Topic A9: Indoor air acoustics and lighting

INDOOR ENVIRONMENTAL QUALITY IN GREEN BUILDINGS UNDER ENERGY-EFFICIENT POWER MANAGEMENT

Huey-Yan LIAO[1], Ruey-Lung HWANG[2,*], Wen-Mei SHIH[2], and Chen-Peng CHEN[3]

[1]Architecture and Building Research Institute, Ministry of the Interior, 13F, No. 200, Sec. 3, Bei-Sin Road, Sindian District, New Taipei City 23143, Taiwan
[2]Department of Architecture, National United University, No. 1 Lien-Da, Kung-Ching Li, Miaoli 36003, Taiwan
[3]Department of Occupational Safety and Health, China Medical University, No. 91 Hsueh-Shih Road, Taichung 40402, Taiwan

[*]Corresponding email: rueylung@nuu.edu.tw

Keywords: EnergyPlus, model simulation, air-conditioning, lighting, occupant satisfaction

INTRODUCTION

The green building movement traditionally focuses on resolving the increasing demand of energy use, and significant effort has been directed at developing strategies for management of energy consumption by the air-conditioning (AC) and lighting in the buildings located in the urban areas. As people nowadays spend a majority of their working hours inside a building, attending to their requirements for the indoor environmental quality (IEQ) has become an emerging issue of importance. Balancing the energy-saving performance of the green building with a properly maintained IEQ is essential to the promotion of a healthy working environment of optimal productivity. In Taiwan, the system of accreditation for the green building, the EEWH, comprises nine indicators of building performance (ABRI, 2009). Among these indicators, the energy saving and water resource were two mandatory criteria to be evaluated in the accreditation, whereas the other seven were optional. To be certified by the EEWH, a building in Taiwan must meet the two mandatory criteria and at least two other optional criteria selected in accordance with the characteristics of the building.

By means of model simulation using the program EnergyPlus, this study compared the expenditures from energy use and from loss of productivity owing to poor IEQ in the green office buildings accredited by the EEWH, and provided insights on how to keep a balance between the energy conservation and IEQ preservation in the green building movement.

METHODOLOGIES

Twenty office buildings accredited by the EEWH were investigated. Seven of them were certified by the IEQ-related criteria while the others were not. The workers' productivity in an office is influenced by the IEQ, and the financial burden resulting from loss in productivity due to poor IEQ may outweigh the gain from energy saving. In this study, the model developed by Jin et al. (2012) was adopted to transform the benefits from proper IEQ in the office buildings into financial gain:

$$\varphi_1 = 1 - PPD \quad (1)$$

$$\varphi_2 = 1 - \frac{1}{2}\left[\frac{1}{1+\exp(3.118-0.00215\,\xi_2)} - \frac{1}{1+\exp(3.230-0.00117\,\xi_2)}\right]; (500 \le \xi_2 \le 1800) \quad (2)$$

$$\varphi_3 = 1 - \frac{1}{1+\exp(-1.017+0.00558\,\xi_3)}; (200 \le \xi_3 \le 1600) \quad (3)$$

$$IES = 1 - \frac{1}{1+\exp(-15.02+6.09\,\varphi_1+4.88\,\varphi_2+4.74\,\varphi_3)} \quad (4)$$

$$IEA = 0.95\exp\{-0.0312\exp[1.7568\,(1-IES)]\} \quad (5)$$

$$SP = 15.097 \times IES + 75.466 (-1 \le IES \le 1) \quad (6)$$

where ξ_2 and ξ_3 in Eqs. (2) and (3), respectively, denoted the CO_2 concentration and the illuminance at working plane and φ_1, φ_2, and φ_3 in Eqs. (1) to (4) the acceptance variables of thermal comfort, air quality and light level. The *PPD* in Eq. (1) was the percentage of predicted dissatisfied on the thermal environment; the *IES* in Eqs (4) to (6) was the level of satisfaction on a scale of −1 to 1 toward the indoor environment. The *IEA* in Eq. (5) represented the predicted IEQ acceptance and the *SP* in Eq. (6) the self-assessed productivity.

The IEQ cost due to loss of the occupants' productivity (C_{IEQ}) was then calculated as:

$$C_{IEQ} = \sum_{h=0}^{h=8760}\left(\frac{Maximum\ occupant\ productivity}{occupant\ productivity\ in\ current\ design\ at\ hour\ h} - 1\right) \times S \times N_h \times w_h \quad (7)$$

where *h* was the number of hours in a year, *S* the hourly wage of the employee, N_h the number of occupants, and w_h the weight of the occupancy during the hour *h*. To calculate C_{IEQ}, the environmental parameters required as model input, including the air temperature, humidity, air speed, mean radiant temperature, ξ_2 and ξ_3, and the magnitude of AC and lighting usage were generated using the EnergyPlus.

RESULTS AND DISCUSSION

Figure 1 shows the mean *IEA* in the investigated office buildings from April 1 to October 31, 2013, a period when the AC was operated during the work hours. Of the evaluated cases, 16 had a yearly mean *IEA* above 90%. All of the four buildings with a mean *IEA* below 90% were not certified by the IEQ-relevant criteria in their initial EEWH review, with three of them receiving a low rank in illumination in the modeling and the fourth in fresh air ventilation. However, the average *IEA* for the seven IEQ criteria-certified buildings was 92.4%, only 0.7% higher than its counterpart for the buildings not certified by the IEQ criteria.

Figure 2 shows the ratio of C_{IEQ} to the cost by energy use (C_{ED}) in the investigated buildings. In most cases, a balance was maintained between the C_{IEQ} and the C_{ED}. However, insufficient lighting occurred in three cases and resulted in an increase of C_{IEQ} to a level 1.5-3.0 fold of the respective C_{ED}. In Case 18, the synergistic effect from insufficient lighting and fresh air ventilation significantly elevated the C_{IEQ} to a level of about 8 folds of the C_{ED}.

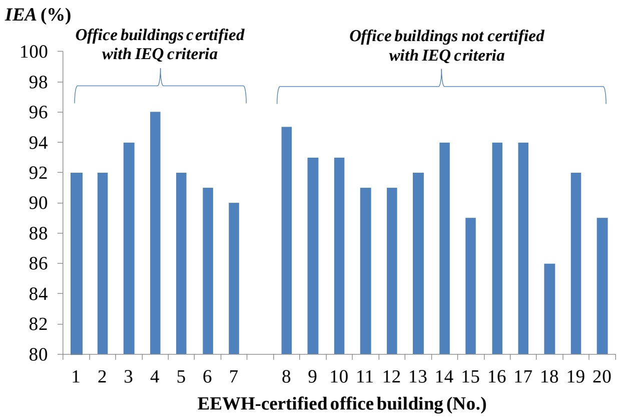

Figure 1. Predicted yearly average for acceptance of indoor environmental quality (IEQ) in the office (*IEA*) among buildings certified by Taiwan's green building accreditation system (EEWH) and investigated in this study.

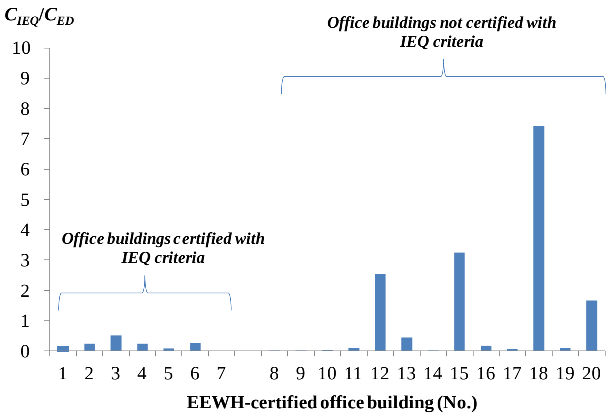

Figure 2. Ratio of IEQ cost due to loss of the occupants' productivity (C_{IEQ}) to energy use cost (C_{ED}) among buildings certified by Taiwan's green building accreditation system (EEWH) and investigated in this study.

ACKNOWLEDGEMENT

The funding to this study was provided by the Architecture and Building Research Institute, Ministry of the Interior, Taiwan, under the project number 10263D0003.

REFERENCES

ABRI (2009) EEWH Green Building Evaluation System of Taiwan, Architecture and Building Research Institute, Ministry of the Interior, Taipei, Taiwan.

Jin Q, Overend M, Thompson P (2012) Towards productivity indicators for performance-based façade design in commercial buildings. *Build Environ*, **57**, 271-281.