# HEAT TRANSFER MEAS GLASS MATERIAL

NORAIN CHIN

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Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

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# ABSTRAK

Satu kaedah untuk mengukur pemindahan haba pada bahan bangunan telah diperkenalkan. Ia adalah berdasarkan kepada penggunaan Perolehan Suhu yang direka untuk membolehkan pengumpulan data bahan kaca melalui bacaan suhu. Kaedah penyediaan projek termasuk rekaan litar dan perisian komputer.Suhu dalam bahan kaca telah diukur selama 4 hari kira-kira dalam 3 jam dari pukul 11.30 pagi hingga 01:30.Hasil masa pada suhu maksimum dan suhu minimum telah direkodkan. Berdasarkan Formula Fourier, kadar haba (nilai Q) telah dikira. Keputusan dalam projek ini boleh digunakan dalam industri pembinaan untuk menjimatkan penggunaan tenaga.

# ABSTRACT

A method for the measurement of heat transfer of building glass material is presented. It is based on the use of a Data Acquisition designed to enable data collection of glass material from temperature reading. Preparation method include the circuit and software design.The glass material was test in 4 days during day time about 3 hour from 11.30 a.m until 1.30 p.m. From the result the time of maximum temperature and the minimum temperature can be observed. Based on Fourier's Law heat conduction formula the heat rate(Q- value) was calculated. Results in this project can be used in building industry in order to save energy consumption.

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| | |
|---|---|
| $\dot{Q}$ | Heat Flow Rate |
| $k$ | Thermal Conductivity Coefficient |
| A | Area |
| $\Delta T$ | Temperature Difference |
| $\Delta x$ | Thickness |

# CHAPTER 1

# INTRODUCTION

## 1.1 PROJECT INTRODUCTION

A high economic growth in Malaysia over the past three decades has seen a dramatic increase in energy consumption. From 1980 to 2009, total electricity consumed versus gross domestic product (GDP) increased by 9.2% and 6.2%, respectively,[2]. Figure 1.1 shows that Malaysia has the highest electricity consumption among all ASEAN countries.

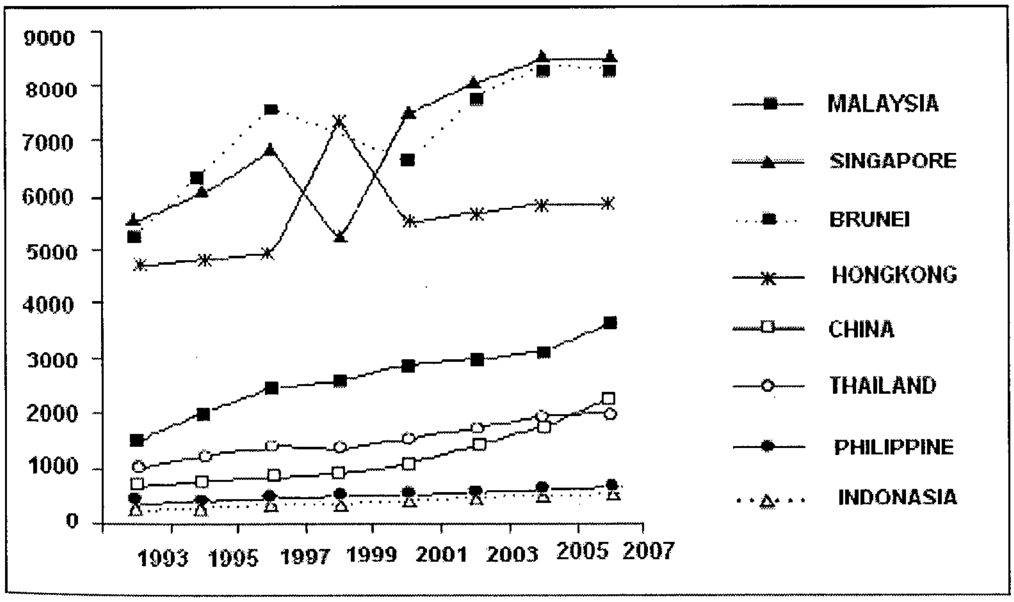


**Figure 1.1**: Electricity consumption in kilowatt hour per capita in ASEAN countries[2]

Figure 1.2 shows the distribution of total energy consumption in Malaysian sectors. It turns out that the commercial sector is the second-largest user, accounting for about 32% of total energy consumed in Malaysia. (Saidur,2009).

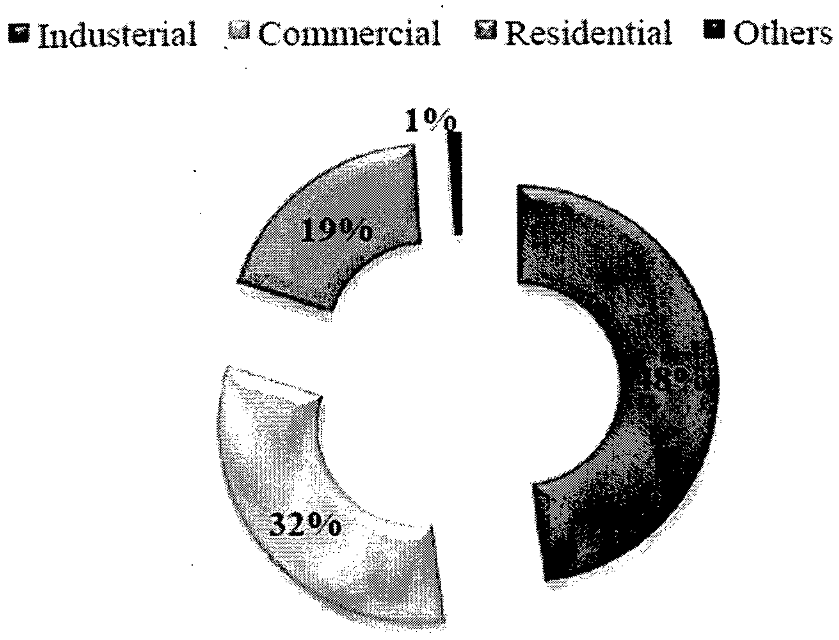


**Figure 1.2**: Statistics of energy consumption in Malaysia (Saidur, 2009)

With increasing energy consumption in sustaining the country's growth over the years, $CO_2$ emission will have an upward trend as long as fossil fuel is used as the critical part in energy mix. As illustrated in Figure 1.3, the total $CO_2$ emission in Malaysia has increased towards the end of 1990s and reached more than 160 million metric tonnes by 2003.

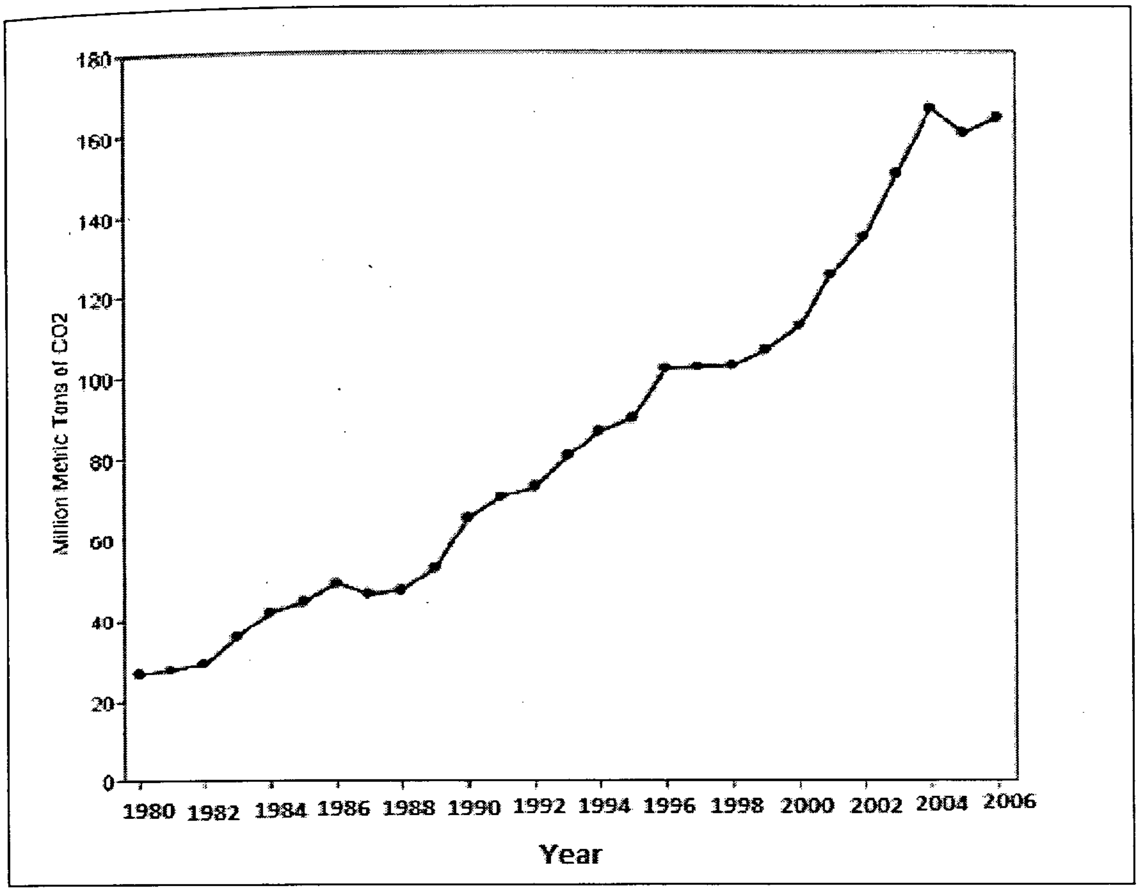


**Figure1.3** Total $CO_2$ emission in Malaysia

## 1.2 PROBLEM STATEMENT

Mathematical model for the heat transfer in a building is a method to reduce the energy consumption and to improve the thermal comfort. A model can be used to select insulation materials, analyze thermal control method or in the design of a suitable heating system. The need for accurate building model is related to energy conservation and thermal comfort as well as to building fabric and environmental health. Accurate predictions of the dynamic temperature distribution at the inside surface of the building is importance because of condensation, which can cause structural damages. Accurate building material modeling and simulation can reduce the energy consumption while maintaining the thermal demand.

Building consumes large energy. Building constitutes a substantial part of the world's total energy consumption thus saving energy within the building is essential. The high energy consumption, the climate changes and scarcity of natural resources require rules of sustainable design in order to ensure the continuing life of modern society. Taking into account that construction sector uses high consumption of resources such as materials, energy and water, it is imperative to use sustainable construction solution.

Todays, improvement of building energy performance can reduce the use of energy. Building designers can contribute to solve the energy problem if proper design decisions are made regarding the selection and integration of building components. Using least cost energy strategy, future energy can be conserved. For every unit of energy saved by a given measure of technology, resources will be saved, and the annual operating costs associated with producing that unit of energy will be reduced.

Nowadays, thermal demand is increasing. In building, indoor thermal discomfort is very challenging and depends on the materials used for ceiling board, walled material sand doors. One of the concerns of the experienced builders is to design building that the indoor condition is thermally tolerable and conducive to the occupants of the building. Human comfort in buildings depends, of course upon the proper design of heating or cooling equipment.

Air conditioners are typically used in homes and in public enclosed spaces due to natural demand for thermal comfort. The major potential for energy conservation in buildings is in the reduction in the use of heating, ventilating, and air-conditioning (HVAC) systems since more than 60% of the building energy consumption is used to condition the indoor environment (Gandrille and Hammond, 1988) and the energy consumption of HVAC systems is increasing (Rousseau and Mathews, 1993). The number of air conditioning in Malaysia has increased significantly from 13,251 units in 1970 to 253,399 in 1991and predicted to be about 1,511,276 in 2020.It shows that the thermal demand has increased rapidly[5]. Sadrzadehrafiei et al. informed that in a typical mid-rise office building in Malaysia, air conditioners utilize the most energy at 58%, followed by lighting (20%), office equipment (19%), and other (3%).[6]

Efficient design of air-conditioning depends on the effectiveness of the thermal insulation. Hence, the design solution for the thermal insulation must base on thorough study of the system.The design of insulation requirements for buildings is not straight forward as the economic calculation of the pipeline thickness or equipment sizing depend on resistance material to heat flow. The building energy model can be used to estimate the energy performance, HVAC sizing, economic feasibility for building energy efficient components, comparison of a building performance with a code standard building, etc. These codes can be used by building designers as guiding tools to develop an optimal energy efficient building. The modeling tools can also be used to predict a cost effective energy efficiency retrofit to an existing building.

As a conclusion, energy saving is obtained by reducing the energy consumption in building. The loss of heat from building will cause waste of energy. Thermal modeling of building material properties is one of the solutions. Because of that, the purpose of this project is to identify mathematical model of a typical building material. In building applications, heat flow is a complex projects because it requires accurate modeling together with experimental results. The approach of this study is to use simple mathematical model of heat transfer coefficient and then apply the heat transfer coefficient to calculate heat flow into a building. The mathematical modeling is verified by conducting heat flow simulation and experiment of a selected building material for various thicknesses.

## 1.4 PROJECTOBJECTIVES

There are three (3) objectives of this project which are:

- To design and build a temperature data acquisition system.
- To collect temperature difference (inside versus outside temperature) of building glass material during day time.
- To analyze data and determine the heat rate of the building glass material based on collected data.

## 1.4 SCOPES OF THE PROJECT

The scopes of the project include:

- This project is only studies building glass material. The experiments are not conducted for other materials such as concrete, steel, polymer or fiber.
- This experiment is conducted at Universiti Malaysia Pahang, Pekan Campus. Typical average daily temperature is 23°C - 32°C.

## 1.5 REPORT ORGANIZATION

This report is organized as follows:

- CHAPTER 1 : Introduction

  In this chapter, an overview of the project which contains motivation of the project, problem statement, objective, scope, and report organization are presented.
- CHAPTER 2 : Literature Review

  This chapter contains detailed descriptions and information of this project. The information is about thermal insulation as well as the parameters used in this project.
- CHAPTER 3 : Methodology

  It explains how the data acquisition is build and the design of experiment.
- CHAPTER 4 : Result and Discussions

  This chapter focuses on the results obtained. Results are analyzed and discussions are presented.
- CHAPTER 5 : Conclusion and Recommendations

  The conclusions of the project are presented. Then, recommendations are proposed for further research.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Thermal properties are the material characteristics that determine how it will react when it is subjected to excessive heat or heat fluctuation over time. Thermal properties are important parameters that affect the temperature of building materials and thermal performance. These properties are required as fundamental inputs for modeling and simulating thermal behavior. Thermal properties are divided into several parameters such as heat capacity, thermal insulation heat transfer, and thermal conductivity.

The heat transfer is the transition of thermal energy from hotter object to cooler object. One of a study that can be practiced to improve thermal comfort and reduce the energy consumption is heat dynamic. The result as mathematical model can be used in selecting insulation materials, analyzing control strategies or in the design of a suitable heating system. Modeling of heat flow through building materials is a process involving convection, conduction and radiation.

Convection is a heat transfer in liquids and gases. It comprises the combined effects of conduction and fluid flow. Convection is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it. In convection, enthalpy transfer occurs by the movement of hot or cold portions of the fluid/gas together with heat transfer by conduction. Convection above a hot surface occurs because hot air expands, becomes less dense, and rises.

Radiation is the form of heat transfer that can occur in the absence of any form of medium (i.e. in a vacuum). Radiation heat transfer is concerned with the exchange of thermal radiation energy between two or more bodies. Thermal radiation is based on the emission of electromagnetic radiation, which carries energy away from the surface. At the same time, the surface is constantly bombarded by radiation from the surroundings, resulting in the transfer of energy to the surface.The wavelength range of 0.1 to 100 microns (which encompasses the visible light regime), and arises as a result of a temperature difference between 2 bodies.

Conduction is the most significant means of heat transfer in a solid. On a microscopic scale, conduction occurs as hot, rapidly moving or vibrating atoms and molecules interact with neighboring atoms and molecules, transferring some of their energy (heat) to these neighboring atoms. The free movement of electrons also contributes to conductive heat transfer.

To quantify the ease with which a particular medium conducts, the thermal conductivity, also known as the conduction coefficient, *k*, has been employed. The thermal conductivity *k* is defined as the quantity of heat, *Q*, transmitted in time (*t*) through a thickness (*x*), in a direction normal to a surface of area (*A*), due to a temperature difference (*ΔT*).

A quantitative expression relating the rate of heat transfer, the temperature gradient and the nature of the conducting medium is attributed to Fourier (1822; Fourier's Law, 1-dim.) and is given by Equation 2.1 below.

$$\dot{Q} = kA\frac{\Delta T}{\Delta x}$$

**Equation 2.1**

## 2.2 THERMAL CONDUCTIVITY

Thermal conductivity is the ability of a material to conduct heat. Accurate modeling of the thermal properties is of prime importance in conduction heat transfer simulation. In order to achieve accurate thermal property modeling, dependence on other variables must be considered, especially temperature and moisture content.

According to American Society for Testing and Materials (ASTM) standard C168, thermal conductivity λ, is the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area (at a given temperature). λ = (W/m2)/(K/m) = W/m .°K. or mW/m.°K. The value of the thermal conductivity is characterized by the quantity of heat passing per unit of time per unit area at a temperature drop of 1°C per unit length. Figure 2.1 illustrate the thermal conductivity rate. It depends on the medium's phase, temperature, density, molecular bonding, humidity and pressure.

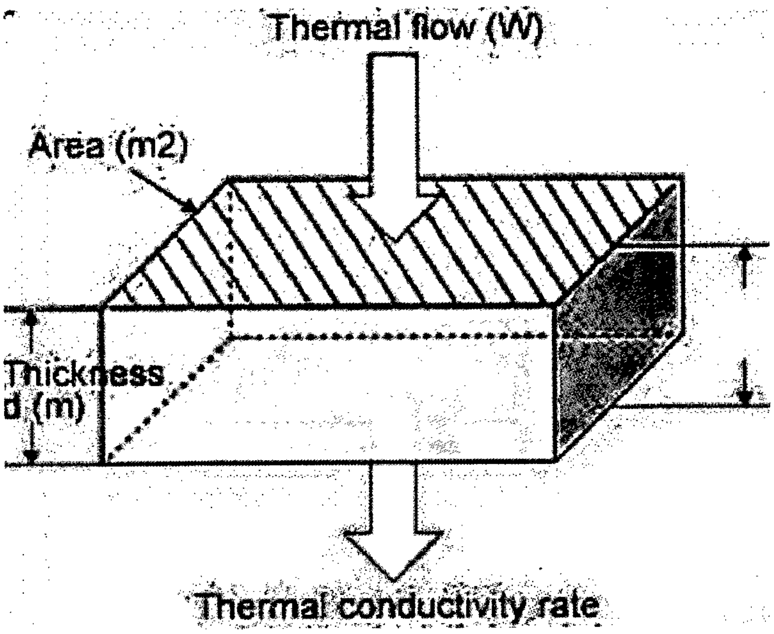
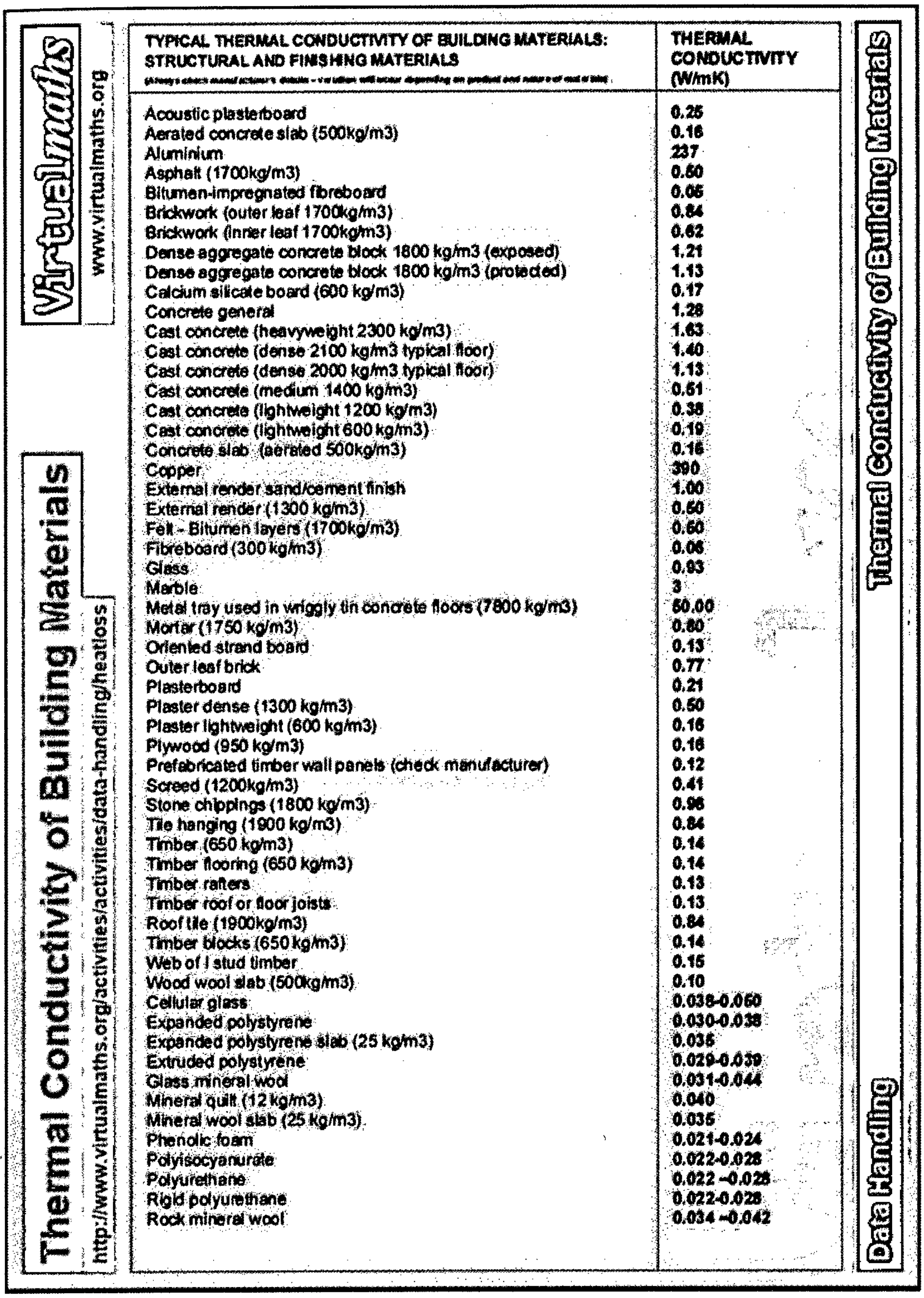


Figure 2.1 Thermal conductivity rate

In general, the thermal conductivity of materials that have relatively few free electrons, such as insulators, increases as the material temperature increases. This is because lattice vibrations increase with increased temperature. Thermal conductivity and its temperature dependence are physical properties of the material. Given two surfaces on either side of the material with a temperature difference between them, the thermal conductivity is the heat energy transferred per unit time and per unit surface area, divided by the temperature difference. The effect of temperature on thermal conductivity is not the same for all materials. Figure 2.2 shows the example of thermal conductivity of building material.



| TYPICAL THERMAL CONDUCTIVITY OF BUILDING MATERIALS: STRUCTURAL AND FINISHING MATERIALS | THERMAL CONDUCTIVITY (W/mK) |
|---|---|
| Acoustic plasterboard | 0.25 |
| Aerated concrete slab (500kg/m3) | 0.16 |
| Aluminium | 237 |
| Asphalt (1700kg/m3) | 0.50 |
| Bitumen-impregnated fibreboard | 0.05 |
| Brickwork (outer leaf 1700kg/m3) | 0.84 |
| Brickwork (inner leaf 1700kg/m3) | 0.62 |
| Dense aggregate concrete block 1800 kg/m3 (exposed) | 1.21 |
| Dense aggregate concrete block 1800 kg/m3 (protected) | 1.13 |
| Calcium silicate board (600 kg/m3) | 0.17 |
| Concrete general | 1.28 |
| Cast concrete (heavyweight 2300 kg/m3) | 1.63 |
| Cast concrete (dense 2100 kg/m3 typical floor) | 1.40 |
| Cast concrete (dense 2000 kg/m3 typical floor) | 1.13 |
| Cast concrete (medium 1400 kg/m3) | 0.51 |
| Cast concrete (lightweight 1200 kg/m3) | 0.38 |
| Cast concrete (lightweight 600 kg/m3) | 0.19 |
| Concrete slab (aerated 500kg/m3) | 0.16 |
| Copper | 390 |
| External render sand/cement finish | 1.00 |
| External render (1300 kg/m3) | 0.50 |
| Felt - Bitumen layers (1700kg/m3) | 0.50 |
| Fibreboard (300 kg/m3) | 0.06 |
| Glass | 0.93 |
| Marble | 3 |
| Metal tray used in wriggly tin concrete floors (7800 kg/m3) | 50.00 |
| Mortar (1750 kg/m3) | 0.80 |
| Oriented strand board | 0.13 |
| Outer leaf brick | 0.77 |
| Plasterboard | 0.21 |
| Plaster dense (1300 kg/m3) | 0.50 |
| Plaster lightweight (600 kg/m3) | 0.16 |
| Plywood (950 kg/m3) | 0.16 |
| Prefabricated timber wall panels (check manufacturer) | 0.12 |
| Screed (1200kg/m3) | 0.41 |
| Stone chippings (1800 kg/m3) | 0.96 |
| Tile hanging (1900 kg/m3) | 0.84 |
| Timber (650 kg/m3) | 0.14 |
| Timber flooring (650 kg/m3) | 0.14 |
| Timber rafters | 0.13 |
| Timber roof or floor joists | 0.13 |
| Roof tile (1900kg/m3) | 0.84 |
| Timber blocks (650 kg/m3) | 0.14 |
| Web of I stud timber | 0.15 |
| Wood wool slab (500kg/m3) | 0.10 |
| Cellular glass | 0.038-0.050 |
| Expanded polystyrene | 0.030-0.038 |
| Expanded polystyrene slab (25 kg/m3) | 0.035 |
| Extruded polystyrene | 0.029-0.039 |
| Glass mineral wool | 0.031-0.044 |
| Mineral quilt (12 kg/m3) | 0.040 |
| Mineral wool slab (25 kg/m3) | 0.035 |
| Phenolic foam | 0.021-0.024 |
| Polyisocyanurate | 0.022-0.028 |
| Polyurethane | 0.022 –0.028 |
| Rigid polyurethane | 0.022-0.028 |
| Rock mineral wool | 0.034 –0.042 |

**Figure 2.1**: Thermal conductivity of building material

## 2.3 HEAT TRANSFER FACTORS

There are several factors that must be considered in order to save the use of energy in building such as the thickness, the moisture content and the density of the building material.

The first one is the thickness of the building. Based on economic analysis, the value of optimum insulation thickness was calculated by life cycle analysis (LCCA). The optimum insulation thickness is the value at which the cost is minimum i.e. the cost of insulation material and cost of energy consumption over life time of the building. The energy saving is at maximum at optimum insulation thickness. The energy saving area is defined as the difference between the energy need of un-insulated and insulated situations. It requires thick building in order to meet the increasingly demanding thermal insulation requirements. Increasing the building envelope thickness in building material, forces new challenges both with respect to reducing consumption of building energy.

In order to reach sufficient low thermal transmittances for buildings in cold, other thermal insulation materials or solutions are needed to avoid too thick buildings envelopes, e.g. walls with thicknesses between 40 cm and 50 cm as to obtain passive house or zero energy building requirements. In Turkey, the thickness of thermal insulation material that should be applied to buildings is determined according to Turkish Standard 825 (TS 825). In TS 825, the thickness of thermal insulation material can be determined according to the annual requirement of heating energy of the building which based on heat losses calculation.

Bolatturk studied the optimum insulation thicknesses for external walls of buildings using cooling and heating degree-hours in the warmest regions of Turkey. Results of his study showed that the use of cooling degree-hours is more suitable in these regions. Ensuring the effective thermal insulation in regions, where the cooling requirement of building with respect to heating requirement is dominant, is very important from the energy economy perspective. In some provinces of Turkey, such as the South-eastern Anatolia Region and in the coastal provinces located in the Mediterranean and Aegean Regions, which have a hot dry or hot humid climate and a longer cooling season (about 7 month) than heating season, the thermal insulation applied considering only heating energy consumption using degree-day concept may be insufficient during summer. Parallel to the economic growth of the country, package air-conditioners are used more and more frequently for thermal comfort in these regions.

Moisture from the passengers, clothes, floor etc. contributes to a higher vapor pressure inside the carriage than its surroundings. Moisture stored in the wall construction might result in loss of thermal resistance of the wall with increased power need for heating and cooling and increased transported weight. The effect of moisture on heat transfer in thermal insulation material is formalized in the ISO 10051. There are researchers who have given contributions to the understanding in this field. Peuhkuri has studied how a number of different porous insulation materials (mineral wool, cellulose fibre, etc.) performed hygrothermally under conditions similar to those in a typical building envelope. Boncina have studied heat transfer in moist light weight concrete and also developed a model for description of thermal transfer in this case.

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Simonson has studied simultaneous heat and mass transfer through a medium-density fibreglass insulation bay. During the study the insulation was open to ambient air at a specific humidity on the warm side. The cold side boundary was an impermeable cold plate at specific temperatures. Thermal hysteresis was noted at high levels of relative humidity, i.e. when condensation occurred in the fibrous insulation material. This study exemplifies how condensation occurs in insulation materials. Fan have developed models for heat and moisture transfer in fibrous insulation (clothing in the first place) that considers phase change and mobile condensates.

Several studies have shown the temperature and moisture content dependence of a material's thermal properties, and the effect on the predicted temperature distributions. Temperature distributions are one of importance in many fields in addition to energy conservation. For example, the analysis of thermal stress requires the knowledge of the temperature distribution. From the knowledge of how the temperature at a point varies with time, the metallurgical conditions can be defined. Tseng and Chu investigated the effect of variable thermal conductivity on transient conduction and radiation in an absorbing, emitting and anisotropically scattering slab. Their results showed that the temperature dependence of thermal conductivity of the medium has a significant effect on both temperature and heat flow distribution.

Density and specific heat capacity are the thermal storage properties. Density is an important thermal property as it affects heat and moisture transport. It is defined as the weight of one unit volume. In building applications, the density typically ranges from 10 *kg/m*3 for the lightest insulation material to 2700-11000 *kg/m*3 for metallic materials. Despite its importance in transient thermal simulation, its dependence on temperature is usually not considered in building energy simulation. This is because of its complex nature and its interaction with other properties and processes. For example, the density changes for a closed system at constant pressure are associated with volume changes. This may require readjustment for the total thermal conductance between two points to account for changes in construction dimensions. Furthermore, the thermal conductivity is a function of a material's density.

Besides that, the other factors that contribute in energy consumption is the ceiling, the door and the roofing materials, used for flooring and carpeting also generate heat thereby contributing in small measure to the thermal insulation of a building. The heat losses in a building generally occur through external walls, ceiling, floor, windows and air infiltration. Heat propagated in interior spaces is through roofs and walls and partly through ceiling and ceiling panels by the process of conduction and radiation. To reduce this heat propagation, materials of tolerable thermal response are needed to be used in the ceiling, walling as well as the roofing design.

In this chapter, brief overviews of thermal properties related to building construction are given. The heat transfer processes i.e. conduction, convection and radiation are also explained. Lastly, several research related to heat transfer in building environment are also presented.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

In this chapter will discuss about the method how to conduct the experimental set up. Figure 3.1 shows the flowchart of the experiment conduct of this project.In this flowchart,it indicates the important process of conducting this project.There is 7 step realizing this project,it is start from doing the mathematical modeling based on the theoretical and finished when the final report or thesis is submitted.

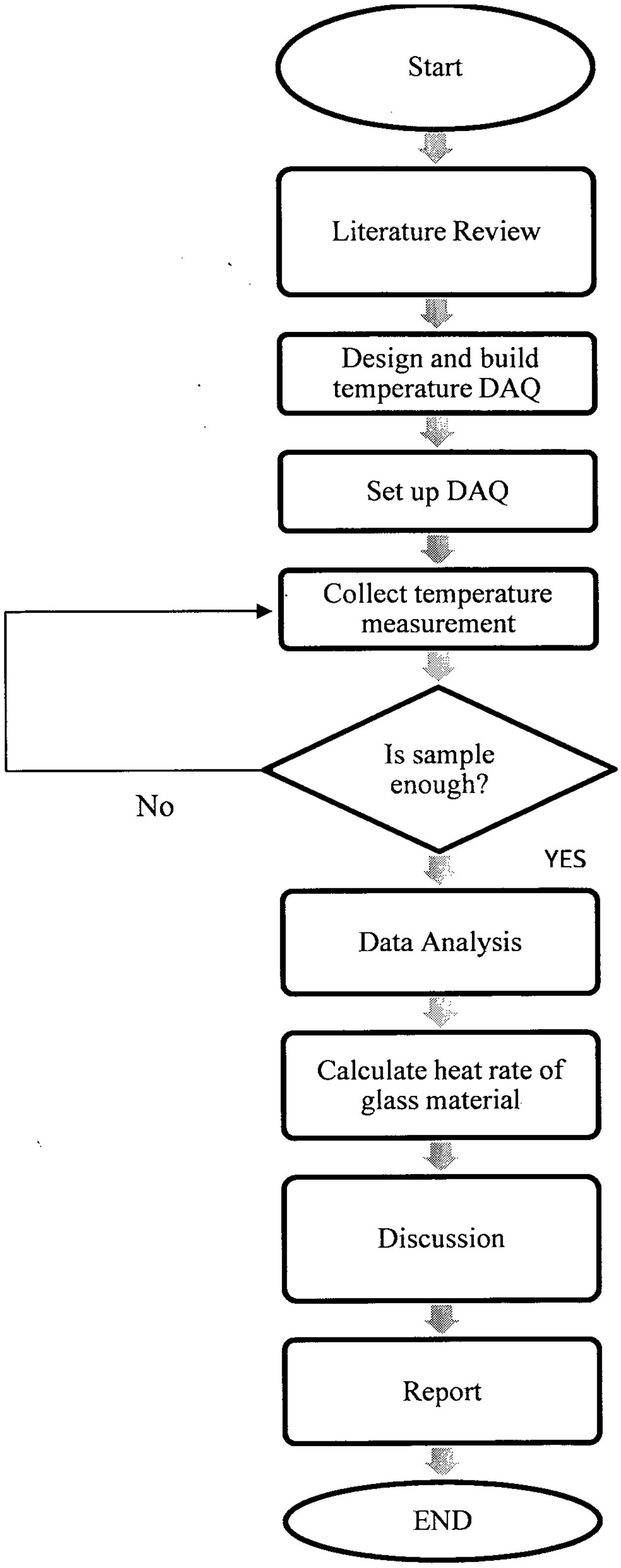

**Figure 3.1** Flowchart of the experiment conduct.

## 3.2 Set up Data Acquisition system

In setting up data acquisition, several important component are required, Temperature sensor, Monolithic Thermocouple Amplifier AD595, Arduino board, and the Visual Basic software as data acquisition to acquire data.

### 3.2.1 Thermocouple Type K sensor

The temperature sensor that is chosen is Thermocouple type K sensor. A thermocouple Type K is a combination of two different metals that is Alumel and Chromel that produces voltage related to the temperature difference. This type of thermocouple is wide range of temperature detection that extends from -200 to 1200°C.Thermocouple type K produces a very small analog output. This small output needs to amplify before 0-5V output can be produced. One method to gain the small signal and at the same time obtain stable output is using AD595 thermocouple amplifier.

### 3.2.2 AD595

AD595 or Monolithic Thermocouple Amplifier is an analog device to amplify Type K thermocouple input.It combines an ice point reference with a precaliberated amplifier to produce a high level (10 mV/°C) output directly from a thermocouple signal. The 10mV/C analog output interfaces nicely with 10-bit found on Arduino.