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Implementation of green building specification credits for better thermal conditions in naturally ventilated school buildings

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ABSTRACT

Most campus buildings in public education in Taiwan are naturally ventilated. Since it is hot and humid in summer, these free-running classrooms are vulnerable to overheating, which may impair the students' learning ability. We studied a Diamond-certified green building campus to determine the effectiveness of the strategies adopted to prevent overheating by quantifying the in-room thermal comfort via long-term in situ monitoring of temperatures. The passive planning and design means used in the case are presented in detail, and the resulting synthesis effect in terms of the relation of indoor thermal comfort to student learning performance is also discussed. The maximum percentage of dissatisfaction in classrooms is 15–22% less than that in the outdoor condition, and the severity of overheating is 12.5%–18.5% of that of the outdoors. The average learning performance is around 1.3% higher than in the outdoor condition. The green building certification system (EEWH) practiced in Taiwan evaluates various aspects regarding thermal comfort enhancement, the studied naturally ventilated school building demonstrates that by complying to these EEWH credits the indoor thermal quality can successfully be ensured.

1. Introduction

Since Taiwan's green building certification system was launched in 1999, school administrators have begun to pay closer attention to sustainable approaches in campus planning and construction. A sustainable school building is a building that consumes less energy, water, and resources and produces less waste than a conventional one. Such a building can also improve the indoor environment. As the classroom is where students spend more than half of each day, it is imperative to ensure that the indoor conditions are suitable for the students to learn. Previous studies [1–3] have shown that indoor environmental conditions can strongly affect student performance. In fact, the influence of the indoor environment on academic performance may be greater than that on adult productivity in an office [4]. Several studies of children's thermal perception in English schools by Teli et al. [5–7] also found that children have a higher sensitivity towards feeling warm than adults. A classroom occupied by 25–35 students has a far denser population density than a typical office. The unique characteristics of the classroom magnify the necessity of building a healthy and comfortable green school.

An on-site investigation by Issa et al. [8] revealed that teachers and students in a green school building are more satisfied with the quality of the classroom environment and have less absenteeism, and students tend to have higher student learning performance than those in conventional schools. Barrett et al. [9] studied 34 classrooms also revealed that the impact of environmental factors alone account for 25% on the learning progression of students. Moreover, green educational facilities are usually highly visible venues for practicing sustainable design and construction principles because they provide a precious learning opportunity for educating faculty, administrators, students, and neighbor communities about the importance of building an environmentally friendly building [10].

Taiwan's green building certification system for campus buildings was implemented in 2003. As of December 2013, a total of 337 newly-built school buildings had been certified as green buildings. Fig. 1 shows the number of green school buildings certified each year. In the past decade, the green school movement has grown

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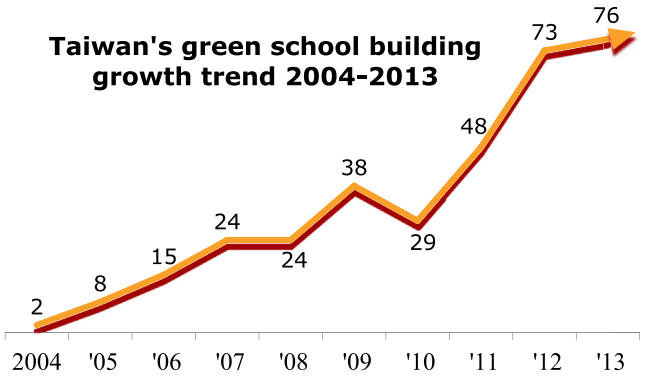

Fig. 1. Growing numbers of school buildings certified as green buildings during 2004–2013.

fast, from a few model buildings to a large-scale mainstream focus. The green building certification system in Taiwan, abbreviated as the EEWH system, comprises four major categories of building evaluation [11]: ecology, energy saving, waste reduction, and health. The EEWH system was expanded in 2004 to cover nine major indicators of building performance under the aforementioned categories, namely, biodiversity, greenery, water-soil content, energy savings, CO_2 emissions reduction, construction waste reduction, indoor environment quality, water resources, and garbage/sewage improvement. The EEWH certifies green buildings into five distinct levels: certified, bronze, silver, gold, and diamond.

In Taiwan, primary and junior schools usually do not have mechanical air conditioning apparatus in the past for the reason of energy saving. Natural ventilation is one of the viable options in alleviating summer overheating problem without the use of energy. A well designed building envelope with adequate microclimatic site planning can help facilitating cross ventilation and reducing interior heat gain, resulting in improving indoor thermal conditions of a naturally ventilated classroom. Paul and Taylor [12] compared a naturally ventilated green campus building with traditional one and confirmed that thermal comfort influences overall satisfaction with the workplace environment. Due to climate change, summer air temperatures are projected to rise in the near future, so naturally-ventilated classrooms in hot and humid climate regions may become severely overheated during the warmer months. In the past two decades, increasing amounts of attention have been focused on the issue of students' thermal comfort. Numerous significant studies have focused on this issue in hot and humid regions, such as Kwok [13] for Hawaii, Araujo and Araujo [14] for Brazil, Wong and Khoo [15] for Singapore, Ahmad and Ibrahim [16] for Malaysia, Hwang et al. [17] for Taiwan, and Zhang et al. [18] for the subtropical region of China. Obviously, it is possible to resolve the summer overheating problem by simply installing air-conditioning systems to maintain indoor thermal comfort. In the past decade, as the economy has grown, this approach has become the prevailing strategy for dealing with summer overheating in the classroom. However, this strategy conflicts with the goal of reducing the greenhouse gas emissions of buildings and is counter to the essence of sustainability. Even worse is that such a strategy will eventually lead to perceptions of air-conditioned environments as the norm, and plans to implement passive building design principles in many school architectural design practices may disappear completely.

Unlike air-conditioned buildings, where occupants' satisfaction depends simply on a single indoor environment indicator [19], naturally-ventilated buildings in the EEWH system are evaluated according to multiple indicators involving aspects of micro-climate, building envelope, and the occupants themselves. As an architect is managed to design a naturally ventilated building in complying with high certificated green building via EEWH system, he would prior consider the passive design strategies, by which would also lead to better indoor thermal environment. The indoor thermal condition, about which physical environments of a free floating space is majorly concerned, is deemed as a combination/synthesis outcome of these passive design effort. In order to describe how Taiwan's EEWH system is implemented to regulate and achieve indoor thermal comfort in practice, a Diamond-certified green building school was studied. This paper details the various design strategies implemented in the building to earn specific credits related to indoor thermal comfort improvement in achieving better thermal conditions in its naturally-ventilated classrooms. The purpose of this research is to evaluate the effectiveness of Taiwan's EEWH system in ensuring thermal comfort in naturally-ventilated classrooms.

2. Design concept and climatic characteristics

The study subject is a naturally-ventilated elementary school located in Taichung, central Taiwan. The school underwent a thorough renovation project from 2007 to 2011 to make its school campus and buildings sustainable. In the planning phase of the project, the planning team, led by the school principal and the architect, aimed to create a campus that would be regarded as a model example of sustainable design and practices, not only for its students and faculty, but also for communities both local and island-wide. As such, passive design techniques and thinking dominated the whole design process. The project team adopted Taiwan's green building certification and rating system as guidelines and criteria, which led to the success of this sustainable school. It is the highest-rated Diamond-certified green school in central Taiwan, according to the Architecture and Building Research Institute, Ministry of Interior, Taiwan (see Fig. 2). The school meets standards for eco-environment, energy and water use, indoor environment quality, and other significant factors. Consistent with the purpose of this study, only strategies implemented in the school aiming to minimize the potential for overheating during warm periods are mentioned and discussed in section 3.

Since the outdoor climate affects the amount of heat flux transferring into buildings, the indoor thermal condition of a building with natural ventilation is closely related to the outdoor climate. Without the aid of a mechanical cooling system, the indoor thermal condition of a free-running building is mainly determined or regulated by its

Fig. 2. The green building designation for the case study.