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A REVIEW ON SUSTAINABLE DESIGN AND INDOOR THERMAL COMFORT OF A GREEN BUILDING

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ABSTRACT

Sustainability is a concept that encompasses a wide range of social, economic and environmental issues. It can also be express as a concept of responsible stewardship that incorporate systems that meet the needs of the present without compromising the future needs.The sustainable design does not only enhance the positive result of the environmental but also reduces the overall life cycle cost of building and increases the occupant's comfort thus help in creating a sustainable community around the world. Subsequently, this paper will delve into the aspects of sustainable and green construction in general. It will also describe on the significant of building the design in optimizing the occupant's comfort in a building. Through a literature review, this paper will discuss the roles of sustainable standard tools in the construction industry. Nevertheless, this paper will also deliberate the findings from the previous study in areas of building façade, indoor environment quality, thermal comfort, occupant's satisfaction and green building. At the end of this paper, the author will describe the future direction and the expected contributions of her in-progress research.

Keywords: sustainable, indoor thermal comfort, green building, façade.

INTRODUCTION

Sustainability includes doing good things for the environment, social and communities that contribute to an improvement in energy conservation, human life as well as country's economic development. The American Institute of Architects (AIA) described sustainability as "the ability of society to continue functioning into the future without being forced into decline through exhaustion or overloading of the key resources on which the sustainability of construction material system depends on".Sustainability is the combination of many components that connected significantly to the social, environmental and the construction processes which includes the development, construction and design that need to be consider in order to achieve sustainability that meets today's need and continue constantly for tomorrow's needs.(Berke& Conroy, 2000), define sustainable development as "a dynamic process in which communities anticipate and accommodate the needs of current and future generations in ways the reproduce and balance local social, economic and ecological systems and link local actions to global concern". The sustainable construction is the application of sustainability principles to the construction, renovation, and maintenance of building while the sustainable design is the "application of sustainability principles to building design" (Kibert, 2008). Nevertheless of its definitions and scope, the transition of the construction industry to sustainable or green construction practice present both challenges and opportunities for the construction, design, material and parties involved to integrates into a sustainable or green building.

LITERATURE REVIEW

Green building

Green building is booming, especially in Europe and along the United States coasts that rapidly moving into the mainstream. The momentum of green building is striking and is driven partly by widening awareness of the environment impact of the built environment to the health implications of occupants in indoor spaces (Erica, 2008). Buildings have a significant and continuously increasing impact on the environment because handle a large portion of carbon emission and use a considerable number of resources and energy. The green building movement emerged to mitigate these effects and to improve the building construction process through encouraging the use of more environmentally friendly and recycle materials, appropriate material selection process, implementation of sustainable techniques to save natural resources and reduce waste consumption that subsequently will contributes to better indoor environmental quality (Moeck and Yoon, 2004), (Wang *et al*., 2006), (Thormark, 2006).

Green buildings mean to improve our design, construction, and landscaping practices so that it will last longer, cost less and contribute to healthy living. It also means guarding natural resources and refining the built environment for the people, communities and ecosystems to grow and live together in prospering (John and Michael, 2007). There are numerous potential benefits of green building including the environmental, economic and social benefit. The environmental benefits include protecting, conserve and restore the biodiversity and the natural resources. While the economic benefits comprises of reducing the life-cycle cost of the building and enhance

profit and rental value. Whereas in social benefits, the implementation of green building can enhance the occupants comfort and health thus improving the overall quality of life. Other benefits of the green building includes improvement of the indoor environmental quality, indoor thermal comfort and occupants' productivity (Edwards, 2003), (Kats, 2003), (Ross *et al*., 2006).

Sustainable building standard

Sustainable development has been a worldwide movement that has been evolving for the last two decades (Kibert 2008). Similarity, the development and introduction of sustainable building standard is taking place around the world (Hanna, 2011). Over the past decade, thesustainable building standard for green buildings has been developed worldwide to promote the construction of green buildings in the industry. According to (Liang *et al,* 2014), among the numerous efforts in the emerging green building is the establishment of green building certification systems as one of the most prominent and systematic approach toward promoting sustainability in construction. (Fraj- Andres and Martinez-Salinas, 2007) believed that the transition from traditional practices to sustainable design and construction will require action on many fronts and support from the prominent organization (Hanna, 2011). There are many great building certification tools globally to assess the environmental performance of building and its sustainability (Todd *et al,* 2001) such as BREEAM in United Kingdom, the Leadership in Energy and Environmental Design Standard (LEED) in the United State of America and Green Star in Australia are an assessments made by awarding credits, points or marks according to the building performance in order to determine the green rated given at the end of the building's assessment process.Benefits of these tools are they can guide the development of construction industry towards best practice and improving the quality of building for tenants and occupants.

In Malaysia, the development of own sustainable rating standard begun in May 2009 where the Malaysian Green Building Index (GBI) was launched as design guides and tools of green building in Malaysia. The Green Building Index (GBI) is always dynamic, being adapt and adopt from other rating systems. Green Building Index (GBI) closely adopted the Leadership in Energy and Environmental Design Standard (LEED) rating award and its criteria, although both are used in a different geographical zone and under different climatic conditions. The Malaysian (GBI) tools is based on the six criteria, which are "Energy Efficiency", "Indoor Environment Quality", "Sustainable Site Planning and Management", "Materials and Resources", "Water Efficiency" and "Innovation" with four categories of rating given which are the "Platinum", "Gold", "Silver" and "Certified" that based on marks obtained by the assessed building.

Sustainable design

Green construction is mainly aimed at reducing environmental impact and improving the safety, health and productivity of a building's final occupants (John and Michael, 2007). The main aims of this green construction are to create facilities and building that are sustainable with huge attention focuses on the satisfaction and sustainability of the end users and end use of the green building. According to (Kibert, 2008), sustainable design can be defined as "application of sustainability principles to building design". It also can be described as the identification of sustainable materials and components that integrates into a sustainable building. Therefore, proper selection of sustainable materials is very essential in producing a green and sustainable building which includes life cycle of the material, cost, energy saved, waste management and environmental impact (Thovichit, 2007). (Mogge, 2001), stressed out that "materials are an important aspect of sustainable outcomes and to the extent feasible should be selected based on the specific needs of the design". Thus, sustainable materials must not only focusing on the material properties itself but also on the integration with the green construction technique as a whole.

Now a days, building designers attempt to enhance better indoor environmental quality with proper choice of sustainable materials and green design that are comfortable for occupants at any time of day, in any climate and all year round.Hence a successful design and construction of building enclosure for building might guarantee the accomplishment of basic building enclosure externally and internal of the building comprises of the acoustics and air control, sustainable structural and enclosure design, heat and moisture control, and last but not least ultimate indoor environmental quality that fulfil the requirement of a building to be certified by sustainable rating standard as a green building.

Building envelope @ Facade

The building envelope is defined as the part of a building that separates the indoor environment from the external environment (Straube and Burnett, 2005). Within the building envelope, there are many outdoor parameter components including the foundation, external wall, windows, and doors and also the roof systems. Therefore the interface between the interior of the building with the building outdoor environment components that serves as thermal barrier plays an important part in determining the amount of energy necessary to maintain a comfortable indoor environment relative to the outside environment. Therefore, every building envelope has to have a high resistance to the outside temperature and climate to enhance the internal comfort of building at the most satisfactory level. The building envelope normally includes physical barriers of building that contribute to effective indoor environment quality that includes energy efficiency, comfort, and air quality. Thus, other popular terms used apart from building enclosure are building

façade, building skin and building exterior. This research paper will use the terms façade in referring to the external wall of the building.

The building façade is an environmental separator that composed of several layers between the building occupants and the external environment in all climate condition which typically consist of two essential parts: walls and windows. There is various type of façade systems, such as the precast concrete panels, steel and metal cladding and most significantly used the glass curtain walling. (Silvia and Ssekulima, n.d), believed that proper selection of materials can be complicated because the energy properties of the entire wall are affected by the design and materials. Hence, the selection of the design and materials will significantly affect the building thermal properties as a building's thermal mass is determined by the materials.

Today's non-residential building facadeis often highly glazed with a large area of glass for aesthetic appearance and prestige. Despite of the nice and prestigious look of the façade area, large amount of solar radiation passing through the glass façade to the internal part of the building that may cause discomfort to the building occupants especially in tropical climate where the heat is trapped inside of the building. (Huang and Shu, 2011) pointed that in buildings glazed perimeter zones, solar radiation and window performance influence the thermal comfort of occupants heavily. Therefore in tropical climate, it is more suitable to construct a highly insulated mechanical ventilation building (air conditioned building) that more suitable to control heat fluxes during the daytime with high surrounding external temperature as one of the critical goals in the building facade design is to lower energy consumption of a building by regulating and optimizing heat loss or heat gain through the facade (Kibert, 2005).

Few researcher (Carmody *et al,* 2007) and (Chua and Chou, 2010) believed that the design parameters of building facade such as orientation and shape of building as well as material types of building envelope can affect the energy consumption of a building in several ways. Apart from its physical appearance, numbers of studies regarding façade images have been conducted which includes the scenic views of façade, environmental facade aesthetics and creativity that influences buyers evaluation (Li and Will, 2005), (Bernasconi *et al*., 2009), (Horn and Salvendy 2009). (Silvia and Ssekulima, n.d) supposed that selecting best facade that can reduce the radiation of the sun into the building façade percentage areas coverage and enhance indoor environment quality.

Indoor environment quality

Indoor environment quality is define by (Garnys ,2007) as "the measurement of the key parameters affecting the comfort and well-being of occupants" elements to provide an environment that is physically and psychologically healthy for its occupants".The National Institute of Occupational Safety and Health in the United States has established a definition of indoor environment quality which includes the integrated physiological and psychological influences of thermal, acoustic and luminous environments and air quality on occupants (Li, You, Chen, and Yang, 2013). According to (Sarbu and Sebarchievici, 2013), the most common and significant environmental factors that define the indoor environmental quality are athermal comfort, indoor air quality, acoustic comfort and visual comfort. The indoor environment was found to affect the health, productivity and comfort of the building occupants. For that reason, few studies conducted and found that there is a relationship between indoor environment quality and occupants satisfaction and work performance that includes increase in the amount of work done, enhanced work performance, improved worker retention, reduced sick day and absenteeism (Clements-Croome & Baizhan ,2000), (Fisk ,2000), (Loftness *et al*. 2005).

As people in developed world spend most of their time 75-90% inside building (Lebowitz *et al*., 1985). (Chen *et al*., 1998) believed that the indoor environment quality is important for people's health and welfare because 90 percent of typical person's time spent indoors. Their productionis also related to the indoor environment. He also pointed that occupants in internal environment that exposed to illuminations, acoustics, air quality, thermal comfort and social environment in the building, reflect the situation that surrounds them by their physiological and mental sensations (sight, hearing, smell, taste, touch and mentality). There are practically large different in terms of the physiologically and psychologically, from person to person who makes it difficult to satisfy everyone in a particular space of the building. As a result, environmental conditions required for to satisfy the comfort needs of building occupants are not the same for everyone.

Thermal comfort and occupants satisfaction

Perceptions of the same indoor environment will vary among different building users. However, it is important for people that they feel comfortable with the environment when are inside buildings. Occupancy comfort is a subjective quality of space and is related to the type of physical activity that an occupant is engaged in. Thus, it is commonly accepted that the main key physical attributes of an internal environment which govern the perception of occupancy comfort include the air temperature, air velocity, radiation and radiant humidity. Most previous study of indoor comfort quality focused on office building with results indicated that gender, education level, age, type of work correlated with perceptions of the indoor environment. Substantial research has therefore been conducted in order to establish how the variables creating the environment in a building should be turned so that the users feel comfortable (Diamond, Remus, and Vincent, 1996), (Highlight and Donnini, 1999).

(Frontczak and Wargocki, 2011), in his research results recommend that when developing systems for governing the indoor environment, the type of building and outdoor climate including season should be taken into account. Findings from his research indicated that thermal comfort is ranked by building occupants to be of greater importance compared with visual, acoustic and air quality. However, the ranking was different in diff countries and depended on the building whether it is private or public. He also pointed that women and men ranked environmental conditions differently. Longitudinal study by (Lai and Yik, 2007) and (Lai and Yik, 2009) on commercial spaces in Hong Kong showed fairly dissimilar results, indicating that thermal comfort had the highest impact on overall indoor environment quality acceptance followed by indoor air quality, acoustic and visual quality. Subsequently, a study by (Frontczak *et al.,* 2012) showed that thermal comfort, air quality, and visual quality are positively correlated with overall indoor environment quality. This was also supported by (Lai, Mui and Law, 2009) who study based on indoor evaluation of occupants living in Hong Kong apartments indicate the thermal comfort has the highest importance impact on overall indoor environment quality. Humpreys as cited in (Flores-Colen and De Brito, 2010) also concluded that the thermal comfort and indoor air quality are the most significant factor in determining occupants comfort and satisfaction of the indoor environment quality in a building. Thermal comfort is defined in the ISO 7730 standard as "that condition of mind that express satisfaction with the thermal environment and is assessed mainly by subjective evaluation".

CONCLUSION AND DIRECTION OF CURRENT STUDY

The need for optimum indoor overall thermal comfort is a real challenge nowadays that worthy of everyone's attention (client, consultants, developer, facilities manager, as well as the building occupants and buyers). Therefore, incorporation of a good design, construction and the selection of appropriate materials for building envelope especially the vertical enclosure (façade) will provide significant effects to the building in terms of optimizing indoor thermal comfort as well as reducing the consumption of energy towards ultimate post-occupancy satisfaction. As much as the importance of the functionality of facade are reemphasized, there are also other criteria that need to fulfil such as providing the ultimate post-occupancy indoor thermal comfort to the building occupants. Facade for green building that rated by various sustainable standard tools worldwide do bear greater responsibilities in meeting this needs as compared to a non-rated buildings. Facades for these rated buildings must be at its maximum performance to reflect the actual environment of the rated building with the given ratings by green tools. Although numbers of studies had been conducted on the building façade, the very limited study had shown the relationship of various façade with the optimum indoor thermal comfort especially for green certified building in hot and humid climate condition.Therefore in filling the gap, the writer currently conducting a comparative study that covers different types of building façade in optimizing the indoor thermal comfort and occupant's satisfaction of Certified Green Building Index (GBI) Malaysia office buildings. Following are the objectives and expected outcomes of the research:

i. To measure Indoor Thermal Comfort (ITC) performance of five different types of building façade in a Green Building Index (GBI) rated office building dry season of Malaysia.
ii. To examine the effects of radiation through the building façade to the overall Indoor Thermal Comfort of Green Building Index (GBI) rated office building.
iii. To analyze the users' perceptions and satisfactions of the Indoor Thermal Comfort in five different types of building façade (in an indoor working space).
iv. To develop an assessment framework on the selection of architectural building facade to be used as a construction façade guideline for office buildings applying for Green Building Index (GBI) in Malaysia.

It is expected that this study can contribute to the following matters:

i. Set of criteria for optimum building façade selection in relation with overall indoor comfort for green office building in Malaysia.
ii. Develop a new façade assessment framework that leads to effective and optimum indoor comfort for office building in Malaysia that target for green certification.
iii. Extend and improve the construction consideration of various façade in relation with the Indoor Thermal Comfort of green office building in Malaysia and tropical context
iv. Enhanced Indoor Thermal Comfort and occupant's performance by sensitivity to the changing needs of occupants with different needs and preferences.

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