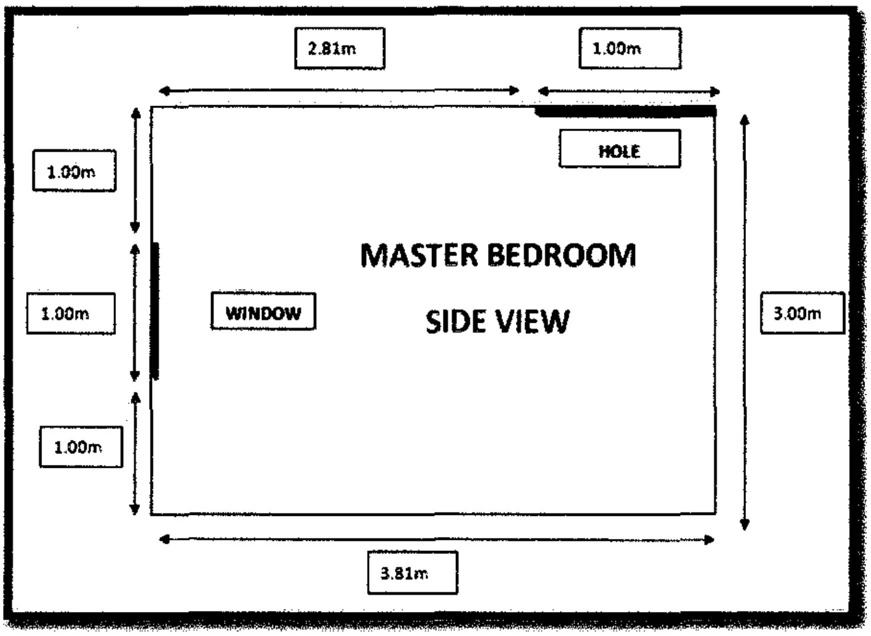

Figure 18: Master bedroom's original side view and dimension.

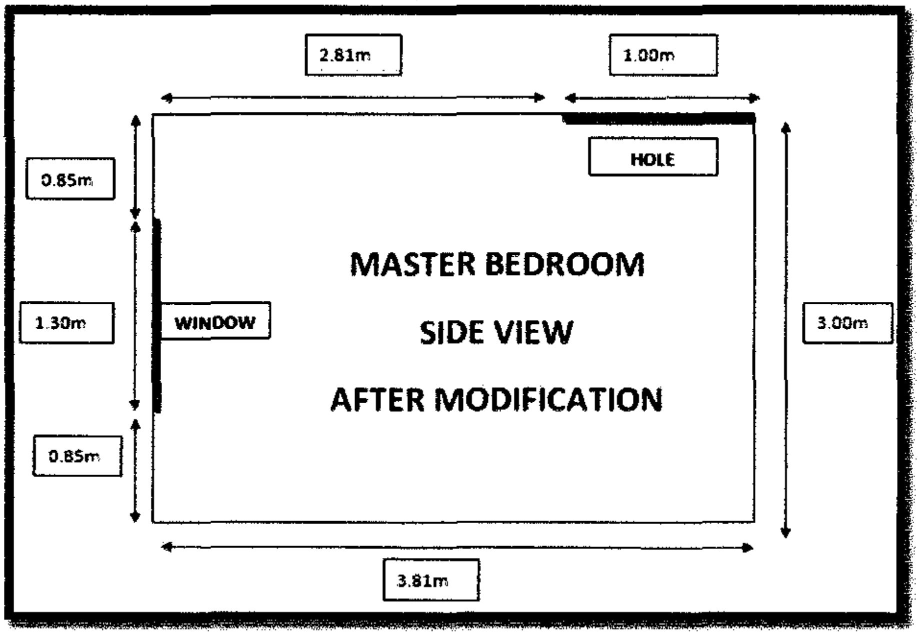

Figure 19: Master bedroom's side view after modification
(Increase window's height)

i. Air velocity (ventilation) – Without modification

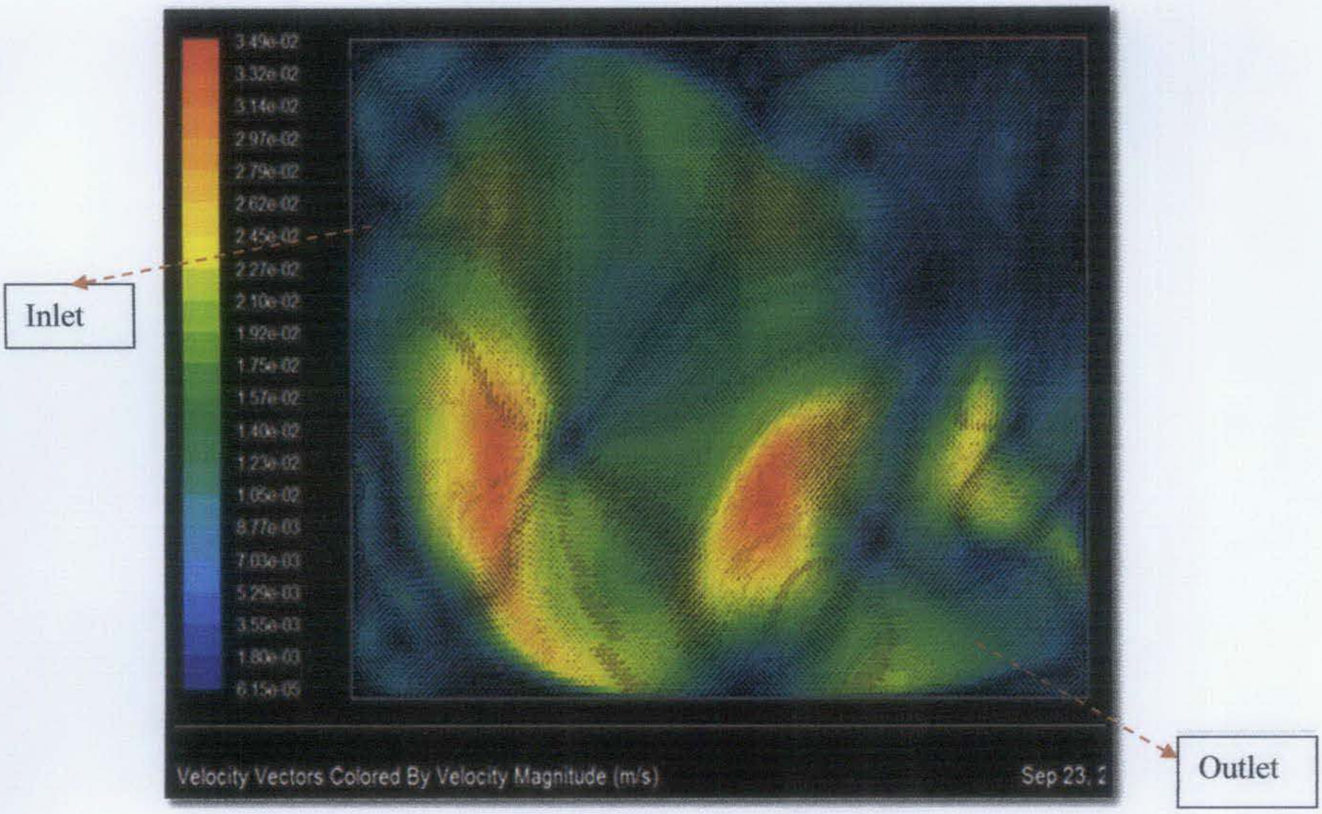

Figure 20: Simulation result for Master bedroom without modification (side view)

- The velocity range is from **6.15×10^{-5}m/s – 3.49×10^{-2}m/s**

ii. Air velocity (ventilation) – After modification

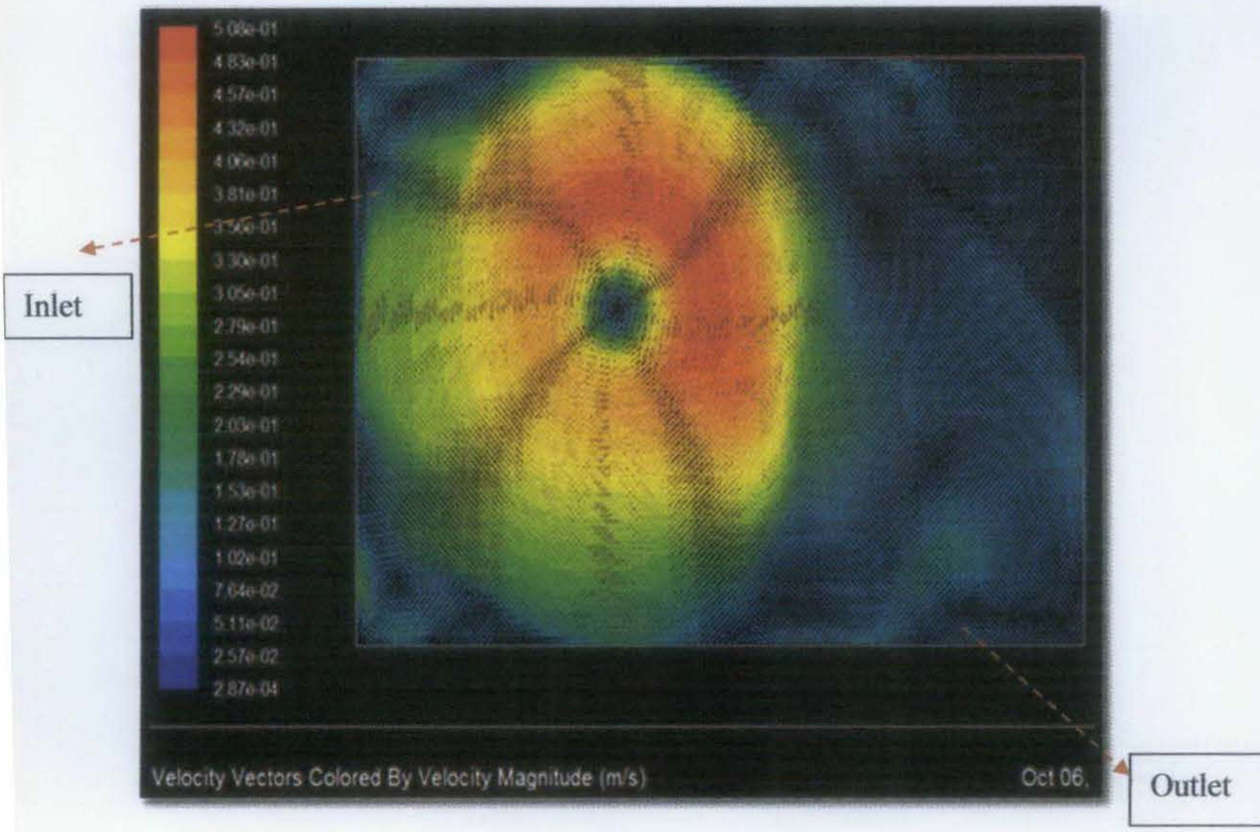

Figure 21: Simulation result for Master bedroom after modification (side view)

- The velocity range is from **2.87×10^{-4}m/s – 5.08×10^{-1}m/s**
- After the modification the air velocity has increase to **5.08×10^{-1}m/s** at maximum spots which is higher than the air velocity without modification.

4.6.3 Single Bedroom (Plan View)

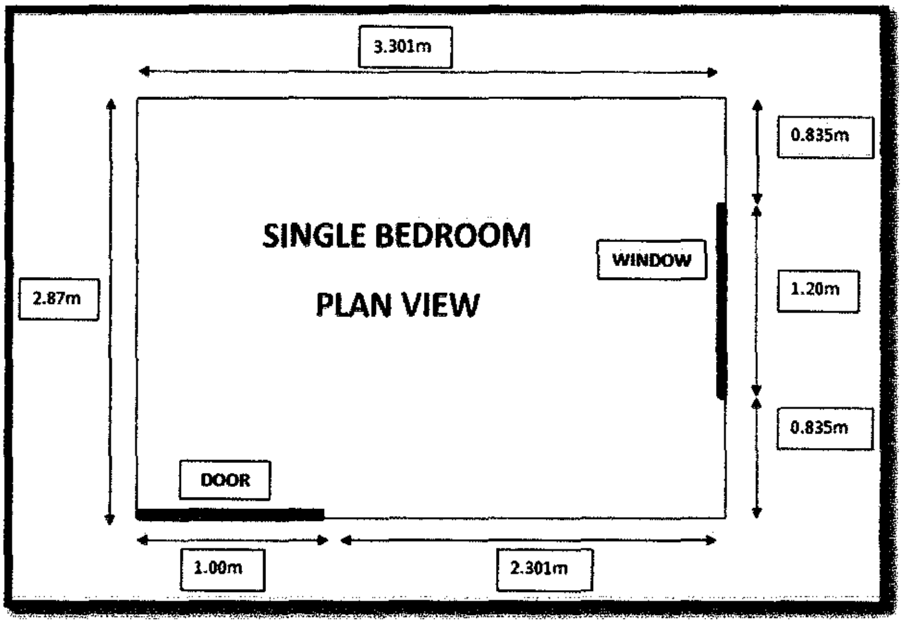

Figure 22: Single bedroom's original plan view and dimension.

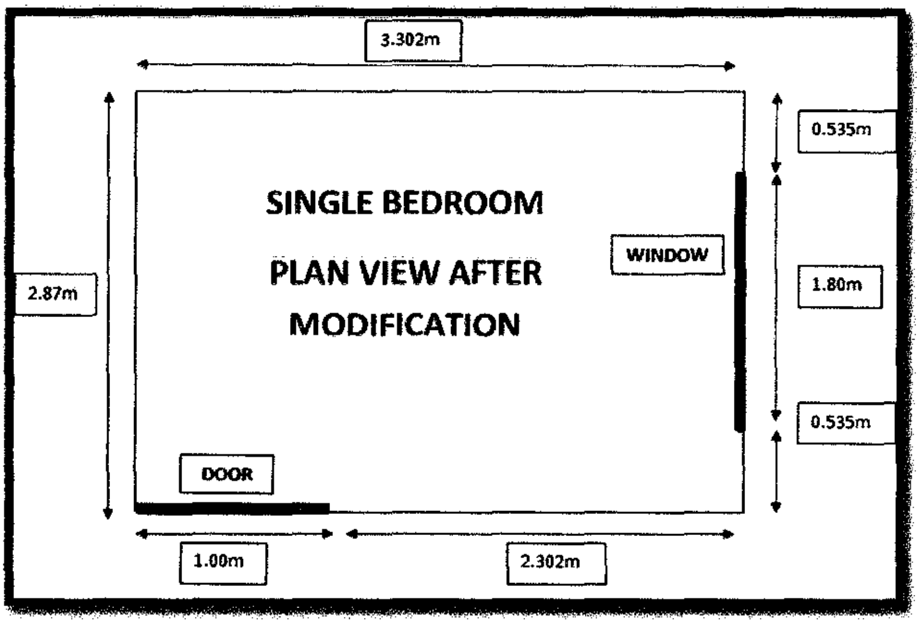

Figure 23: single bedrooms after modification plan view and dimension.

i. Air velocity (ventilation) – Without modification

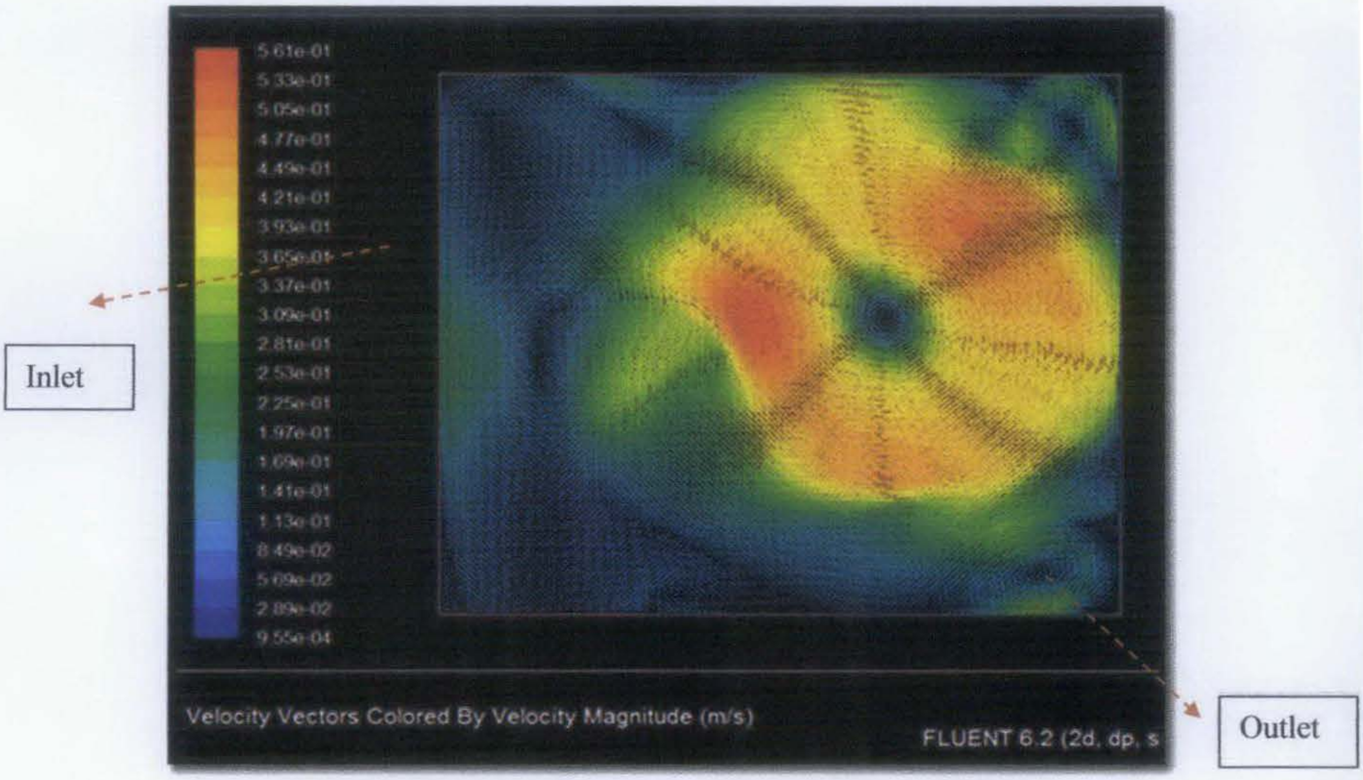

Figure 24: Simulation result for single bedroom without modification

- The velocity range is **from $9.55x10^{-4}$m/s – $5.61x10^{-1}$m/s**

ii. Air velocity (ventilation) – Without modification

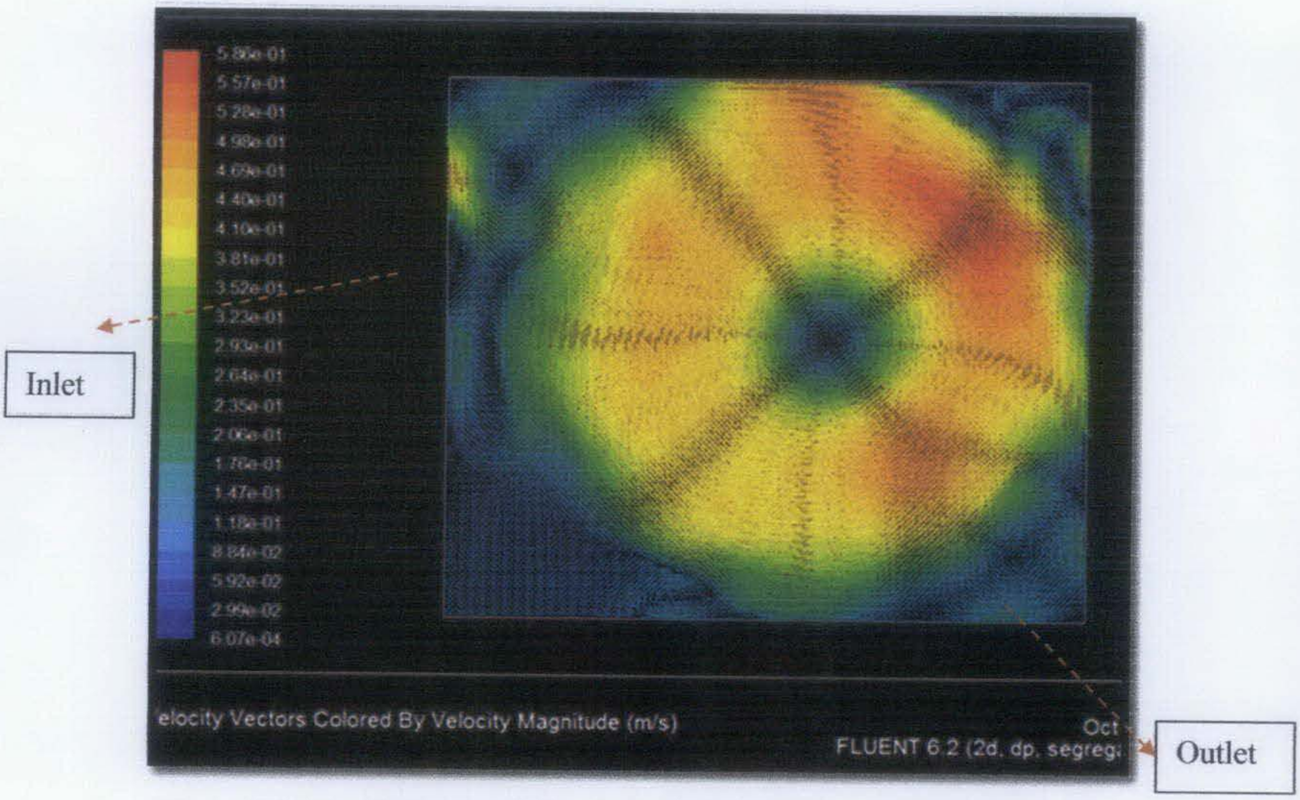

Figure 25: Simulation result for single bedroom after modification

- The velocity range is from **$6.07x10^{-4}$m/s – $5.86x10^{-1}$m/s**
- After the modification the air velocity has increase to **$5.86x10^{-1}$m/s** at maximum spots which higher than the air velocity without modification.

4.6.4 Single Bedroom (Side View)

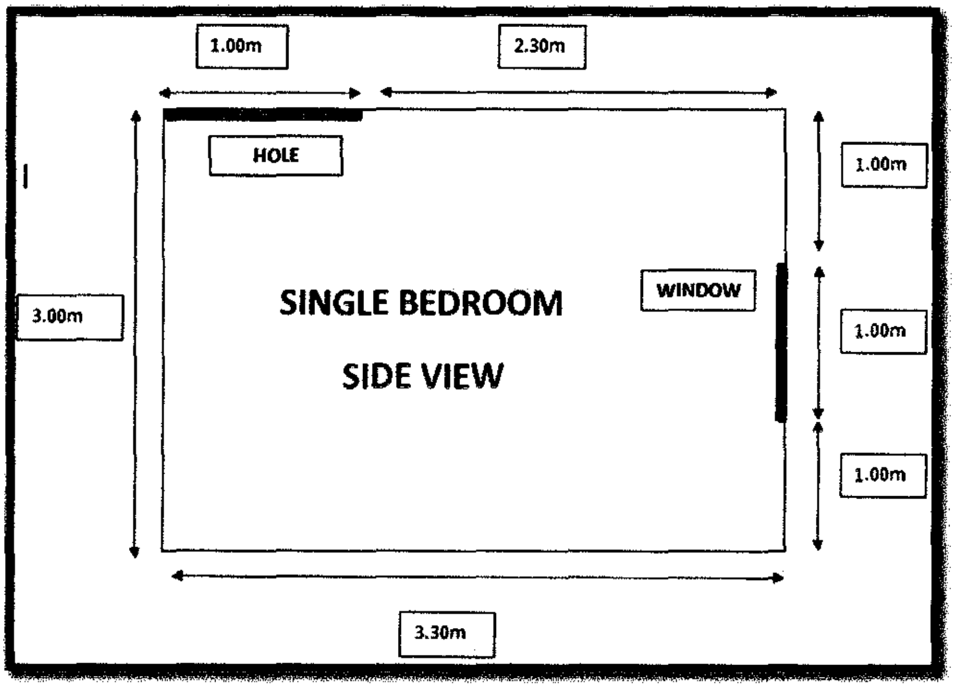

Figure 26: Single bedroom's original side view and dimension.

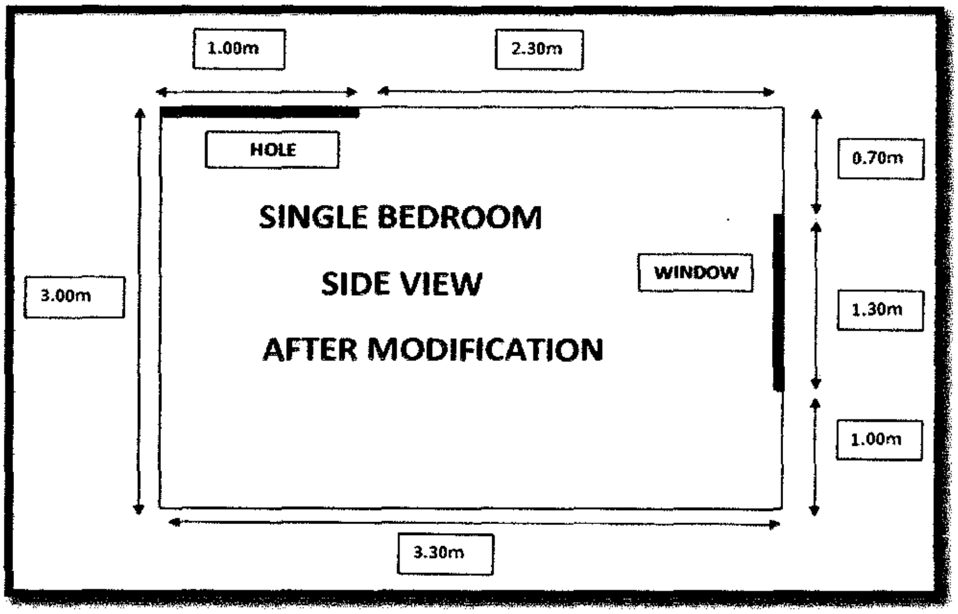

Figure 27: Single bedroom's after modification side view and dimension.

i. Air velocity (ventilation) – Without modification

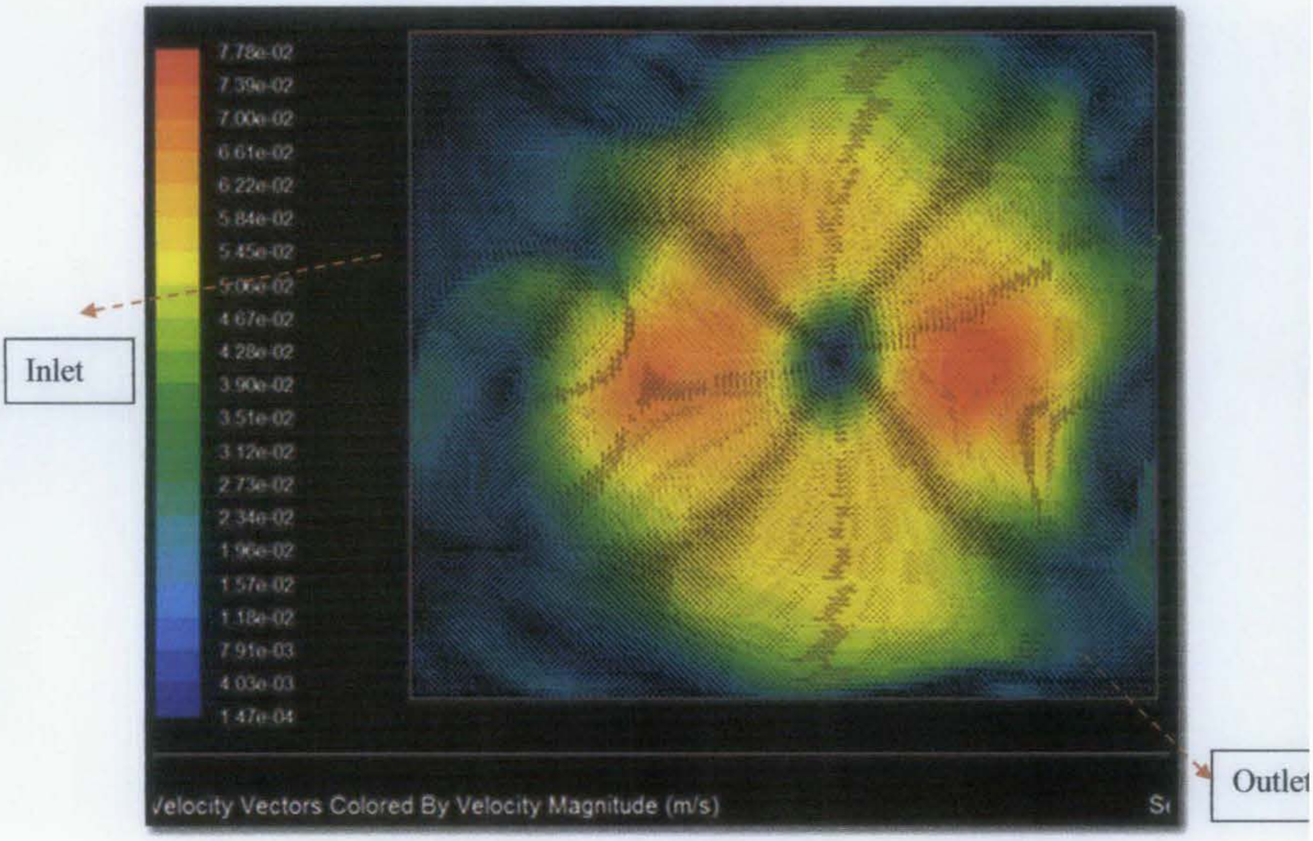

Figure 28: Simulation result for single bedroom without modification (side view)

- The velocity range is from **1.47×10^{-4}m/s – 7.78×10^{-2}m/s**

ii. Air velocity (ventilation) – Without modification

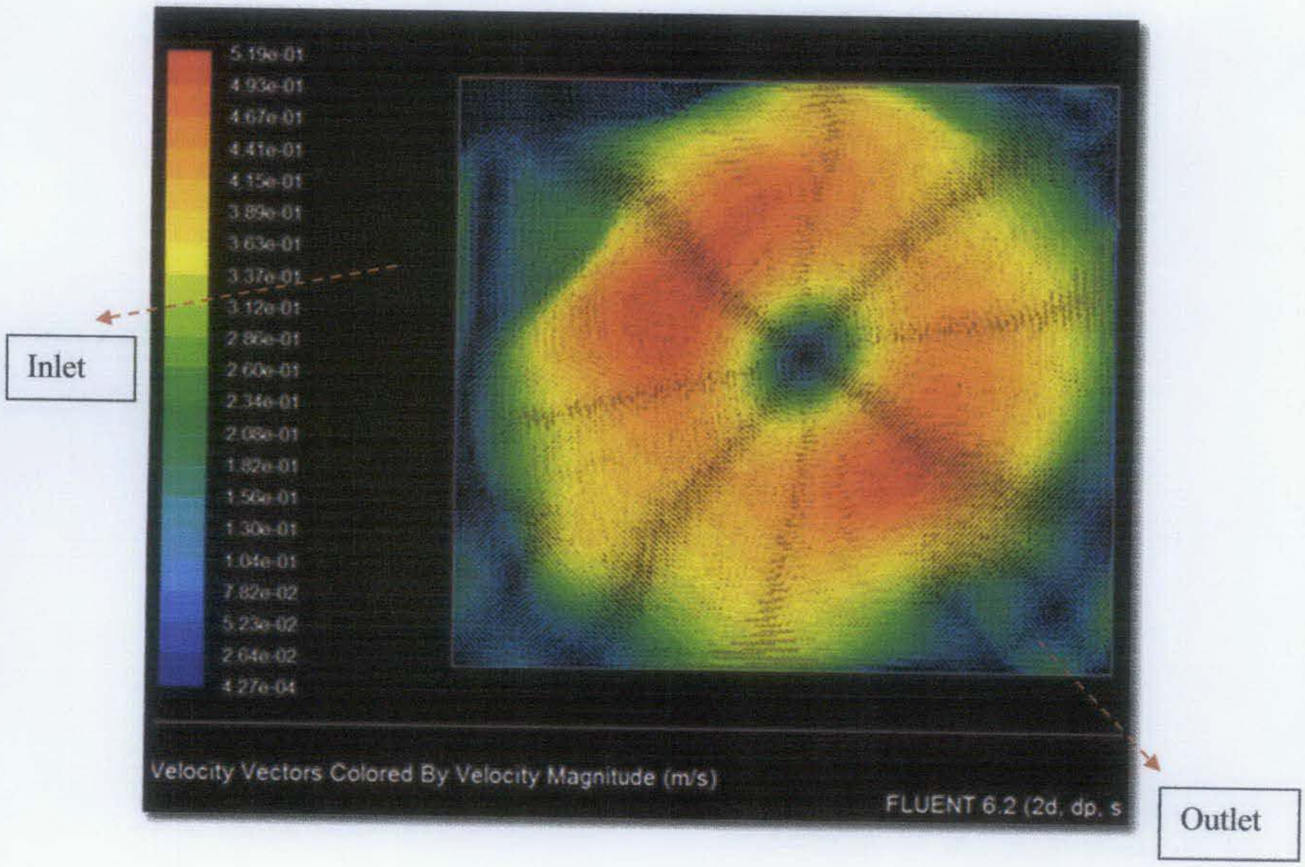

Figure 29: Simulation result for single bedroom after modification (side view)

- The velocity range is from **4.27x10^{-4}m/s – 5.19x10^{-1}m/s**
- After the modification the air velocity has increase to **5.19x10^{-1}m/s** at maximum spots which is higher than the air velocity without modification.

4.7 Discussion of simulation result

The result from the simulation is almost the same with the result from experiment. This indicates that the simulation using Computational Fluid Dynamic (CFD) software can help to get the correct data. Designer can use this software to conduct a design of any building during the preliminary stage so it will help them study the impact of each ventilation and passive solar element before final decision to be made.

After the modification has been made, we can see the result is getting better than before the modification. The air velocity is getting higher and the temperature is getting lower (Refer figure 14-29).

CHAPTER 5

Conclusion and Recommendation

5.7 Conclusion of simulation analysis

From the analysis and simulations that have been done, Computational Fluid Dynamic **(CFD)** that is Gambit and Fluent for this scope is possible method to do analysis for Ventilation Design and Passive Solar System whereby it will help to predict the air movement at specific place in particular condition.

However, in order to increase the accuracy of result, simulation needs to be done several times because it will help to overcome both human and software errors thus producing more accurate result.

Three Dimension **(3D)** simulations also need to be conducted in order to increase the system accuracy. A **(3D)** modeling and analysis is a good step towards more accuracy results compare to **(2D)** analysis because the simulation will judge every space in the room compared to specific area. However, this will consume longer time.

From the analysis of the single storey residential building in UTP which has never been designed for green building concept, the size and orientation are randomly built without considering the wind and solar direction. From the survey, the orientation and the shading system for windows is very important. For the Guest House, the window facing directly toward the sun without proper shading system make it hard to reach comfort human comfort level.

The house location that is in the middle of other houses also make it not suitable due to not able to receive proper wind blow from outside. The orientation is very important since good orientation will help to replace the electrical lighting with passive solar and at the same time the comfortable condition can be achieved.

5.8 Recommendation for future work continuation

i. Other Green Building Software

There is a lot of software available in the market today that can be used in Green Building design. Each of them has their own advantages. Each software be utilized in research work for a variety of feature.

ii. A prototype modeling

A prototype modeling can be very good work for further works, with help of computer simulation system, the result would be very accurate and applicable. The models need to be constructed in a scale and with several design features. Then the design can be analyzed simultaneously with the simulation software.

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