Investigation Energy Optimization in Architecture of Residential Buildings

Hamidreza Salehi

PhD student of Architecture, Baku State University, Baku, Azerbaijan

Abstract: The main purpose of this study is investigation energy optimization in architecture of residential buildings. So, thermal perceptual aspect from daily activities in residential buildings have been evaluated. To drive renewable energy technologies for practical application on a large scale, highly efficient energy conversion and high-density power storage technologies, together with cost-effective production process, are urgently required. The research uses the cases of small detached houses in Bangkok to examine the best manipulation of architectural elements to optimally provide thermal comfort in the Thai living context applying a multi-facet research methodology. Nanostructured materials tend to agglomerate because of their high surface energy, which usually inhibits their cycle-life stability. Test result indicates that the various combinations of voids and interior configurations are responding to wind directions, which could obtain the interior air velocity.

[Hamidreza Salehi. **Investigation Energy Optimization in Architecture of Residential Buildings.** *Nat Sci* 2017;15(8):34-38]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 6. doi:10.7537/marsnsj150817.06.

Keywords: Energy Optimization; Residential Building; Architecture

1. Introduction

The current global energy crisis has called for local actions involving the reduction of energy consumption. The “think globally act locally” notion brought about awareness and cooperation from the design discipline, where energy-efficient design has become among the crucial design elements taken into consideration by architects and designers. In the past, architects had designed interior environment with respect to its local climate and living context. However, the Western designs and ideologies have recently created a huge influence on interior design by aiming to meet residents’ use values and ways of lives. As a result, most of the modern designers have adopted the technological aspects from the West to maximize the living comfort and paid little attention to the use of interior environmental management in creating the thermal comfort from passive energy. The principles and techniques of Eastern interior designs are greatly different from the Western perspectives. In the West, the living comfort is induced by the design strategy that creates warm and comfort living ambiance. Meanwhile, in the tropical climate, designing for comfort living environment can be created by decreasing indoor temperature, for instance producing the ventilation through the manipulation of architectural elements and the treatment of interior spatial arrangements.

To drive renewable energy technologies for practical application on a large scale, highly efficient energy conversion and high-density power storage technologies, together with cost-effective production process, are urgently required. Recently, the beneficial effect of nanotechnology for various energy harvesting, conversion and storage materials has shown great promise, which can be summarized briefly as follows.

First, nanotechnology results in increased surface and interface area of the materials; second, short length scales within a material lead to efficient ion transportation; and, third, numerous energy-conversion processes, such as the intercalation and deintercalation in batteries and supercapacitors, lead to volume expansion which can be accommodated by using nanostructured materials. However, nanostructured materials tend to agglomerate because of their high surface energy, which usually inhibits their cycle-life stability. In addition, undesired aging effects can significantly reduce the performance gain of the energy storage devices leading to a compromise be-tween good performance and long lifetime. Thus, a strategy for maintaining the structure and functionality of nanomaterials during their life cycles is essential for energy conversion and storage.

Each of the remedial choices for energy-efficient design has its pros and cons and they could interact with each other when applied simultaneously. Applicability of combined remedial actions depends much upon the most efficient interaction effect providing the occupants an optimal living thermal comfort. Utilizing the small detached house in Bangkok as a case study, the research endeavours to examine the best manipulation of architectural elements which can optimally serve to provide a thermal comfort in the Thai living context. And finally, the study attempts to derive an interior environmental management model for the optimization of thermal comfort design.

One promising approach to address this issue is the encapsulation of pre-synthesized nanostructured materials by another coating layer, which ideally should protect the inner-core nanomaterials to avoid agglomeration and to be functional and another method is to form the heterostructured nanocomposite in a confining matrix using one-step process. These encapsulation strategies have been demonstrated to be effective in a variety of energy-conversion devices. In the field of supercapacitors, the encapsulation strategy is also employed to fabricate composite electrodes with core–shell heterostructures.

It is well-known that the energy density of supercapacitors is inferior to that of batteries, but they are capable of storing and releasing the energy much faster and have a much longer cyclic lifespan. Generally, supercapacitors can be di-vided into two categories: electrochemical double layer capacitors and pseudocapacitors. EDLCs store charge electrostatically at the interface of high-surface-area carbon electrodes and an electrolyte, whereas pseudocapacitors, or redox capacitors, store charges through fast surface and near-surface redox reactions or through the intercalation of ions.

As a pseudocapacitive material, transition metal oxides enjoy a significant advantage. Due to their inherent chemical charge storage mechanism, pseu-docapacitors exhibit high energy density and storage capacity, but usually suffer from slow charging and a limited lifetime. Increasing the energy density of supercapacitor electrodes without negatively impacting their power density and rate capability is an important challenge that can be addressed by electrode design and by producing a core–shell composite of metal oxide nanomaterials and conductive polymers. The image on this issue's cover of Materials Today shows a composite consisting of core–shell nanomaterials with beautiful sphere-like and dendritic microstructures synthe-sized on three-dimensional nickel foam skeleton.

Literature Review:

Derived from the literature review, theoretical basis as a foundation of the research framework comprises principles of tropical architectural designs, outdoor thermal conditions, physical requirements for passive designs, human thermal perception and comfort zone, and spatial behavioral pattern of residential usage. The passive means of heating, cooling, and lighting are closely related to building forms. The passive means are the most important energy uses in a building and creating a strong influence on its form. These effects should be known and taken into consideration in the design process. The following section presents four lines of thoughts on which the study is based.

The nanocomposite with core–shell structures is designed to decrease the diffusion limitation for electrolyte ions moving through the elec-trode and to increase the electrode conductivity, which directly determines the performance of a supercapacitor device. To date, the high performance of species has been demonstrated only for thin film electrodes. Three dimensional electrodes with high mass loading for practical supercapacitor application have yet to be adequately investigated due to higher areal capacitance.

We address this issue by the fabrication of core–shell nanocomposites. This hybrid composite was synthesized by a controllable hydrothermal process and subsequent electrodeposi- tion methods in which the formations of core-like nano-structure and the deposition of shell-like conduct polymer were performed step-by-step. Moreover, it is notable that the conduc-tive polymer shell could be further decorated by transition metal oxide nanomaterials to form sandwiched structures. We have recently reported that the core–shell–shell nanocomposites for supercapacitor electrodes, which combine the benefits of hierarchical nanostructure architectures and encapsulation strategies, are capable of efficient charge and ion transport. The effective use of active nanomaterials is a key part of this fabrication strategy.

In order to create thermal comfort to the interior environment, studies on architectural design need to take into account some crucial elements of outdoor conditions and should also truly understand the particular climatic conditions in that region. Architectural design in the Tropics is typically required to take a serious consideration on its local hot and humid climate, particularly in the coastal zones of South- East Asia. Designing the traditional architecture in the region has been experiencing difficulty from local climatic conditions including high humidity, little naturally air movement in a building, and constantly high temperature during a day and at night. As a result, these local factors have been influencing the varieties of design features adapted to the local climate, especially passive cooling techniques. The architectural design in the tropical region is usually aimed to reduce the temperature in the interior environment. Three major design techniques that could bring down the indoor temperature include (1) minimizing exposure to direct sunlight, (2) increasing cooling rate during the afternoon, and (3) introducing passive cooling elements to the building.

Besides the physical environment factors, human comfort is considered to be associated with a number of factors including a human body itself. The body condition is one of the major factors influencing people comfort perception. Body heat, as we all know, is naturally generated as a by-product of metabolic system. The aim of creating human thermal comfort is, therefore, to eliminate the heat generated from inside the human's body. The changes of body temperatures can be explained by the transfer of "sensible heat" from human body to the surrounding environment. To manipulate thermal comfort, one needs to understand these key factors: air temperature, air movement, amount of clothing worn, and activity level. In addition, the amount of heat generated from human body also depends on gender, age, and other factors.

It was reported that thermal comfort perceived by Thai people has been proved to be 4 degrees higher than the index suggested by The American Society of Heating, Refrigerating and Air Conditioning Engineers, since dwellers in the tropical areas are more tolerable to heat than those in the higher altitude. With appropriate amount of ventilation and wind speed, the upper limit of thermal comfort for dwellers in the tropical zone could be as high as 31 degrees Celsius.

According to the literature review, it summarizes that natural thermal comfort, in the Thai context, consists of comfort conditions temperature between 26-31 degrees Celsius, relative humidity level between 50-80%, and maximum air velocity within 1.0 meter per second. Besides, personal factors are influence sense of thermal comfort. This research thus applies this condition as the targeted threshold to be reached by the optimal passive strategy, namely, room temperature between 26-31 degrees Celsius, 50- 80% relative humidity and wind velocity up to 1.0 meter per second. Clothing and activities of dwellers are treated as controlled variable and are held constant.

Methodology

Derived from the literature review, the background presented in the previous section attempts to explain the relationship among variables which link interior environmental design elements and optimal degree of comfort, see Fig. 1. The research bases its framework on two lines of thoughts: theories regarding physical environment and theories of comfort zone. The research initially hypothesized that the interior environment and management can be effectively designed to benefit energy conservation purposes and simultaneously serve to provide a thermal comfort living conditions.

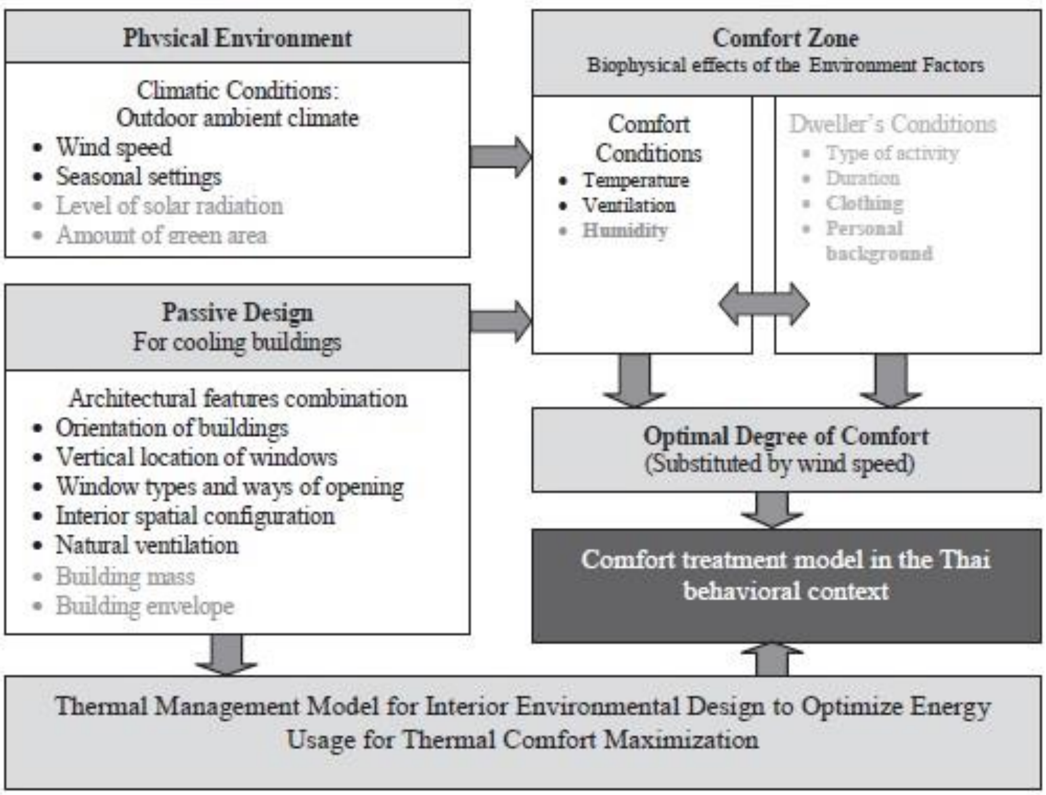

Fig. 1. Conceptual Framework

An integration of multi-facet research methodologies are applied towards the modelling of the optimization of comfort design. Firstly, information regarding microclimate of the Bangkok Metropolis is retrieved from the meteorology office to be compiled to derive the average outdoor ambient temperature and humidity as an input in the Bio-Climatic Chart. A perceptual comfort zone in the Thai context is then derived by the literature review. The second stage involves the classification of physical settings vis-à-vis the level of perceived comfort to be used as input in the modelling computer programming. In the testing state of research tools, typical dwelling units of villa houses could be classified into four categories in accordance with the location of building core (stair well and baht)—centre front, centre back, side of buildings, and inner center of dwelling unit. This study chose the most popular front centered stair-well type with first floor bath located adjacent to the stair as case study, see Fig. 2. The research found that among the eight orientations of building under investigation, there are only four directional groupings which needed separate testing with two seasonal wind directions of Bangkok in accordance with the micro climatic wind charts.

Result and discussion

As the research inspiration, it attempts to acquire the set of critical environmental features and local factors that provides the optimal degree of thermal comfort. In the first phase, the research found that, basically, Thailand thermal pattern can categorize into two patterns: From December to January: Low temperature, high humidity, and the highest comfort level. From February to November: High temperature, high humidity which requires ventilation for comfort thermal in the day time. However, it requires air condition if temperature is over 33 degrees Celsius.

For the second phase, it was found that interior wind speed could be enhanced with different types of interior opening manipulations with the constant exterior average wind velocity of 0.83 meter/second.

Research examines thermal comfort of internal building with the variance temperature from 20 to 40 degrees Celsius of external building by increasing every one degree Celsius. Various patterns are observed. Researcher categorized the patterns into three groups by utilizing the manipulated external temperature as the conditions. First: from 20 to 29 degrees Celsius, it is the thermal comfort, in the Thai context, without architectural feature management. This thermal condition is the average temperature for winter season in Thailand—from November to February. Second: from 30 to 33 degrees Celsius, it is the range that architect can manipulate thermal comfort by increasing air velocity (Air Movement Effect) into internal building. The research found that increasing the velocity of air movement does not either decrease temperature or expand comfort zone in the building but evaporate human's sweat. Third: from 34 to 40 degrees Celsius, this temperature range occurs during the daytime of summer season from March to June. This range requires convectional air conditioning to create thermal comfort. The research, also found that the sensation of feeling hot or cold is not only just dependent on air temperature. Relative humidity, air velocity and human activities are also influencing sense of thermal comfort. The second condition represents the period when particular portion of the day is still within the comfort zone of 30-33°C; and the research hypothesizes that, with the manipulation of opening, wind speed could be increased to compensate the relatively high temperature beyond the comfort conditions.

Test result from the modeling shows that with opening of the villa house facing the 90° wind direction and with larger intake openings than the outflow side, the building settings could increase the interior wind speed up to 1.05 m/s to compensate a large portion of high temperature areas. This condition also covers a larger portion of the day time living period, which makes passive cooling possible with little compromise on the thermal comfort.

Conclusion:

The modeling is able to show the exact temperature contour and velocity of wind speed with both positive and negative pressures. The research suggests that functional settings in negative pressure area should be reduced or assigned to some particular types such as kitchen, and bath which are prone to odor emission. These areas should be assisted by active measures such as electric fan to enhance thermal comfort during daytime activities. However, thermal comfort could be achieved by means of airflow to reduce body temperature when ambient temperature is still slightly above the comfort zone. Test results also verify the fact that increasing wind speed does not reduce room temperature apart from its convective effect on body heat. Thus manipulation of ventilation alone can hardly lower the room temperature in the high humidity condition, as such; it makes passive cooling more complicated during the high temperature of summer period.

References:

1. Brown, G.Z. (2014), *Sun, Wind, and Light*. New York: John Wiley & Sons, Inc.
2. Daghigh, R. & Sopian, K. (2015), *Effective Ventilation Parameters and Thermal Comfort Study of Air-conditioned Offices.* American Journal of Applied Science, 5, 945.
3. Givoni, B. (2013), *Man, Climate and Architecture* (2nd ed.), New York: Applied Science Publishers, Ltd.
4. Givoni, B. (2015), *Climate Considerations in Building and Urban Design.* New York: Van Nostrand Reinhold Company Inc.
5. Khedari, J., Yamtraipat, N., Pratintong, N. & Hirunlabh, J. (2015), Thailand Ventilation

Comfort Chart, *Energy and Buildings*, 32, 245-249.

6. Lauber, W. (2016), *Tropical Architecture*, New York: Prestel Publishing.
7. Moberg, C. L. (2016), *Rene'Dubos, friend of the good earth: microbiologist, medical scientist, environmentalist.* Washington, DC: ASM.
8. Randall, T. (2016), *Environmental Design* (3th ed.), New York: Taylor & Francis Inc.
9. Robinson, I. M. (2012), Trade-off games as a research tool for environmental design, in Bechtel R. B., Marans R. W. & Michelson.
10. W. (Eds) *Methods in environmental and behavioural research*. New York: Van Nostrand Reinhold Company Inc.
11. Tantasasdi, C. (2014), CFD Approach towards Natural Ventilation Design: Guidelines for Houses in Thailand. *Journal of Architectural Research and Studies*, 49-50.
12. KJÆRGAARD, T. (2012): Den danske Revolution 1500-1800. En økohistorisk tolkning. København: Gyldendal.
13. LUND, N. (2015): Nordisk Arkitektur. København: Arkitektens Forlag.
14. SMITH, T.G. (2015): Vitruvius on Architecture. New York: The Monacelli Press, Inc.
15. EOR refers to a range of techniques to increase the amount of crude recovered in drilling operations and extend the lifetime of diminishing assets. Among EOR techniques, carbon dioxide flooding involves pumping large quantities of CO2 into reservoirs to reduce the viscosity of hydrocarbons and facilitate their recovery.
16. *World Energy Outlook Special Report 2013: Southeast Asia Energy Outlook*, September 2013. Paris, France: IEA.
17. *State of the World's Cities, 2014. UK and US: United Nations Human Settlements Programme (UN-HABITAT).*
18. *Zambia Energy Sector Profile*, *2013*. Zambia Development Agency.

5/28/2017