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Achieving energy and cost savings through simple daylighting control in tropical historic buildings

Syahrul Nizam Kamaruzzaman[a,*], Rodger Edwards[b], Emma Marinie Ahmad Zawawi[c], Adi Irfan Che-Ani[d]

[a] Department of Building Surveying, Faculty of the Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, PO Box 88, Manchester M60 1QD, UK
[c] Department of Construction Management, Faculty of Architecture, Planning & Surveying, University Technology MARA, 40450 Shah Alam, Malaysia
[d] Department of Architecture, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), UKM Bangi, 43600 Selangor, Malaysia

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ABSTRACT

Electricity is an important element used to run plant, lighting and other equipment in buildings. An appropriate well-designed lighting system is required for energy saving since the lighting consumption is dependent on the activities of the occupants of the buildings. Lighting consumption in a building can be affected by the building's purpose, the use of daylight, illumination levels and hours of usage by the occupants. The present study aims at accentuating the use of computational modeling techniques towards significantly improving the effectiveness of daylighting control on energy and cost savings for historic office buildings. For this purpose, lighting performance of the Klang District Historic Office building in Malaysia was investigated through a simple daylighting control. The present study was carried out to investigate the lighting performance in a historic office building which is known as the Klang District Historic Office. Lighting performance is assessed using a simulation modeling that includes artificial lighting, daylighting, sun position, weather statistics, sky type, shading and a 3D Model. The study found that almost all cellular offices are adequately served by daylighting but that open plan offices needs some artificial lighting to supplement inadequate daylighting. The results are presented and the approaches for energy saving discussed.

1. Introduction

Energy consumption varies between different industries, buildings and sites. It is influenced by the duration and nature of the building's use. For instance, in countries with a temperate climate, the energy consumed in buildings is mainly related to cooling, heating and lighting. Energy is used to heat the building during winter, cool it during summer, and provide hot water, as well as for lighting and the operation of equipment.

The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased reaching figures of 20% to 40% in developed countries [3,5,19,22,27]. In tropical countries such as Malaysia, the major energy consumption in buildings is for air-conditioning and lighting which should be properly managed to avoid high costs. Lighting consumption depends on the purpose of the building, the use of daylight, illumination levels for certain areas and the hours of usage. A well-designed lighting system in buildings would not only significantly diminish long-term energy use, but it would also reduce long-term costs.

The study of lighting performance in buildings tends to concentrate on aspects relating to energy consumption, and involves building design including that of fenestrations and lighting levels, whether daylighting and artificial lighting [17,30]. Several design tools are required to address both issues: physical scale models, simplified design tools (such as charts, tables and protractors), computer simulation and other computer programs.

This paper is intended to develop an accurate computer model of historic office buildings in Malaysia with regard to artificial lighting and daylighting, to ensure that the model is accessible and adaptable for future users, to investigate the lighting performance within the historic office buildings using simulation models, to concentrate on the energy saving through daylighting control, and to predict the long-term cost savings that could be achieved by implementing simple daylighting control.

* Corresponding author. Tel.: +60 379676833; fax: +60 379675713.
E-mail address: syahrulnizam2013@yahoo.com (S.N. Kamaruzzaman).

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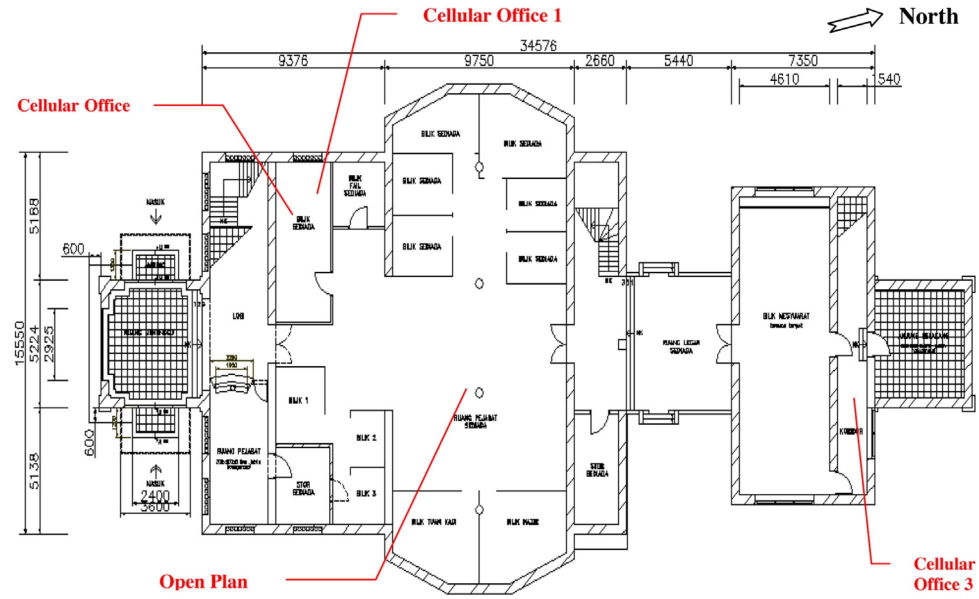

Fig. 1. Ground floor plan of the office building.

2. Review of literature

2.1. Lighting energy efficiency

Lighting is responsible for the most significant energy consumption and is a major component of the services cost. Nevertheless, inefficient use of electricity for lighting is still considered a worldwide issue. Various studies have been conducted to find potential approaches to improving the energy efficiency of lighting systems throughout the world, and it has been found that the implementation of lighting technology can reduce the amount of energy used in commercial and industrial buildings [4,25,28,24,2].

Developments in lighting technology have created opportunities for dramatic energy savings, in some cases up to 50% with little or no efficiency loss [11]. With significant savings on energy, the running costs of a building can be reduced. Significant development of the technologies over recent decades can reduce lighting costs by 30% to 60%, not only enhancing lighting quality but simultaneously reducing the environmental impact [9]. The energy consumed by a lighting installation depends on the power consumption of the luminaires and the length of time for which they are switched on [7]. The potential energy and cost savings in existing buildings, for instance, can be considered as much as 30% to 50%.

2.2. Interior illumination

Lighting is considered a core human need, and its sources are daylight or lamps. Lighting is vital for human activities and can affect awareness, comfort and emotional state. In short, the lighting performance is related to human psychology [8,10,16,29,32,33].

A building's energy saving is assessed by integrating daylight in the architectural and building designs [21,18,12]. Daylighting can result in energy saving by reducing the expenditure on electric lighting and reducing the electrical demand during peak seasons. Moreover, daylighting is able to reduce energy consumption for cooling and is suitable for smaller air-conditioned spaces. Operating costs can therefore be reduced by the efficient use of energy, thus providing a positive impact on the environment.

3. Method

The study of daylighting performance of buildings can be achieved by experimental measurements and computer modeling. As the experimental measurements are mainly costly and time-consuming, computer modeling tools have recently attracted great attention for their simplicity and reliability. Computational simulation is the best method for this study because it can predict the lighting performance in a building. Actual measurement of the lighting performance of the building cannot be quantified. Computer-based building energy simulations have proven a useful tool in analysing lighting schemes. Computer-based energy simulations of buildings have been proven as a useful tool in analysing lighting schemes [15,6,26].

For this study, a computer-based simulation tool called "Virtual Environment" (VE) by the company "Integrated Environmental Solutions" (IES) was used. The principle for using this modeling software is on the basis of the following criteria.

The IES-Virtual Environment software can be used to assess the lighting performance of a building either retrospectively or during the design stages of a construction project. Moreover, it does not require the user to have professional knowledge of computer programming or of the mathematics and equations that govern building physics, as all the interaction between the user and the software is done through a graphical user interface. The program has been used throughout the world [31] and thus demonstrates an enormous capability to simulate various lighting design features and daylighting implications.

The Floor plan for the ground and first floors is shown in Figs. 1 and 2. Through the IES simulation software, Light-Pro was used to input the existing artificial lighting installations in the building. Luminaires and lighting fixtures were selected from the available database in Light-Pro. Investigation of the illuminance level of the office area was then carried out using Flucs Pro for artificial lighting.

As for daylighting, the IES module Flucs Pro was used to analyse the likely daylighting levels within the office area. The daylight availability and average daylight factors were calculated for the working plane based on the standard CIE overcast sky. The standard overcast sky provides the worst daylighting condition; however the