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A study investigating the characteristics and strategies in office building's design that ensure the success of the building's lighting performance and consequent occupant satisfaction

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Abstract

This research aims to investigate the key characteristics in the office building design that ensures the success of the building's lighting performance and consequently, the occupants' satisfaction. A secondary research is undertaken across the fields of energy consumption, sustainability, and history and physics of light. The study also lists a number of benefits, making daylight so desired. A real case study is being investigated through a field survey based on questionnaires and spot measurement of daylight levels. A computer based analyse using Radiance in Integrated Environmental Solution (IES) software, is then undertaken to further define glare, contrast and uniformity problems. However, this paper presents the investigations of daylight factor distribution based on different window's configurations. It is concluded that a good lighting design not only has a beneficial environmental and financial impact but also improve human satisfaction and performance at work.

Keywords: Daylight; Office lighting; Occupant satisfaction; Glare; Illuminance

Introduction

Current directions in architecture towards green and sustainable buildings incorporate not only the sustainable and passive design but also a healthy environment for occupants (Hansen, 2006). According to the CIBSE Journal (2011), lighting in office buildings uses 33% of the total electricity consumption, which makes it a research area of significant importance for meeting the UK government's 2050 target. Reducing the energy consumption for lighting can provide savings in electrical energy, leading to savings in carbon emissions, reduction in greenhouse gases and global warming. Office buildings are used mostly during daylight hours. However, electric lights are widely used during the day. Although artificial light provides sufficient levels of illumination for visual tasks, it cannot provide the physiological and psychological benefits of daylight and it is being increasingly recognized that there are important workplace health and productivity issues for artificially lit buildings (Boyce et al, 2003). According to Bean (2004), lighting in

office buildings is of great importance to the economy because it affects both the performance and the well-being of a large section of the working population. Along with the importance of daylighting related to energy efficiency, studies have demonstrated the nonenergy related benefits of daylighting because the benefits from daylighting extend beyond architecture and energy. This paper summarizes the benefits of daylighting on energy efficiency and building occupants. The aim is to establish the key characteristics and strategies in the office building design that ensures the success of the building's lighting performance and consequently, the occupants' satisfaction. The objective is to understand the importance of the subject and to consider strategies for future designs that provide not only the energy efficiency, but also occupants' satisfaction. However, in this paper it is investigated only the analysis of daylight factor's distribution and the way it affect the building users. The way daylight is distributed in the room and interreflected, is founded to be more important to the building occupants than the amount of daylight entering the space and its quality is evaluated with the absence of the glare and contrast, good uniformity, effective shading and personal and quick controls. However, it is challenging to provide a good distribution of the daylight within the space because the daylight is always variable. However, a purely energy efficient approach to workplace lighting, which pays little or no attention to user comfort, could turn out to be both ugly and ineffective.

Methodology

A qualitative study of the literature according to benefits of natural light and its history in architecture is undertaken. A survey of Abercrombie building (part of Headington Campus at Oxford Brookes University) was conducted, evaluating technical elements with user's subjective point of views. Qualitative and quantitative questions were devised and tested in a pilot study with the permanent staff. From 66 employee of the new extension, only 22 of them answered the questionnaires. For this reason, analysis will be more qualitative than quantitative as it cannot provide a statistical report. Furthermore, simulations of current daylight performance are modeled in IES, Integrated Environmental Solutions: Virtual Environment using RadianceIES tool. In order to compile guidance for future design projects strategies are investigated and evaluated using simulations in Radiance

Importance of the research

Daylighting become one of the main points of possible energy reduction and cost savings. Electric lighting currently consumes 19% of current total global electricity production, producing 1.9Gt of carbon emissions every year (IEA, 2006). According to McNicholl and Lewis, (1994), artificial lighting counts as much as 50% of electricity consumption in office building. Therefore, studies of offices undertaken by BRE (Crisp et al, 1988) have defined that a positive use of daylight can obtain potential savings from 20% to 40% in energy. However, there are even larger the benefits of daylighting that are noenergy related. The introduction of daylight has been a fundamental design element of the wondrous interiors since in Ancient times to modern Architecture. Moreover, throughout history, daylight in buildings has impacted human behavior and human factors and has

reduced the stress and discomfort of users (IEA, 2000), along with directly influencing the design of buildings including the layout of space. A lack of natural light can lead to disorders of the autonomic nervous system, loss of energy, fatigue, a tendency towards self-insulation and metabolic disorders Köster (2004). Moreover, the view through the windows in offices has more psychological than physical benefits of which the occupants themselves were aware (Tabet and Shelley, 1993). However, daylight and sunlight delivered through glass can have adverse effects on people who are sensitive to ultra-violet radiation (Boyce and Raynman, 2009) and this human desire for the nature and light is not cost free (Phillip, 2004). In order to provide daylight inside the building the designer has to deal with other factors such as sunshading, excessive energy required to control heat gains and heat losses. However daylighting is undoubtedly desired by majority of people and in order to achieve success in daylighting installation is essential how it is done.

Daylight factor analysis

Only a small proportion of staff interviewed responded not to have sunlight on their worktop at any time, while all the others experienced difficulties to work with the presence of the sunlight present on the worktop. The staff experienced direct glare (sun in user's immediate field of vision) and background glare (brightness contrast between monitor and monitor background), affected by the office's layout and windows design (See Figure 1). Form the questionnaires, the building users complained mostly about window's configuration, no uniformity of the daylighting distribution within the space, and high contrast between bright windows and dark grey walls.

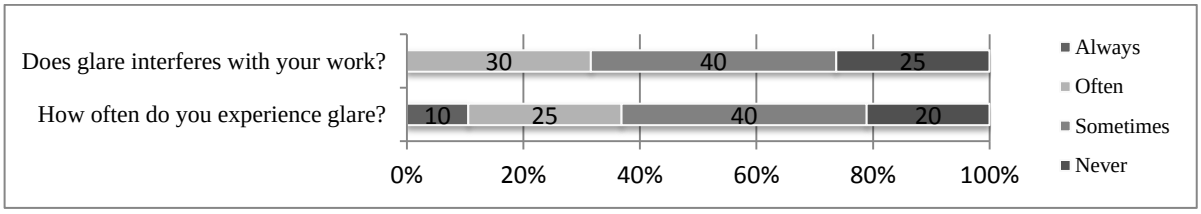

Figure 1: Respondents experiencing glare

In order to analysis the daylight factor distribution in the room, simulations of the current scenario are provided using IES, Integrated Environmental Solutions. Using the results, a south-north section of the office in the second floor (15m x 7m) is then investigated in Figure 2. It has a ratio of the glazed area to the floor area of 20%, taking into considerate the windows facing the atrium. It is clearly noticed that the person working in the desk near the window is under a very high daylight factor of over 20%, which means that the glare is inevitable. In contrary, the next desk is under the recommended daylight factor's range of 2%-5% by British Standards (2008). This fact explains the results of the questionnaires, where some of them always had to work under glare conditions. The uniform ratio that expresses the ratio of the level of daylight at the back of the room to that at the front of the room should not be less than 0.1. In this case, it is 0.03 and such uniformity will perceive by occupants as gloomy and may lead to the switch on of electric lighting (Table 1).

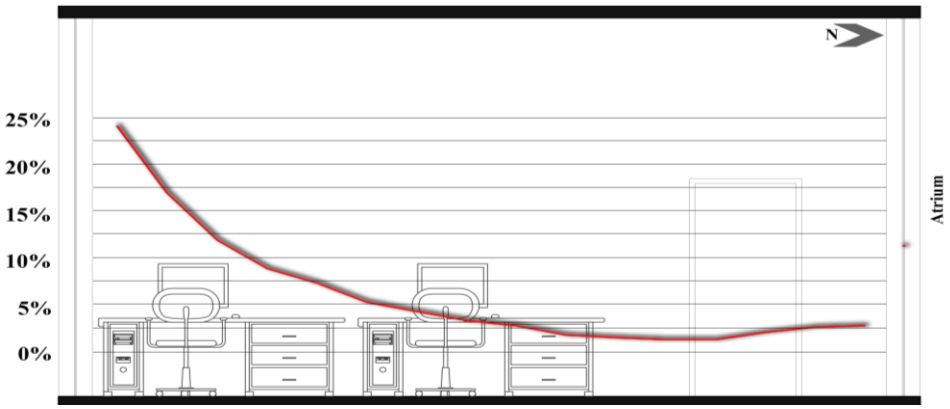

Figure 2: Daylight factors on the work plane of the open plan office. Section A-A.

Table 1: Daylight distribution in the office

Window position	Min DF	Max DF	Uniformity ratio	Mean
Full room height	0.8	24	0.03	5.9

However, glare is not the only issue with the workplaces next to the windows. Daylight distribution is complained to be non-uniform. To investigate this, an east-west section (B-B) of the same office running 1m away from the south façade is illustrated in Figure 3. It is noticed a variation of daylight factor from 2% to 17%. Only the desks in the middle of the room experience a daylight factor within the recommended range of 2%-5%.

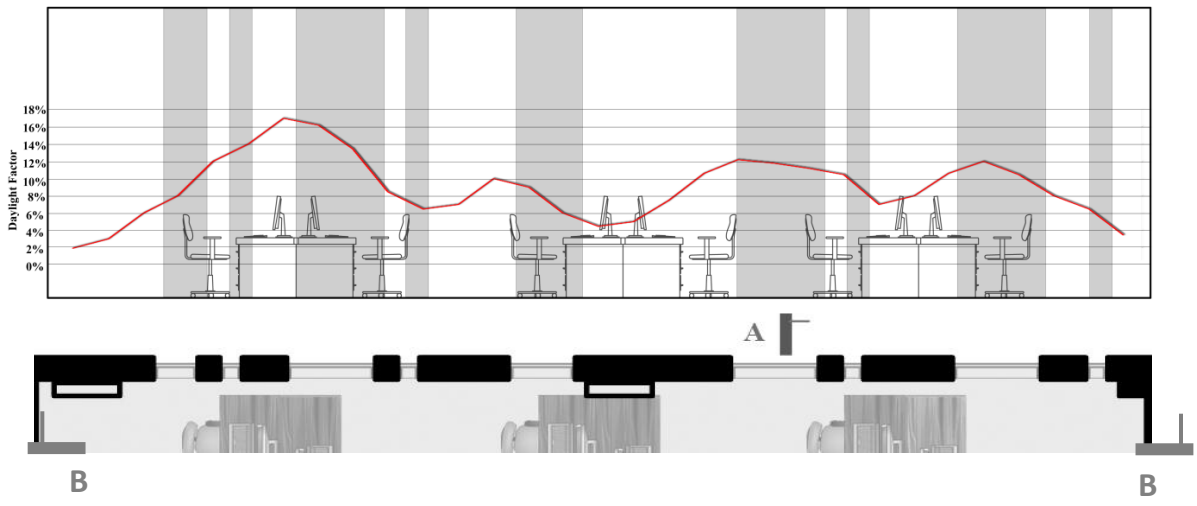

Figure 3: Daylight factors on the work plane of the open plan office in second floor

In order to improve the daylight distribution, different window's shape and positions are investigated (See Figure 4). It is founded that the higher the window position in the wall, the better the daylight distribution is deep in the room. The wide and narrow window

limits the adequate daylight penetration after 3m, while the higher the window, the deepest daylight penetration.

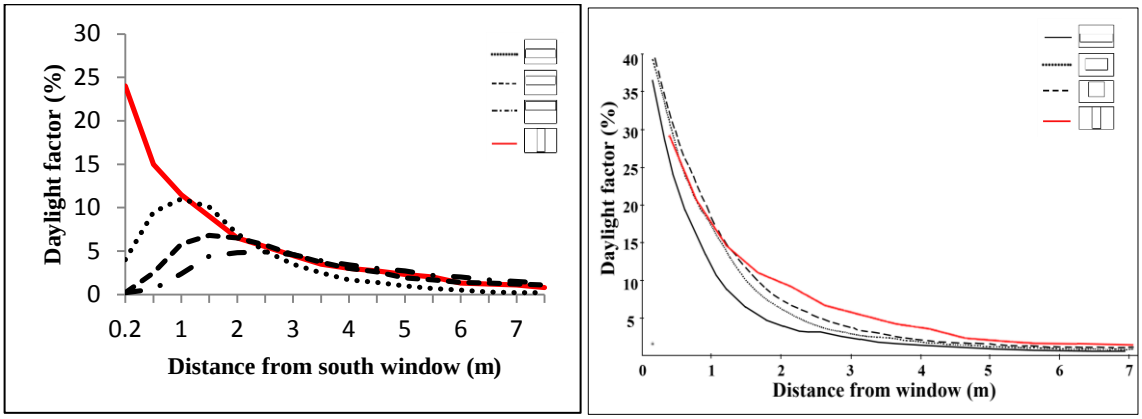

Figure 4: Influence of different windows position and shapes

The full room height windows designed in Abercrombie building not only produce very high daylight factors next to the window, but they also create different zones with different levels of daylight (See Figure 5). Moreover, the window proportion as the more exaggerated the horizontal or vertical proportions, the more restricted will be the position of occupants who can experience the view.

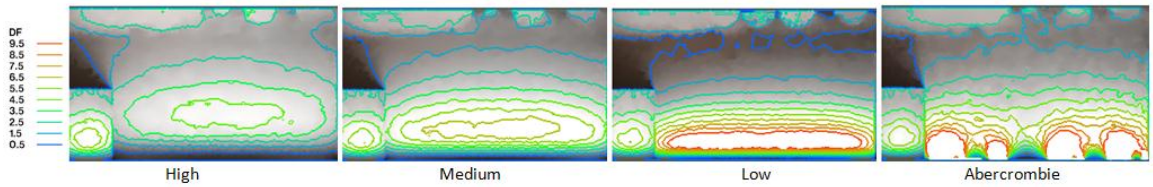

Figure 5: Daylight distribution for different window position

Discussion and conclusions

From this research it is concluded that daylight is very beneficial in office buildings because it both positively affect users' health and productivity by enhancing working conditions and can reduce the energy consumption. It is founded that excessive glare, bad distribution of light in the space and high contrast are the most common issues in the office buildings that affect most the occupant satisfaction. Windows' configuration was found to be very important in the amount of daylight that enters the room and its distribution within the space. The higher the window was placed in the wall and the more vertical proportion the window has, the deeper the daylight penetrates in the space. However, this does not provide a suitable view and provides a low uniformity. It is founded that although the average daylight factor is within the recommended range by British Standards of 2%-5%, the uniformity ratio could be very low. This leads to the use of electric lighting in order to improve the light uniformity and prevent contrast, increasing the energy consumption. Moreover, vertical strip windows arranged in an ordinary order created produced a low uniformity which was highly complained from the occupants. They also did not provide the same working conditions for all the employees. Therefore, designing high windows and ceilings will provide daylight deeper in the room.

The materials used as finishes of surfaces should be of high reflectance to benefit from the first reflection of light and other interreflections and in order to provide low contrast within the space, alternative components can be used in order to redirect light towards the ceiling such as external louvers, venetian blinds, blind systems that employs absorptive and reflective specular transmitting films, etc. Moreover, occupants need to control their environment. They must have the possibility to control the direct sunlight that enters the space and they should have additional light source in case they need supplementary light.

To conclude, adequate daylight, no glare and a good uniformity and contrast increase the users' satisfaction. Moreover, good shading, appropriate lighting and controls increase not only the productivity and health, but also have a direct effect on energy efficiency through minimizing electric consumption for lighting, cooling and heating.

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