



**UNIVERSITI PUTRA MALAYSIA**

**DESIGN ASSESSMENT OF THERMAL COMFORT USING COMPUTATIONAL  
SIMULATION OF A TERRACE HOUSE IN  
KUALA LUMPUR, MALAYSIA**

**NASIBEH SADAFI**

**FRSB 2008 5**



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**By**

**NASIBEH SADAFI**

Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in  
Fulfilment of the Requirements for the Degree of Master

September 2008



Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment  
of the requirement for degree of Master

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**Chairman: Prof. Dato' Ar. Elias @ Ilias Bin Salleh**

**Faculty: Design and Architecture**

Terrace housing is the most common type of housing in Malaysia. They have been increasingly common in cities and towns in comparison to the detached single-family houses. However, comfort conditions in such house types vary according to the designs, modifications and adaptations of the occupants. Meanwhile, indoor environment studies in Malaysia revealed that most of the modern terrace houses are above upper thermal comfort level during day and night. The cause is simply because of unsuitable climatic design. In fact bioclimatic design considerations in terrace houses of Malaysia are not fully exploited according to occupant's comfort needs. This study investigates the influence of different design factors in enhancing thermal condition of the house.

Firstly, current condition of thermal comfort sensation for a case study terrace house in Kuala Lumpur Malaysia is investigated, using Fanger's Predicted Mean Vote thermal



comfort index. The case study was chosen in ‘Oversea Union Garden’ (OUG) area where field measurement was conducted during a three-day recording of air temperature, humidity, globe temperature and air velocity in naturally-ventilated spaces of the house. The study shows that the house is thermally comfortable for almost 15 hours during day and night, when comfort conditions mostly occurred during night hours. For improving the thermal conditions during the day, ceiling fan was used to increase the air velocity in the building. When the air temperature reaches its maximum amount, reducing the absorption of sun radiation will help more to enhance the thermal comfort condition of the house.

Baseline model for the computational experiment was developed according to the results from field measurement as well as selection and adjustment of the tool. In the next step ECOTECT software has been applied for constructing the computer model of the case study terrace house. Consequently, thermal analysis part in ECOTECT has been used to assess internal thermal properties of the house in three different months of the year including: March, Jun and December. Testing of the model consists of evaluating the existing condition, testing for the shading condition and testing for the effects of including internal courtyard in the house. These evaluations revealed that suitable shading design will improve the thermal conditions, especially during noon hours when the house has the most penetration of the sun from the windows as well as highest internal temperature. Introducing the internal courtyard will increase the thermal interactions between the building and outdoor environment especially in adjacent zones. However it can improve the thermal condition by applying suitable shading design as well as suitable materials for the fabrics.



According to the results of the study care should be taken for designing terrace houses in order to provide an optimal solar protection while considering the values of natural light. In courtyard buildings, the potential of courtyards to act as passive cooling can be correlated with the building composition in terms of air flow pattern.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi  
keperluan ijazah Sarjana

**PENILAIAN REKABENTUK BAGI KESELESAAN SUHU DENGAN  
MENGUNAKAN SIMULASI KOMPUTER UNTUK RUMAH TERES DI  
KUALA LUMPUR, MALAYSIA**

Oleh

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Rumah teres adalah rumah yang paling banyak didapati di Malaysia. Hari semakin hari rumah teres lebih biasa dilihat di bandar-bandar dan pekan jika dibandingkan dengan rumah sebuah. Walaubagaimanapun, keselesaan sesebuah rumah bergantung kepada rekabentuk, pengubahsuaian dan penyesuaian penghuninya. Selain daripada itu, kajian tentang suasana dalaman di Malaysia menunjukkan kebanyakan rumah teres berada pada paras keselesaan suhu yang tinggi pada siang dan malam. Hal ini disebabkan hanya oleh rekabentuk persekitaran yang tidak sesuai. Hakikatnya di Malaysia, pertimbangan bioclimatic tidak memenuhi keselesaan penghuni. Kajian ini telah mencari pengaruh

kepada faktor perbezaan rekabentuk untuk meningkatkan keadaan terma sesebuah rumah.

Kajian keadaan terma rumah teres di Kuala Lumpur telah dilakukan menggunakan indeks keselesaan suhu Fanger's Predicted Mean Vote. Kajian kes telah dilakukan di Oversea Union Garden (OUG) di mana pengukuran suhu udara, kelembapan, suhu bumi, dan halaju udara diukur didalam rumah yang pengudaraannya neutral. Pengukuran dijalankan selama 3 hari. Hasil kajian menunjukkan, rumah dalam keadaan selesa selama hampir 14 jam sehari dimana keselesaan ini cenderung berlaku pada waktu malam. Bagi meningkatkan keselesaan pada waktu siang, kipas siling digunakan untuk menambah halaju udara didalam rumah. Apabila suhu udara mencapai jumlah maksimum, pengurangan penyerapan radiasi matahari akan membantu peningkatan keselesaan suhu di dalam rumah.

Berdasarkan penemuan tolok-ukur pada langkah berikutnya, program Ecotect telah digunakan untuk membina model komputer pada kes ini. Analisis suhu pada Ecotect digunakan bagi menilai ciri-ciri terma dalam rumah bagi 3 bulan yang berbeza: Mac, Jun, dan Disember. Penilaian keatas model termasuklah pertimbangan suasana semasa, ujian keredupan, dan ujian terhadap kesan taman di dalam rumah. Penilaian-penilaian ini menunjukkan keredupan yang sesuai mempengaruhi keadaan terma, terutamanya pada waktu siang dimana rumah menerima cahaya matahari dan seterusnya meningkatkan haba. Penggunaan taman di dalam rumah juga akan meningkatkan interaksi haba diantara bangunan dan kawasan luar rumah. Terutama sekali pada zon berlawanan. Walaubagaimanapun, ia boleh meningkatkan suhu dengan menggunakan rekabentuk teduhan yang sesuai dan juga bahan fabrik yang sesuai.

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## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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NASIBEH SADAFI

Date:



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## ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Clo	Clothing Level
C	degree Celsius
DBT	Dry Bulb Temperature
DOSM	Department Of Statistics Malaysia
ET	Effective Temperature
F	degree Fahrenheit
$f_{cl}$	the ratio of a person's surface when area while clothed, to the surface area while nude
$h_c$	convective heat transfer coefficient
$I_{cl}$	thermal resistance of clothing
Met	Metabolic Rate
MRT	Mean Radiant Temperature
PMV	Predicted Mean Vote
PPD	Predicted Percent of Dissatisfied
$p_a$	partial water vapor pressure
RH	Relative Humidity
$T_a$	Air Temperature
$T_n$	Thermal neutrality
$T_{ave}$	monthly mean outdoor Temperature



$T_o$	operative Temperature
$T_{eq}$	equivalent Temperature
$t_{cl}$	surface temperature of clothing
$t_r$	mean radiant temperature
$Vel$	Air Movement
$V_{ar}$	relative air velocity
$W$	external Work

# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

As a developing country, Malaysia is facing problems to accommodate the urban population. The migration of rural population to cities caused the government and private agencies to built 1.8 millions units of house from 1976 to 1995. Most of the houses were built in rows, called terrace houses with façade of 20-24 feet and depth of 70-80 feet , constructed either one or two story high and openings only on the front and back elevations; actually they are an efficient vertical use of scarce urban space (Mohammed Ali, 2003).

In architectural aspects, similar forms and facades resulted in the urban landscapes without variety and character (Said, 1994), also since 1981 several researchers have determined that these buildings are not designed in response to the country's inclement climate which is characterized by four main features; seasonal uniformity, low wind velocities and small diurnal temperature range as well as high humidity. In fact most terrace house designs have ignored the importance of thermal comfort zone in the interiors (Takahashi, 1981).



## 1.2 Background

The first major issue of most discussions about climate is the thermal comfort level (Salleh E, 2004). Thermal comfort can be defined as ‘the state of mind, which expresses satisfaction with the thermal environment’ (ASHRAE, 1985); the definition quickly perceived, but hard to exploit in physical parameters. Air temperature, air movement, radiation and humidity are not the only climatic characteristics that affect human comfort but they are the dominant ones. Thermal-comfort problems are varied and as they may be caused by different factors such as conversion of building operational and physical characteristics and occupant behavior and interference, they can be difficult to identify and solve (Van Hoof J, 2007).

For buildings in tropical regions with warm-humid climate various strategies have been suggested in previous studies in order to handle the warmth and humidity in relation to thermal comfort (Koenigsberger et al, 1971, Evans, 1979 and Salleh E, 2004). As Koenigsberger et al (1971) suggested in warm humid climate indoor comfort is largely dependent on the control of air movement and radiant heat. Maximum air movement passing over the body must be encouraged and solar gain must be prevented from reaching the building’s occupants either directly through doors and windows or indirectly by heating the structure. But exploitation of these various strategies seems to be neglected in contemporary modern constructions.

In Malaysia, as a country located in warm-humid tropics, the new type of modern housing sprang up after its independence, called “terrace housing” which brought about

a new and alien life style (Salleh R, 1989). Large numbers of terrace houses have been constructed in Malaysia. In cities and towns the terrace houses have been increasingly common in comparison to the detached single-family houses. They are attached houses with similar façade treatment. Found in the inner city they look similar to the row housing of Europe, which are built on a rectangular plot and the frontage form is the narrow section of the lot.

The terrace house is low-rise, but it can be built at a very high density in a regimented layout. About 40 units can be built on one-hectare area (Mohammed Ali, 2003). However, in spite of their adaptability, the climate and urban conditions of the country has not been considered in the design stage of their construction, so air-conditioning systems are common ways for controlling indoor comfort despite their increase of energy demands (Pattaranan, 2006).

### **1.3 Problem Statement**

Bioclimatic design considerations in terrace houses of Malaysia have not been fully explored according to occupant's comfort needs.

Thermal comfort should be considered as the main concern apart from other comfort criteria such as visual, acoustic and indoor air quality. Passive means should be given priority first and active systems should also be provided whenever they are required to minimize the thermal stress. To achieve this aim, it is important to consider climate at all design stages (Pattaranan, 2006). In spite of the importance of comfort sensation on the

indoor environmental quality perception, climatic, behavioral and adaptive factors affecting thermal comfort requirements are normally being neglected by the architects and systems designer at the time of designing buildings. In the process, a significant opportunity to save energy and providing the optimum environmental settings for thermal satisfaction will be missed out (Mahdavi A et al, 2001).

Indoor environment studies in Malaysia revealed that most of the modern terrace houses are above upper thermal comfort level during day and night (Davis et al, 1998). The mass housing programs resulted in dwelling units which are not designed suitable for the warm-humid tropical climate of the country. The importance of thermal comfort of the house has been ignored in most of the common housing designs (Said et al, 1994).

So this study is intended to investigate the effects of suitable bioclimatic designing in preventing indoor overheating conditions and lowering maximum indoor temperature below the ambient, in warm humid climates. It is hypothesized here that applying such strategies in modern terrace houses can enhance indoor comfort conditions.

In this case the following research questions are deemed relevant:

1. How to apply suitable bioclimatic design principles to ameliorate the thermal conditions of terrace houses in hot-humid climate of Malaysia?
  - a. What are the current thermal comfort conditions in existing Terrace house of Malaysia?



- b. What is the relationship between shading design and thermal sensation?
- c. What are the effects of introducing internal courtyard on indoor comfort conditions in terrace houses?

#### **1.4 Objectives of the research**

The main objectives of this research are:

- To investigate the thermal performances of an existing terrace house under warm- humid climate.
- To examine the effects of different aspects of climatic design to improve the current condition.
- To propose appropriate design measures in ensuring indoor thermal comfort in terrace houses of warm-humid climate.

#### **1.5 Scope of the study**

The study focuses on the effects of design variables on thermal comfort, under naturally ventilated conditions, with reference to the family area in a terrace house.

These design variables are limited to:

1. Shading device
2. Internal courtyard