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To all my family members

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ABSTRACT

This project is to evaluate the current thermal comfort conditions of air-conditioned office rooms through collecting data from site and subjective assessment. The field measurements consider the environment parameters such as temperature, relative humidity, radiation (mean radiant temperature) and air velocity.

It was found that the measured air temperatures, relative humidities, mean radiant temperatures and air velocities were within the limits of thermal comfort standard, although temperature and relative humidity were located at the extreme of the limits. The predicted results showed good distributions of airflow and temperature gradient.

The overall comfort vote, predicted mean vote and predicted percentage of dissatisfied indices found the occupants to be comfortable even though the thermal sensation vote was within the slightly cool category. Additionally, recommendations were made to improve the thermal comfort condition and reduce the energy-cost by temperature control in the office rooms.

ABSTRAK

Projek ini adalah bertujuan untuk menilai keadaan keselesaan 'terma semasa' di dalam ruang pejabat yang berhawa dingin menerusi kaedah pengambilan data di kawasan kajian dan juga kaedah subjektif iaitu penggunaan borang soal selidik. Data-data yang diambil di kawasan kajian merangkumi faktor-faktor persekitaran seperti suhu udara, kelembapan relatif, purata suhu radiasi dan halaju udara.

Kesimpulan yang diperoleh daripada kajian ini adalah suhu udara, kelembapan relatif, purata suhu radiasi dan halaju udara berada dalam had anggaran yang telah ditetapkan piawai bagi keselesaan terma. Hasil kajian juga menunjukkan sistem agihan udara dan tetapan suhu di dalam bangunan adalah baik dan memuaskan.

Undian keseluruhan keselesaan, indeks 'PMV dan PPD' menunjukkan para pekerja berasa selesa walaupun undian 'sensasi terma' adalah di kategorikan sedikit sejuk. Sebagai tambahan, beberapa panduan telah di cadangkan bertujuan untuk mempertingkatkan kadar keselesaan terma dan juga mengurangkan penggunaan tenaga dan kos secara pengawalan suhu di dalam ruang pejabat.

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NOMENCLATURE

°C	-	Degree Celsius
kWh	-	Kilowatt per hour
$kWh/m^2/yr$	-	Kilowatt per hour per square meter per year
RM	-	Ringgit Malaysia
mm	-	Millimeter
m	-	Meter
m/s	-	Meter per second
hr	-	Hour
a.m.	-	Morning
p.m.	-	Evening
t_a	-	Air Temperature
t_o	-	Operative Temperature
t_r	-	Mean Radiant Temperature
t_{eq}	-	Equivalent Temperature
T_n	-	Neutral Temperature
T_{mmo}	-	Mean Monthly Outdoor Temperature
CET	-	Corrected Effective Temperature
PMV	-	Predicted Mean Vote
PPD	-	Predicted Percentage of Dissatisfied

RH	-	Relative Humidity
HVAC System	-	Heating, Ventilating and Air-Conditioned System
%	-	Percent

CHAPTER ONE

Introduction

1.0 Introduction

The local climate has great influence on the indoor thermal environment. The building's characteristics influence the impact of outdoor climate and play a major role in controlling the indoor thermal conditions. In tropical Malaysia, the warm and humid climate may have an adverse impact on occupant comfort indoors. This is more importance for building in the tropics an air-conditioned of the indoor environment is common.

The ultimate aim of conditioning the interior environments of office buildings is to provide a comfortable and healthy indoor environment for the occupants. In many particular situations, failure to provide satisfactory thermal conditions has resulted in discomfort and eventually leads to a breakdown of health. As such, there has been a constant need to study the thermal conditions of these indoor environments. Numerous studies had been conducted to explore the conditions of residential and commercial buildings, in which occupants spend a large amount of their time everyday (*Cheong et al, 2003*). Likewise, in offices the

occupants spending long hours working are subjected to similar sets of problems, thus giving rise to the need for research into the indoor thermal environment in office buildings.

1.1 Structure of thesis

The Final Year Project Report consists of six main chapters.

First Chapter is the introduction part, which consists of aim and objectives of this study, introduction to thermal comfort and the primary factors that influencing thermal comfort, and comfort temperature that is one of parameters to create thermal comfort.

Chapter Two consists of literature review which describes the study of thermal comfort in air-conditioned office buildings in Kuching. This chapter mentions about energy-cost saving by temperature control, study of energy efficiency in office buildings and field studies on thermal comfort in the tropics.

Chapter Three is on the methodology of conducting this study. This part, the explanation on how the data is being collected and the importance of each data is emphasizing. In this chapter also describes about the procedures of field measurements of environmental factors that influencing thermal comfort. The data

set are important as entry data in computer BASIC program. The results will show the PMV and PPD indices that is used to evaluate the current thermal comfort condition. Beside that, the questionnaire is used to obtain the PPD index by thermal sensation and impressions of comfort with regard to air temperature, humidity and air movement.

Chapter Four describes on Results. The results obtained is presented in the form of case study and using tables and graph which consist of typical thermal parameters, PMV and PPD indices and monthly air-conditioned energy consumption for the year of 2004. The analysis of the data collected also being carried out in this chapter.

Chapter Five discuss about the results of field measurements, subjective assessment – questionnaire surveys, thermal comfort indices (PMV and PPD) and also the computation of the thermal comfort temperature.

Chapter Six is mainly for conclusion and recommendation of the study. All the findings and results obtained are summarized in this chapter.

1.2 Thermal comfort

There are a number of the thermal comfort studies carried in the recent decades have been devoted to determine thermal comfort temperatures in various settings, in climate ranging from tropical to temperate.

Thermal comfort by definition is a consideration of the environment comfortable if no thermal discomfort is present (*ASHRAE, 1997).* The first comfort condition is thermally neutrality, which means that a person feels neither too warm nor too cold. *Watson and Labs, (1983)* stated that the definition of thermal comfort as being "*That condition of mind which expresses satisfaction with thermal environment*".

Human response to the thermal comfort environment does not depend on air temperature alone. It has been established beyond doubt that air temperature, relative humidity, radiation and air movement all produce thermal effects, and must be considered simultaneously if human responses are to be predicted (*Koenigsberger et al, 1973*). To appreciate the effect of these climatic factors, it is necessary to examine briefly the basic thermal processes of the human body. The subjective factors depend on each individuals and the ability to adopt in the surrounding environment.

The differences of temperature ranging 3°C either less or more from this level (critical temperature) need a serious attention. Although, people was creating

a lot of body movements for body temperature stabilization. Beside that, they also strive to construct the climatic building design for comfortable condition (*Jansen, 1999*).

1.3 Thermal comfort factors

Thermal comfort factors can be classified into environmental factors such as air temperature, relative humidity, radiation (mean radiant temperature) and air velocity. And the subjective factors are clothing, gender and age, body weight, state of health and food and drink. However, for the purpose of this study are covers environmental factors that influence thermal comfort.

1.3.1 Air Temperature

At any point near the ground the air temperature is dependent upon the amount of heat gained or lost at the earth's surface and any other surfaces with which has recently been in contact.

Heat exchange at surfaces varies between night and day, with the season, latitude and the time of year, always influenced by the amount of cloud cover.

During the day, as surfaces are heated by solar radiation, the air nearest to the ground acquires the highest temperature. In calm conditions the air within 2m of the ground remains stratified in layers of differing temperatures.

1.3.2 Relative Humidity

The relative humidity depends much on the air temperature as on the actual amount of water vapor present in the air.

During the day, as the lowest layer of air is being heated by the ground surface, its relative humidity is rapidly decreased. With a lower relative humidity the rate of evaporation is increased, if there is water available to be evaporated. An open surface of water would provide an abundant supply of water. With air movement the rate of evaporation is increased, but with the mixing of air temperature and humidity differences tend to be evened out.

At night the situation is reversed. Especially on a clear night with still air, as the lowest layer (of the highest *Absolute Humidity*) cools, its relative humidity increases, the point of saturation is soon reached and with further cooling the excess moisture condenses out in the form of dew (hence the term 'dew point') (*Koenigsberger et al, 1973*).

1.3.3 Radiation (Mean Radiant Temperature)

Watson and Labs, (1983) mentions that mean radiant temperature is defines as "*The uniform surface temperature of an imaginary black enclosure with which man exchanges the same heat by radiation as in the actual environment*". In other words, mean radiant temperature is the average of all room surfaces, weighted according to emissive (which is nearly constant for most building materials). The radiant heating or cooling ability of any surface, therefore, must be evaluated in the context of its area in proportion to the area and temperature of other surface in the room. The angle of surface to body and the orientation of exposed parts of the body also are considered.

Radiation on a vertical building surface will be affected by its orientation, but not by the slope and orientation of the site.

The magnitude of thermal effect of such incident radiation will depend on the surface qualities of the recipient ground or objects. If it is vegetation, some of solar energy is converted into chemical energies and evaporation, but a stone, concrete, also mitigates the heating or especially an asphalt surface can reach a temperature up to 44°C higher than the surrounding air temperature (*Koenigsberger et al, 1973*).

1.3.4 Air velocity

Air velocity is a parameter that often is referenced in thermal design. Air can only be heard when it is moving. Still air is quite but the faster air moves the louder the noise. When air changes direction the noise level is increased because of the fluctuation in the pressure of the air. Another consideration for air velocity is the proximity of moving air to people, not only from noise aspect, but also because of 'draughts'. A draught is created either the air velocity is too high or the temperature of the air is too low.

The advantage of mechanical ventilation over natural ventilation it is controllable, thus the velocity can be governed and the temperature varied if required. A natural air velocity between 0.15 and 0.5m/s is usually acceptable. Mechanical air movement up to 0.3 m/s can be acceptable provided people not directly in the airflow.

1.4 Comfort Temperature.

The comfort environment is the result of simultaneous control of temperature, humidity, cleanliness and air distribution within the occupant's surrounding area. This set of factor includes radiation (mean radiant temperature) as well as the air temperature, odor control and the control of the proper acoustic level within the occupant's vicinity.

Physical comfort requires continuing dissipation of body heat by convection, radiation and evaporation. Convection is circulation of liquid or gasses caused by temperature different. When the air temperature is less than skin surface temperature, body heat can be lost by convection to the surrounding air. Radiation is heat transfer by electromagnetic wave, from a warmer to a cooler surface. Body surfaces radiate heat to cooler surroundings and receive radiant heat from warmer surroundings. The magnitude of radiant heat flow is dependent on the temperature difference between source and receiver.

The human body also dissipates heat by evaporation. Evaporation is a change of state from liquid to vapor. Water vapor is expelled with each breath, and the evaporation rate can be increased by increased respiration or by perspiration. Humidity, the amount of water vapor in the air can affect comfort. However, the human body tolerates a wide range of humidity before becoming uncomfortable in very wet or very dry air.

Comfort temperature is a subjective quantity that is depends to the individual or occupant and it is hard to be determined. Most of the researcher found that the definition for comfort temperature is a satisfactory feeling of occupant to the surrounding environment.

The comfort of an individual is affected by several factors such as environment, physical factor and subjective factors. The environment factor includes the air temperature, relative humidity, airflow and radiation. However,

the subjective factors depend on each individual and their ability to adopt in the environment.

The neutral temperatures of subjects in the naturally ventilated building and air-conditioned buildings were 28.5 and 24.2 °C (t_o), respectively (*De Dear et al*, 1991).

Karyono, (1993) was carried out a field of study in Jakarta office buildings. As a results, the neutral temperature was 26.4°C (t_a, *air temperature*) or 26.7°C (t_o, *operative temperature*) or 25.3°C (t_{eq}, *equivalent temperature*). Then, the temperature is applicable with Malaysia climate.

Hanafi, (1999) was mentioned that comfort temperature for Malaysia is in a range of 24°C to 27°C during daytime and 20°C to 23°C at night. This range is determined according to Mahoney table and the average temperature taken from eight cities over Malaysia.

Halipah, (2004) using 25°C to 28°C as a range that could applied to evaluate thermal comfort temperature in modern low-income housing in Malaysia.