THE EFFECTIVENESS OF RADIANT BARRIER AS REFLECTIVE INSULATION IN ROOFS OF RESIDENTIAL BUILDINGS IN TROPICAL CLIMATE

by

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CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project in this project, that the original work is my own except as specify in the references and acknowledgements and that original work contained herein have not been undertaken or done by unspecified sources or person.

(Dayang Farah Ziela Binti Abang Maamon)

ABSTRACT

Nowadays, global warming have been an international issues and world problem. Global warming happens due to the continuing rise in the average temperature of Earth's atmosphere and oceans. It is because of increased concentrations of greenhouse gases in the atmosphere, resulting from human activities such as deforestation and burning of fossil fuels. These activities contribute to the CO_2 gasses emissions. Finding has made by IPCC SRES in year 1990 to 2010, the carbon emission increased by year from 21 to 31 (billion tons per year). In order to reduce the heat, a few campaign was conduct and rehabilitation work been done. Every sector in industries especially in building construction they also contribute to the gasses emission by energy consumed by human for living and working.

Based on case study, buildings consume one-third of the world energy and worldwide building energy consumption is expected to grow by 45% from year 2002 to year 2025. As in tropical countries experience high levels of heat radiation from the sun and leads to discomfort to humans and surroundings. Air conditioning is widely used to encounter this problem, which consumes high levels of energy. Therefore, this research aims to quantify the reduction in indoor temperature and to verify the positive effect of installing reflective insulation in roofs on indoor parameters. The research methodology consist of 1) construction of 2 down –scale model of experimental house (600 x 600 x 500mm) to study the effect of reflective insulation of indoor temperature and 2) insulation material 3) Roof color and 4) the house allocated. Data collection is conducted every hour from 8am to 5pm for seven days. The result shows that the insulated houses quantify the most reduction with 37.69% and the reduction of temperature difference is at 10.27%. From the result, the behavior of parameters measured show that insulated house has a better thermal performance compared to the control house. In future it is important to implement a cool roof to preserve our nature and sustainability development.

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1.0INTRODUCTION

Nowadays, global warming have been an international issues. Global warming happens due to the continuing rise in the average temperature of Earth's atmosphere and oceans. It is because of increased concentrations of greenhouse gases in the atmosphere, resulting from human activities such as deforestation and burning of fossil fuels. These activities contribute to the emissions of CO_2. IPCC SRES, in year 1990 to 2010 reported that carbon emission increased with each year from 21to 31 (billion tons per year).[1].

The ozone layers become thinner and no longer filtering the sun radiation. Effect from this the Tropical countries experience high levels of heat radiation from the sun which leads to discomfort to humans and their surroundings. Air conditioning is widely used to encounter this problem, which consumes high levels of energy.

These hot climates are the contribution made of the energy usage that we used to for daily routine. The more energy we consume, more Carbon dioxide (CO_2) is released. Therefore to reduce heat, installing reflective insulation will reduce the heat inside the house and help to decrease energy usage eventually

1.1. Background of Study

1.1.1. Tropical Climate

Tropical climate extends northward and southward from the equator at 15° - 25° latitude. Based on Köppen climate classification system, tropical climate is categorized based on annual and monthly averages of temperature and rainfall whereby mean temperatures throughout the year are above 18°C. Tropical temperatures remain relatively constant throughout the year and seasonal variations are dominated by precipitation with an average of 60 mm [2]. Figure 1 show the climatic zones and the red zone indicate tropical climate zone.

Below are ten countries with tropical climates and their locations:

- Malaysia
- Papua New Guinea
- Madagascar
- Indonesia
- Congo
- Mexico
- Brazil
- Peru
- Cuba
- Bahamas

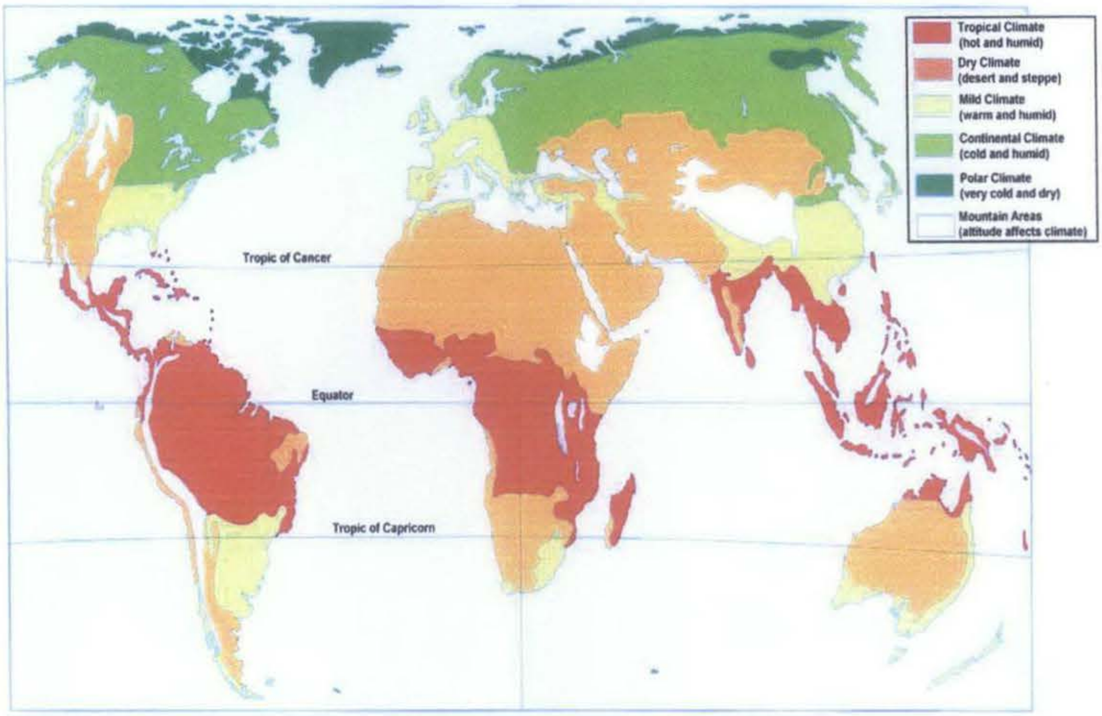


Figure 1 : Global Climatic Zones [3]

Table 1. Highest temperatures recorded in 2010 for ten tropical countries[4]

Country	Highest Temperature Recorded in 2010
Malaysia	40.1 °C
Papua New Guinea	37.2 ° C
Madagascar	38.6° C
Indonesia	38.8° C
Congo	37° C
Mexico	52.0 °C
Brazil	44.7 °C
Peru	33.9 ° C
Cuba	36.5 ° C
Bahamas	36.5° C

Malaysia geographical location made it received the sun directly overhead most of the day throughout the year. And major heat gain of Malaysia houses are from the roof and it give a huge impact on the thermal performance of the whole building especially [5][6].

1.1.2. Energy Consumption in Buildings

In tropical climate countries, indoor conditions are required to be kept thermally comfortable [7]. Increase in temperature makes occupants uncomfortable, which leads to low productivity. Therefore most buildings in Malaysia resorted to mechanical cool technologies that consume electricity. A report states that buildings consume about one-third of the world's energy and for worldwide energy, which is expected to grow by 45% starting from 2002 to 2025 [8].

Different type of buildings consumes energy at different rates and buildings are divided into residential and non-residential. Non-residential buildings consist of commercial and industrial buildings. Table 2 shows examples of building types:

Table 2 . Building Types

Industrial building

Office Building

Residential House

In 2002, 44% of the total energy is used in the residential sector in Malaysia and 75% for the non-residential sector. 50% of electric usages are from lighting and air conditioning [9]. Therefore, potentially the practice must start from buildings.

Housing types are terrace houses (61%), apartments (27%) and detached houses (12%). In average, more than 56% of the houses have installed air conditioning [10]. Current trend indicates that bigger houses tend to be air conditioned and for those purchasing small houses the occupants are offered to install air conditioners.

Table 3. Types of consumption in buildings

Residential Buildings	Fans
	Televisions
	Air-conditioners
	Refrigerators
Commercial Buildings	Air-conditioners
	Computers
	Printers
	Air-conditioners
Industrial Buildings	Machines
	Computers
	Lighting
	Air- conditioners

Figure 2 shows the energy consumption for residential building in Malaysia:

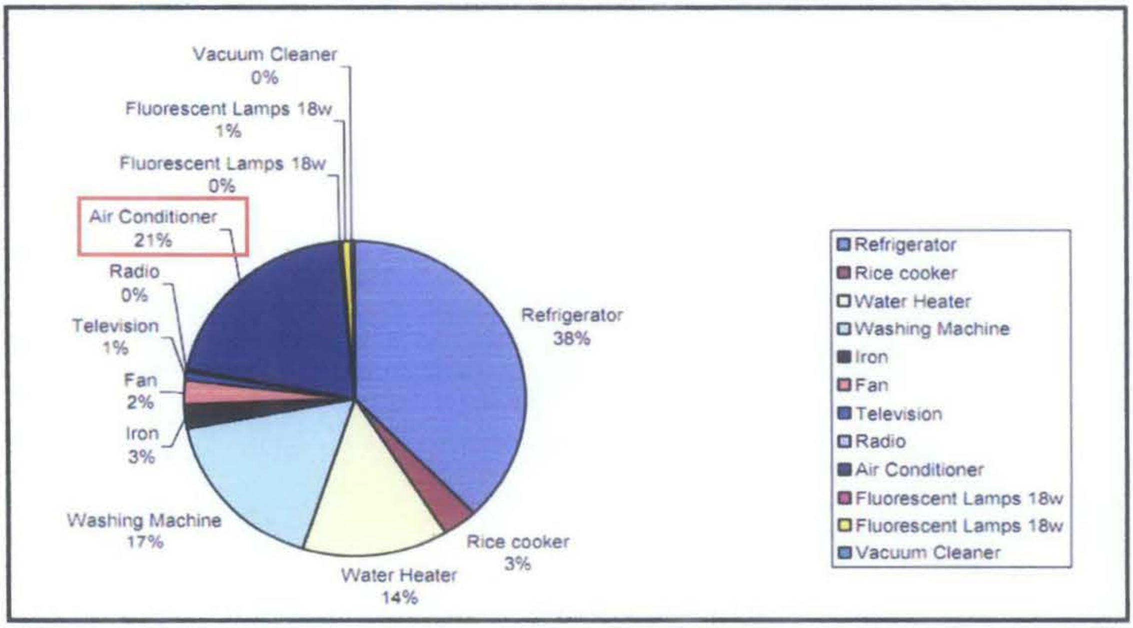


Figure 2. Energy consumption for residential building usage in Malaysia for 180m2 area [11]

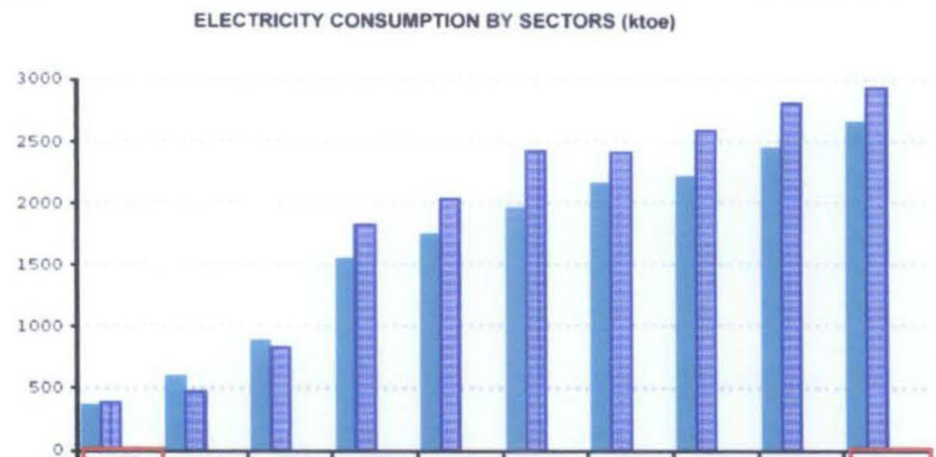
Figure 3 shows that air conditioning is the second largest contributor to electricity consumption in residential building in Malaysia and the highest contributor to emission of CO2 gas into the atmosphere. Changes in the atmosphere due to the contribution of CO2 influenced changes into the climate such as changes to temperature, precipitation, storms and sea levels [1].

High temperatures and humidity causes discomfort among occupants in residential buildings. Frequent usage of air-conditioners to lower temperatures and humidity leads to high electricity consumption which increases rates of carbon emission.

1.2. Problem Statement

Buildings are often overlooked when people think of their impact to their lives and the environment. 40% of energy is consumed by buildings, and it is one of the major causes of greenhouse gas emissions. Buildingsare divided into three types which are residential, commercial, and industrial buildings. Most of the energy consumed in buildings is due to usage of electrical appliance.

Research shows that electrical consumption in Malaysia, residential and commercial type of houses shows the energy consumption are increased by year. Starting from year 1980 to year 2001 the increasing value up from 363 ktoe till 2660 ktoe [11]. Figure 3 shows the electrical consumption by sector from year 1980 to 2001 and the chart indicates that electrical usage is increasing by year.



	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001
Resid. & Comm.	363	604	885	1,549	1,747	1,961	2,165	2,220	2,453	2,660
Industrial	384	475	830	1,826	2,029	2,422	2,411	2,591	2,805	2,930
Transport	0	0	0	0	1	1	1	4	4	5.17
Total	747	1,079	1,715	3,375	3,777	4,384	4,577	4,815	5,263	5,594

Source: Department of Electricity and Gas Supply Malaysia, Ketua Merinyu Elektrik Sarawak, TNB, SESCo, SESB, and GDC (M)

Figure 3 . Electrical Consumption by sectors [11]

Focusing on residential building, factors affecting energy use in the residential are cause of air conditioning, lighting, occupancy, climate and building design and construction. [11]. This is because; tropical countries experience high levels of heat radiation from the sun. High indoor temperatures lead to increased usage of fans and air conditioners and frequent usage of fans and air conditioners for long period increases energy consumption.

Research on installing roof insulation and result on material used aluminum foil give a best impact on decreasing the human thermal discomfort [12]. Strongly recommended by using double sided aluminum foil reflective insulation it will helps to overcome the problem. Therefore in this field measurement case study, a radiant barrier are choose to be verified its effectiveness towards reducing indoor temperature thus decreased thermal discomfort.

1.3. Objectives

This research aims to fulfill the following objectives:

1) To verify positive effect of installing radiant barrier as roof insulation on indoor temperature and humidity.

2) To quantify reduction of indoor temperature and humidity induced by installation of radiant barrier.

1.4. Scope of Study

The scope of study is:

- Using two experimental houses which scale – down, 600mm length x 600 mm width x 500 mm height and roof double pitched with 45 degrees slope.
- There a two set of experimental houses that are use to investigate the differences of temperature with and without using insulation. One house are installed with insulation and another one house will be none.
- Insulation used are bubble type with 10 mm thick consist of 3 layer material.
- The micro climatic properties to be investigate :
    1. Indoor Temperature
    2. Indoor Relative Humidity
    3. Roof Surface Temperature
    4. Outdoor Temperature

- The experiment will be conduct simultaneously for both houses and data records will be collected using data loggers and probes. It also will be analyzed using data logging software.
- The experimental house will be placed at open area next to building 13 which no interference of trees and will received the maximum sun heat. The houses also placed accordingly based on the sun rotation (east to west).

1.5. Relevancy of the Study

Green building is a best practice of green technology in increasing the efficiency of the building sites energy used such as water, electrical energy, materials and reducing the building impacts on human health and environment. These green building concepts extend beyond the walls of building starting from planning, community and land use planning issues too.

This study is very important because of the growth and development communities have the largest impact on our natural environment. Start with the manufacturing process, design, construction and operation of the building responsible to consume many natural resources. In order to reduce the usage of energy especially on electricity and air-conditioning, which is where the energy mostly used construction materials are slowly modified to suit and help us to reduce the energy consumption.

As we alert, the usage of air conditioning has been widely use. It is because of the natural climate of Malaysia. Which is, the surrounding area are hot and humid tend to make the occupants feeling uncomfortable with windless and less ventilation area. The study of radiant barrier in roofs is basically to investigate the effectiveness of the material to insulate and to absorb the heat from solar reflection from fully penetrate to the residential interior. Since roof is the most critical and frequent component that exposed to the sun heat other than wall and windows.

Based on research, roofing received more than 80% of the sunlight. As to reduce the heat transfer to the house, insulation are needed and most of the roof insulation that are used at Malaysian houses are wool, polystyrene, fiberglass, rocks and plastic fiber, to minimizes the rate of heat transfer. But it wasn't enough to cool the house to the max and based on the study, the insulation can reduce indoor temperatures by 3°C to 5°C only [13].

Based on the experiment, the result then will be analyzed to get an optimum thickness of insulation used and optimum costing estimation on the construction usage, as well as the reduction of electricity and long term effect on the occupant.

1.6. Feasibility Study

1.6.1. Research duration

Time frame for experimental setup and data collection is two semesters that is equivalent to eight months.

1.6.2. Research cost

The cost of installing radiant barrier will be compensated by long term returns due to reduction in electricity bills.

1.6.3. Research benefit

The benefit to the user as the electricity bills decrease and help to reduce heat penetration to the house.

2.0LITERATURE REVIEW

2.1. Introduction

Building envelope is the outer layer of the building that separates the internal space from the external environment, both above and below grade [14]. Many older homes have high heating requirements because of high rates of air leakage and building envelope areas that are not well insulated. It includes all components of a building that enclose conditioned space [14].

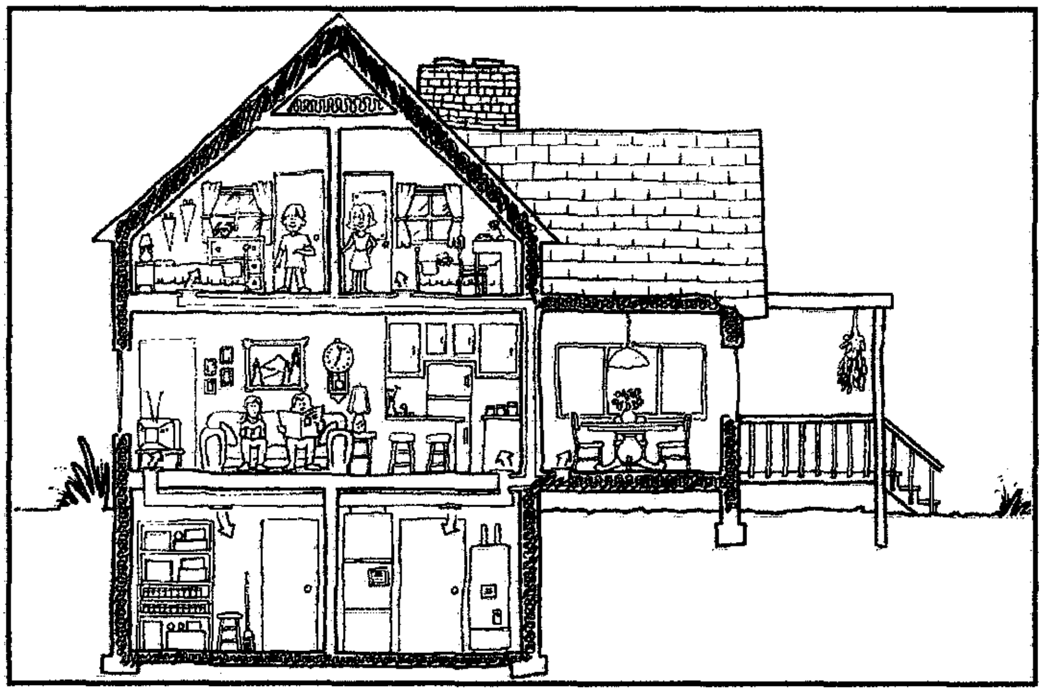


Figure 4. In the graphic, the building envelope is the areas that separate the internal and external environment. [14] *pink line.

2.2. Building Envelope

Buildings provide a comfortable indoor environment for occupants. It is consist of walls, roofs, windows, doors and floors. They allow heat to flow from the exterior to the interior [15]. Thermal characteristics on the building influence heating, ventilating and air conditioning systems and affect both equipment capacity and energy required for their operation. To measure the optimization of thermal performance of the building need to incorporate at the design stage where it is not easy to implement and many things need to be considered.

Building in Malaysia most major problems for residential development is roof spaces. Roof spaces overheating are caused by the inappropriate selection of roofing systems and material. And in this tropical climate temperature, roof has been a major source of heat gain. So, the solar protection of the roof had become a main concern in thermal design of building. [16][17][18][19].

Such improvement relatively expensive, but the result in lower heating turns the result in downsizing the equipment and lowering energy consumption. And considered on a life cycle basis it is financially viable [15].

2.3. Heat Transfer

When heat gain in the roof and hot air reach the internal space, it will retained for most of the night and this excessive heat will radiated from the attic to the occupants thermal comfort zone through radiation, convection and conduction [17].The percentage of heat transfer from the roof to indoor space through radiation is 87% and the remaining percentage heat is transferred through conduction and convection [20].

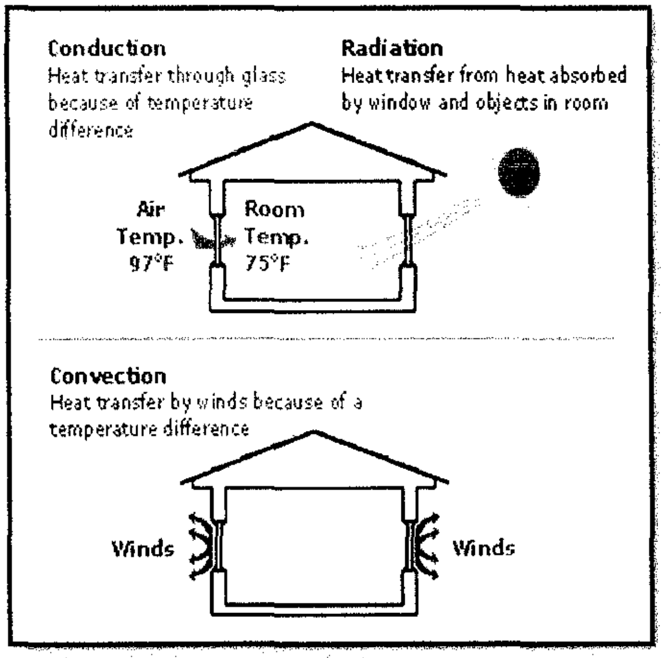


Figure 5 : Heat gain/loss mechanism for building envelopes

From Figure 5, conduction and convection occur due to heat transfer across the walls, roofs, windows and floors. The transfer depends on the differences in temperature between internal and external surface that can make it easy flow. Heat transfer due to radiation happens through the fenestration and mainly cause of the solar radiation flow. And for the air leakage depends on the differences pressure in an outside the building in any direction.

2.3.1. Conduction

Conduction takes place when the heat transfer across a solid object and there is different temperature gradient between both surfaces. The rate of heat transfer depends on the thermal conductivity of the material, its thickness, the temperature gradient, and the surface area available for heat transfer [15]

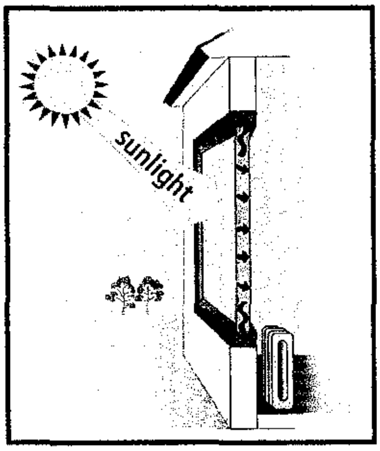


Figure 6 : Conduction

The rate of the transfer by conduction can be expressed using Fourier's law:

$$q_{conv} = kA\frac{dT}{dx}$$

Where k = thermal conductivity of the material

A = area (perpendicular to the heat flow)

dT = temperature gradient

dx = thickness

In buildings, heat is transferred by conduction mainly through walls, roofs and floors. Heat also travels by conduction through glazing of building envelopes.

2.3.2. Convection

Convection takes place when heat transfer contact with a surface at a different temperature by liquid form. Normally, in building walls, roofs and windows, heat transfer by convection takes place at both the interior and external surfaces.

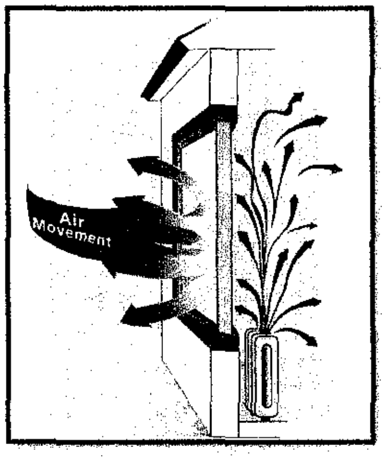


Figure 7 : Convection

Heat transfer by convection can be expressed using Newton's Law of cooling, as follow:

$$Q_{conv} = h_c A(T_s - T_f)$$

Where h_c = surface heat transfer coefficient

A = surface area

T_s= surface temperature

T^f= fluid temperature

The amount of convection heat transfer depends on the surface area, temperature difference between the surface and fluid, and the surface heat transfer coefficient. The surface heat transfer coefficient depends on the wind conditions for outdoor surfaces, while for indoor surfaces it is depend on the airflow over the surface caused by HVAC systems.

2.3.3. Radiation

Radiation takes place due to electromagnetic waves, which travel at the speed of light. Mainly for building, the radiations transmit the solar heat through fenestration on the building envelope.

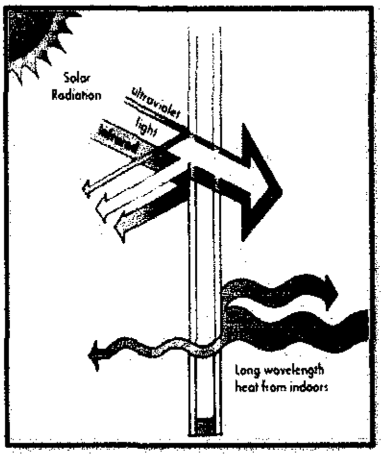


Figure 8 : Radiation

The amount of radiant heat transmission between two surfaces depends on the absolute surface temperatures of the bodies exchanging heat and the area of the body at the higher temperature. Radiant heat transfer can be expressed as follow:

$$q_{rad} = \sigma A_1 \varepsilon_1 (T_1^4 - T_2^4)$$

Where σ = Stefan – Boltzmann constant

A_1= area of surface 1

ε_1 = emissivity of surface 1

T_1 = absolute temperature of surface 1

T_2 = absolute temperature of surface 2

Radiant heat transfer can also be described by simple expression using radiant heat transfer coefficient (h_r), as follow:

$$q_{rad} = h_r A_1 (T_1 - T_2)$$

Majority of the energy consumed by buildings are to provide a cooling and heating space, in order to decreased the energy and saving energy, reduce heat gain and loss by building need to be achieved. Else it will give impact on building consumption.

2.4. Radiant Barrier

Radiant barrier is a material that can be used to insulate buildings from solar radiation and heat from penetrating into the ceiling of building, residential type especially. Heat loss and gain by transferring air leakage through the building envelope, which can be transferred in three way: Conduction, Convection and Radiation while infiltration and exfiltration occurred during air leakage [15].

The transfer of heat occurs from a warmer to a colder region. The mechanism of conduction and conduction can only be transferred through a medium or physical contact, whereas radiation can perfectly across through a vacuum in a straight line as the radiant energy. Below are the radiant heat transfer charts through all source of material [21]

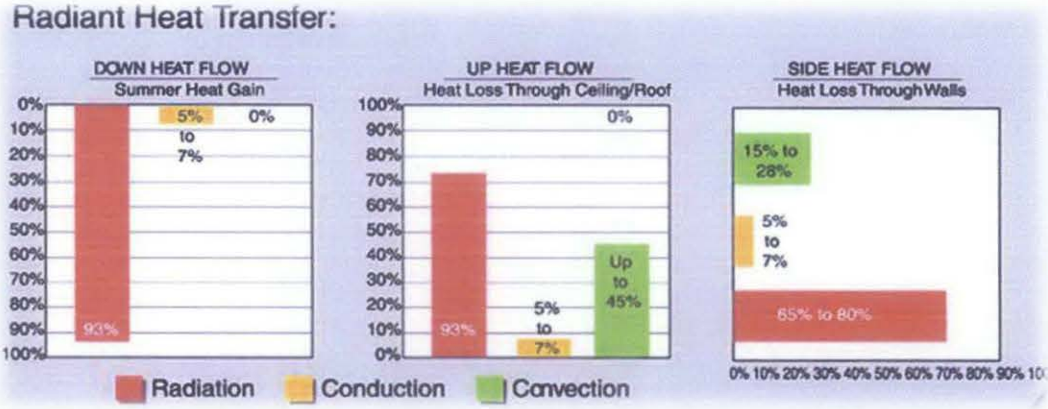


Figure 9 . Close environment, the contribution of radiation is the highest among all sources of heat [21]

The chart show that the roof is the most source exposed to the solar radiation. The solar then absorbed by the roof is directly transmitted down to the attic space. Radiant barrier is material, placed underneath the roof covering, leaving an air space and eliminated all the radiant heat. Below is how the radiant barrier mechanism works.

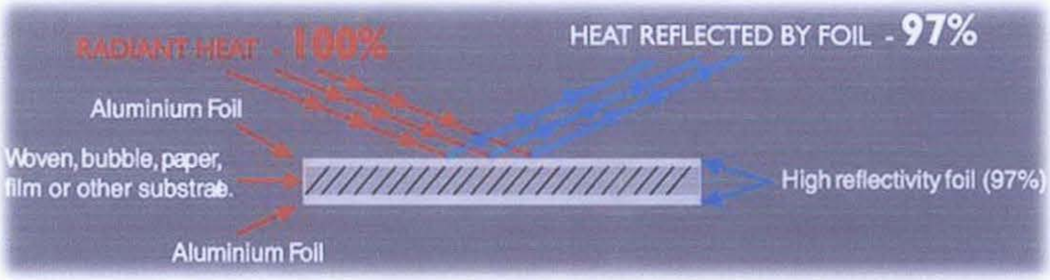
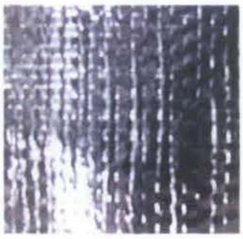
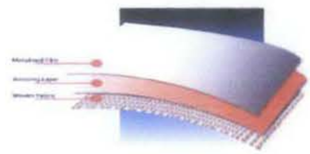
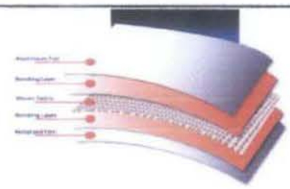
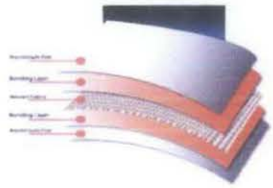
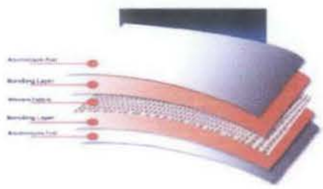


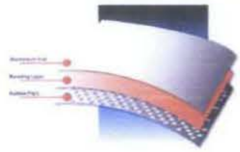
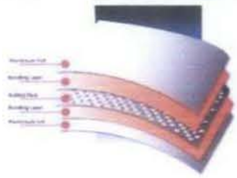
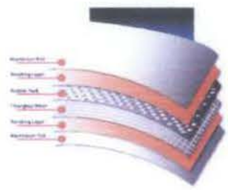
Figure 10. Radiant Barrier mechanism concept [21]

Suggested to installing the Radiant Barrier to save energy and it is can be used in a hot or cold climate region. It is the best saving material to be used and provided a batten cavity space and also ventilation.

Table 4 : Type and Component of the foil of Radiant Barrier

Type	**Component of the foil**
Woven Foil 	**Camel W118** **Product Description** CAMEL W118m is a 3 layer radiant barrier, using 1 layer of highly reflective metalized film bonded to 1 layer of extra strong woven fabric. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping. 
	Camel W228 **Product Description** CAMEL W228am is a 5 layer radiant barrier, using 1 layer of highly reflective metalized film bonded to 1 layer of pure aluminum foil at the other side bonded to 1 internal layer of extra strong woven fabric. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping.

	
	Camel WFR/D **Product Description** CAMEL W888a is a 5 layer radiant barrier, using 2 layers of pure aluminum foil bonded to 1 internal layer of extra strong woven fabric. Additionally, fire retardant additives are used. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping. 
	Camel WFR-S **Product Description** CAMEL WFR-S is a 4 layer radiant barrier, using 1 layers of pure aluminum foil bonded to 1 internal layer of extra strong woven fabric. Additionally, fire retardant additives are used. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping. 
Bubble Foil 	**Camel B 118a** **Product Description** CAMEL B118a is a 3 layer radiant barrier, using 1 layers of pure aluminum foil bonded to 1 layer of bubble pack film **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping.

	
	Camel B 228a **Product Description** CAMEL B228a is a 5 layer radiant barrier, using 2 external layers of pure aluminum foil bonded to 1 layer of bubble pack film **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping. 
	Camel B 888a **Product Description** CAMEL B888a is a 6 layer radiant barrier, using 2 external layers of pure aluminum foil bonded to 1 layer of bubble pack film and reinforced with fiberglass mesh. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping. 
Paper Foil 	**Camel C118m** **Product Description** CAMEL C118m is a 4 layer radiant barrier, using 1 layer of highly reflective metalized film bonded to 1 layer Kraft paper and reinforced with polyester yarn. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing and Poultry Houses Metal Roofing.

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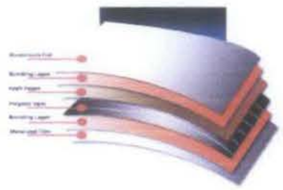
Camel C228m

Product Description

CAMEL C228 am is a 6 layer radiant barrier, using 1 layer of highly reflective metalized film at one side and 1 layer of pure aluminum foil at the other side bonded to 1 internal layer of Kraft paper and reinforced with polyester yarn.

Suggested Application

Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing and Poultry Houses Metal Roofing.



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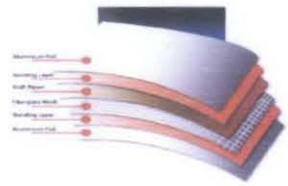
Camel FR450a(6L)

Product Description

CAMEL FR450a (6L) is a 6 layer radiant barrier, using 2 external layer of pure aluminum foil bonded to 1 layer of Kraft paper and reinforced with fiberglass mesh.

Suggested Application

Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing, House Wrapping and Air-con Ducting.



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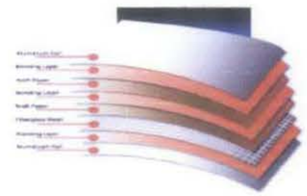
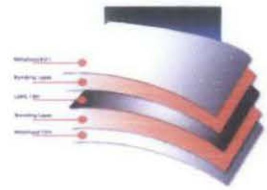
	Camel FR450a(8L) **Product Description** CAMEL FR450a (8L) is a 8 layer radiant barrier, using 2 external layer of pure aluminum foil bonded to 2 layer of Kraft paper and reinforced with fiberglass mesh. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing, House Wrapping and Air-con Ducting. 
Film Foil 	**Camel SUPER FOIL 228m** **Radiant Barrier** Product Description CAMEL Super Foil 228m is a 5 layer radiant barrier, using 2 external layers of highly reflective metalized film bonded to a LDPE Film substrate. **Suggested Application** Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping 

2.5. Solar Reflection Index (SRI)

Solar reflectance are also called "albedo" is a measure of the ability of a surface material to reflect sunlight. It have its own scale index called Solar Reflectance Index (SRI) which in 0 to 1. The value of index varies from 100 for a standard white surface to zero for a standard black surface. The lowers index means the material has low reflection and high absorption. To measure the coolness of the roof, solar reflectance and thermal emittance are the two radiative properties are used [22].

Defined by the Lawrence Berkeley National Laboratory, SRI is the roof's ability to reject solar heat, as shown by a small temperature rise. It is defined so that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. Due to the way SRI is defined, particularly hot materials can even take slightly negative values, and particularly cool materials can even exceed 100.

This *SRI* is a value that incorporates both solar reflectance and emittance in a single value to represent a material's temperature in the sun. SRI quantifies how hot a surface would get relative to standard black and standard white surfaces and this fraction laid out in ASTM 1980 [24].

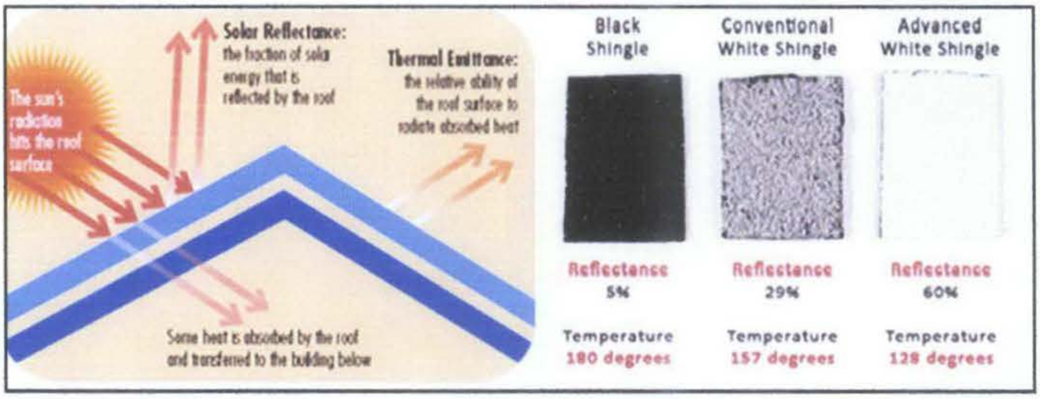


Figure 11: i) Diagram of solar reflectance from the sun ii) example of roof tile reflectance (%) and temperature (°C)

From the diagram above, we can see the more light color of roof is, the less temperature, and the higher reflectance it can do to cool the indoor temperature. Based on Energy Star, study the color of roof coating plays role to reduce the amount of air conditioning needed in the building and can reduce energy bills [24].

Reflectivity is the percentage of the sun's heat a roof keeps off a building, and emissivity is the percentage of heat a roof lets out of a building. Lighter colored (white) roof coatings reflect the suns heat and UV rays and often lower the temperature of the roof by up to 100° degrees F.

3.0METHODOLOGY

3.1. Introduction

This chapter elaborates the research methodology implemented to obtain thermal parameters of two experimental houses, which provides information required to evaluate effectiveness of radiant barriers as roof insulation.

In this project, data collection and data analysis will be involved. A few of data will be taken for comparison and using insulation as control parameter. Technically, the insulation will be placed in one of the scale down experimental house and the other will be none. The radiant barriers that will be used are bubble type 10mm thick in size. Based on this experiment, they are 4 parameter need to be recorded:

1. Indoor Temperature
2. Outdoor Temperature
3. Indoor Relative Humidity
4. Roof Surface Temperature

All of this parameter will be recorded throughout the scheduled period. This act is significant to determine the validity of the field measurement's data. Data will be recorded by using data logger installed and have been setup in the instruments. Readings are taken for 1 hour interval for 10 hours from 8am in the morning until 5pm in the afternoon. This experiment will be conducted simultaneously for both houses for 7 days.

Below are the sequence and material used to build the experimental houses.

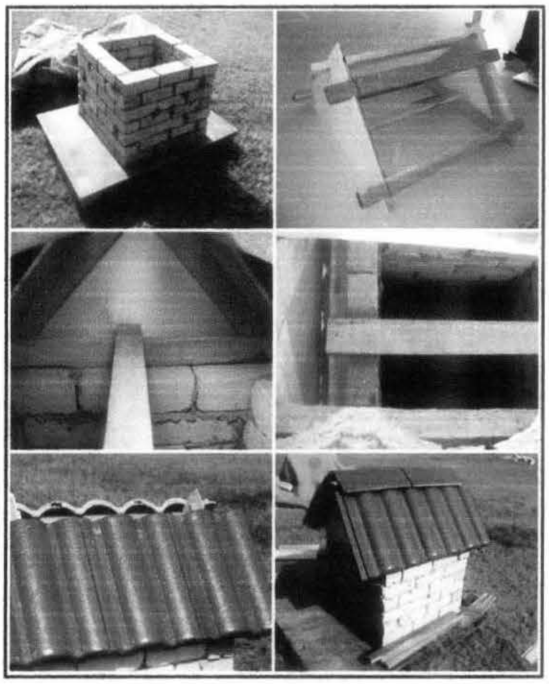


Figure 12 : Process of Experimental house fabrication & construction

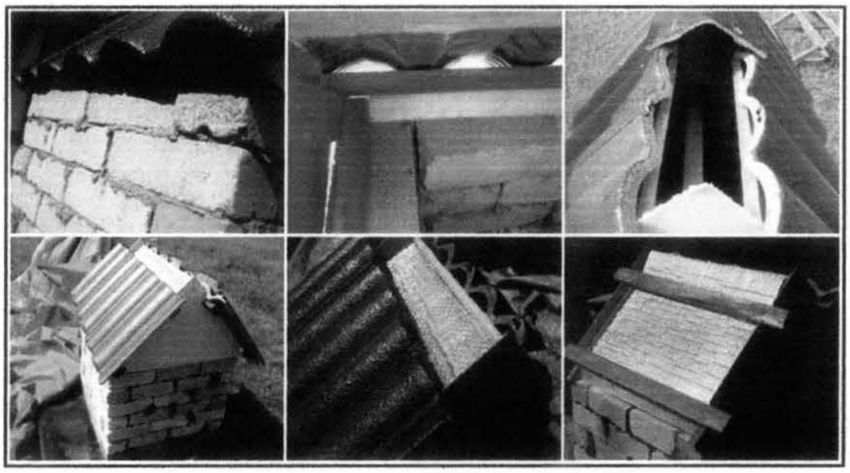


Figure 13 : i) Without insulation experimental house ii) with insulation experimental house

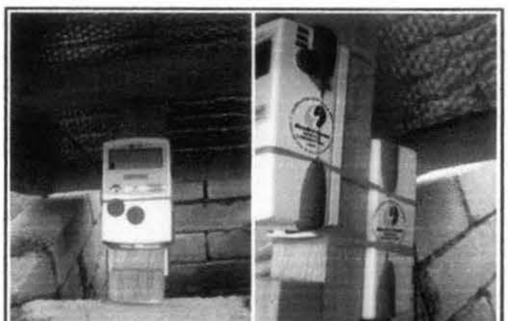


Figure 14 : Instrument been placed in the experimental house

For this project, the instruments are placed in the middle of the house. Not at the roof neither at the floor. The instruments are hanging in the middle of the house to make sure we get the indoor temperature accurately.

3.2. Insulation

For this project, radiant barrier that we choose for experiment is bubble foil type (CAMEL B118a) which content 3 layers of materials, using 2 layers of pure aluminum foil bonded to 1 layer of bubble pack film. Based on study, the bubble foil can reduce heat in certain percent from attic to living spaces by 16 – 24% and most of the reflective insulation reflect 95% of sun radiant energy that typically trap in the attic.

For this experiment we need to verify the objective of the project is to investigate the effectiveness of installing radiant barrier as reflective insulation in roof on indoor temperatures and humidity and to quantify the reduction value based on percentage heat reduced. Below are the insulations material properties:

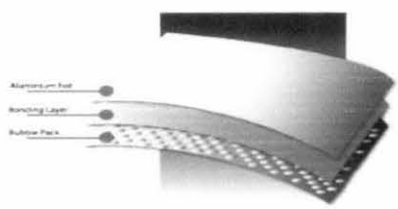
Camel B 118a

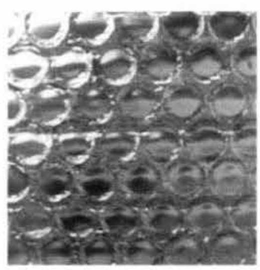
Product Description

CAMEL B118a is a 3 layer radiant barrier, using 1 layers of pure aluminum foil bonded to 1 layer of bubble pack film

Suggested Application

Residential Concrete / Clay Tiles Roofing, Industrial / Commercial Metal Roofing, Poultry Houses Metal Roofing and House Wrapping.





3.3. Roof Color

In order to have the maximum sun heat for indoor temperature, we are using Dark Grey color for roof tile in experiment. Dark Grey Ebony (color with SRI 22, Reflectance 0.25 and emmittance 0.83) which means the lesser it reflects the sunlight it absorb more the heat. In these experiments we need the maximum heat in order to have the worst case scenario.

Figure 15: Dark Grey (SRI 22) [25]

3.4. Experimental Setup

In this experimental work, a scale down experimental house have been build to observed and investigate the effectiveness of radiant barrier as a reflective insulation material for residential house. The scales down model of house were built to suite the real condition of the actual house in tropical climate, Malaysia especially. It made of bricks pallet for the walls, standard concrete and roof type.

The dimensions of the experimental house are 600 mm length by 600 mm width by 500 mm height. The experimental house position build based on the observation of sun rotation in order to have a maximum solar heat to the roof. The orientation for the house is the long axis of the roof is heading to the east to west according to the sun rises. Below shows the experimental house orientation taken from google earth and measurement on degree of experimental house rotation from east to west shown below.

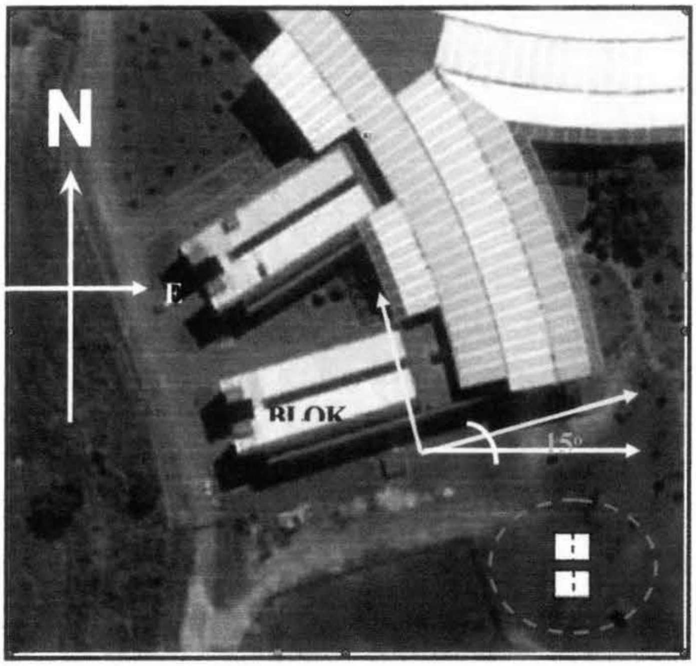


Figure 16: Block 13 (Location of the Experimental House)

Experimental house was located at an open space area to allow the minimum exposure to the sun heat (radiation) throughout the experiment. During the experiment, data collection for indoor temperature and relative humidity will be taken every hour interval same goes with roof surface temperature. Above figure in blue line shows the experimental house location.

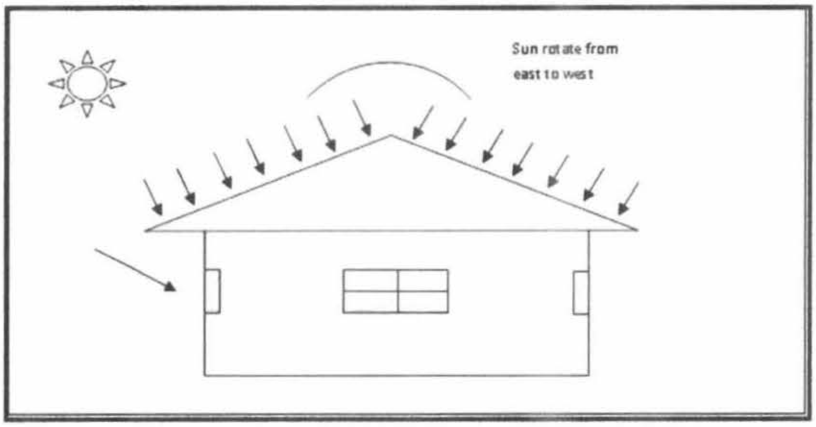
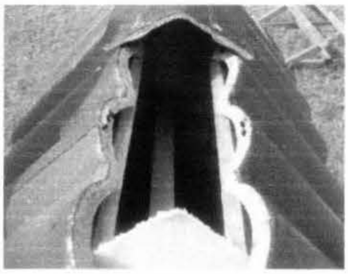


Figure 17 : Here is the schematic diagram on how the temperature or heat transfer to the house from the roof and the wall, and 80% of the heat received from the roof.

Table 5 : Experiment Setup

Properties	House Model 1(H1)	House Model 2(H2)
Roof	Double-pitched 45°	Double-pitched 45°
Colour	Grey	Grey
Wall	Concrete brick	Concrete brick
Insulator	None 	Bubble (10mm thick) 3layer 

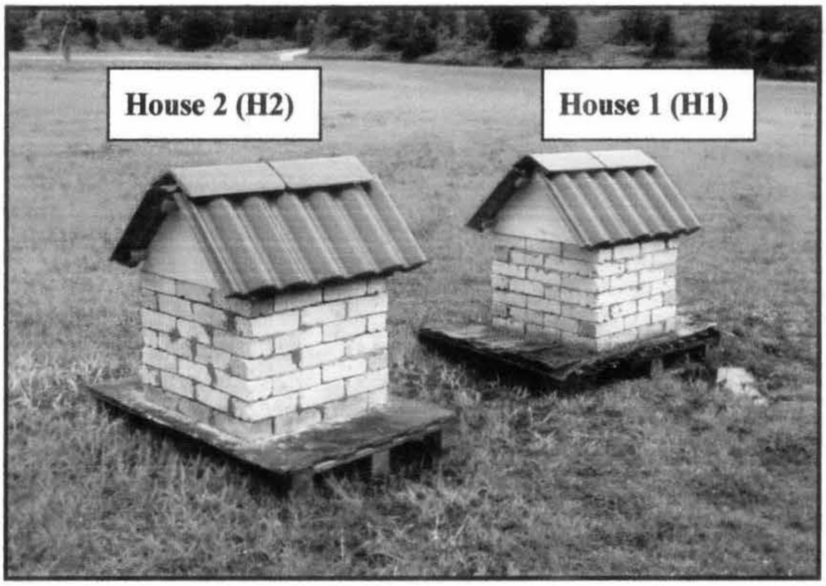


Figure 18 : House Model

3.5. Apparatus Preparation

Throughout the field measurement, the parameters were measured by using hygro thermometer and a few thermometers. They are:

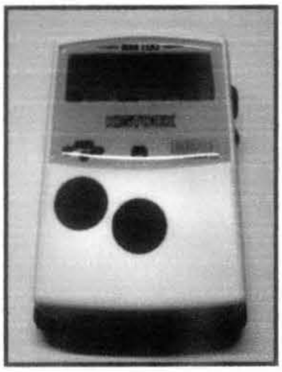
1. Instrument

    I. Single Input Thermometer (KTT 300)

    This instrument is used to measure temperature for roof surface.

    II. Hygro-Thermometer (KH 100)

    This instrument is used to measure humidity and temperature of interior houses. Relative humidity was measure in percentage (%) and temperature in degree Celsius (°C).



    III. Hygro – Thermometer (445713)

    This instrument is also used to measure humidity and temperature of the house. It can measure both indoor and outdoor temperature. But in the experiment this instrument placed outside the house. Relative humidity in percentage (%) and temperature in degree Celsius (°C)

3.6. Procedure

Before collecting data, need to make sure the house position must be receiving the maximum heat from sun during the day. The position of the house must be same as below orientation shown at Figure 19. For this experiment research has been done on where to allocate the house correctly to ensure the house received the most heat. These experiments were conducted behind the Civil Engineering Concrete Lab. Figure 20 shows the house orientation.

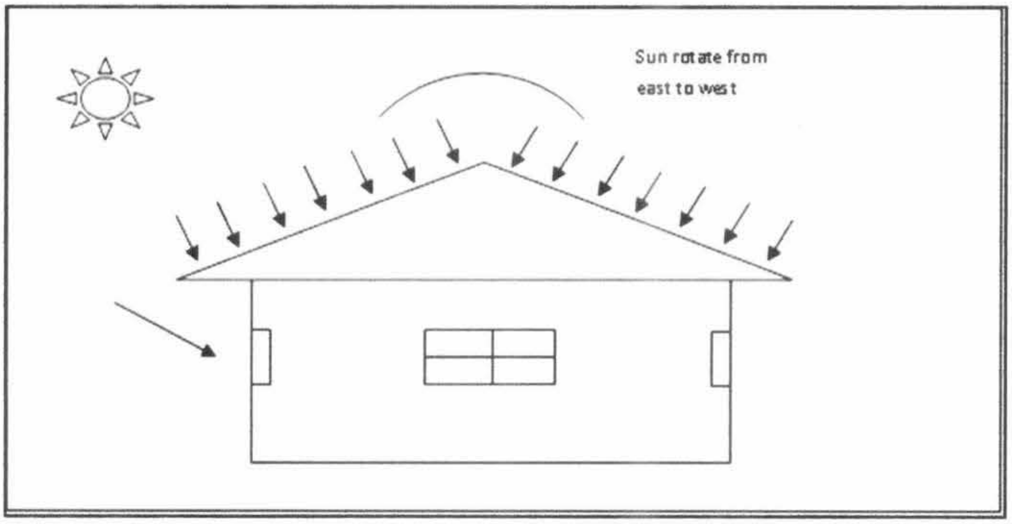


Figure 19 : Shown the house orientation based on the sun rotation (east to west)

1. After allocate the house position, installed the instrument 1 hour before data collection supposedly take place. This is because to stabilize the temperature around the house with the environment to make it equal to the real situation.

2. After 1 hour then, data collection can be start. Since the data collection used were installed with data logger, both house can collect data simultaneously roof surface, indoor and outdoor temperature with relative humidity.
3. Data will be collected from 8 am until 5 pm.
4. The process will be repeat for 6 days.

3.7. Data Collection

All the data collection will be set up and download by using KILOG data logger software. Data collection will be automatically filled in the table as shown at Appendix 1.

3.7.1. Data Analysis

For data analysis, I will compare the Roof Surface Temperature with indoor temperature and differences between outdoor and indoor temperature to quantify the different percentage of reduction of heat for both houses with radiant barrier and without radiant barrier. Base on this analysis and the percentage of reduction we know the radiant barrier effectiveness as a reflective insulation material and to apply it in a real scale.

To download and set the data collection from the instrument, software KILOG is used. This software will collect and analyze the data and automatically plot the graph based on data collected as shown at Appendix 2.

3.8. Gantt chart Work For Final Year Project 2

Table 6 : Gantt chart work for Final Year Project 2

No.	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continuous														
	Preparation														
	i) Buying Material														
	ii) Fabrication														
	iii) Field Measurement														
	iv) Data Analysis														
2	Submission of Progress Report								**						
3	Project Work Continuous														
	i) Field Measurement														
	ii) Data Analysis														
	iii) Poster Preparation														
4	Pre – EDX											**			
5	Submission of Draft Report												**		
6	Submission of Dissertation (soft bound)													**	
7	Submission of Technical Paper													**	
8	Oral Presentation														**
9	Submission of Project Dissertation (Hard Bound)														**

** Milestone

Time constrain

Time Planned

3.9. Milestone for Final Year Project 1 &2

Table 7 : Milestone for Final year Project 1 &2

No.	Details/Month	May	Jun	Jul	Aug		Sept	Oct	Nov	Dec	Jan
1	Selection of Project Topic	■									
2	Preliminary Research Work		■								
3	Submission of Extended Proposal Defense		■								
4	Proposal Defense			■							
5	Project Work Continuous			■	■						
6	Submission of Interim Draft Report				■						
7	Submission of Interim Report				■						
8	Project Work Continuous				■	SEMESTER BREAK	■	■	■		
9	Submission of Progress Report								■		
10	Project Work Continuous								■	■	
11	Pre – EDX									■	
12	Submission of Draft Report									■	
13	Submission of Dissertation (soft bound)									■	
14	Submission of Technical Paper									■	
15	Oral Presentation										■
16	Submission of Project Dissertation (Hard Bound)										■

3.9.1. Summary

Here is the flowchart summarized the project linked with the milestone.

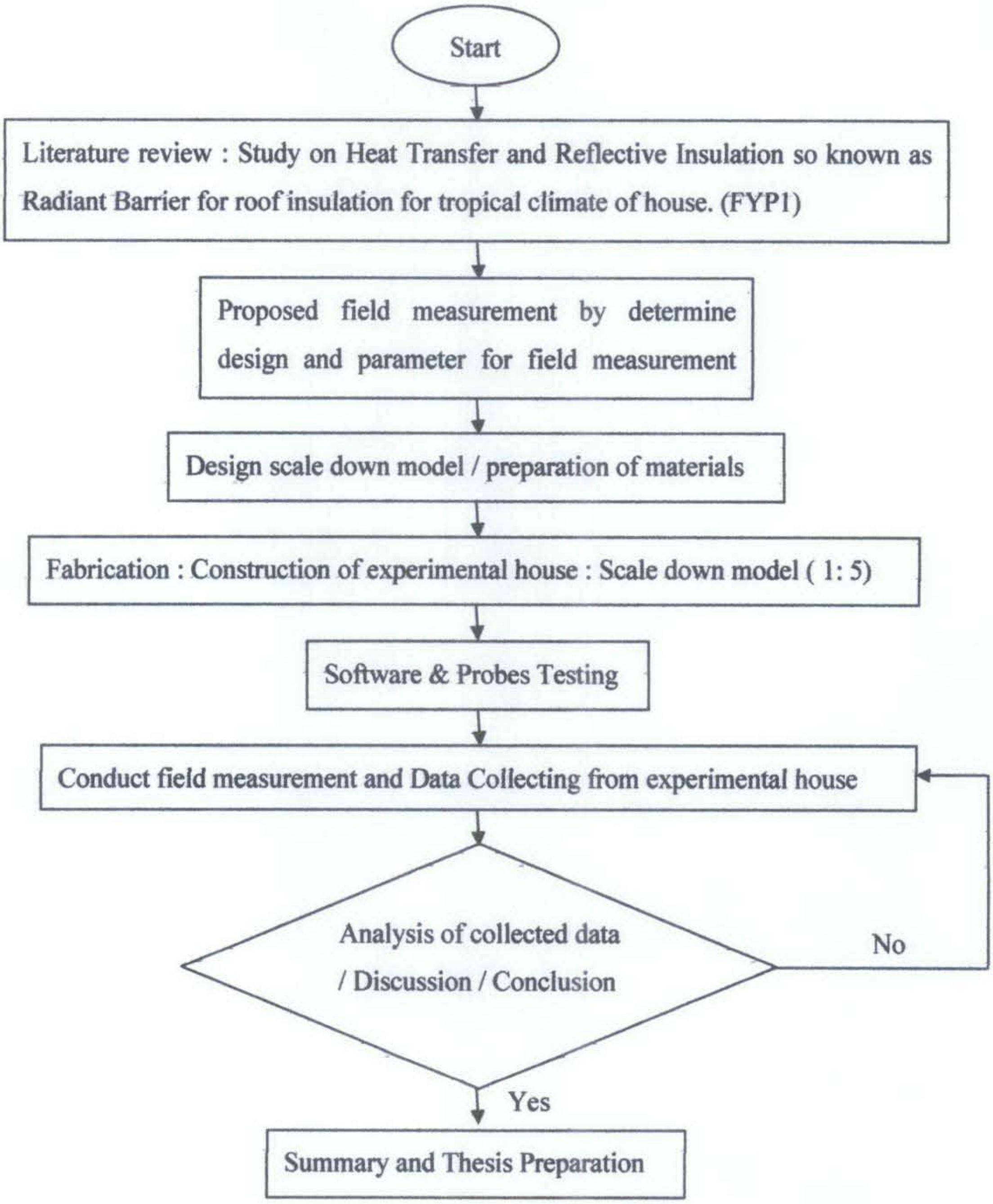


Figure 20: Flowchart of Methodology Summary

4.0 RESULT AND DISCUSSION

4.1. Introduction

Result and discussion section was to evaluate the results obtained from the field measurement. Data collected for House 1 without insulation and for House 2 with insulation within 6 days per house. Show at figure 19. This experiment was conducted simultaneously and the evaluation on the measured parameters is based on hourly data. Both experimental house data collected for 10 hours started at 8.00am until 5.00pm with time interval of 1 hour. It is conducted at open area beside block 13, with oriented position based on sun rotation

4.2. Comparison on Temperature

The purposed of conducting the experiment is to obtain the temperature and humidity of the project. It is also to verify the positive effect on installing the insulation on interior temperature and humidity.

During conducting the field measurement, the weather is unsteady due to sunny and cloudy condition. Hence, in this tropical climate, yearend is monsoon season and most of the day a raining. Due to this fluctuation temperature, polynomial line is the best line to show the present fluctuation to ease the comparison purposes.

Figure 21 to Figure 26 show the Temperature (?C) and Relative Humidity (%) versus Time (hour) for 6 days field measurement. The graph line fluctuation is consistence. The blue line indicate house with no insulation and the red line indicate house with insulation of the scale down model respectively. While the box mark on the line shows data for Relative Humidity and the circle shows data for differences between Outdoor and Indoor temperature.

From the graph below, the temperature is lowest in the morning and late evening but the temperature strikes starting from 10.00am until 3.00pm where the sun almost straight on top of the roof surface. For indoor temperature, both scales down models indoor temperature are decreased. This is because of the roof absorb heat from the sun before it penetrate into the interior. Some of the heats penetrate inside others reflect back to the air. Even the temperature decreased, the highest came from scales down models with insulation rather than with no insulation. Mean that the indoor temperature in the insulated house is lower than non insulation model.

Below are the graphs for 6 days data collections:

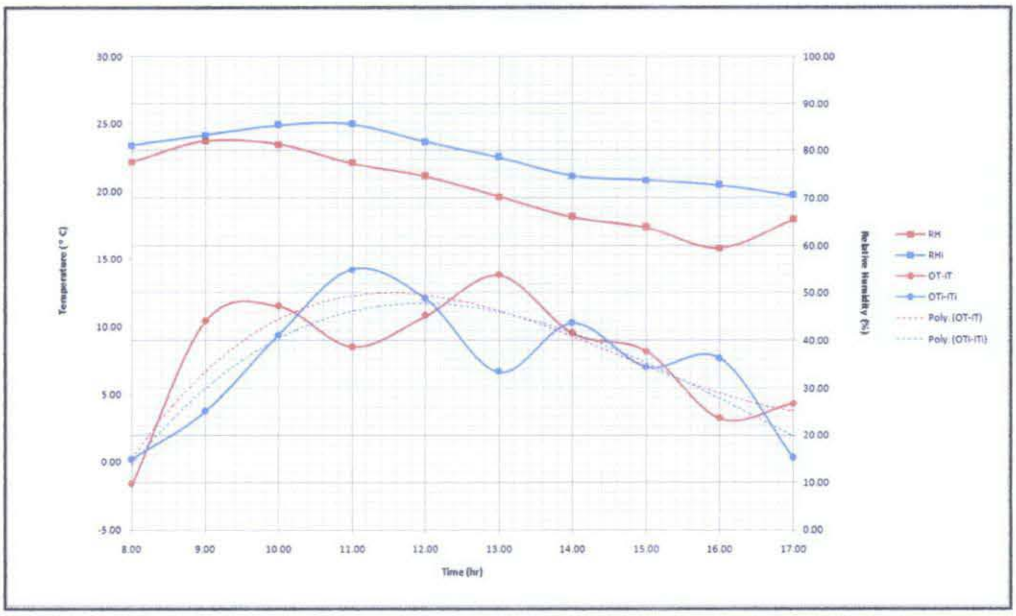


Figure 21 : Graph Time Vs Temperature and Relative humidity for Day 1

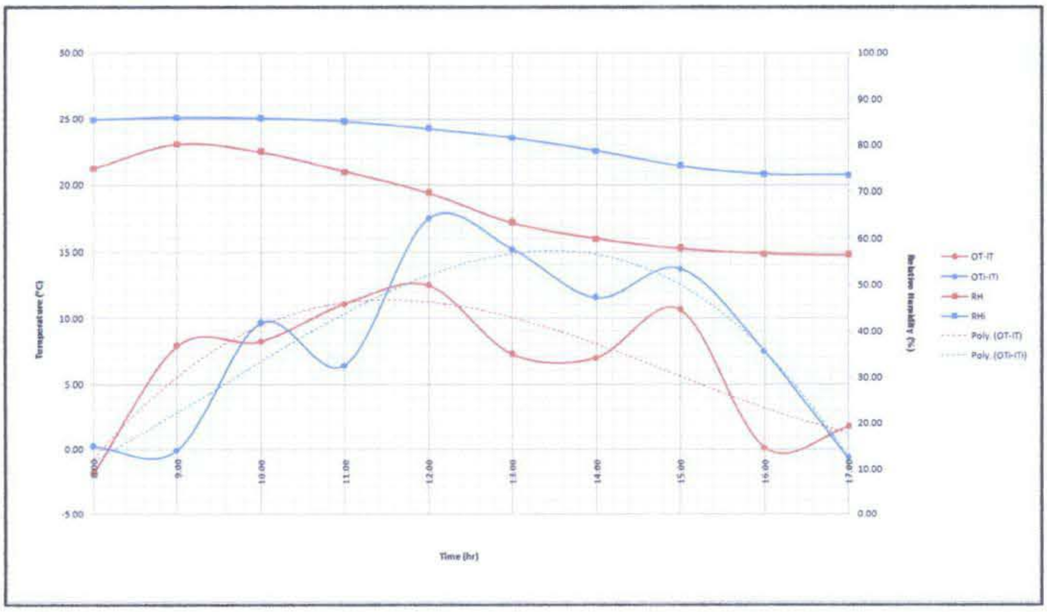


Figure 22 : Graph Time Vs Temperature and Relative humidity for Day 2

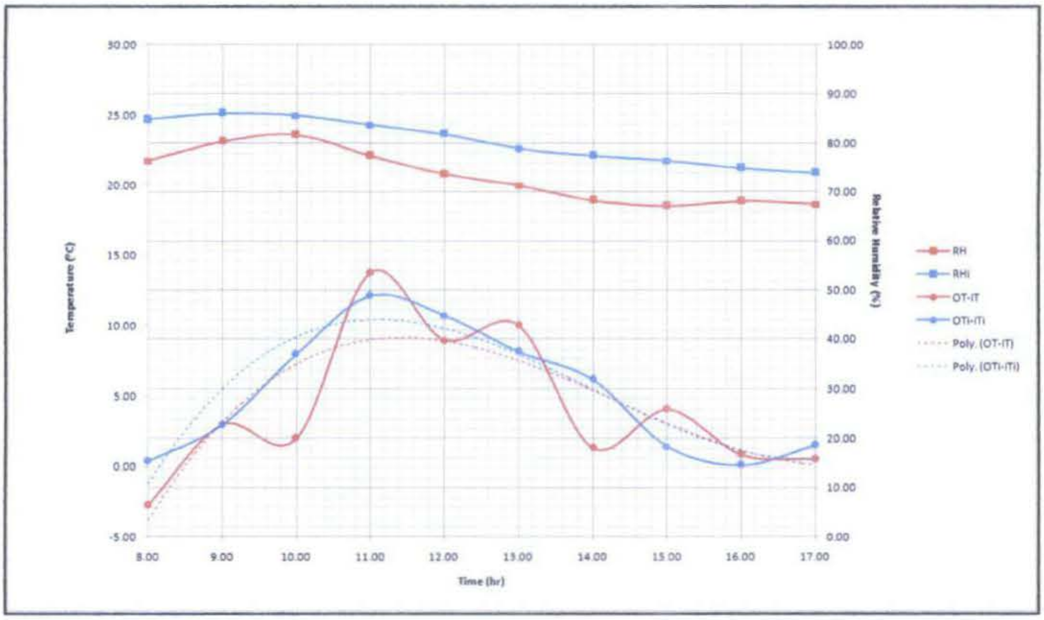


Figure 23 : Graph Time Vs Temperature and Relative humidity for Day 3

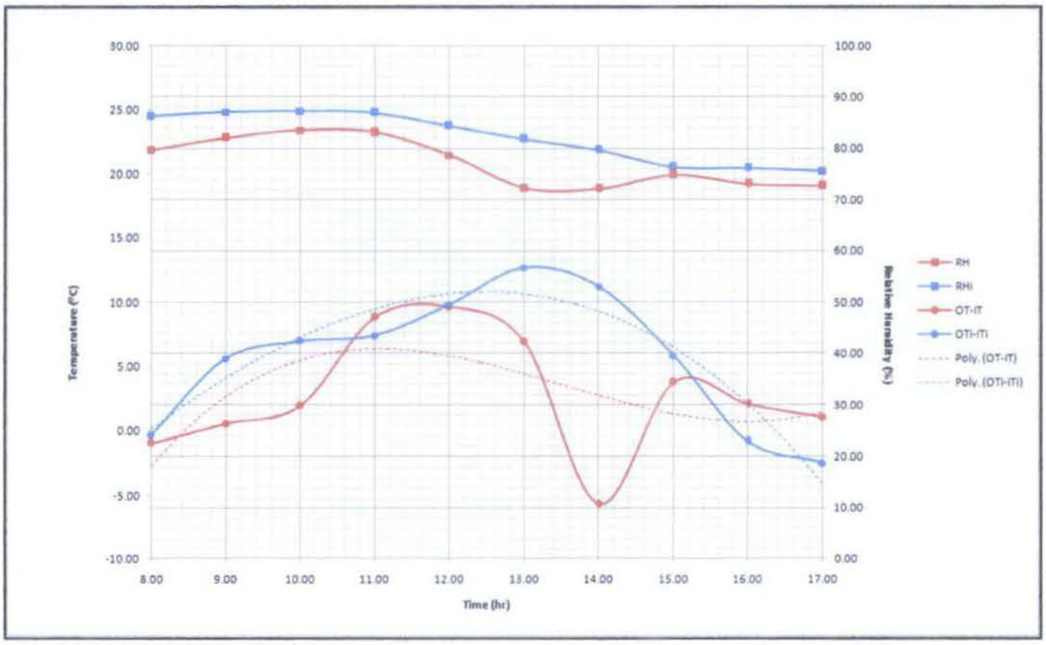


Figure 24 : Graph Time Vs Temperature and Relative humidity for Day 4

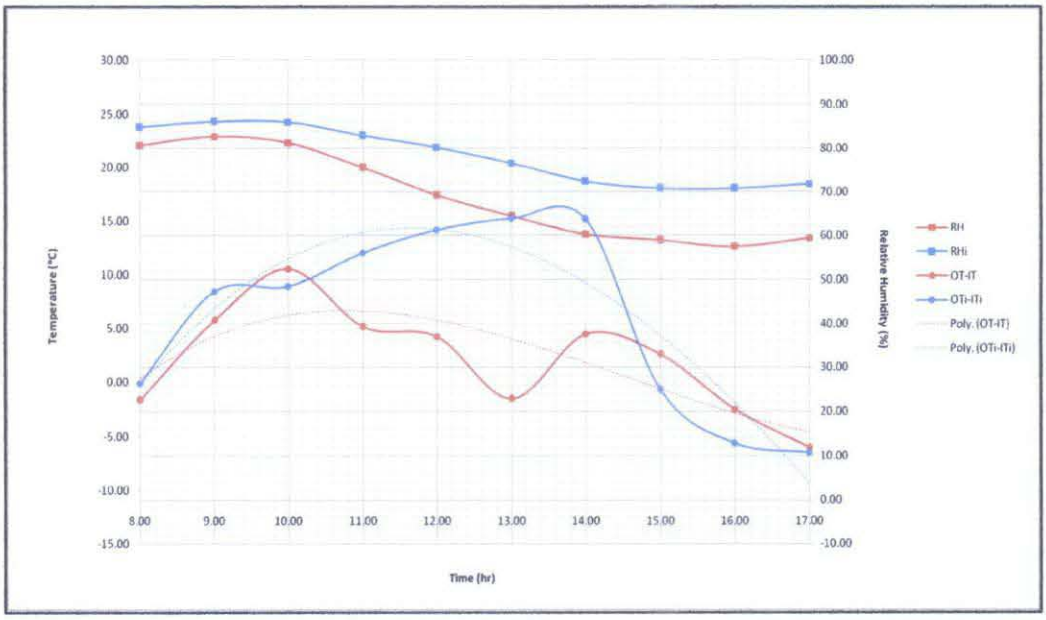


Figure 25 : Graph Time Vs Temperature and Relative humidity for Day 5

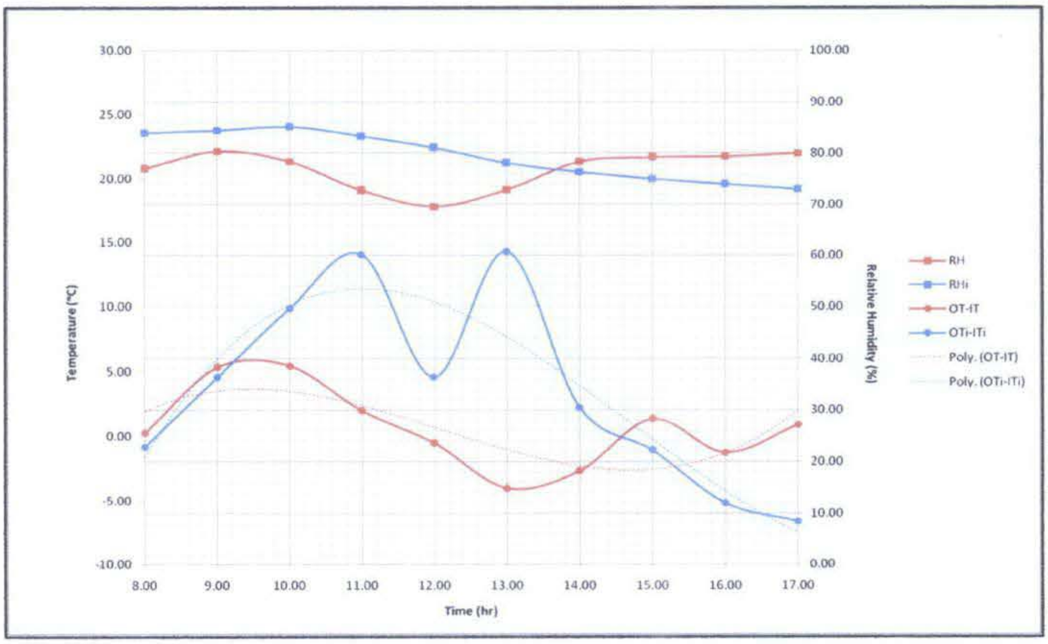


Figure 26 : Graph Time Vs Temperature and Relative humidity for Day 6

From graph above, the consistence readings are from Day 2, Day 4 and Day 6. From these 3 days, the comparisons on temperature reduced are conducted. At day 2, shows at figure 22, the graph line shows consistency whereby starting in the morning session the temperature is low and increasing towards the afternoon at 12 noon until 3pm. highest temperature reduced is at 12 noon with 17.45°C using insulation. Compared to non insulated house, the temperature is 12.45 °C. And the highest reduction from the day is at 13hours (1.00pm) with 7.94°C.

At Day 4 graph, shows at figure 24 the red line, house without insulation shows increasing temperature starting at 8am to 12pm. At 1pm the temperature decreased till 2pm. This is because of sudden raining in the afternoon. After a while the temperature increased back at 3pm to 5pm. For blue line, house with insulation the fluctuation of the graph is consistence. It increased starting from 8am till 1 pm and after that the temperature decreased till 5pm. From the graph, the highest temperature reduced is at hour 13 (1 pm) with 12.68°C using insulation. Compared to non insulated house, the temperature is 6.87 °C. And the highest reduction from the day is at 14hours (2.00pm) with 16.88 °C.

For graph at Day 6 shows at figure 26, both of red line is more consistence than the blue line. The graph at 11am and 1pm shows a higher decreased of temperature compare to other hours. The highest temperature reduced is at hour 13 (1 pm) with 14.3°C using insulation. Compared to non insulated house, the temperature is -4.04 °C. And the highest reduction from the day is at 13hours (1.00pm) with 18.34 °C. From these 3 days, the amount of temperature reduced quantitatively from the house that not using insulation.

Most of the 6 days show the same fluctuation except for Day 5 at particular hour. This is cause of sudden rain on that particular hour that is why the temperature reduced outside. The mechanism of heat transfer cause the heat circulate inside the indoor space and the temperature inside reduced when the cool breezy temperature penetrate into the house.

Furthermore from the graph, the percentages of relative humidity are decreased whiles the temperature high and happen to be the opposite when the temperature is low. This is because the evaporation of water is rapid in high temperature. Means the space is dry and no moisture. As we known the relative humidity are similar to moisture content in air [26][27].

Table 8 : Comparison for temperature reduction for 3 days

Temperature (?C)/ Day	2	4	6
OTi – Iti	17.45	12.68	14.3
OT – IT	12.45	6.87	-4.04
Highest reduction	7.94	16.88	18.34

Based on the table above, the temperature of the house reduced quantitatively using insulation.

4.3. Comparison between Roof Surface and Indoor Temperature

During the experiment, the data were collected simultaneously for both models. The Roof surface temperature parameter was measure outside the model right on the higher pitch and the data collect at the same point accurately. Similar to indoor temperature parameter was measure inside the house. Figure 27 to figure 32 illustrate the difference between roof surface and indoor temperature (?C) versus time (hour) for both models in 6 days.

Figure 27 show the graph of the Differences between roof surface and indoor temperature with and without insulation in 6 days. From the graph, shows that the fluctuation of is consistence. The blue line indicates the insulation model and the red line indicates model without insulation. The difference between roof surface and indoor temperature versus time compared to the insulation and non insulation models, the higher decrease was at blue line which is at insulation models.

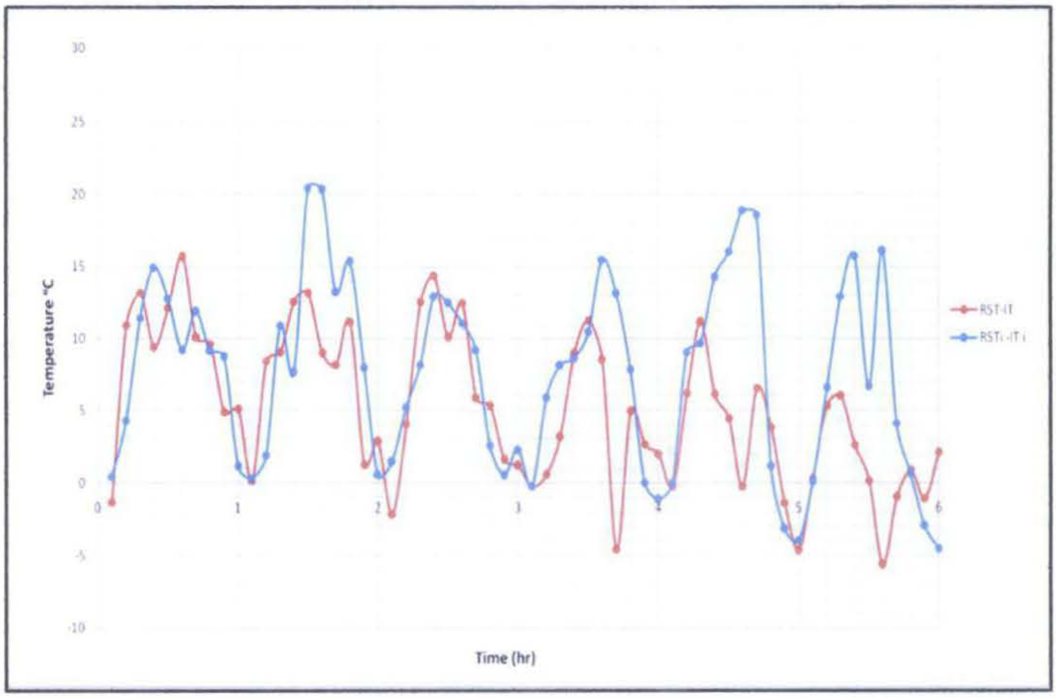


Figure 27 : Differences between roof surface and indoor temperature with and without insulation in 6 days.

For figure 32 the graph was fluctuated unstably because of the weather. It was a sudden heavy rain that affects the indoor temperature. Supposedly indoor temperatures lower during the rain but it happen the opposites because the heats from the previous hour trap inside the model and did not circulate. Besides the base of the models is made from wood and plywood which is a material that easily to absorb water. This made the temperature inside fluctuation unsteadily.

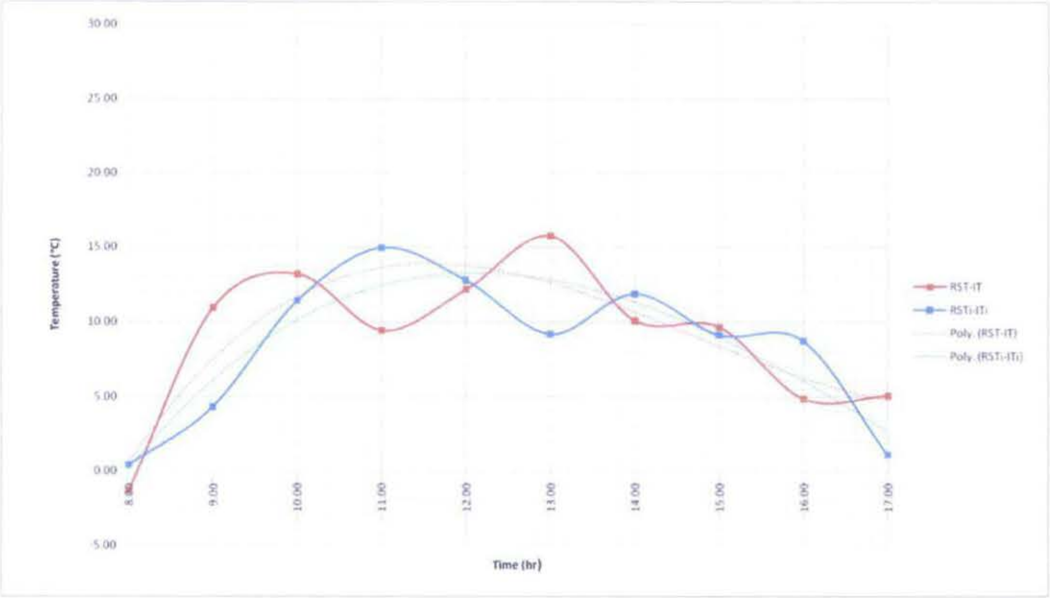


Figure 28 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 1

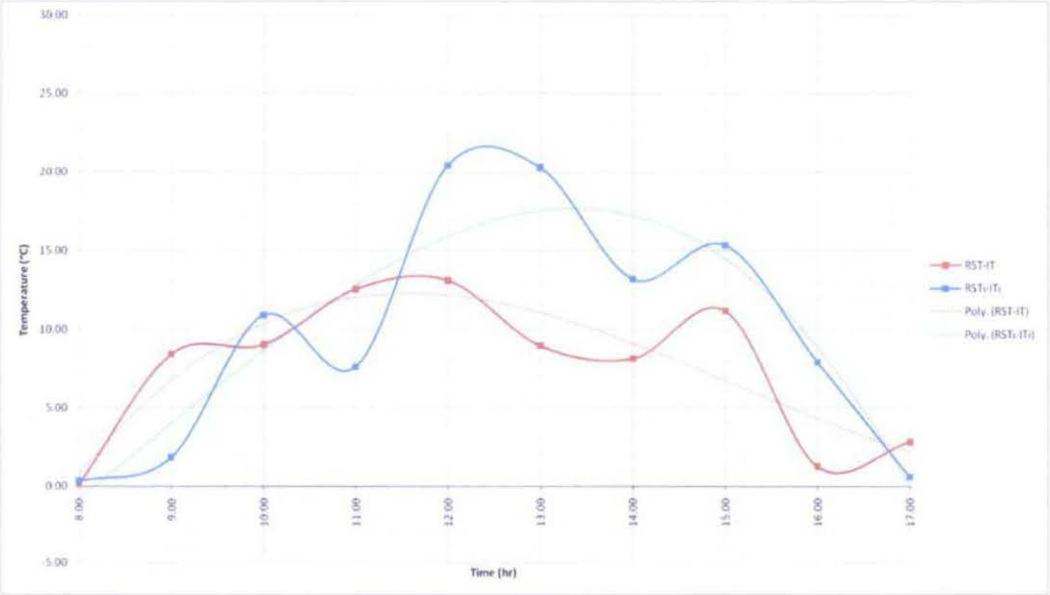


Figure 29 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 2

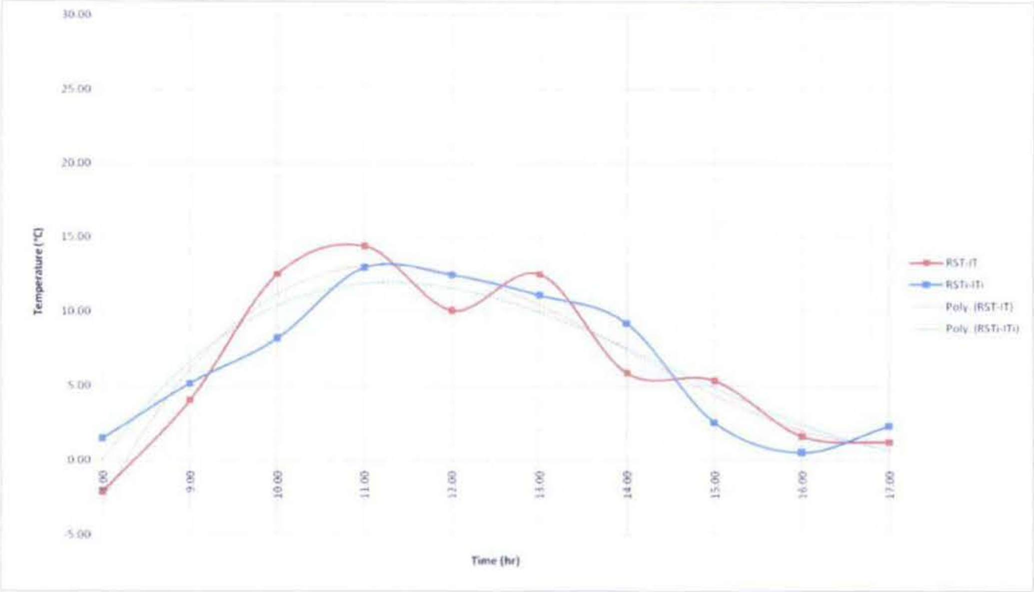


Figure 30 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 3

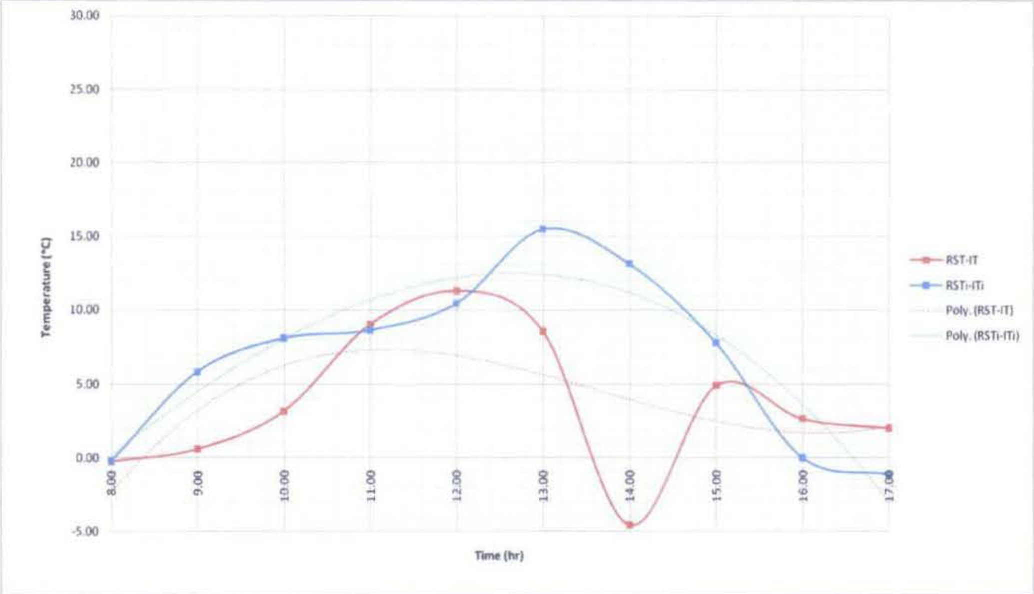


Figure 31 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 4

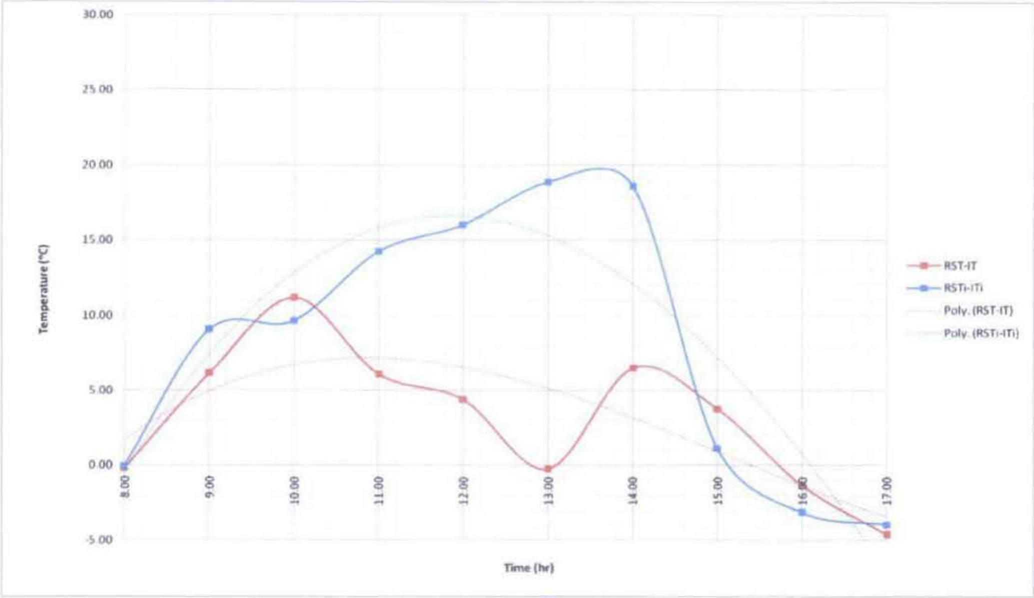


Figure 32 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 5

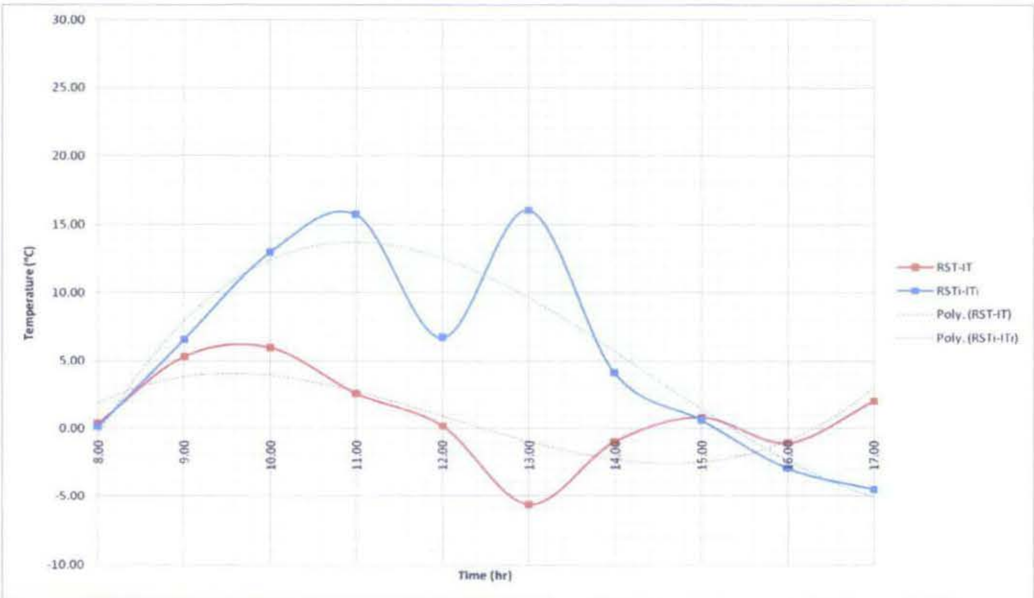


Figure 33 : Graph on the Difference between Roof Surface and Indoor Temperature (°C) versus Time (hour) Day 6

From graph above, the consistence readings are from Day 2, Day 4 and Day 6. From these 3 days, the comparisons on temperature reduced are conducted. At day two (2), result shows that insulated house heat decreased heat from 27.42% to 37.69% at 12pm and the percentage of reduction is 10.27%. The highest reduction percentage for the day is at 1 pm at 15.97%.

At day four (4), the result shows that the insulated house heat decreased from 17.16 % to 29.62% at 1pm and the percentage of reduction is 12.46%. The highest reduction percentage for the day is at 2pm at 48.32%.

Compare with day six (6), the graph shows the heat decreased of insulated house from 5.75% to 32.88% at 11 am with the percentage of reduction 27.13%. The highest reduction percentage for the day is at 1 pm at 47.01%. Below show the comparison between 3 days.

Table 9 : Comparison of percentage of 3 days temperature reduced

Percentage (%) / Day	Day 2	Day 4	Day 6
Percentage reduction	37.69 - 27.42 = 10.27	29.62- 17.16 = 12.46	32.88 - 5.75 = 27.13
Highest reduction	15.97	48.32	47.01

Based on the table above the comparison shows the percentage of temperature reduced quantitatively in these 3 days. And from the result obtain, finding shows some of the data for outdoor and roof surface temperature are higher than indoor temperature. This is because heat radiated from the sun is absorbed by the roof surface in which the ceiling of the house absorbs the radiated heats. It eventually causes the attic temperature rise and the living spaces to be hot. This mechanism of heat transfer is also known as radiation, convection and conduction. Figure 34 show illustration how the heat circulation in the attics of the house.

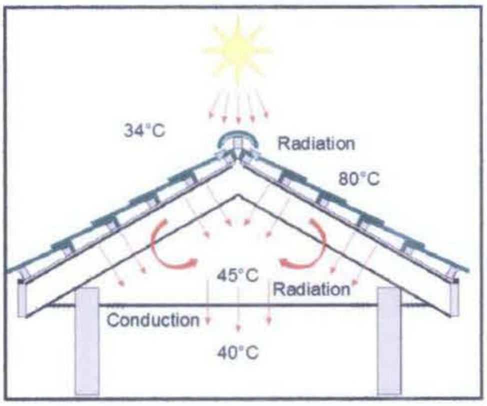


Figure 34 : Heat transfer mechanism [28]

Table 10 :Data collection of Percentage reduced by using insulation

		WITHOUT INSULATION			WITH INSULATION			
	TIME	OT-IT	RST-IT	Percentage reduced (OT-IT/ OT) x 100	OTi-ITi	RSTi-ITi	Percentage reduced (OTi-ITi/ OTi) x 100	Percentage of Reduction
	8.00	-1.65	-1.31	-6.79	0.18	0.42	0.73	7.52
	9.00	10.41	10.93	28.52	3.73	4.3	13.09	-15.43
	10.00	11.49	13.19	28.65	9.42	11.43	26.57	-2.08
	11.00	8.51	9.43	21.76	14.23	14.94	33.40	11.63
	12.00	10.78	12.17	25.48	12.06	12.77	28.48	3.00
Day 1	13.00	13.79	15.72	29.40	6.68	9.18	17.49	-11.92
	14.00	9.50	10.07	21.30	10.27	11.87	23.94	2.64
	15.00	8.20	9.63	18.89	7.05	9.13	17.30	-1.60
	16.00	3.22	4.85	8.21	7.67	8.72	18.05	9.83
	17.00	4.35	5.05	11.36	0.31	1.12	0.86	-10.49
	8.00	-1.81	0.16	-7.54	0.21	0.34	0.85	8.39
	9.00	7.89	8.44	23.59	-0.07	1.85	-0.28	-23.87
	10.00	8.23	9.04	22.30	9.6	10.92	26.97	4.66
	11.00	11.07	12.57	26.29	6.43	7.64	18.86	-7.44
	12.00	12.45	13.11	27.42	17.45	20.43	37.69	10.27
Day 2	13.00	7.27	8.98	17.26	15.21	20.3	33.23	15.97
	14.00	6.98	8.17	16.34	11.52	13.21	26.24	9.91
	15.00	10.60	11.18	22.27	13.72	15.34	29.19	6.92
	16.00	0.12	1.27	0.32	7.49	7.95	17.84	17.52
	17.00	1.68	2.84	4.40	-0.64	0.58	-1.87	-6.27
	8.00	-2.74	-2.15	-11.42	0.39	1.43	1.58	13.00
	9.00	2.97	4.03	10.49	2.98	5.15	10.49	0.00
	10.00	2.01	12.50	6.72	7.92	8.18	22.69	15.97
	11.00	13.75	14.39	31.25	12.08	12.93	28.29	-2.96
	12.00	8.93	10.07	21.92	10.7	12.44	26.32	4.40
Day 3	13.00	9.97	12.47	23.56	8.15	11.08	20.49	-3.07
	14.00	1.34	5.86	3.83	6.17	9.22	15.82	11.99
	15.00	4.04	5.34	10.79	1.44	2.53	4.16	-6.63
	16.00	0.84	1.59	2.49	0.12	0.5	0.37	-2.11
	17.00	0.54	1.19	1.64	1.52	2.3	4.62	2.98
	8.00	-0.96	-0.26	-3.98	-0.31	-0.23	-1.34	2.65
	9.00	0.52	0.60	2.06	5.59	5.82	18.71	16.65
	10.00	1.92	3.15	7.00	6.95	8.1	21.29	14.29
	11.00	8.84	9.02	23.91	7.39	8.63	21.35	-2.57
	12.00	9.64	11.28	24.09	9.81	10.42	25.52	1.43
Day 4	13.00	6.87	8.54	17.16	12.68	15.46	29.62	12.46
	14.00	-5.69	-4.59	-22.31	11.19	13.12	26.01	48.32
	15.00	3.76	4.90	10.99	5.83	7.79	15.12	4.12
	16.00	2.05	2.64	6.03	-0.81	0.02	-2.52	-8.54
	17.00	0.99	1.99	3.07	-2.5	-1.14	-8.32	-11.38

	TIME	WITHOUT INSULATION			WITH INSULATION			
		OT-IT	RST-IT	Percentage reduced (OT-IT/ OT) x 100	OTi-ITi	RSTi-ITi	Percentage reduced (OTi-ITi/ OTi) x 100	Percentage of Reduction
Day 5	**8.00**	-1.69	-0.23	-7.35	-0.1	-0.06	-0.41	6.94
	9.00	5.72	6.14	18.06	8.42	9.07	24.78	6.72
	10.00	10.50	11.16	27.16	8.91	9.68	24.48	-2.68
	11.00	5.14	6.08	14.20	12	14.26	29.11	14.91
	12.00	4.20	4.39	11.06	14.14	16.02	31.18	20.12
	13.00	-1.58	-0.25	-4.76	15.16	18.86	31.52	36.28
	14.00	4.44	6.53	10.94	15.1	18.57	30.64	19.70
	15.00	2.53	3.76	6.40	-0.74	1.13	-2.18	-8.58
	16.00	-2.56	-1.38	-7.51	-5.63	-3.16	-19.82	-12.32
	17.00	-6.06	-4.66	-21.21	-6.51	-3.96	-24.69	-3.48
Day 6	**8.00**	0.22	0.33	0.85	-0.88	0.1	-3.69	-4.53
	9.00	5.30	5.33	16.56	4.49	6.56	15.14	-1.42
	10.00	5.41	5.98	15.49	9.84	12.94	27.11	11.62
	11.00	1.93	2.60	5.75	14.04	15.71	32.88	27.13
	12.00	-0.61	0.16	-1.91	4.56	6.68	12.95	14.85
	13.00	-4.04	-5.63	-16.19	14.3	16.05	30.83	47.01
	14.00	-2.71	-0.99	-11.20	2.19	4.11	6.24	17.44
	15.00	1.28	0.81	4.50	-1.15	0.61	-3.60	-8.10
	16.00	-1.33	-1.07	-5.08	-5.19	-2.96	-18.91	-13.84
	17.00	0.86	2.05	2.99	-6.63	-4.53	-26.78	-29.77

5.0 CONCLUSION

The results discusses above, it is conclude that:

1. Insulated house has better thermal performance than non-insulated house.
2. The highest temperature difference between outdoor and indoor air temperatures obtained is 10.27°C for day 2, 12.46 °C for day 4 and 27.13°C for day 6 , while the highest temperature reduction between roof surface and indoor air temperatures obtained is 15.97% at day 2, 48.32% at day 4 and 47.01% at day 6.
3. From the result obtain and the comparisons, the installation of radiant barrier as a reflective insulation give a positive effect to indoor temperature and the quantity of reduction shows a great decreased. Therefore the experimental work objectives are achieved.

6.0 RECOMMENDATION

6 days of experimental has revealed the positive responses and the effectiveness of installation radiant barrier as reflective insulation for housing in hot and humid climate. The decreasing value shown in the graph proved that the insulation are really works on insulate and prevent heat from penetrate. Therefore, it is recommended to continue the field measurement for accuracy to prove the effectiveness in quantitatively and to enhance the imperfection in research.

For future improvement in our research, there are several suggestion that can be taken to further this research. The suggestion as stated below:

1. Should be revised the material used to built a down scale house so that it can be equal to the real house.
2. Suggestion to build down scale base by using concrete base than plywood or wood to prevent the plywood and wood to wet and affect the indoor temperature.
3. Roofing material suggested using gypsum board to make the scale model equal to the real house. This helps to prevent hot air from penetrate to indoor space.
4. Since we are using a down scale house, the brick size cant be in a small size either. So, the inner part of the brick wall house must be insulated by using polystyrene.
5. And lastly for future research recommendation, besides using bubble foil as insulation, replace it with nanotechnology material (mearogel) which will increased the reduction quantitatively in indoor temperature.

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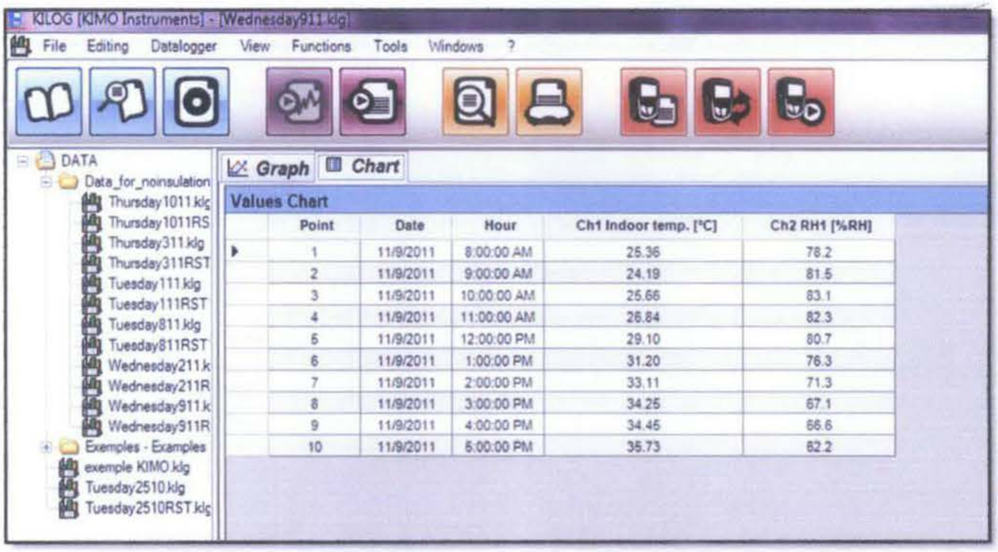
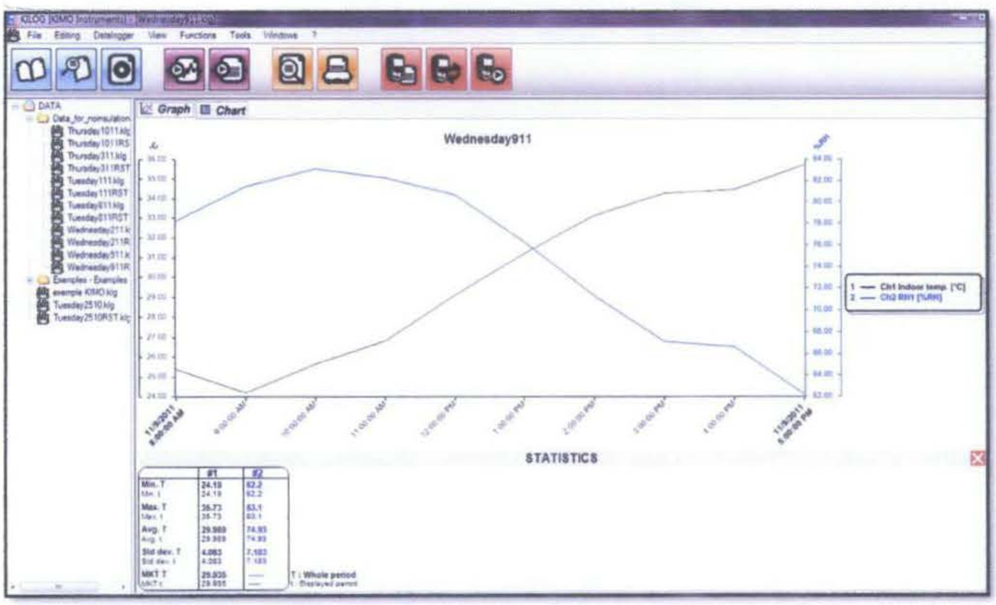
8.0APPENDICES



Appendix 1 : Data collection transfer from the instrument to the software database



Appendix 2 : Data Collection and Graph Produced by the KILOG software