THE EFFICACY OF INDOOR ENVIRONMENTAL QUALITY (IEQ) IN THE CONTEXT OF MICRO CLIMATE AND MACRO CLIMATE FOR SUSTAINABLE HOUSING DESIGN IN TROPICAL CLIMATE

by

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CERTIFICATION OF APPROVAL

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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.

NURITA BINTI ZAKARIA

ABSTRACT

Buildings are the largest source of greenhouse gases. Greenhouse effect is a natural process that plays a major part in shaping the earth climate. Climate, whether of the earth as a whole or of a single country or location, is often described as the synthesis of weather recorded over a long period of time. The core questions assess occupant's satisfaction with the following indoor environmental quality areas are building layout, furnishings, thermal comfort, indoor air quality, lighting and building cleanliness and maintenance. It is a generally held view that, in tropical countries, traditional house is more sympathetic to the prevailing climate and provides comfortable indoor environmental quality however not in the modern house. Greenhouse gas emissions effect the environment. The aim of this investigation is to examine relationships among macroclimate, microclimate and residential building characteristics and compare with difference weather data set. This study uses weather data set in various cities in Malaysia such as Kuala Lumpur, Georgetown and Kuching. Simulation with Autodesk ECOTECT is carrying out to detect any significant trend and focus on sustainable housing design in tropical climate. ECOTECT is the most suitable simulation programme for this study that can fulfill all experiment requirements and can easily be integrated into the building design process. From the research, ECOTECT software is useful design tools for microclimate and macroclimate for housing and provides a good platform for design guideline.

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CHAPTER 1

INTRODUCTION

1.1 Background

Located near the equator, Malaysia's climate is categorized as equatorial, being hot and humid throughout the year. The average rainfall is 250 centimetres a year and the average temperature is 27 °C. The climates of the Peninsula and the East differ, as the climate on the peninsula is directly affected by wind from the mainland, as opposed to the more maritime weather of the East. Malaysia faces two monsoon winds seasons, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March. The Northeast Monsoon brings in more rainfall compared to the Southwest Monsoon originating in China and the north Pacific. The southwest monsoon originates from the deserts of Australia. March and October form transitions between the two monsoons.

Local climates are affected by the presence of mountain ranges throughout Malaysia, and climate can be divided into that of the highlands, the lowlands, and coastal regions. The coasts have a sunny climate, with temperatures ranging between 23 °C and 32 °C and rainfall ranging from 10 centimetres to 30 centimetres a month. The lowlands have a similar temperature, but follow a more distinctive rainfall pattern and show very high humidity levels. The highlands are cooler and wetter, and display a greater temperature variation. A large amount of cloud cover is present over the highlands, which have humidity levels that do not fall below 75%.

The tropics regarded as a region where the human evolved and comfort has often been taken for granted, built environments are increasingly becoming issues of public concern. The tropical outdoor environment has been regarded as important as indoors in the life of the populace and which is remarkably evident in the vernacular architecture of the region. However, today many cities in the region experienced rapid urban growth often without much reference to the evolving urban environment. This tendency has put increased demand on the comfort requirements in the design of buildings. Comfortable outdoor spaces have a significant bearing on the comfort perception of the indoor ambience. The demand for comfort conditions in buildings are significantly increased as a result of exposure to uncomfortable outdoors (Ahmed, 2003). In the context of Malaysia, overheated outdoor environment of the city has contributed to a growing preference for a lower comfort temperature indoors. This in turn has put an immense pressure on the energy demand in the cities.

Local climate greatly affects the indoor thermal environment in buildings. In tropical climates, buildings are overheated during the day due to solar heat gain through the building envelope and solar penetration through windows (Rajapaksha, 2003). From a thermal comfort point of view it requires lowering of indoor daytime temperature below the outdoor temperature using building elements and by passive or active systems. Techniques for such thermal modification have been widely addressed (Givoni, 1994). From a thermal comfort point of view, climatic and physical factors other than air temperature are important. In outdoor conditions the radiant exchange of the human body with the environment is of special importance due to exposure to solar radiation, the cold sky-vault, and warm and cool urban surfaces. The other factors influencing thermal comfort, air movements and humidity vary much more outdoors than indoors. There are, however, few studies has assessed the thermal comfort by calculation of the physiologically equivalent temperature (PET) (Johansson, 2006). A comfort index is determined by the environmental parameters that influencing thermal comfort: temperature, radiation, humidity and the wind speed.

1.2 Problem Statement

Hot humid tropical conditions in Malaysia affect the high temperature, and low air flow which affect on the comfortable indoor environment. Residential buildings are subject to significant cooling requirements due to high intensity of heat transient from building envelope. Tropical building design principle can significantly decrease air temperature in the rooms and large energy savings can be achieved. An application of tropical building principle design reduces internal heat gain, high temperature in the room and make comfortable indoor environment. In hot humid climate, the problem emphasized by the fact that it is important to understand the solar radiation, temperature and wind profile outside buildings in order to achieve indoor thermal comfort.

1.3 Objective

The main objective of this study is to examine relationships among macroclimate, microclimate and residential building characteristics, compare with difference weather data set and propose indoor environmental quality indicators for sustainable house in tropical climate.

1.4 Scope of Study

The scope of this study is to study the efficacy of indoor environmental quality (IEQ) in the context of microclimate and macroclimate for sustainable housing design in tropical climate. This study is entirely carried out using Ecotect computer simulation program and thus bears the limitations of the simulation tool used.

CHAPTER 2
LITERATURE REVIEW

2.1 Energy Consumption in Building

Indoor environmental quality is one of the factors affecting energy use in the buildings. The amount of energy used in buildings depends on what it is used for. A 2006 study of household Energy use by CETDEM found that air conditioning and the refrigerator take up nearly 70% of the average household electricity consumption and air conditioning is the largest consumer of electricity in the home. (MS1525, 2007).

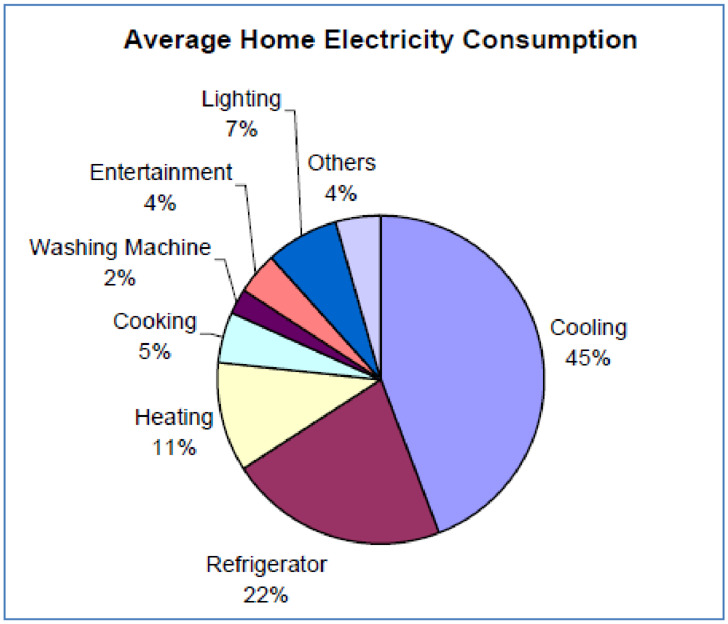


Figure 2.1: Average Home Electricity Consumption

(Source: MS 1525, 2007)

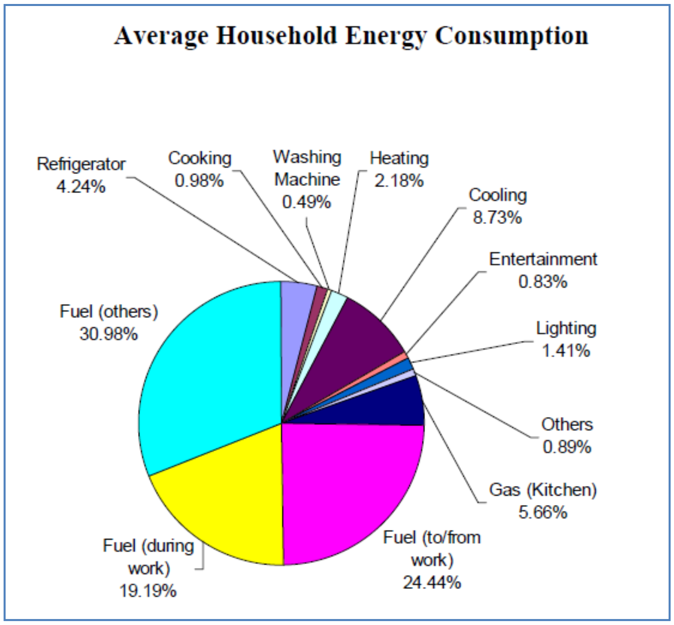


Figure 2.2: Average Household Energy Consumption

(Source: MS 1525, 2007)

According to (IPCC AR4,2007) In 2004, emissions from the buildings sector including through electricity use were about 8.6 GtCO2, 0.1 GtCO2- eq N2O, 0.4 GtCO2-eq CH4 and 1.5 GtCO2-eq halocarbons (including CFCs and HCFCs). Using an accounting system that attributes CO2 emissions to electricity supply rather than buildings end-uses, the direct energy-related carbon dioxide emissions of the building sector are about 3 Gt/yr. The largest savings in energy use (75% or higher) occur for new buildings, through designing and operating buildings as complete systems. Global CO2 emissions resulting from energy use in buildings have increased at an average of 2.7% per year in 1999 until 2004 for which data is available. Electricity can be derived from fuels with lower carbon content than current fuels, CO2 emissions from electricity use in buildings can also be altered on the supply side. The largest regional increase in CO2 emissions for residential buildings was from Developing Asia accounting for 42% and Middle East/North Africa with 19%. Non-CO2 emissions (largely halocarbons, CFCs, and HCFCs, covered under the Montreal Protocol and HFCs) from cooling and refrigeration contribute more than 15% of the 8.6 GtCO2 emissions associated with buildings.

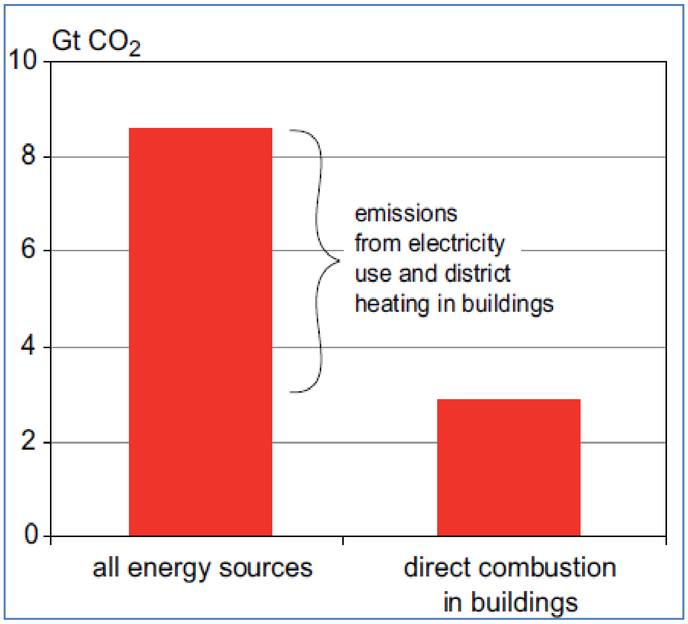


Figure 2.3: Carbon dioxide emission from energy

(Source: IEA, 2006e and Price et al. 2006)

2.2 Green Building Index

What is a green building? According to Tony Arnel, a green building focuses on increasing the efficiency of resource use such as energy, water and materials while reducing building impact on human health and the environment during the building's lifecycle through better sitting, design, construction, operation, maintenance and removal. Green buildings should be designed and operated to reduce the overall impact of the built environment on its surroundings.

Indoor Environmental Quality (IEQ) is one of the factors affecting energy use in the buildings according to Ar Chan Seong Aun in his article Code of Practice on Energy Efficiency. He said the amount of energy used in buildings depends firstly on what it is used for. Thus, the initial and most important step in isolating the factors affecting energy use is to determine its end-use. Air conditioning and the refrigerator take up nearly 70% of the average household electricity consumption and air conditioning is the largest consumer of electricity in the home. Keeping the home cool will become increasingly important in the future. The amount of air conditioning load required and thus air conditioning energy used depends very much on the air temperature maintained in the buildings. Besides that, climate affects the energy consumption in a building primarily by influencing the space cooling and heating requirements. The main climatic variable influencing the amount of energy needed for air conditioning are solar radiation, air temperature, wind and rain and night sky radiation.

2.3 Urban Heat Island

The effect of global warming has significantly contributed to the increases of temperature in Malaysia and to some extent; the temperature trend over the urban areas is relatively higher as compared to the rural. Azhar Ishak in his article "The Effect of Local Climate on Urban Heat Island Trend" said Local Urban Heat Island (UHI) could have been contributed in small fraction towards higher temperature due to urbanization that could cause increasing concentrations of greenhouse gases. UHI is considered as one of the major problems in this century posed to human beings as a result of rapid urbanization and industrialization of human civilization.

Urbanization and industrialization improve our material life and comfort; however they also induced many problems to human beings, such as global warming, industrial waste, and air pollution (Rizwan, 2008). The UHI most often refers to the increase of air temperature, in the near surface layer of the atmosphere within cities relative to their surrounding countryside and it is so called because the pattern of isotherms forms an island shaped pattern (James A. Voogt, 2002).

The rapid increases and expansion of urban areas in terms of land used, population growth and urban activities have intensified adverse urban environmental impacts. The adverse effect of UHI includes the deterioration of living environment, increase in energy consumption (Konopacki and Akbari, 2002) and even mortality rates (Changnon et al., 1996).

The UHI is most noticeable during clear, still nights when rural areas are most effectively able to radiate the heat gained during the day back to space, while the urban environment retains a greater proportion of heat. Depending on the weather conditions, overnight temperatures in the centre of a large city can be up to 10°C warmer than the rural surroundings. The urban landscape has other impacts on the local climate, such as reduced average wind speed due to the blocking effect of buildings and greater frequency of flash flooding owing to the higher proportion of ground sealed with concrete and asphalt and a corresponding reduction in natural drainage.

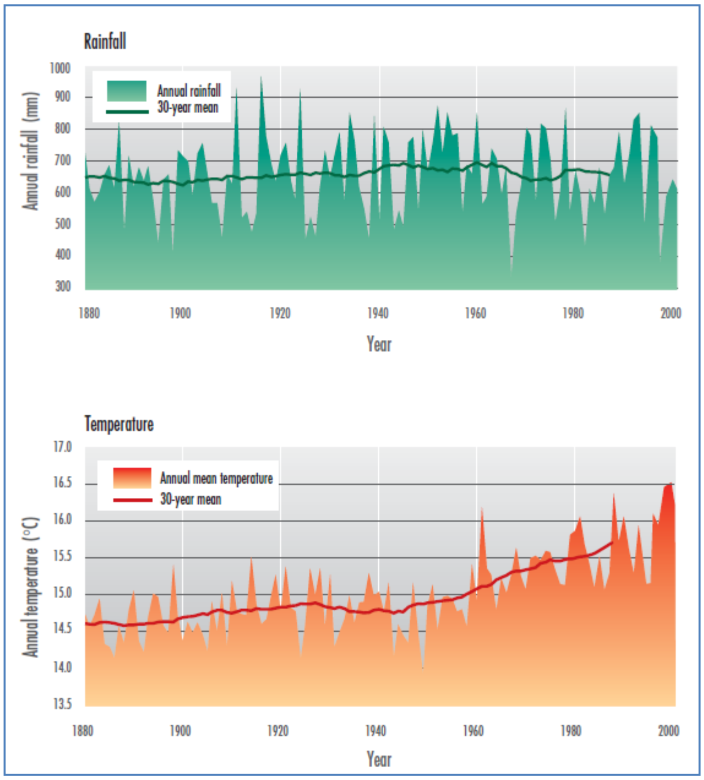


Figure 2.4: The historical record of annual rainfall (top) and temperature (bottom). The 30-year running mean is also shown. It is evident that while there appears to be no significant long-term trend in rainfall, there is an apparent significant warming trend since the 1950s.

(Source: Synthesis Report, IPCC 2001)

2.4 Tropical Building Design Principles

Generally the tropical zone is defined as the area of land and water between the Tropic of Cancer (latitude 23.5˚ N) and the Tropic of Capricorn (latitude 23.5˚ S). Occupying approximately forty percent of the land surface of the earth, the tropics are the home to almost half of the world's population. There are variations in climate within the tropic. However ninety percent of the tropical zones embody hot and humid climatic regions, whether permanent or seasonal. The remaining ten percent is desert like, and characterized as hot and dry climate (Baish, 1987). Local conditions may also differ substantially from the prevailing climate of a region, depending on the topography, the altitude and the surroundings, which may be either natural or built by humans.

The presence of conditions like cold air pools, local wind, water bodies, urbanization, altitude and ground surface can all influence the local climate strongly (Gut et al., 1993). According to Gut et al. (1993) the main climatic factors affecting human comfort and relevant to construction are air temperature, humidity and precipitation, incoming and outgoing radiation and the influence of the sky condition, air movements and winds. The main points to take into consideration when designing a tropical responsive building are minimize heat gain during daytime and maximize heat loss at night in hot seasons, minimize internal heat gain in the hot seasons, select the site according to microclimatic criteria, optimize the building structure, control solar radiation and regulate air circulation.

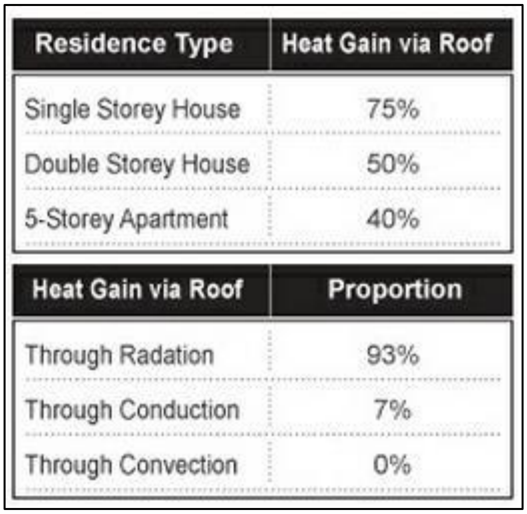
The interaction of solar radiation by the building is the source of maximum heat gain inside the building space. The natural way to cool a building, therefore, is to minimize the incident solar radiation, proper orientation of the building and adequate layout by using proper shading devices to help control the incident solar radiation. If ambient temperatures are higher than the room temperature, heat enters into the building by convection due to undesirable ventilation, which needs to be reduced to the minimum possible level. The tropical building principle are discussed thus include the elements of roof, wall and opening.

2.5 Roof Design

The roofing should be tightly fixed and the material should insulate the building from both excessive heat and humidity. Pitched or sloping roofs are recommended, specially designed to stand tropical showers as well as the violent winds, from gusty to cyclonic. Metal roofs made from aluminum, zinc, copper or stainless steel have the disadvantage of being very effective heat conductors, as well as possibly suffering from corrosion caused by contact with sulphur dioxide in the atmosphere (Duchein, 1988).

According to Agrawal (1974), a light roof color to reflect unwanted summer heat may reduce the heat transmission into the building. The reflectance of a surface is a measure of the energy that is neither absorbed nor transmitted and is expressed as a ratio of the reflected energy to the total incident radiation energy.

Appropriate external shading devices can control the amount of solar radiation admitted into the room, which could largely reduce cooling loads and improve indoor thermal comfort and day lighting quality. Bouchlaghem (2000) presented a computer model, which simulate the thermal performance of the building taking into account design variables related to the building envelope and optimize window-shading devices with optimization programs. According to Sharma (2003) if the external surfaces of the building are painted with such colors that reflect solar radiation (in order to have minimum absorption), but the emission in the long wave region is high, then the heat flux transmitted into the building is reduced considerably. Garde (2004) showed that the major importance of good insulation of the roof in tropical climate is thickness and color of insulation.

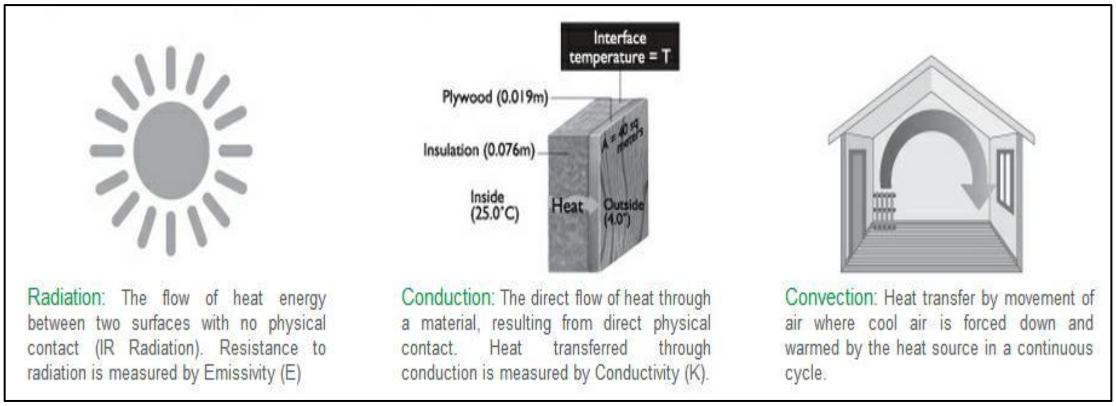


Residence Type	Heat Gain via Roof
Single Storey House	75%
Double Storey House	50%
5-Storey Apartment	40%

Heat Gain via Roof	Proportion
Through Radiation	93%
Through Conduction	7%
Through Convection	0%

Figure 2.5: Percentage of heat gain

(Source: Terreal, 2012)



Radiation: The flow of heat energy between two surfaces with no physical contact (IR Radiation). Resistance to radiation is measured by Emissivity (E)

Conduction: The direct flow of heat through a material, resulting from direct physical contact. Heat transferred through conduction is measured by Conductivity (K).

Convection: Heat transfer by movement of air where cool air is forced down and warmed by the heat source in a continuous cycle.

Figure 2.6: Heat gain through radiation, conduction and convection

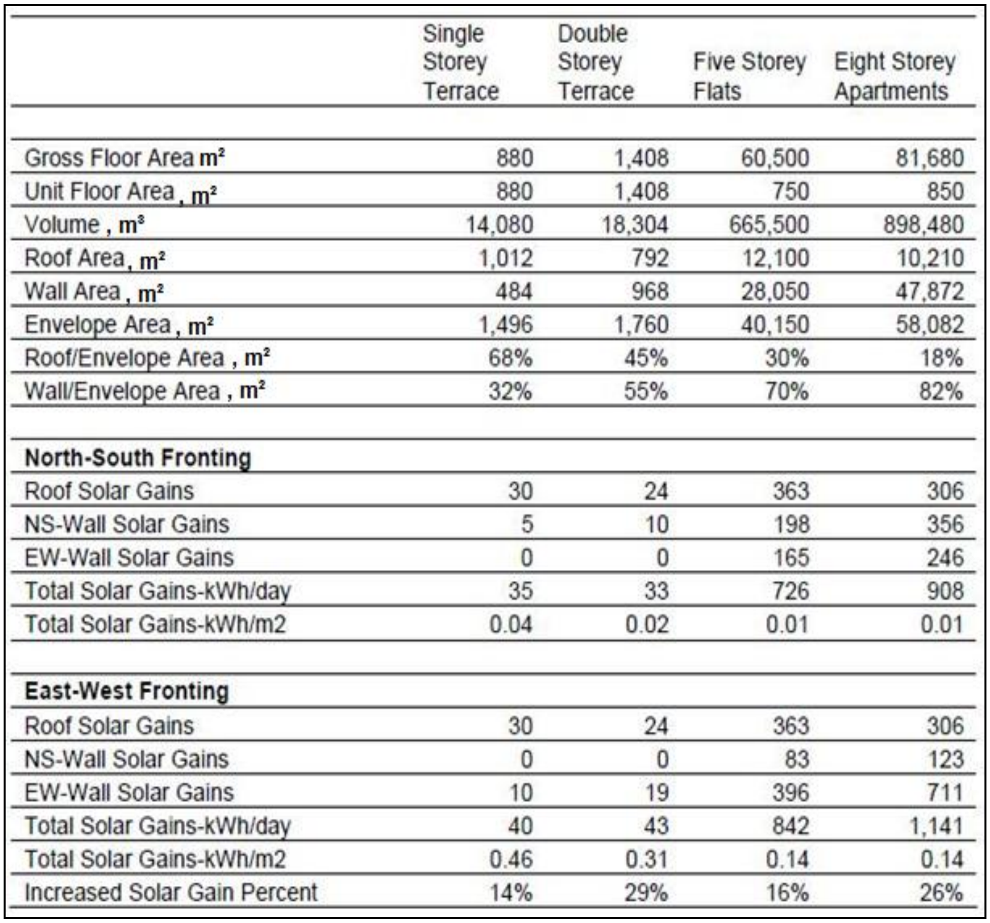
(Source: Terreal, 2012)

2.6 Wall Design

The design of wall is a potential for passive control of a building’s indoor conditions by managing the transference of external outdoor temperature. Construction materials such as concrete, brick, cement block and other solid masonry materials are considered as having high thermal mass. Lightweight materials of timber, steel and the various building wall materials absorb heat quickly and conversely cool down quickly. A composite construction wall may be a compromise solution ideally suited to the local climatic conditions. Garde (2004) highlighted that an overheating of 2ºC was observed in rooms with colored concrete walls exposed to the solar radiation compared to rooms with no walls exposed.

The use of reflective surfaces to avoid solar gains and the use of reflective insulation are the most effective means of improving attic performance. According to Rosangela (2002) the use of a white reflective surface indicated the best performance, and minimized the need for insulation. The variation in wall thickness makes a significant difference in the comfort performance of houses. Fuad H Mallick (1996) indicated rooms with thicker walls tend to be more comfortable. Comparison of temperature measurements in houses that have wall thicknesses ranging between 125 mm and 500 mm shows that rooms with thicker walls tend to be more comfortable. Houses which have thick walls and are on lower floors can be comfortable all year round as opposed to ones that are on top floors. Thermal transmission in a certain material depends upon the thermal property (in this case the thermal conductivity) and the thickness of that material. The lower value thermal conductivity will have less thermal transmission.

Thermal insulation is a major contributor and obvious practical and logical first step towards achieving energy efficiency especially in envelope-load dominated buildings located in sites with harsh climatic conditions. The thermal performance of building envelope is determined by the thermal properties of the materials used in its construction characterized by its ability to absorb or emit solar heat in addition to the overall U-value of the corresponding component including insulation. The placement of insulation material within the building component can affect its performance under transient heat flow. The best performance can be achieved by placing the insulating material close to the point of entry of heat flow. However, for practicality it is common to use insulation to the inside or between wall cavities (Al-Homoud, 2005).



	Single Storey Terrace	Double Storey Terrace	Five Storey Flats	Eight Storey Apartments
Gross Floor Area m²	880	1,408	60,500	81,680
Unit Floor Area , m²	880	1,408	750	850
Volume , m³	14,080	18,304	665,500	898,480
Roof Area, m²	1,012	792	12,100	10,210
Wall Area , m²	484	968	28,050	47,872
Envelope Area , m²	1,496	1,760	40,150	58,082
Roof/Envelope Area , m²	68%	45%	30%	18%
Wall/Envelope Area , m²	32%	55%	70%	82%
North-South Fronting				
Roof Solar Gains	30	24	363	306
NS-Wall Solar Gains	5	10	198	356
EW-Wall Solar Gains	0	0	165	246
Total Solar Gains-kWh/day	35	33	726	908
Total Solar Gains-kWh/m2	0.04	0.02	0.01	0.01
East-West Fronting				
Roof Solar Gains	30	24	363	306
NS-Wall Solar Gains	0	0	83	123
EW-Wall Solar Gains	10	19	396	711
Total Solar Gains-kWh/day	40	43	842	1,141
Total Solar Gains-kWh/m2	0.46	0.31	0.14	0.14
Increased Solar Gain Percent	14%	29%	16%	26%

Table 2.1: Solar heat gain in typical Malaysian housing

(Source: PertubuhanArkitek Malaysia, 2009)

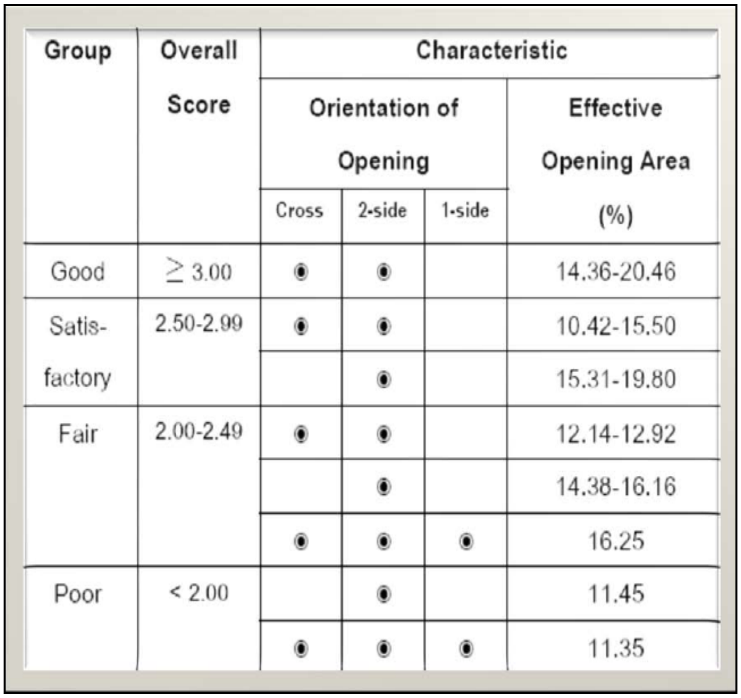
2.7 Opening Design

In traditional buildings, designers place windows at certain points to create a current of air. Further, opening windows can reduce heat and humidity, but on the other hand the existence of windows can increase inside temperatures with solar penetration. East and west-facing walls and windows are the most important to shade, as solar heating is most intense on these orientations. Reduce unwanted morning and afternoon solar heat gain by minimizing or protecting extent of walls and windows facing east or west. Planting trees around the building is one way of controlling the temperature in repositories and keeping the sunlight out as well. (Gut *et al*., 1993).

The primary design strategy implies that exploration of the shading potentials is to reduce the total heat gain through the wall openings. These strategies in broad term can be achieved by two means; natural devices and sun control devices. The natural shading strategies are the means of shading the building with orientation of the sun and by the use of vegetation. Apart from the natural devices, sun control devices are used to exclude the unwanted solar radiation penetration into the building. The design, fixing location, effectiveness in terminating the direct sun and operational systems are attributes of the sun control devices. They can broadly divided into two; internal and external devices.

Internal devices to control solar radiation can be categorized into two types; firstly, solar shading using blinds, louvers, drapers and screens which are other than the window glazing pane. Secondly, the use of special glazing without the use of external or internal shading devices. External devices are projections attached to the building skin or an extension of the skin to eliminate unwanted solar heat. They are more effective as they intercept the solar radiation before it reaches the vertical surface of the building envelope.

Main objective of the building design in tropical climates is to avoid the overheating of the indoor temperature by keeping it at least below the outdoor temperature. The comparison of the indoor air temperature shows a gap of more than 1.5 °C between the cross-ventilated dwelling and natural ventilation (IPCC AR4, 2007).



Group	Overall Score	Characteristic			
		Orientation of Opening			Effective Opening Area (%)
		Cross	2-side	1-side	
Good	≥ 3.00	●	●		14.36-20.46
Satis-factory	2.50-2.99	●	●		10.42-15.50
			●		15.31-19.80
Fair	2.00-2.49	●	●		12.14-12.92
			●		14.38-16.16
		●	●	●	16.25
Poor	< 2.00		●		11.45
		●	●	●	11.35

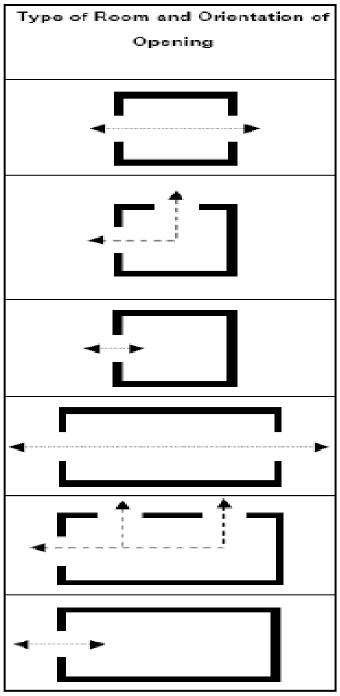


Table 2.2: Orientation of Opening (Source: Nastiti, Teddy and Ngurah,2009)

2.8 Computer Simulation

New design tools approach enable all simulation model being simulated under virtual condition. Computer simulation tools developed by scientist and researcher provide accurate result and the models in simulation adequately represent real-world complexity (Sonia, 2005). However they require extensive training, for learning on how to use them, preparing input, running and interpreting the result to the requirement of the research. Sonia (2005) recognizes the need for building simulation or performance tools that can be integrated into the building design process. The complexity of simulation tools created by scientists, who are more technically oriented, discourages architects or designers who are more visually oriented people to use them. The selected computer simulation programme must provide a design tool that is user-friendly and easy-to-use. Sonia (2005) describes the following factors to be integrated into the programme:

a. Provide designers with a building performance tool that would aid in the design process.
b. Provide designers with building design information tool that requires the least amount of training and yet is very easy to learn and use.
c. Provide designers option to create their own custom databases of building components.

CHAPTER 3
METHODOLOGY

In order to achieve the objectives of the research that have been laid in chapter 1, this research is divided into two main stages. Firstly, for the microclimate the elements divided into some elements parameters which are roof, wall and opening. Secondly, for the macroclimate the data will be simulating with ECOTECT software. These methodologies were reviewed and selected for the purpose of this research.

3.1 Research Design

In order to achieve the research objectives, the following steps are suggested: preparing climate data, field measurement, ECOTECT software validation, simulation of double storey terrace house model and indoor comfort analysis. In this study, the climate data of Malaysia with Kuala Lumpur weather data will be adopted for analysis. The weather data will be used to determine the trend of the monthly dry bulb temperature, wind speed and relative humidity available for thermal environment. This step will involve the testing of a modification the double storey terrace house design principle in order to fulfill previous stated objective. Several elements of a double storey terrace house principle design (roof, wall, opening, and floor) are built. After modification of the elements, the best modification element was chosen and used three different weather data from Kuala Lumpur, Georgetown and Kuching to simulate the best modification model.

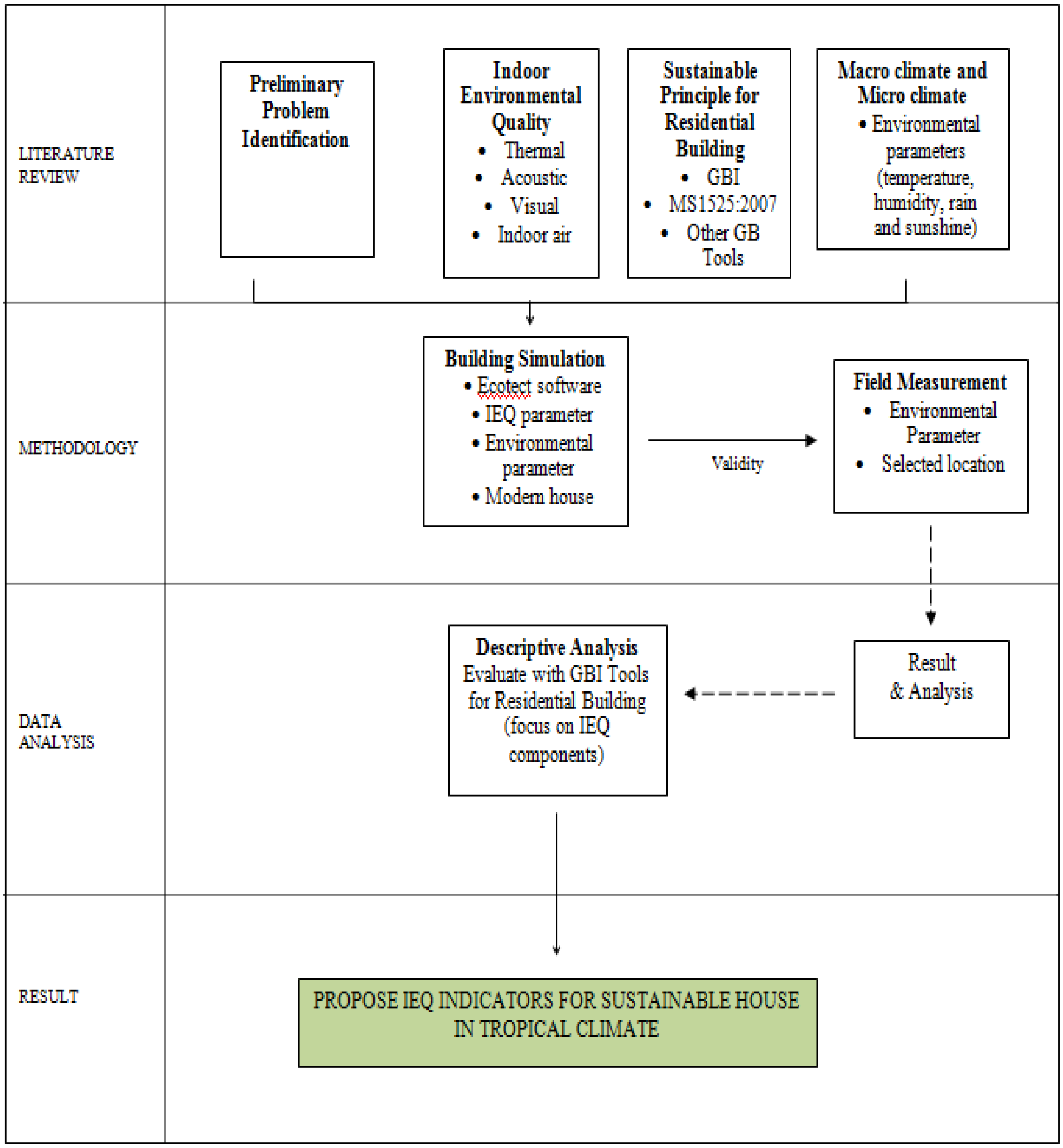


Figure 3.1: Methodology - Efficacy of Indoor Environmental Quality (IEQ) in the Context of Micro Climate and Macro Climate for Sustainable Housing Design in Tropical Climate.

3.2 ECOTECT Simulation

The ECOTECT software is relatively unique amongst performance analysis tools as it is aimed primarily at architects and is intended for use during the earliest, conceptual stages of design. It integrates a relatively simple and intuitive 3D modeling interface with a range of analysis functions. These include sun penetration and shading device design, hourly thermal comfort, natural and artificial lighting levels; acoustic reflections and reverberation times and environmental impact.

The original ECOTECT software was written as a demonstration of some of the ideas presented in a PhD thesis by Andrew Marsh (2000). Its modeling and analysis capabilities can handle geometries of any size and complexity. Its main advantage is that it focuses on feedback during conceptual building design stages. The intention is to ease design process to create a truly low energy building. Analysis results can be mapped over building surfaces or displayed directly within spaces that generate them. It provides the designer the best chance of understanding exactly how their building response to the climate conditions.

3.2.1 ECOTECT Simulation Data Requirement

This section will outline the sequence of the simulation approach, from the required data and the construction of geometric models to the output of the results. One tool vital to any pre-design analysis provides for the visualization of climate data. Using this tool, data can be viewed in a number of different ways, ranging from a monthly summary with wind roses after Szokolay (Szokolay, 1982) to simple hourly graphs. Hourly data can be imported from a wide range of file formats including TMY, TMY2, TRNSYS TRY files. Custom formats also can be defined and saved within the software.

3.2.2 ECOTECT Simulation Geometric Modelling

One of the major challenges in the development of ECOTECT was to produce an interface within which geometric modeling could be as simple, loose and disposable as a traditional hand sketch, yet still be used for both general and detailed analysis. In ECOTECT, a relational modeling system is used in which the role of each element and its relationship to others is automatically derived from the way it is created. This means deriving the geometry and type of one element from the geometry and type of another, and storing the rules used. If the parameters of these rules are subsequently changed, or the parent element moved, the geometry of the child can be automatically updated.

It was, however, of fundamental importance to know the function of each element within the model. As a result, whenever elements are created, they are created as a particular type. For example, the user chooses to create a floor plane, or insert a window into a wall, a skylight into a ceiling, a partition within a zone. The following is a list of the 12 basic element types defined in the application are void, roof, floor, ceiling, wall, partition, window, panel, door, point, speaker and light. These type definitions imbue the model with an inherent knowledge base.

3.2.3 ECOTECT Simulation Analysis

The thermal analysis calculations were performed with the software ECOTECT Analysis 2011. The model of double storey terrace house was constructed. The thermal modeling was based on a series of assumptions. All spaces (ground floor and upper floor) were assumed with natural ventilation. All the thermal analysis calculations, which are presented, concern all zones of the building.

3.2.4 ECOTECT Simulation Result

The very nature of the architectural design process is visual. This is especially true of the early stages of design where the building form itself is still being established. In addition to simply displaying results, ECOTECT attempts to relate the analysis directly back to the geometry. This is relatively simple in the case of solar and lighting calculation, however it is not always possible as some results can only be displayed as a graph. Where possible, however, graphs are displayed as separate interactive windows that automatically update to reflect changes in the model. In some cases, changes in the graph can also automatically effect changes in the model. Many building analysis tools also provide very little visual feedback during calculations. This means that the process being undertaken is essentially hidden from the user, who has to trust in the fact that what is being modeled is correct. Mistakes in modeling that are not immediately visually apparent must be determined from a detailed examination of any output. Whilst the majority of calculations are not inherently visual, there are techniques that can be used to make them more so. For example, when using sampling or ray tracing techniques, it is a simple matter for ECOTECT to display each point or ray as it is generated and tested. This acts to provide an indication of how the calculation is progressing as well as allowing the user to identify possible problems with the model by observing anomalies in the display. Such techniques have been implemented during surface area, volume, day lighting and acoustic calculations (Robert, 2002).

3.3 Microclimate

There is a clear definition of architectural elements and can be categorized into three main zone. The top zone, which covers the roof element, the middle zone for wall and the bottom zone which is the floor. The methodology of the field measurements is described in the following section. The model will be developing by modifying the configurations of roof, wall and openings, and the floor. Other parametric studies related to building form and orientation, window size, type and orientation can be performed.

3.3.1 Field Study of Efficacy of Indoor Environment Simulation

The basic filed study model is a typical house configuration with overall size of 12m x 5.5m x 3m high. The original model of double storey terrace house was modeled using ECOTECT. Weather data from Kuala Lumpur was used as a base of the weather data. Simulation was performed in the hottest day of Kuala Lumpur weather data which is on 6th July.

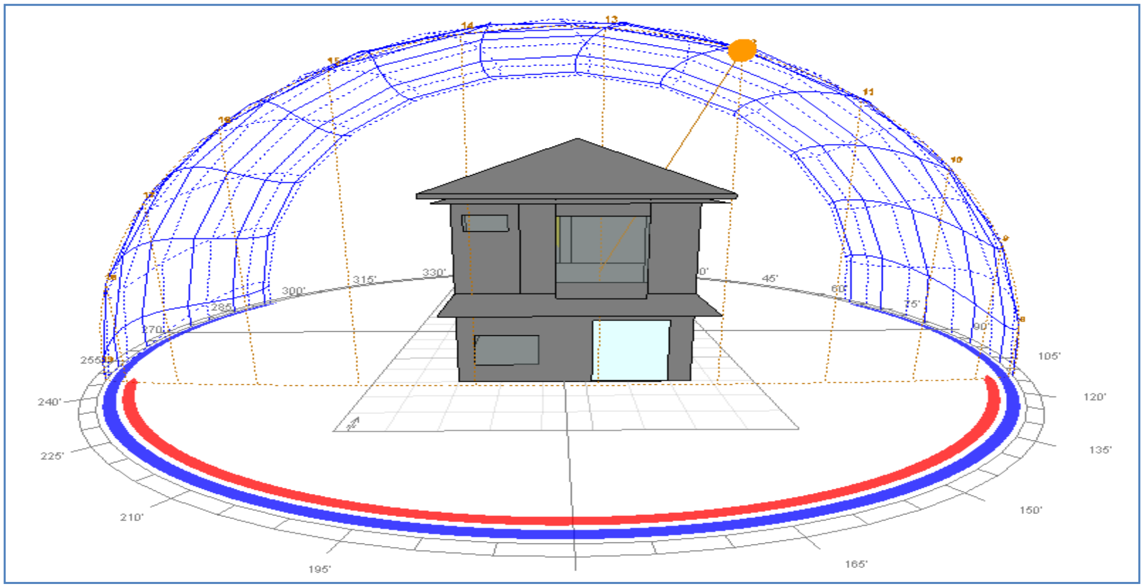


Figure 3.2: Original model house

3.3.2 Modified Tropical Building Design Principle

The modified tropical building design principles are extension of the field study model. In this stage, the basic tropical building models are modified physically into four alternative modifications. The modifications are performed at roof, wall, and opening and floor elements.

3.3.2.1 Roof Modification

In this study, the shape of the roof model is assumed as similar with base case model. The aperture above the roof of tropical principle model is assumed effective in decreasing the indoor temperature, while the area below the window has no effect on air movement on the sitting plane. However, when considering the effect of roof design, several modifications were simulated: ceiling and without ceiling, roof color such as light and dark color.

3.3.2.2 Wall Modification

The basic wall of double storey terrace house is brickwork and light color wall. Hence, the modification elements tested are color of the walls.

3.3.2.3 Opening Modification

The opening of tropical design is an independent variable in this study. The main purpose of this study is to determine the optimizing of the opening design in terms of decrease air temperature and achieving comfort indoor temperature. The opening was modified with minimum opening and extra opening.

3.3.2.4 Floor Modification

The original model and the modified configurations with different floor elements will be used to investigate the objectives of the study. Further, the characteristics of the thermal models will be determined based on the types of floor variables to be investigated. Following parameters were used to determine the influence of floor element on the thermal performance of the tropical house; color of the floor.

3.4 Macroclimate

In order to achieve the research objectives, the following steps are suggested: preparing climate data, field measurement, ECOTECT software validation, simulation of Kuala Lumpur, Georgetown and Kuching weather data and indoor comfort analysis. In this study, the climate data of Malaysia with Kuala Lumpur weather data will be adopted for analysis. The weather data will be used to determine the trend of the monthly dry bulb temperature, wind speed and relative humidity available for thermal environment. Climate data consist of annual climate data and design day of dry bulb temperature of each month.

Figure 3.3: Three different places for weather data set collection

CHAPTER 4

RESULT, ANALYSIS AND FINDING

4.1 Field Study on Comfortable Indoor Environment

Field study using one model was measured and simulated for sustainable housing design. The height for first floor and second floor was 3.0 meter high, 5.5m width and 12m length, supported structurally by reinforced concrete frame. In the Ecotect simulation, the following boundary condition area used: the material and size are based on the model, while the climatic condition is set similar to the site climatic conditions. Sample graphs used for these studies are illustrated below.

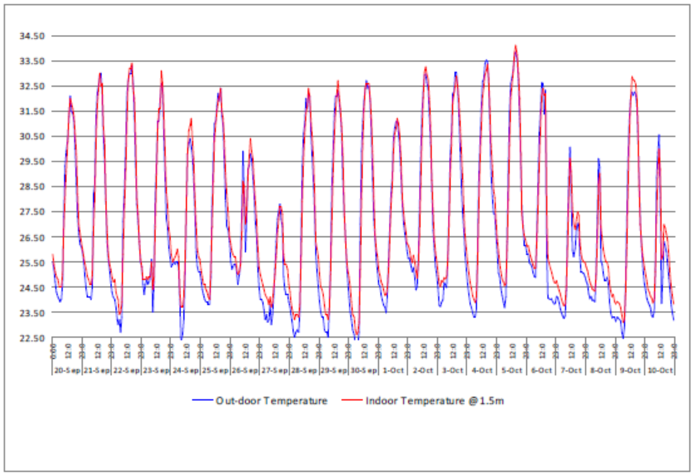


Figure 4.1: Comparison of internal and external temperature at 3m height for each floor

4.1.1 Indoor Environment Result of Field Study Measurement

A typical diurnal variation of the mean indoor temperature against the outdoor temperature is illustrated in Figure 4.2. It can be observed that the double storey house model temperatures were significantly below the outdoor in 11:30h until 17.00h. High ambient temperature (indoor temperature) of 33.3°C at 14:00h in the house. Figure 4.2 showed that the indoor and outdoor temperature of model house.

The outdoor humidity was generally lowest than the humidity in the model house. Relative humidity in outdoor and indoor decrease start in 08:00h until 18:00h with similar pattern.

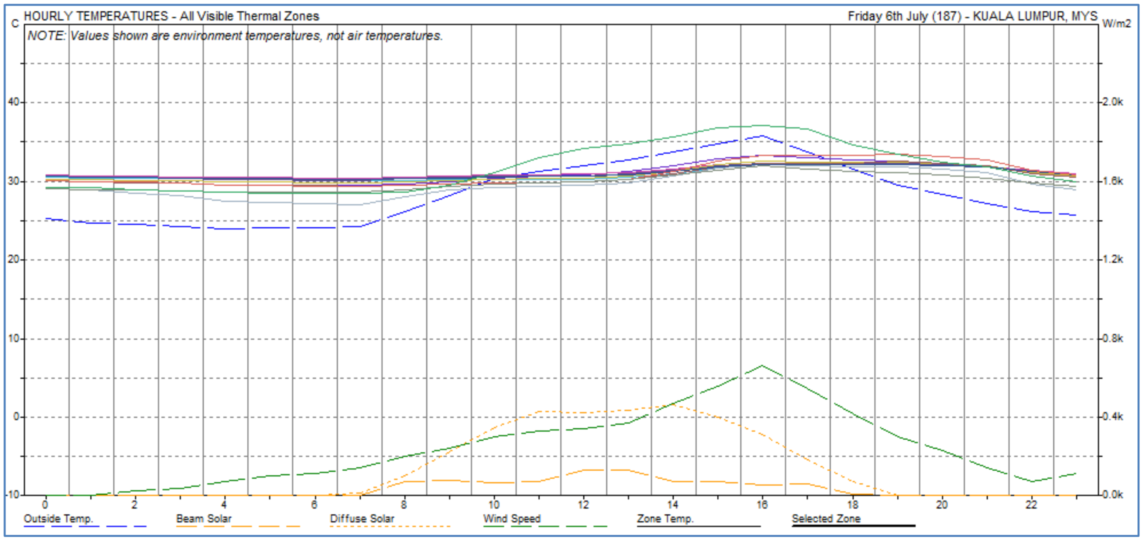


Figure 4.2: Hourly temperature profile for all thermal zones for double storey terrace house model

4.1.2 Results Analysis of Field Study Measurement

A typical diurnal variation of the indoor model house temperature against the ambient temperature is illustrated in figure 4.2**.** It can be observed that the indoor temperatures were significantly below the ambient. A typical value of mean indoor temperature is 30°C compared with mean outdoor temperatures of 28°C. Corresponding average indoor temperature elevations ranged 2°C below outdoor temperature at 10:00h until 17:00h. The result illustrates the effectiveness of the principle of the tropical building design employed in this study and the need for the maximal temperature reduction to achieve upper limit of neutral temperature within the room.

The incorporation of a combined roof, wall, opening and floor element design can be increase temperature reduction in the house. To obtain such a neutral temperature inside the room should be extended the new tropical design based on field study.

4.1.3 Finding and Conclusion of Field Study of Double Storey Terrace House

The results obtained from the simulation of double storey house has illustrated that tropical principle if designed properly can maintain indoor temperatures consistently below the outdoor temperature in the morning. The maximum indoor temperature on the simulation is achieved at 16:00h. The indoor temperature profile also indicates similar trend against the outdoor temperature. The neutral temperature performance was achieved with modification of tropical building design principle studied. Better performance was obtained with a maximum temperature reduction within the house. The results do, however illustrate the desired effectiveness of the tropical principle model.

4.2 Modification of Tropical Building Design Principle Model in Selected Climate Condition

Developing the new tropical building design principle had been undertaken on hottest day (on 6 July) with Kuala Lumpur weather data. It was simplify to make a comparison between field study and the different design principle configuration because of the same climatic conditions. However, general and subjective conclusions were formulated. Predictions of the impact of new tropical building principle configuration were performed for variety of main building design configuration (roof, wall, opening, floor). The influence of these variables on the indoor temperature performance is discussed below. An example of variation of new tropical building elements is given in figure 4.10 and figures 4.11 shows that the indoor temperature of modeling house is changing along with the modification of tropical building elements. The ability of the modification tropical building elements to offer comfortable indoor environment is expressed by the air temperature inside of the model.

4.2.1 Roof Modification

To evaluate the effect of roof tropical building element, several modifications were simulated: roof without ceiling, roof with light color and dark color.

In figure 4.3, a comparison between indoor temperatures for double storey terrace house model is made, for different values of roof elements. The other building elements are similar with field study (wall, opening and floor). It was found that average air temperatures decreased with used ceiling which is obvious as less radiation was absorbed by the room. In addition, temperature is at a maximum at the roof with material U value 6 as shown in figure 4.3.

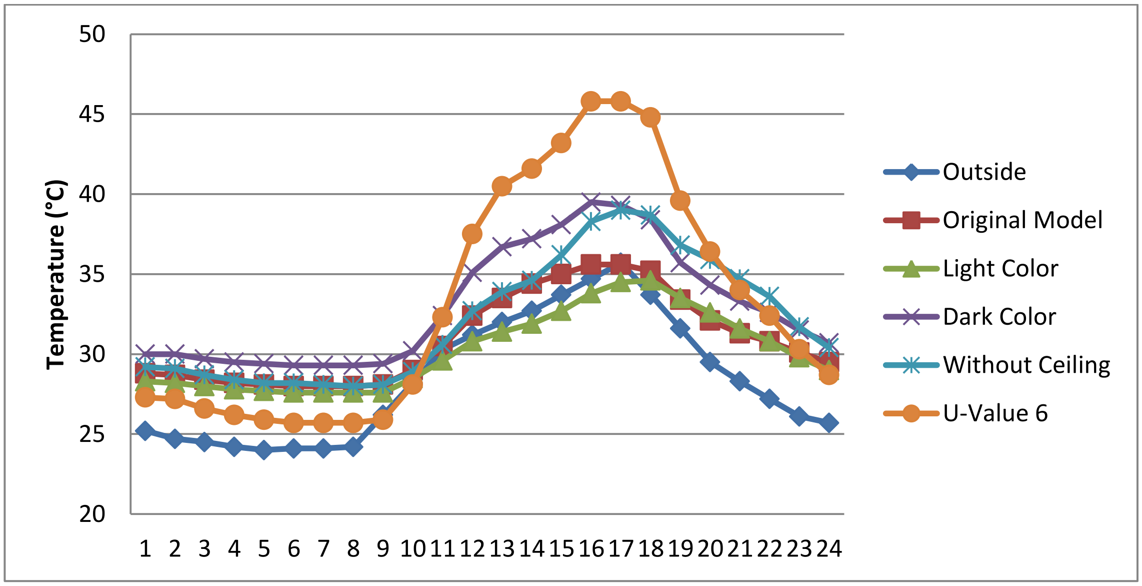


Figure 4.3: Indoor temperature in relation to roof modification

4.2.2 Wall Modification

To evaluate the effect of wall elements on indoor temperature, several modifications were simulated: wall with high U value (3 W/m²K), wall with light color and wall with dark color, which correspond to roof, opening and floor similar with field study. Figure 4.4 show the indoor temperatures of a double storey house for three different modifications. It was found that indoor temperatures decreased with increased

U value of the wall. In fact, those previous researchers regarded the fact that big U value will cool the inner surface of the wall leading to decreased temperature of the room.

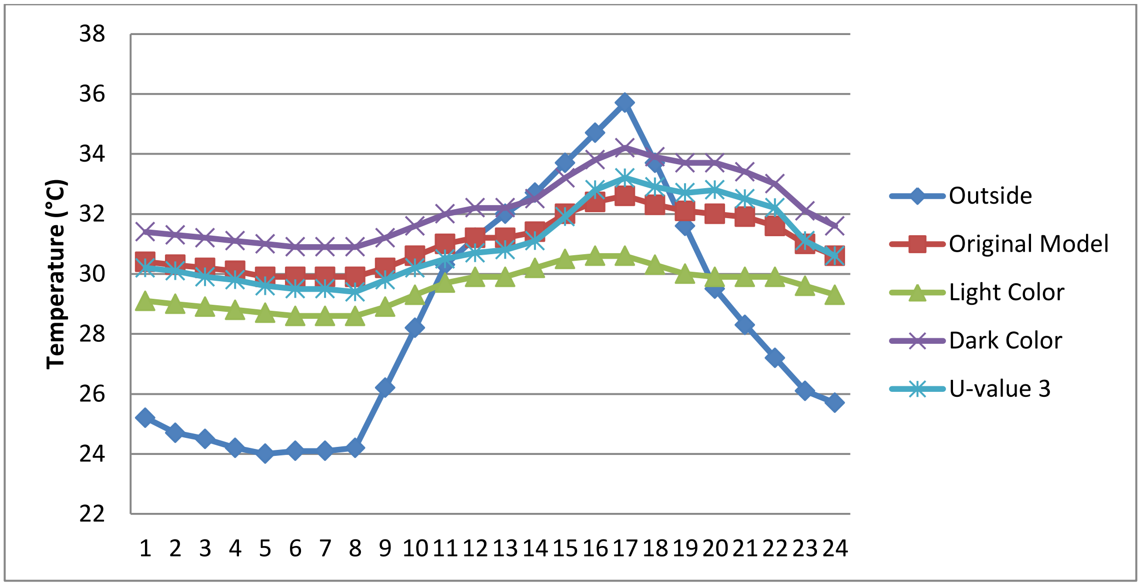


Figure 4.4: Indoor temperature in relation to wall modification

Figure 4.4 shows the simulation results of the temperature different produced by the wall modification. It can be seen that the temperature differences increased with U value material of 3W/m²K. Figure 4.5 show the comparison of temperature difference in the field study, wall U value 3W/m²K (maximum reduction) and wall with light color (minimum reduction).

Figures 4.5 illustrates that the similar indoor temperature are obtained on wall modification. However, on U-value 3, average indoor temperature indicated a lowest value. This can be explained that on U value 3, the wall reduce solar radiation; therefore the indoor temperature values are low.

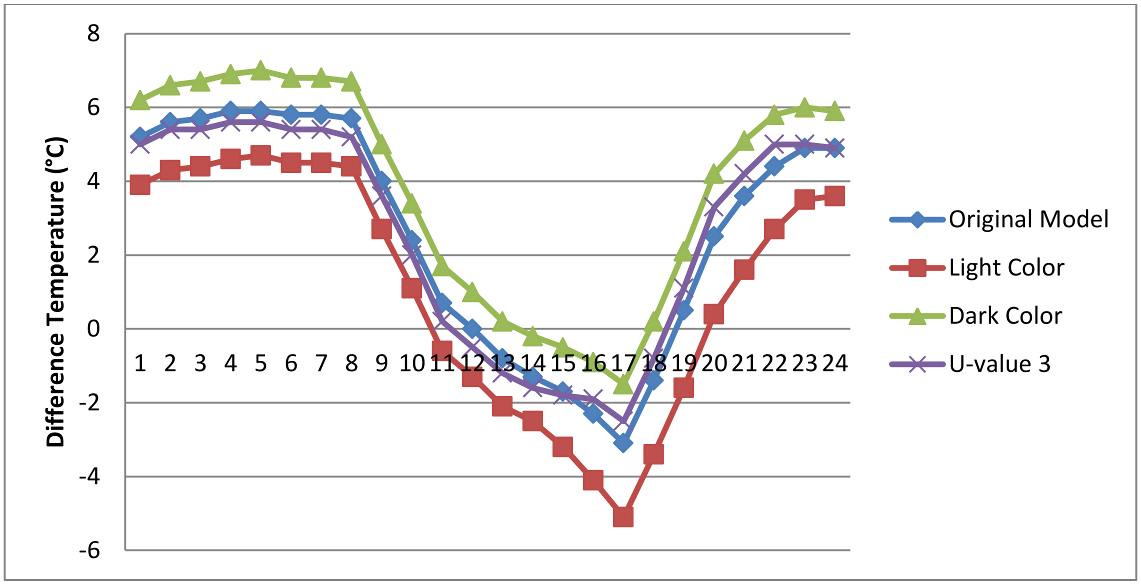


Figure 4.5: Temperature differences in relation to wall modification

4.2.3 Opening Modification

A combined opening modification between maximum opening and normal opening should be solved for same field study design elements (roof, wall, floor). Figure 4.6 show the indoor temperature and outdoor temperature of the double storey house with different sizes of opening. Generally, decrease the opening size decreased the indoor temperature, which is a consequence of the large opening impact decreased indoor temperature similar with outdoor temperature. Further, closed opening with good insulation and wall material make indoor temperature cooler than outdoor temperature.

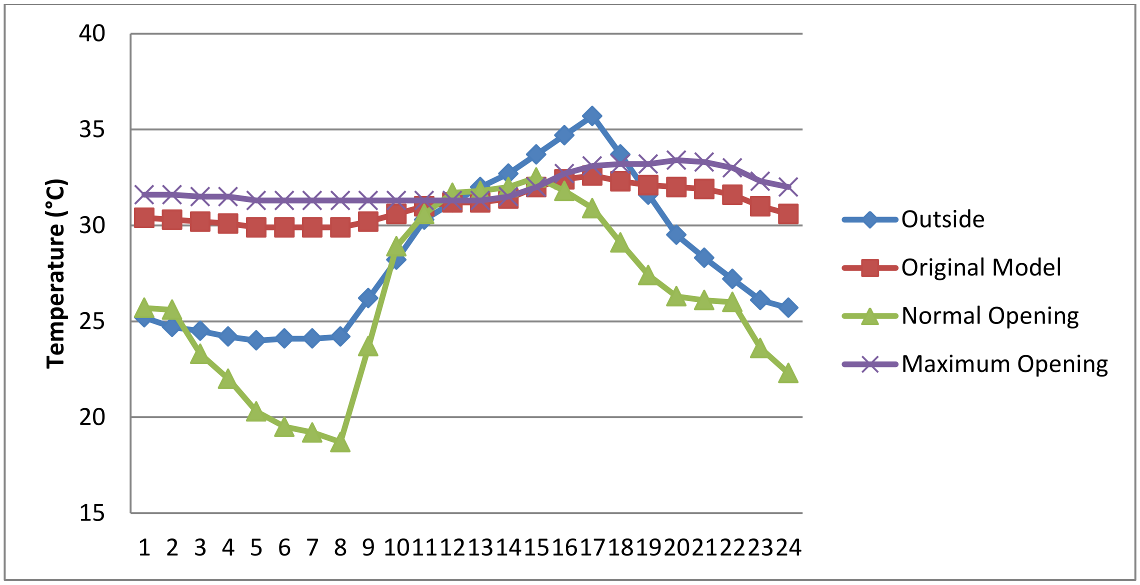


Figure 4.6: Indoor temperature in relation to the opening modifications

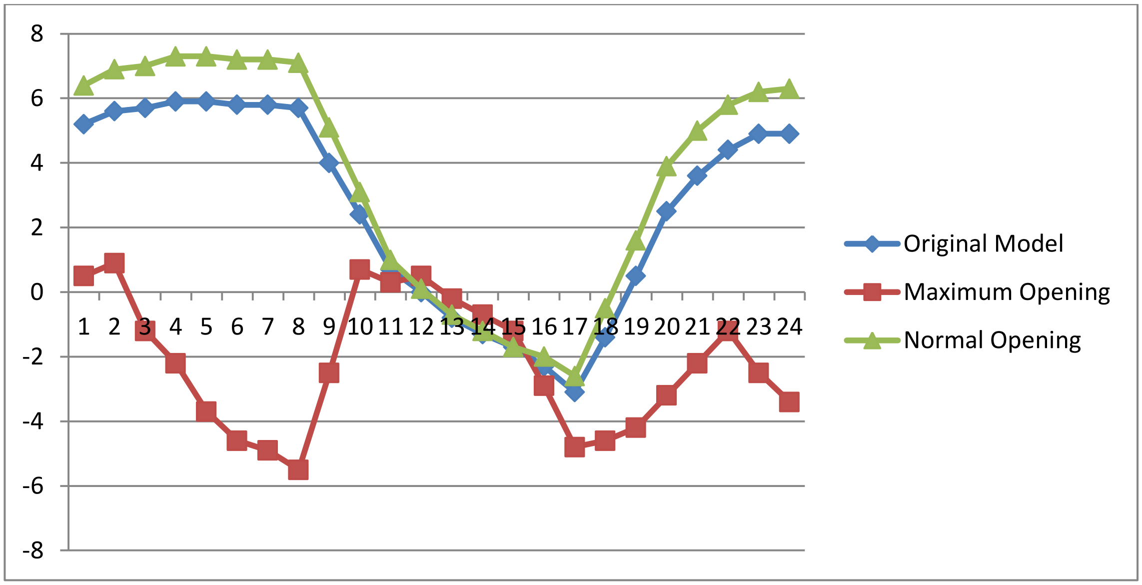


Figure 4.7: Temperature differences in relation to opening modification

4.2.4 Floor Modification

The effect of floor modification was analyzed by performing simulations for floor color. Figure 4.8 show indoor temperature profiles for different floor modification, as well as modification results with a floor with light color. Floor modification does not change significantly the indoor temperature and temperature differences, the maximum being obtained at 16:00h.

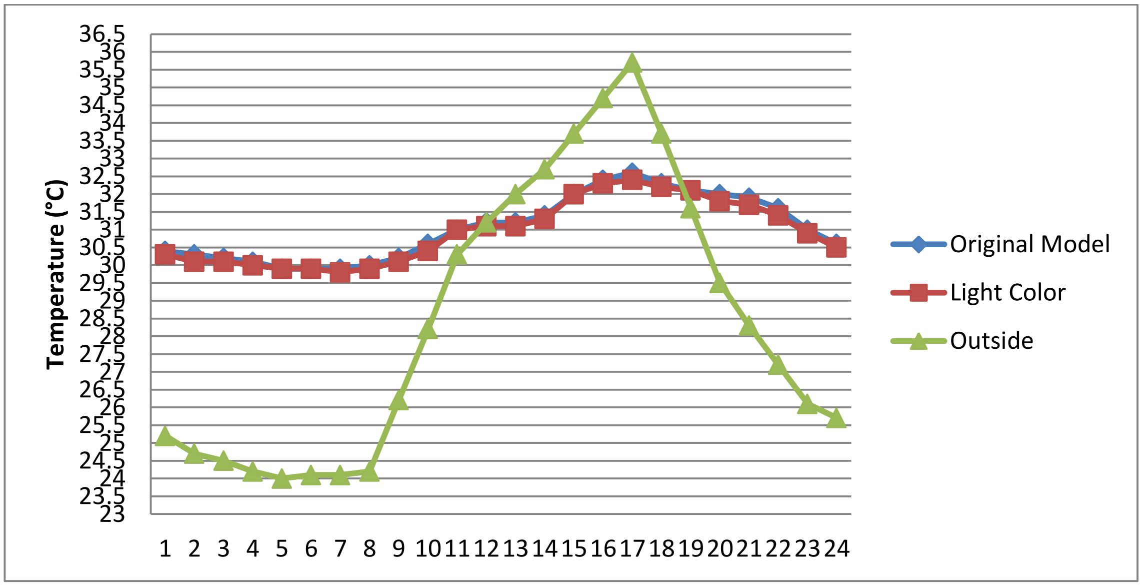


Figure 4.8: Indoor temperature in relation to the floor modification

Figure 4.9 show plot of temperature differences at different floor modification values. Similarly, higher temperature difference at floor with light color caused the small temperature differences. By changing the floor color from solar absorption 0.1 to 0.3 the temperature difference derived in the house is increased to the maximum value of 5.9°C at 04:00h. The maximum temperature in floor modification was still above the minimum target of neutral temperature. Figure 4.9 shows the color light of floor have significant impact to reduce indoor temperature. The present result is similar with previous study by Bajwa (1995) which the color of floor surfaces has a great deal to do with the heat absorption and re-radiation. Lighter color with rough surface finishes was used to reduce direct heat gain in the buildings (Bajwa, 1995).

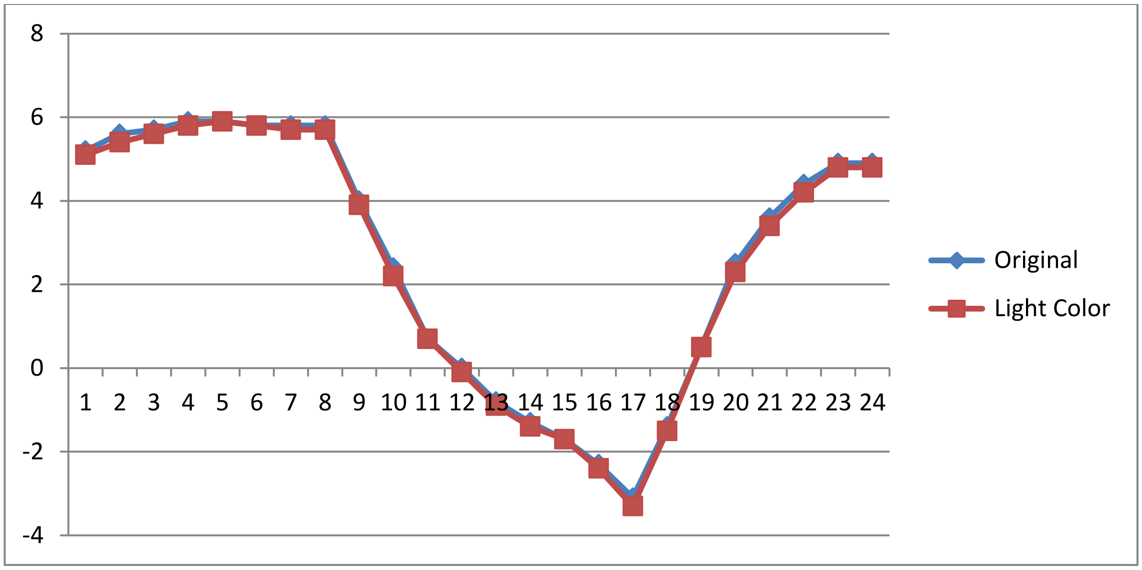


Figure 4.9: Temperature differences in relation to opening modification

4.2.5 Selected Modification Model

The discussions of the results of this simulation modification are referred to the field study configuration; model A, B, C, D, E, F and G. Below is the table for seven difference models.

	Original Model	**Model A**	**Model B**	**Model C**	**Model D**	**Model E**	**Model F**	**Model G**
Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Without Ceiling
Roof Color	Gray	Light	Dark	Light	Light	Light	Light	Light
Roof u-value	Small	Small	Small	High	Small	Small	Small	Small
Wall Color	Gray	Light	Light	Light	Dark	Dark	Dark	Dark
Opening	Normal	Normal	Normal	Normal	Normal	Maximum	Maximum	Maximum
Floor Color	Gray	Light	Light	Light	Light	Light	Dark	Light

Table 4.1: Difference type of model

For the purpose of comparative analysis on the effect of the new principle design model and the original model (field study) indoor temperature and temperature difference value were used to determine the deviation of values at the proposed configurations.

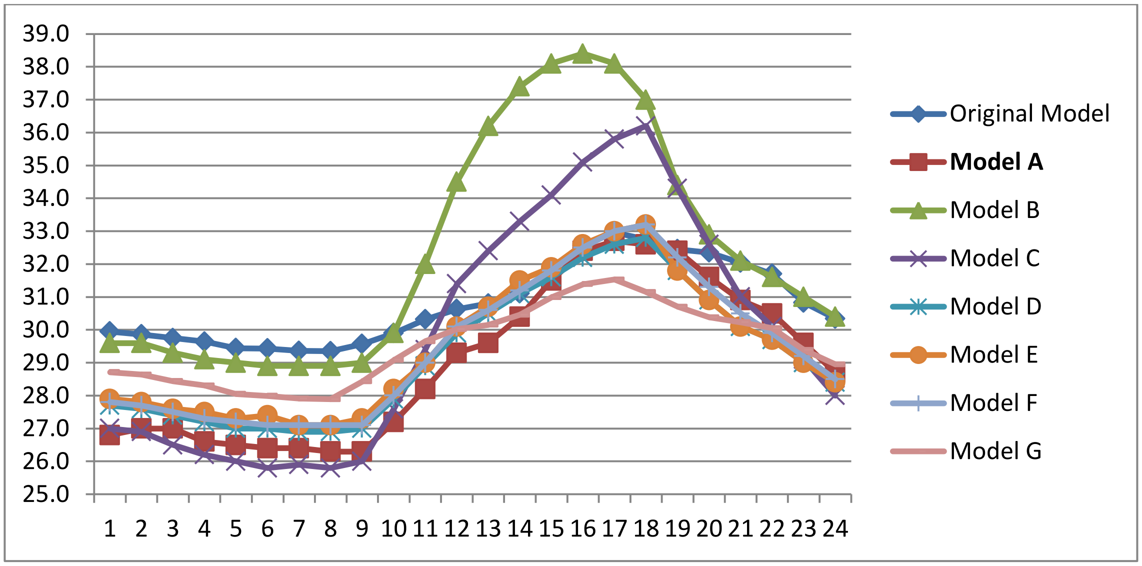


Figure 4.10: Indoor temperature in relation to the proposed model

The indoor temperature data shows that at proposed A the temperature value is the lowest at 06:00h (27°C-28°C). The highest temperature reduction effect is recorded at model A of the big U value wall and decreases towards the increase of the ratio opening. The average indoor temperature of proposed model A and other models for the house are shown in figure 4.10. The minimum indoor temperature was obtained in proposed model A.

The temperature reduction value increases significant at model A. The temperature reduction obtained from the proposed model A shows that maximum temperature reduction achieve in the day time and maximum temperature addition at night. The effects of model A will be simulated to show the thermal environment performance of the new building design.

4.3 Findings of the Performance of New Tropical Building Model

Figure 4.10 illustrate effectiveness of proposed new building model in rising indoor temperature reduction for the type of materials. The calculations were compared to indoor temperature on the new building design model. The effects of new tropical building design on the average indoor temperature were assessed during hottest day in a year (6 July) at 12:00h. The maximum average indoor temperature reduction can be achieved by new tropical building model (model A) at 16:00h (4.2°C).

The results, analysis and findings of the simulation exercise are done to determine the influence of the new tropical building design for hourly conditions in term of indoor temperature were presented in this chapter. This chapter has analyzed the results obtained for the proposed house model and original model for improved thermal comfort.

Comparison of the average indoor temperature on field study and new tropical building model indicated that new tropical building obtained the minimum air temperature and within upper limit of neutral temperature. The average air temperature on original model indicated above of neutral temperature for mid-day. Further, new tropical building decreased the average temperature up to 4°C on respective conditions. The new tropical building design provides the optimum indoor comfortable. It enabled us to understand the influence of tropical principle design components on the overall indoor comfortable. The results showed that ceiling, material and opening were main contributors on improving indoor comfortable. The results revealed that the use of ceiling, wall material with $3 W/m^2K$ U value and large opening were the three important aspects towards building's indoor comfortable environment.

4.4 Use New Tropical Building Model in Different Weather Data

After the proposed new building design was selected (model A), the design is used in three different cities: Kuala Lumpur, Georgetown and Kuching.

4.4.1 Kuala Lumpur

The average of indoor temperature was calculated on the hottest day (6th July) in Kuala Lumpur at 12:00h. The maximum indoor temperature recorded was at 14:00h with 32.75°C and the minimum indoor temperature recorded was at 07:00h with 23.37°C.

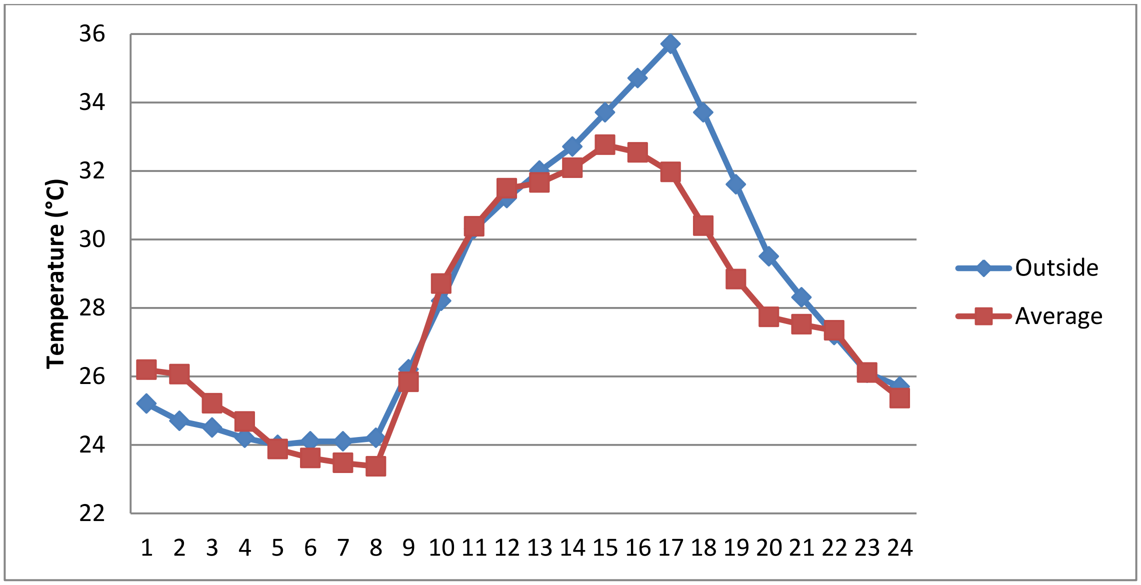


Figure 4.11: Indoor temperature and outside temperature in Kuala Lumpur

4.4.2 Georgetown

The average of indoor temperature was calculated on the hottest day (14th March) in Georgetown at 12:00h. The maximum indoor temperature recorded was at 14:00h with 31.28°C and the minimum indoor temperature recorded was at 06:00h with 23.85°C.

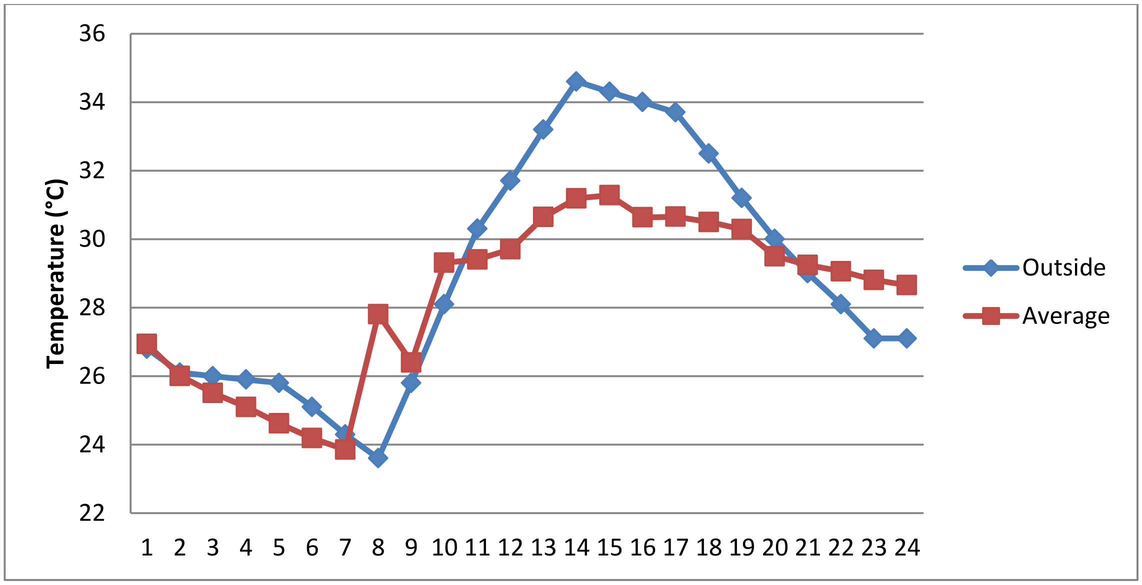


Figure 4.12: Indoor temperature and outside temperature in Georgetown

4.4.3 Kuching

The average of indoor temperature was calculated on the hottest day (2nd June) in Kuching at 12:00h. The maximum indoor temperature recorded was at 11:00h and 13:00h with 32.74°C and the minimum indoor temperature recorded was at 02:00h with 24.83°C.

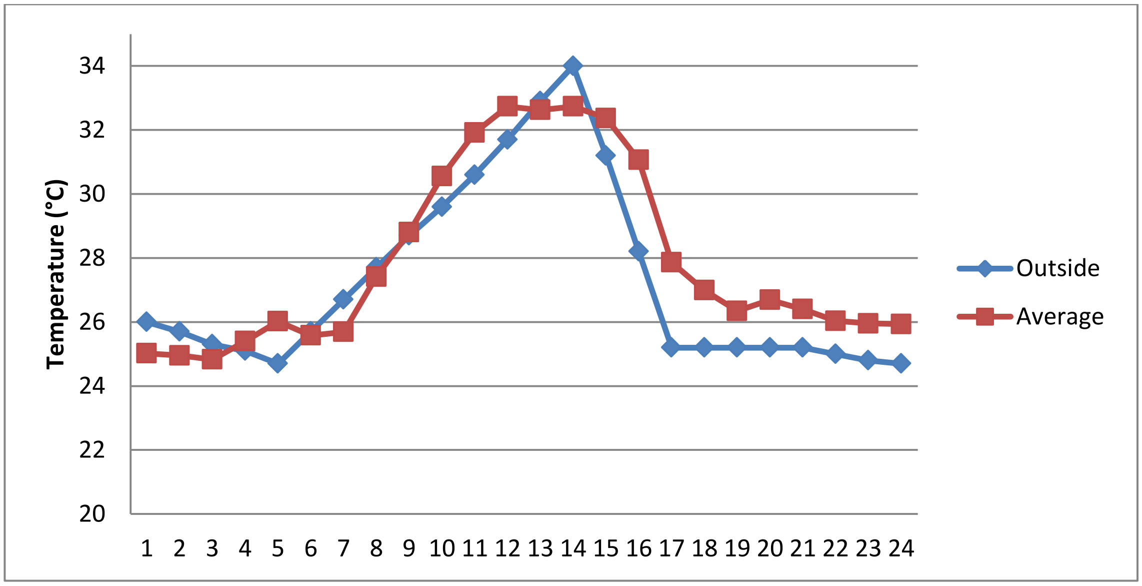


Figure 4.13: Indoor temperature and outside temperature in Kuching

In figure 4.15, indoor temperature for three difference cities were calculated. All data was taken during hottest day in the cities, Kuala Lumpur (6th July), Georgetown (14th March) and Kuching (2nd June) at 12:00h.

Georgetown has minimum indoor temperature throughout the day follow by Kuala Lumpur and Kuching. The highest indoor temperature record at 14:00h is 31.28°C and outdoor temperature 34.30°C. The inside temperature is cooler by 3°C.

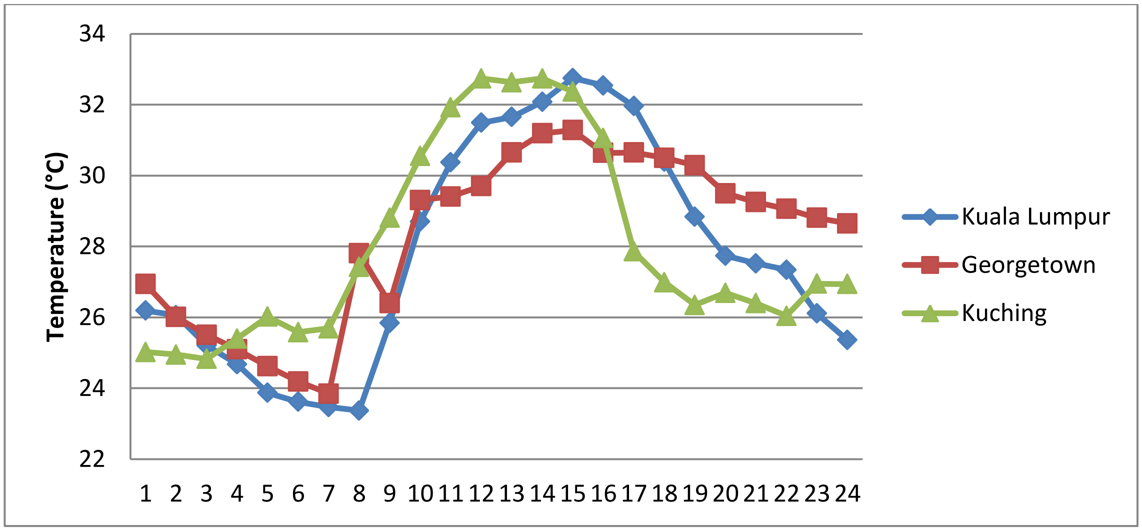


Figure 4.14: Indoor temperature difference for three cities in Malaysia

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The findings of the research have been presented and discussed in the previous chapter. This final chapter will conclude the overall findings of the report. The application of the research findings are also discussed in relation to the aims and objectives of the report as set in Chapter 1. Finally, further work related to this study will be suggested in this chapter in order to strengthen and compliment this report.

5.1 Review of Study Objectives

As stated in Chapter 1, the main aim of this study is to examine relationships among macroclimate; microclimate and residential building characteristics. Other specific objectives of the study are as follows:

a) Compare with difference weather data set
b) Propose indoor environmental quality indicators for sustainable house in tropical climate.

5.2 Research Conclusion

This section attempts to conclude the research by summarizing the major findings of the study and answering the research questions as stated. They are as follows:

5.2.1 Comfortable Indoor Environment of Field Study

Based on the measurement and simulation results, significant impact on indoor temperature is above the neutral temperature for selected conditions. The investigation of the indoor temperature also showed that this double storey house experienced the temperature value of an uncomfortable condition. Generally, the double storey model house received the highest indoor temperature in the afternoon. Therefore, it is important to consider the indoor temperature in existing house especially in the afternoon times with respect to outdoor conditions.

5.2.2 Modification of Building Design Principle

a) The study indicated that the proposed new building design (Model A) achieved the minimum indoor temperature. The modifications were done to roof structure, wall component, opening and floor to achieve minimum indoor temperature. Hence, it can be concluded, that for an indoor comfortable house, model A building modification can be used to develop the appropriate design of tropical building design and provide lower temperature.

b) The air temperature values indicated lower value in the U value and color wall modification compared to another wall modification house models. Considering the material attributes to develop the model; therefore the study suggest that wall material with high U value and light color wall are required to achieve maximum temperature reduction.

c) The indoor temperature on opening modification indicated minima indoor temperature during normal opening size. Influence of the opening size indicated a decrease opening size in indoor temperature and has significant impact on the comfortable condition.

d) Simulation of double storey house model with floor modification on light color resulted in better indoor temperature performance than the other floor modifications. This implies that changing floor color surface had an impact to indoor temperature reduction. These results can be combined with another building modification to obtain the indoor environmental quality.

5.2.3 New Tropical Building Design Principle

a) The relationship between the indoor environmental quality and the proposed tropical building were determined based on the assumptions of the indoor temperature and temperature reduction on the selected climate condition. The optimum proposed model suggested that the proposed model A can be achieved best proposed model as the new tropical building.

b) The indoor temperature of model A is lower than the original double storey house and model B.

Time	Outside	Original Model	Model A	Model B
0	25.2	29.95	28.71	31.76
1	24.7	29.86	28.64	31.65
2	24.5	29.75	28.44	31.50
3	24.2	29.64	28.31	31.34
4	24	29.44	28.05	31.13
5	24.1	29.43	27.99	31.12
6	24.1	29.36	27.91	31.04
7	24.2	29.35	27.89	31.02
8	26.2	29.57	28.43	31.26
9	28.2	29.90	29.08	31.76
10	30.3	30.32	29.65	32.55
11	31.2	30.63	30.02	33.33
12	32	30.80	30.15	33.66
13	32.7	31.11	30.46	34.17
14	33.7	31.78	30.99	35.91
15	34.7	32.56	31.39	38.00
16	35.7	32.96	31.53	38.95
17	33.7	32.75	31.15	38.50
18	31.6	32.45	30.70	37.90
19	29.5	32.35	30.38	37.94
20	28.3	32.04	30.23	37.07

21	27.2	31.70	30.05	35.98
22	26.1	30.83	29.39	33.71
23	25.7	30.34	28.95	32.62

Table 5.1: Indoor temperature for difference models

5.2.4 New Tropical Building Model in Different Weather Data

a) Different cities will give different indoor temperature depending on the hottest day in a year. For this research the minimum indoor temperature is in Georgetown follow by Kuala Lumpur and Kuching. The temperature also depends on the latitude and longitude of the cities.

5.3 Suggestions for Further Research

This research has revealed two significant findings. Firstly, the introduction of the double storey terrace house is significantly produced environmental quality house in the morning. It can maintain neutral temperature for comfort (28°C) in the morning and night. Some of the area even achieved indoor temperature below 28°C. The introduction of the new tropical building design (model A) with light color roof, wall material, u value, maximum opening and light floor at the house increases and further improve the thermal comfort condition.

This study has suggested that how a simple tropical building principle house strategy can be effectively used to reduce the indoor temperature and increase environmental quality. The new tropical building design strategies require simple and rational modifications in material of the wall and window openings. However, several areas of study need further investigation, to develop the knowledge of the tropical building design strategies in Malaysia and regions with design of similar climates. Therefore, it is recommended that future research could look further into this area in order to strengthen and compliment this research.

The following are some suggestions:

a) Investigation on the effectiveness of the wall material. Apart from higher U value of wall material, the other factors need to be investigated are the combining between several local material.
b) Further investigations are required to determine the effects of the new tropical building strategy on different room size on various building forms.
c) Further study and analysis on existing Malaysia house design should be carried out to give a better indication on the indoor environmental quality performance. Hence, a better comparison on the performance can be carried out.
d) Investigation with difference weather data with urban and rural areas. This study only focuses on cities area only. Further study need to be carried out to determine indoor temperature in the rural areas.

Finally, it can be acknowledged that this work is a significant contribution by the researcher towards providing indoor comfortable house. It is hoped that it can induce good design solution that is not impossible in term of its low cost towards providing better comfort and more beneficial to the user.

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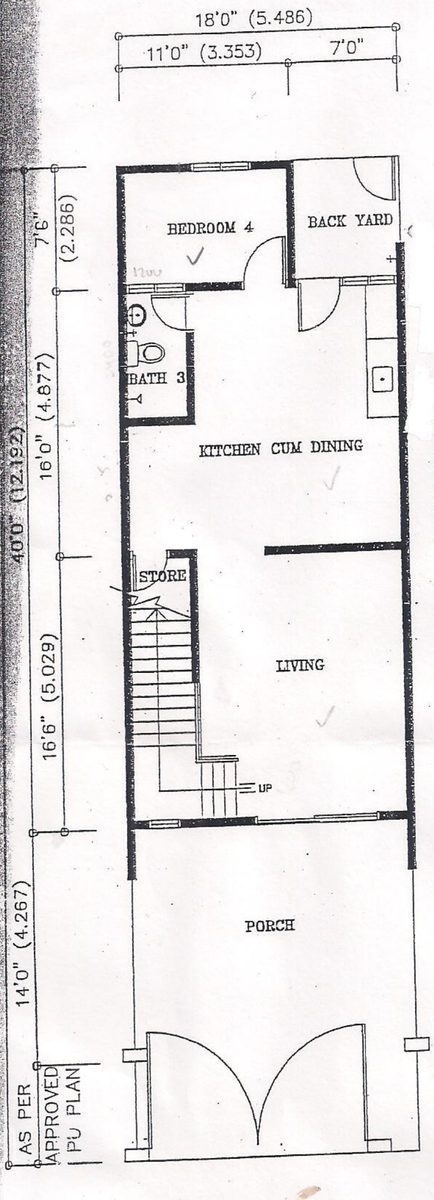
APPENDIX

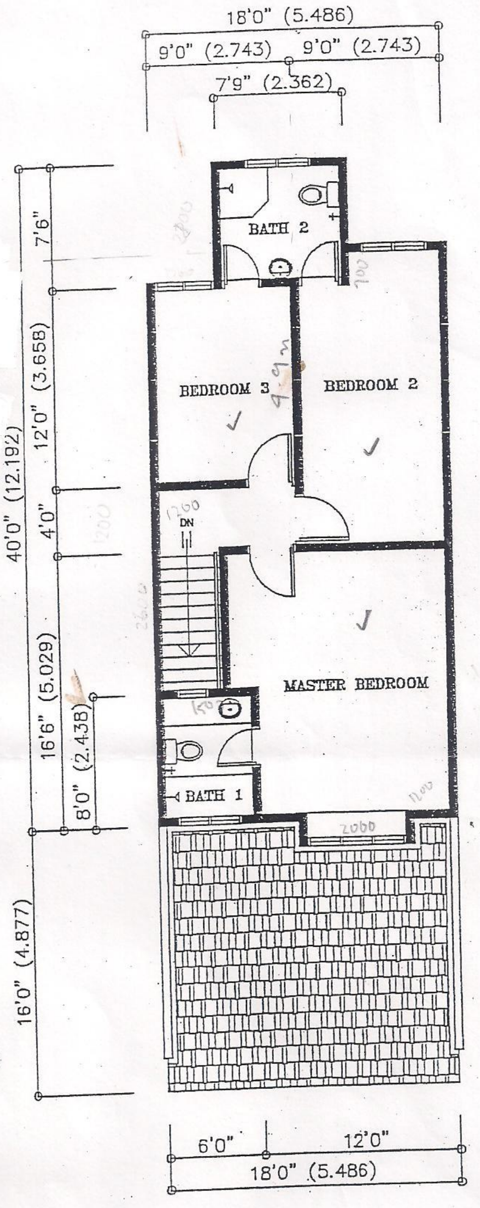
Double Storey Terrace House Plan

BANDAR SERI BOTANI

SERI MARGOSA - PH1.6A (154 UNITS DOUBLE STOREY TERRACE)



TYPICAL GROUND FLOOR PLAN

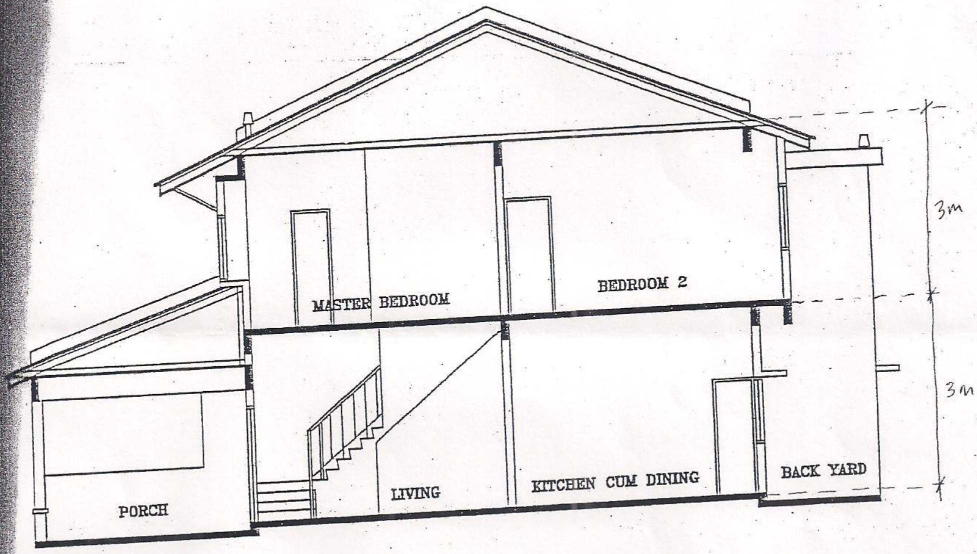


TYPICAL FIRST FLOOR PLAN

126 UNITS – INTERMEDIATE UNIT : TYPE B
LOT SIZE – 18' x 60'
BUILT UP – 1330 sq. ft.
ON PT NOS – PT 200905–200908, 200911–200914, 228471, 202830–202832, 202835–202838, 200917–200924, 200927, 228471, 202841–202848, 202851–202860, 202863–202870, 202873–202881, 202884–202889, 202892–202899, 202902–202906, 202909–202923, 202926–202940 & 202943–202958.

Date: 3rd JAN 2011

BANDAR SERI BOTANI
SERI MARGOSA - PH1.6A (154 UNITS DOUBLE STOREY TERRACE)



TYPICAL SECTION VIEW
INTERMEDIATE UNITS

126 UNITS – INTERMEDIATE UNIT : TYPE B
LOT SIZE – 18' x 60'
BUILT UP – 1330 sq. ft.
ON PT NOS – PT 200905–200908, 200911–200914, 228471, 202830–202832, 200917–200924, 200927, 228471, 202841–202848, 202835–202838, 202863–202870, 202873–202881, 202884–202889, 202851–202860, 202902–202906, 202909–202923, 202926–202940 202892–202899, & 202943–202958.

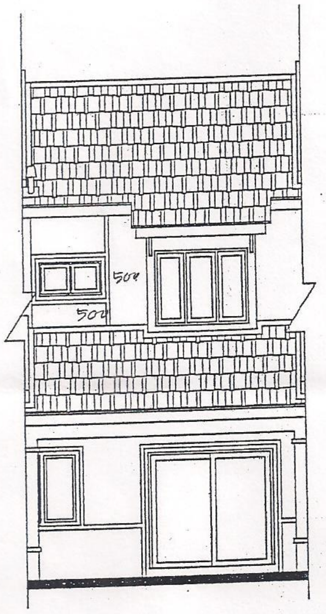
Date: 03 JAN 2011

BANDAR SERI BOTANI

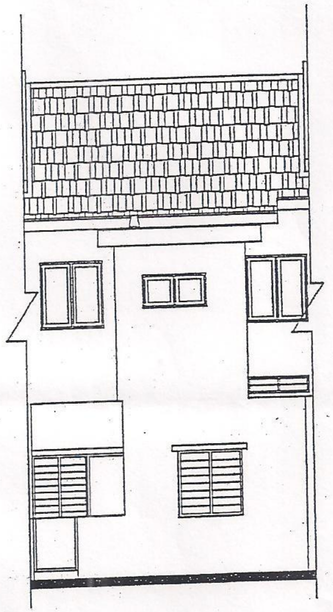
E: SERI MARGOSA - PH1.6A (154 UNITS DOUBLE STOREY TERRACE)

600 x 1200

900 x 2100



TYPICAL FRONT ELEVATION



TYPICAL REAR ELEVATION

126 UNITS – INTERMEDIATE UNIT : TYPE B
LOT SIZE – 18' x 60'
BUILT UP – 1330 sq. ft.
ON PT NOS – PT 200905–200908, 200911–200914, 228471, 202830–202832, 202835–202838, 200917–200924, 200927, 228471, 202841–202848, 202851–202860, 202863–202870, 202873–202881, 202884–202889, 202892–202899, 202902–202906, 202909–202923, 202926–202940 & 202943–202958.

Date: 3rd JAN 2011

information, specifications & colour scheme of the building contained herein may subject to changes and/ or amendments as may be required by the relevant authorities or project consultants.

FOURTH SCHEDULE
(Clause 13)

BANDAR SERI BOTANI
ZONE SERI MARGOSA : PHASE 1.6A
(154 UNITS DOUBLE STOREY TERRACE)

SPECIFICATIONS

STRUCTURE	Reinforced concrete frame	
WALLS	Brickwork	
ROOFING FRAMING	Cement roofing tiles	
ROOF TRUSSES	Timber	
CEILING	Plaster ceiling / cement fibre sheet / skim coating	
WINDOWS	Aluminium frame windows / metal frame glass louvre	
DOORS	Front / back	- Aluminium sliding doors / timber doors
	Baths	- PVC doors
	Others	- Timber doors
FLOOR FINISHES	Living, dining, kitchen, kitchen cum dining, bathrooms, bedrooms, hallway & staircase	- Ceramic tiles
	Car porch / driveway & covered terrace (if any)	- Homogeneous tiles
	Balcony (if any)	- Ceramic tiles
	Other areas	- Cement plastered
WALL FINISHES	Kitchen & kitchen cum dining	- 5'0" high ceramic wall tiles to designated areas
	Bath 1 & 2	- Ceiling height ceramic wall tiles
	Bath 3	- 7'0" high ceramic wall tiles
	Other areas	- Cement plastered
SANITARY AND PLUMBING FITTINGS	Sitting WC	- 3 nos
	Wash basin	- 3 nos
	Stainless steel single bowl Kitchen sink	- 1 no. / 2 nos*
	Shower points	- 3 nos
ELECTRICAL INSTALLATION	Lighting points	- 19 nos
	Fan points	- 6 nos
	13 amp power points	- 18 nos
	15 amp power point	- 1 no
	T.V. aerial points	- 2 nos
	Astro point	- 1 no
	Telephone point	- 1 no
	Air-cond point (without starter)	- 1 no
	Door bell point	- 1 no
	Auto gate point	- 1 no
PAINT	Internal wall	- Emulsion paint
	External wall	– External paint
	Timber / metal surface	- Gloss paint
FENCING	Front / side elevation	- Brickwall fencing with metal grilles / full brickwall fencing
	Other	- 4'0" high full brickwall fencing
GATES	Front / back	- Metal grille gate
MISCELLANEOUS	Letter box	- 1 no
SECURITY METAL GRILLES	All aluminium windows & sliding doors Rear timber doors at the ground floor	
TURFING	Nil	

Date : 03 January 2011

* Applicable for corner units (type A1) only