UNIVERSITI PUTRA MALAYSIA

THERMAL COMFORT AND USER'S PERCEPTION OF BAMBOO AS SHELTER IN SCHOOL OUTDOOR ENVIRONMENT

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By

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

THERMAL COMFORT AND USER'S PERCEPTION OF BAMBOO AS SHELTER IN SCHOOL OUTDOOR ENVIRONMENT

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November 2017

Chairman : Nur Dalilah binti Dahlan, PhD
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The quality of outdoor and semi-outdoor spaces influences the well-being and performance of people. Among many factors, thermal conditions play a significant role in the satisfaction of individuals in such areas. The exploration of human thermal comfort in outdoor and semi-outdoor spaces, especially in a tropical climatic condition, is vital, and the numbers of studies which mainly focus on this context are few. A bamboo shelter, as a semi-outdoor space, can significantly affect the thermal comfort of users during the day. Hence, the primary purpose of this study is to focus on the general user's perception of the semi-outdoor shelters located at Secondary School (S.S) and Primary School (P.S) in Serdang, Malaysia. Consequently, a quantitative field study together with a subjective questionnaire survey were conducted to evaluate thermal sensation and thermal preferences of respondents, simultaneously.

The results of the quantitative field study and questionnaire survey revealed that the bamboo shelter located at the P.S provides a better thermal state and are more comfortable to the respondents in their thermal condition. Moreover, the results of this study also illustrates that shading has a significant effect on the thermal satisfaction of people and well-covered spaces provide a better thermal environment for users. The findings of this study can be applied in future design decision-making, concerning outdoor and semi-outdoor spaces to provide thermally comfortable non-indoor spaces that can lead to increasing the usage of such spaces. In conclusion, the findings of this study contribute towards improving the design of shelters as semi-outdoor spaces for users in the tropical climate of Malaysia to enhance the quality of life in urban areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

TERMA KESELESAAN MENGGUNAKAN BULUH DI KAWASAN LUAR PERSEKITARAN SEKOLAH

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Kualiti yang terdapat pada ruangan sepenuh luaran dan semi luaran akan memberi kesan terhadap kesejahteraan dan prestasi individu. Salah satu faktor ialah keadaan terma yang membawa peranan penting dalam kepuasan individu dalam ruangan tersebut. Penerokaan individu tentang penyesuaian dari segi terma mengikut ruangan luar dan semi luaran, terutamanya di kawasan bercuacakan tropikal, adalah penting namun penyelidikan terhadap konteks tersebut hanya sedikit. Dalam perlindungan yang berunsurkan buluh pada ruangan semi luaran, boleh membawa efek yang ketara terhadap kawalan haba pada waktu pagi. Oleh itu, tujuan utama kajian ini adalah untuk membandingkan persepsi umum pengguna tentang keberkesanan menggunakan perlindungan berunsurkan buluh sebagai material utama pada ruangan semi di Sekolah Menengah Kebangsaan Seri Serdang (Secondary School) dan Sekolah Kebangsaan Sri Serdang (Primary School) di Kuala Lumpur, Malaysia. Oleh yang demikian, kajian dalam bidang kuantitatif bersama dengan kajian soal selidik subjektif telah dilaksanakan untuk menilai sensasi terma dan keselesaan terma pada responden, pada masa yang sama.

Keputusan kajian kuantitatif dan soal selidik mendedahkan responden yang terdapat pada perlindungan buluh di kawasan sekolah rendah merasa lebih selesa pada keadaan terma. Keputusan kajian menunjukkan teduhan membawa efek dalam kepuasan terma pada individu dan kawasan yang terlindung sepenuhnya memberi suasana terma yang lebih baik kepada pengguna. Penemuan dalam kajian ini mampu dipergunakan dimasa hadapan ketika membuat keputusan dalam reka bentuk, yang berkaitan dengan kawasan luaran sepenuhnya dan kawasan separa luaran bagi

menyediakan keselesaan terma di ruangan luaran di mana boleh meningkatkan pengunaan kawasan tersebut. Kesimpulannya, hasil kajian ini mampu memberi sumbangan dalam menambah baik reka bentuk kawasan perlindungan seperti kawasan semi luaran bagi pengguna yang bersuhukan tropikal seperti Malaysia untuk meningkatkan taraf kualiti di kawasan bandar.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of the thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Ruled 2013 (Revision 2012-2013) are adhered to.

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LIST OF EQUATIONS

LIST OF ABBREVIATIONS

ASHREA	American Society of Heating Refrigerating and Air Condition Engineers
P.S	Primary School
S.S	Secondary School
clo	Clothing insulation level
°C	Degree Celsius
met	Metabolic Rate
PET	Physiological Equivalent Temperature
TPC	Thermal Perceptions Classification
RH	Relative Humidity
Ta	Air Temperature
Ga	Globe Temperature
Va	Air Velocity
Tmrt	Mean Radiant Temperature
TSV	Thermal Sensation Vote
TA	Thermal Acceptability
TP	Thermal Preference
AM	Air Movement
AP	Air Preference
TC	Thermal Comfort

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Since people spend most of their time indoors, researchers concerned with thermal comfort have generally focused on indoor environments. Thermal comfort is a condition of mind which expresses satisfaction within the thermal environment and therefore, needs to be assessed subjectively. Nikolopoulou, et al., (2001) found that the thermal environment conditions of semi-outdoor and outdoor environments significantly influenced user's utilization rate Hwang, (2007). For multi-functional public places, it is important to ensure thermal comfort in both outdoor and indoor environments. In hot and humid weather, such as in Malaysia, where mean air temperatures are between 22°C to 33°C, and relative humidity generally exceeds 80%, it is also important to discuss both semi-outdoor and outdoor thermal comfort in hot and humid weather. Although some detailed thermal comfort prescriptions such as ASHRAE Standard 55 (ASHRAE, 2004), ISO 7730 (1994) have been established for indoor environments, no prescriptions have yet been developed regarding thermal comfort in outdoor environments for tropical climates such as Malaysia.

Nikolopoulou, et al., (2001) claimed that the conventional comfort theory relies on a steady state model where the production of heat is equal to the heat loss to the environment, aiming to keep a constant core body temperature of 37°C, so that the environmental conditions which provide thermal satisfaction, dependent only upon the activity of the subjects and their clothing level, fall within a narrow band. Subsequently, work showed that people take action to improve their comfort conditions by modifying their clothing and metabolic rate, or by interacting with the building, referred to as 'adaptive' actions (Nicol, 1990). Separating thermal sensation from thermal satisfaction, it was further demonstrated that 'adaptive opportunity' (the degree to which people can adapt to their environment) is important for their satisfaction with space. Conversely, when the adaptive opportunity is limited, departure from neutrality causes stress and dissatisfaction (Baker & Standeven, 1996).

Based on studies done by Cheng, (2012), outdoor thermal comfort has attracted extensive attention in the last decade. Research studies have been done elsewhere in the world to understand the thermal sensation of people in different outdoor spaces and under a wide range of climatic conditions (Ahmed 2003; Nikolopoulou et al., 2006; Spagnolo et al., 2003). (Ahmed, 2003) Suggested that comfortable outdoor spaces have a significant bearing on the comfort perception of the indoor ambiance. The demand for comfort conditions in buildings is significantly increased as a result of the exposure to the uncomfortable outdoor setting.

Based on (Chuna, 2004) thermal comfort research traditionally focuses on the interior environments of buildings. Recently, there has been interest and substantial research about outdoor thermal comfort. In architectural place-making, spaces that are both inside and outside of buildings deserve special recognition, not only because of their aesthetic, physical character but also for their potential to save energy. And, with increased interest in the symbiotic building, the need for places where occupants can contact and feel nature is also growing. These spaces, defined in this research as transitional spaces are locations where the physical environment bridges the interior and exterior environment. A modified climate is characterized by highly variable physical conditions. People may use transitional zones as spaces to sit and relax and enjoy their surroundings, such as shelters.

Current comfort standards do not explicitly address transitional spaces. We have to consider this kind of space independently, and not use the same standards for spaces inside or outside of buildings. Currently, there is little information regarding the significance of such transitional spaces. Referring to (Chuna, 2004) transitional spaces are divided into three categories. Type 1 is a transitional space contained within a building, such as a hotel lobby or entry atrium where conditions are continuously mixed as people move in and out of the building. Type 2 is categorized by an attached, covered space connected to the building (or between buildings, where outdoor conditions predominate, such as a balcony, porch, corridor, covered street or arcade). Type 3 transitional space is not attached to a building and is essentially an outdoor room, entirely influenced by how the design of the structure modifies the outdoor climate, such as pergolas, shelters, or pavilions. (Figure 1.1, Figure 1.2, and Figure 1.3).

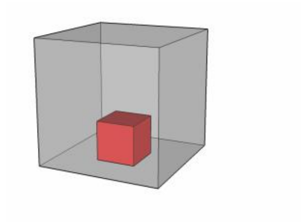

Figure 1.1 : Type 1

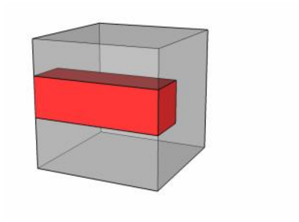

Figure 1.2 : Type 2

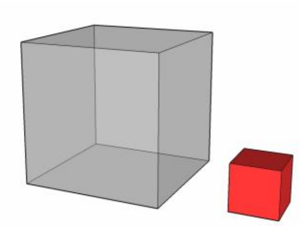

Figure 1.3 : Type 3

Furthermore, (Ghaddar, 2011) claims that in hot and moderate humid climates, people spend a significant time in unconditioned transitional spaces that rely on natural or mechanical ventilation. With global warming, more days of the year are marked with warmer environments in which work may result in an increase of thermal discomfort.

1.2 Research Problem

Research conducted in hot and humid regions indicated that few people visit squares when the temperature is high (TP, 2009). The largest numbers of people visit squares when the thermal condition is close to their thermal comfort range. Therefore, outdoor thermal environments affect the evaluation of thermal comfort and usage of outdoor spaces. (Nikolopoulou, et al., 2001; Thorsson, 2004; Eliasson, 2007; Thorsson, 2007)

Another study done by Makaremi, (2012) showed the quality of outdoor spaces in urban areas plays a significant role in the quality of life within various cities. Meanwhile, the rapid urbanization of the cities in recent years has increased the need for the creation of more outdoor environments for leisure and recreational activities of its residents (Oliveira, 2007; Nikolopoulou, 2003). Likewise, the condition of human comfort in outdoor spaces is a vital factor to be considered during the design process of outdoor spaces, as it is affected by a wide range of parameters. Hence, creating thermally comfortable environments based on the climatic conditions is deemed to be one of the substantial criteria during the design of outdoor spaces (Mayer, 2008; Nikolopoulou, 2007). However, with regard to understanding the outdoor climatic comfort conditions, the studies were mostly limited to temperate regions (Nikolopoulou, 2007; Metje, 2008; Nikolopoulou, Baker, et al.,, 2001). Therefore, there is a significant lack of information on thermal conditions and the importance of the role of human thermal comfort in relation to the outdoor environmental quality in tropical regions (TP, 2009; Johansson, 2006; Ahmed, 2003; Lin a, 2010).

1.3 Research hypothesis

According to the previous studies, one of the main factors in thermal comfort determination related to human in tropical regions is to understand the thermal condition of each user in the same climate condition. In this regard, we have designed a platform to study the effective parameters on thermal comfortability through survey questionnaire and field measurements. Based on this hypothesis, the research conducted on the two determined schools in two locations, which were chose by pre-studying on their shelter regional position. The survey questionnaire was designed to find out the differences between the user's thermal condition in each shelters and factors involved in effecting the thermal comfort condition in each space. It can be expected to find one of the shelters to be more thermally comfortable comparing to the other one due to the site conditions and factors that are not being shared in both schools.

1.4 Research gap

One of the insufficient analysis in thermal comfortability in such climates is the lack of environmental studies on human thermal comfort in tropical regions. With regard to understanding the outdoor climatic comfort conditions, the studies were mostly limited to temperate regions (Nikolopoulou et al., 2007; Metje N, 2008; Nikolopoulou, et al., 2001). Moreover, study done by (Nastaran Makaremi, 2012) showed how the quality of outdoor spaces in urban areas plays a significant role in the quality of life within various cities. . In this regard, a high consideration was carried out for effective parameters on human's thermal comfortability such as location of the space, the material and the proximity of the space, which can individually play a significant change in human thermal comfort.

1.5 Research questions

This study surrounding the following research questions:

Research Question 1
"What are the differences in terms of human thermal comfort between two semi-outdoor bamboo shelters in different proximities?"

Research Question 2
"What are the human comfort responses inside the semi-outdoor shelter with the bamboo materials?"

Research Question 3
"What are the recommendations and design suggestions for shelter design in terms of thermal comfort in semi-outdoor shelters?"

1.6 Research Objectives

The primary purpose of this study focuses on the general user's perceptions of the effectiveness of using bamboo as the main material for semi-outdoor shelters located in the Serdang area secondary School (S.S) and primary School (P.S) in Serdang, Malaysia. In order to achieve this, the objectives of the study are as follows:

i. To assess the thermal conditions in a bamboo shelter at a S.S and P.S.
ii. To appraise people's thermal sensations in reference to the performance of the bamboo material in semi-outdoor shelters.
iii. To suggest and recommend the shelter design based on the perimeters discusses in PET.

1.7 Significance of Research

The importance of this study refers to the contribution and the benefits that this research can carry:

i. The users will benefit, since it will provide shade for outdoor use.
ii. Bamboo is a sustainable material; therefore, it contributes to sustainable construction in tropical climates.
iii. Other matters are highlighted in the research problem section.

1.8 Scope of Research

This study is looking into general user's perceptions for shelter within a tropical climate. Field measurements conducted on existing semi-outdoor shelters included logged Ta, RH, MRT, and Va, hourly from 9 am until 5 pm. The two selected bamboo shelters are located in the Serdang area. Choosing Serdang as the location of the study was based on pre-screening on shelters in both schools. Some of the main factors involved in pre-screening were the same material, Size and shape that they carried but only different in proximity and their surroundings which then gives the ability for the research to be conducted so that the importance of the site locations and the surroundings of a shelter can be learned. Conducted computer simulation will then validate the existing shelter's thermal performance; the data is also used to predict the performance of proposed bamboo shelter's design to look for improvements in thermal conditions.

1.9 Limitation of Research

The main limitations of this study are the changing weather conditions in Malaysia, during the field measurement. Moreover, both case studies are located in the Serdang area, which would limit the research to a particular location in Malaysia. Other limitations, which can be mentioned, is the measurement, which was only conducted in the daytime, and not the entirety of the day because of the school's operating hours.

1.10 Research Flowchart and Framework

Figure 1.4 elaborate on the flow chart of the proposed research on human thermal comfort in tropical regions. In this regard, related research questions based on human thermal comfort between two case studies were designed and separated between users located in case studies. A high consideration is taken to the limitations of data collection such as weather conditions that were constantly changing during the field measurement. Moreover, both case studies are located in the Serdang area, which would well limit the research to a particular location in Malaysia and the field measurement time. Finally, the obtained data was analyzed in detail to achieve the entire research objective.

Following the selected fram work of study as well as obtaining relible deta's, a pre-screening method was used to choose the effective parameters on users termal comfortability. In this regard, several parametrs were stidued based on both litriture reviw as well as intial results of primery experiments. The most influenced parametrs were seccufully chosen and a quetinaries as well as the location of filed mausrment also were designetaed to well establish the data collection. PET caculation aslo was preformed by Rayman software and the related analysis were caculated through the obtained results of filed masurments. Based on the obtianed results, all parametrs namly: (6 parametrs) were compared to achive users termal comfortability of each school. Finally, the users termal comfortability of schools were compared and the associated justifications were investigated to prove the results.

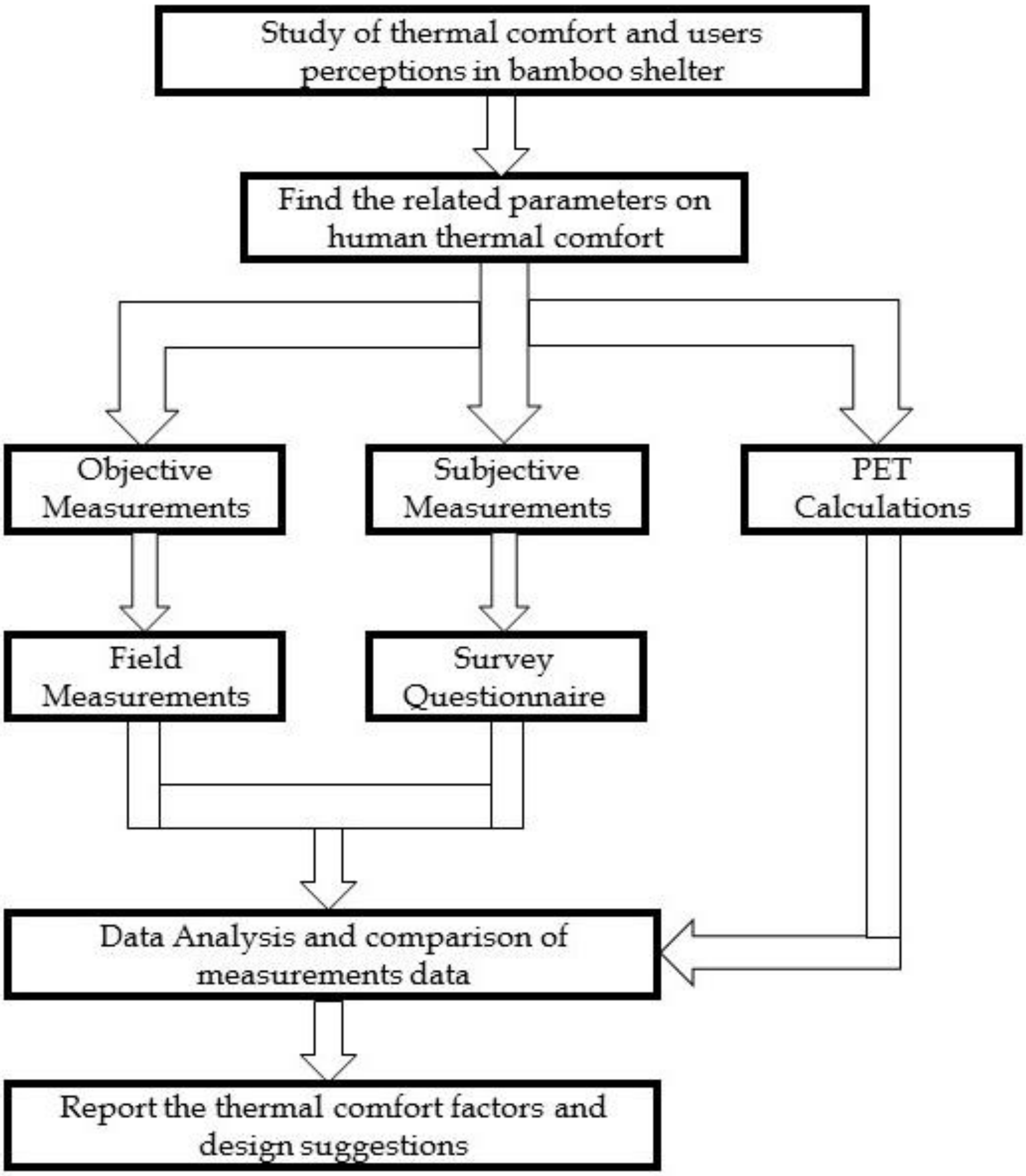

Figure 1.4 : Research Framework

1.11 Structure of thesis

The structure of the study is based on separated contexts, which help in the findings of the results. Hence, the thesis is apportioned in five chapters, which are presented respectively. The first chapter introduces the whole thesis in details. It is comprised of the elements of this research and the procedure for inspection. The second chapter states the features of Malaysia's climate as typical characteristics of a tropical climate. Moreover, this part focuses on the literature review through assessing human thermal conditions in semi-outdoor shelters. In addition, meaning of thermal comfort and theories are represented, and the relevant guidance is explained. The main aim of chapter three is to describe the research method, the process of data collection and the unit of analysis. In this chapter, the reasons for each question of the questionnaire along with the procedure of the field measurements are clarified in detail. The findings of the objective measurement and the subjective assessment are interpreted in chapter four. This chapter explains the data analysis and the results of current research. In the final chapter, the findings of this study are described for future investigation. In addition, chapter five has recommendations for shelter design base on permeters discusses in PET.

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