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Energy Conservation in Office Building by Utilization of Daylighting

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Abstract

The purpose of this study was to examine the possibility of daylight utilization by means of windows opening and closing in different time periods of the day. The illumination level and temperature were recorded at intervals of one hour from morning till evening by opening and closing of the windows. The results revealed that the opening of windows and turning off the electrical appliances results in rapid increase of illuminance level and temperature in the offices as compared to laboratories and classrooms due to their size. It was found that the opening of all windows for six hours per day can save 4956.0 kWh energy with cost saving of Rs. 74339.0 and reduces 0.089 kg of CH_4, 0.015 kg of N_2O and 33,00.0 kg of CO_2 per year.

Keywords: Electrical Load, Daylighting, Energy utilization, Energy Conservation, Gases emission reduction

INTRODUCTION

Daylighting is a controlled admission of sun light into a building to provide enough brightness without undesirable side effects. It not only helps to save energy but also to reduce the use of electric lighting [1]. Since, the electric lighting shares 35% to 50% of the total electrical energy consumption in the commercial buildings [2]. It is stated that optimal daylight design can help to save the one-third of that cost [3]. Therefore, it is necessary to minimize the consumption of electric lighting in the buildings. The exploitation of daylight reduces the greenhouse gas emissions as well as increases the performance and competency of occupants by providing a positive environment inside the building [4]. The proper utilization of daylighting can be made by integrating many technologies and design philosophies, like, proper configuration of buildings and extension of buildings along an east-west axis [5]. Moreover, locating important visual tasks near the building's perimeter and conveying the light in high, admitting daylight from more than one side of an opening, controlling direct sunlight, using light-colored interior surfaces, and placing workstations and computer screens upright position to windows can also reduce the electric lighting cost [6]. Many researchers investigated different possibilities and applied different approaches to enhance the daylighting systems in buildings. Al-Ashwal and Budaiwi [7] examined the energy performance of office buildings by integrating daylighting with artificial lighting systems. Ho et al. [8] investigated the feasibility of fitting windows with sun-shadings in order to minimize the lighting power costs in daylight-illuminated classrooms. It was concluded that the daylight devices not only improve the illuminance conditions within the classroom but also reduces the lighting power cost by 71.5%. Sharp et al. [9] evaluated the design and implementation of various daylighting systems. Three primary designs namely skylights, solar concentrators, and tubular daylighting devices were discussed and found that each design has unique uses and limitations. Vázquez-Moliní et al. [10] focused on a sunlight collection device for solar lighting systems aimed at non-residential buildings. Sabry et al. [11] defined solar screen designs that achieve visual comfort and at the same time minimum energy consumption in residential desert settings. Liu et al. [12] proposed a three-step design procedure to fully utilize natural ventilation with a performance simulation of daylighting. The building spacing and orientation was optimized through outdoor velocity and pressure field simulation with computational fluid dynamics method. It was found that the energy saving potential of natural ventilation could be up to 40% in terms of electricity consumption. Yu et al. [13] carried out a quantitative analysis of annual energy saving potential from daylighting in a real building using various methods. The annual energy saving potential in from daylighting was estimated to be 40 to 46%. Jakhrani et al. [14,15] reported that power reliability and cost are the two influential factors for solar system selection and installation. Higher the power reliability higher will be the cost and vice versa.

It was revealed from the literature review that enough energy can be saved by introducing daylighting system inside the buildings. However, most of the researchers investigated different daylighting techniques for possible utilization of daylight in new planned buildings and proposed various methods for alteration in existing buildings. However, less literature is available for already constructed buildings without any alteration. This study has focused on the analysis of daylighting utilization without modification of existed building structure, shape and form but only by means of windows opening and closing in different time periods. The findings of this study will be helpful for possible saving of energy with little awareness of building occupiers.

METHODOLOGY

Study Area

The study was conducted in Nawabshah (26.14°N 68.23°E) City, District Shaheed Benazirabad, Sindh, Pakistan. The research for the utilization of daylighting was conducted in the building of Energy & Environment Engineering Department, Quaid-e-Awam University of Engineering, Science and Technology Nawabshah. The study area is one of the hottest places of Pakistan and locates at the elevation of 38 meters above sea level. The climate is suitable for the exploitation of solar energy to enhance natural lighting system inside the buildings.

Experimental Program

First, the detailed survey was conducted for calculation of building appliances load and energy consumption. All number of installed appliances was counted and the power ratings of each appliance were noted except the instruments used for practical purposes both at the ground floor and first floor of the building. Then, the daylighting was enhanced through the opening of windows of the building. The level of daylighting was examined in four numbers of offices, class rooms and laboratories to increase natural illumination. The number of windows were different at each location of the building. Every office at the ground floor has two windows and at first floor, three windows. Whereas, every laboratory and classroom consisted of six windows each as shown in Fig.2 There were ten numbers of energy savers in each of four laboratories. Two conditions were applied during determination of illumination level and indoor temperature. In first condition, all number of lighting appliances were switched on with various numbers of windows opened and closed. Whereas, in second condition, all numbers of windows were opened and all numbers of lighting appliances were switched off.

All selected locations of departments were surveyed and daily results on hour basis were recorded. The results were obtained during the month of May and June, 2015 in all selected laboratories, classes and offices excluding Saturday and Sunday.

The different parameters like, indoor and outdoor temperature, illumination level were examined. The temperature (indoor and outdoor) illumination level were measured using thermometer, (model KT302) and digital lux meter (model 545) respectively.. Then, the saving of electricity on daily basis in kWh was calculated by turning off the installed electric lighting appliances in the examined locations. The impact of window openings on illumination level and energy saving was explored. Finally, the environmental benefits of daylighting was analyzed by calculation of conserved quantity of CH4, N2O and CO2 gases using electricity-specific emission factors of Pakistan as shown in Table 1.

Data Analysis

The recorded data and results were arranged in tabular form on daily basis and placed in a cumulative table for calculation of total parameter values and average conditions by means of Statistical Package for Social Sciences (SPSS) software. Average values of measured parameters for four laboratories, four classes and two offices were graphically represented. The data was recorded from morning till evening. The energy savings was calculated based on daylight utilization while keeping lighting appliances switched off.

RESULTS and DISCUSSIONS

Calculation of Electrical Load

The total connected load with air conditioners and without air conditioners of the building was 85.49 kW and 36.74 kW respectively. The load of lighting appliances was only 5.89 kW which was 6.8% of the total connected load.

Analysis of Daylighting

Natural illumination level was enhanced in four laboratories and two offices on ground floor and four classes and two offices on first floor of the building. It was observed from the study that the opening of more number of windows produced more illumination inside the building. Since, the temperature was increasing, which was undesirable. Therefore, the study was conducted to make comfortable indoor environment for employees without compromising their efficiency.

Illumination and Temperature Level in Laboratories

The increase of illuminance and temperature has contradictory role on human comfort especially in hot climatic conditions. Inside the working places, the increase of illuminance has positive and increase of temperature has a negative impact on human comfort and behavior. Therefore, it requires increasing the illuminance conditions inside the working places without increasing temperature. Results revealed that, the opening of windows has effect on the illuminance and temperature by increasing the number of windows as shown in Fig 3.

In first condition, when all windows were closed, then the hourly average illuminance and temperature were 110.1 lux and 29.9°C respectively and when all numbers of windows were opened, then the illuminance and temperature values were 169.1 lux and 34.7°C respectively. When two and four numbers of windows were opened then, the values of illuminance and temperature were 144.9 lux, 156.8 lux and 32.2°C and 33.4°C respectively. In second condition, the average illuminance and temperature were 132 lux and 34.3°C respectively. It is obvious from the results that opening of all windows (second condition) have more illuminance than that of all lighting appliances and closing of all windows, however temperature also increased as shown in Fig.3. The same conditions were applied in offices and classes and the results are shown in Table 02.

Energy and Cost Saving with Utilization of Daylighting

Lighting appliances such as energy savers and tube lights were used to provide illumination inside the examined building. These appliances consumed 6.8% of total conventional electricity in the examined building. The type and number of lighting appliances was different in different sections of the building. The energy saving was calculated based on turning off lighting appliances and opening of windows to utilize the natural daylighting. If the windows are opened for two hours per day, it will save 1651.99 kWh energy with cost saving of Rs. 24779.85 per year as shown in Fig. 4. Similarly, if the windows are opened for six hours per day can save 4956.0 kWh energy with cost saving of Rs. 74339.0 per year.

Environmental Benefits of Daylighting

The application of daylighting reduces the utilization of fossil fuel combustion. The combustion of fossil fuels emits various gases like methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). The electricity-specific emission factors of these gases used for this study were given by Brander et al. [16] as given in Table 1. The emission factors were used based on saved electricity by application of daylighting. It was revealed from the study that if the windows are opened for two hours per day, it will reduce 0.029 kg (0.0639 pounds) of CH_4, 0.005 kg of N_2O and 0.011 x 105 kg of CO_2 per year as shown in Fig. 5. If the windows were opened for six hours of the day, then 0.089 kg of CH_4, 0.015 kg of N_2O and 33,00.0kg of CO_2 per year can be reduced. Consequently, it gives environmental friendly atmosphere for work.

CONCLUSIONS

The study was conducted to see the possibility of daylight utilization without modification of existing building structure, shape and form but only by means of windows opening and closing in different time periods. The load of lighting appliances was 6.8% of the total appliances load of the building. It was observed from the results that the opening of windows and closing of electrical appliances resulted in rapid increase of illuminance level as well as temperature in the offices as compared to laboratories and classrooms. The results revealed that opening of all windows for Six hours per day can save 4956.0 kWh energy with cost saving of Rs. 74339.0 per year. The utilization of daylighting by opening of windows and closing of electrical appliances reduces 0.089 kg of CH_4, 0.015 kg of N_2O and 33,00.0kg of CO_2 per year. It is concluded from the study that the human comfort at the workstations inside the building can be maintained by limiting the opening of windows up to time period when outdoor temperature is comfort.

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Table 1. Electricity-specific emission factors [16]

Emissions per kWh of electricity consumed			
Country	**kgCO_2/kWh**	**kgCH_4/kWh**	**kgN_2O/kWh**
India	1.800805423	0.00002096774	0.00002716280
Oman	1.035857493	0.00002324486	0.00000317856
Pakistan	0.615374995	0.00001798722	0.00000316016
Bangladesh	0.704746617	0.00001367462	0.00000211553

Table 2. Average illumination and temperature level of Classes and Offices

Locations	Condition	Windows Open	Illumination (Lux)	Temperature (^{0}C)
Four Class rooms	**First**	00	217.5	31.2
		02	284	32.8
		04	312.8	33.2
		06	331.8	34.6
	Second	06	237.3	34.8
Two Offices in Ground Floor	**First**	00	75	30.7
		01	300.7	32.5
		02	385.1	33.8
	Second	02	347.8	33.6
Two Offices in First Floor	**First**	00	181.9	31.2
		01	222.2	32.5
		02	244.1	33
		03	264.8	34.1
	Second	03	178.8	34.3

Figure 1. A view of Energy and Environment Department

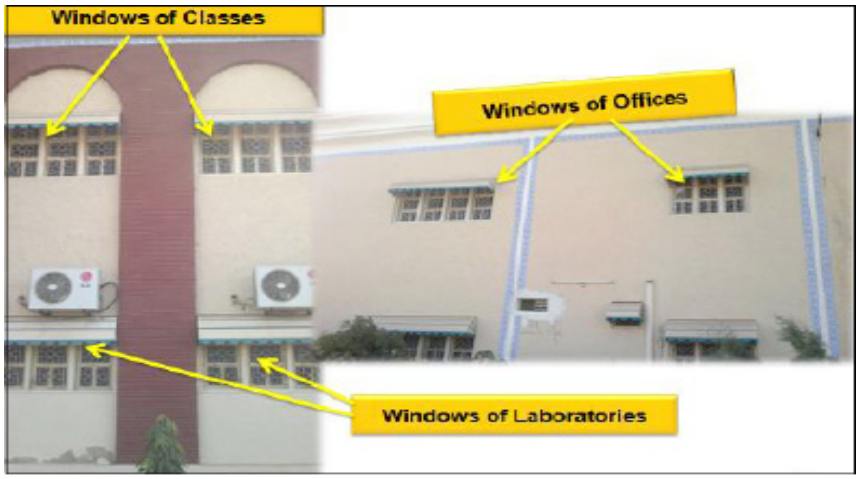

Figure 2. Location of windows in classrooms, offices and laboratories

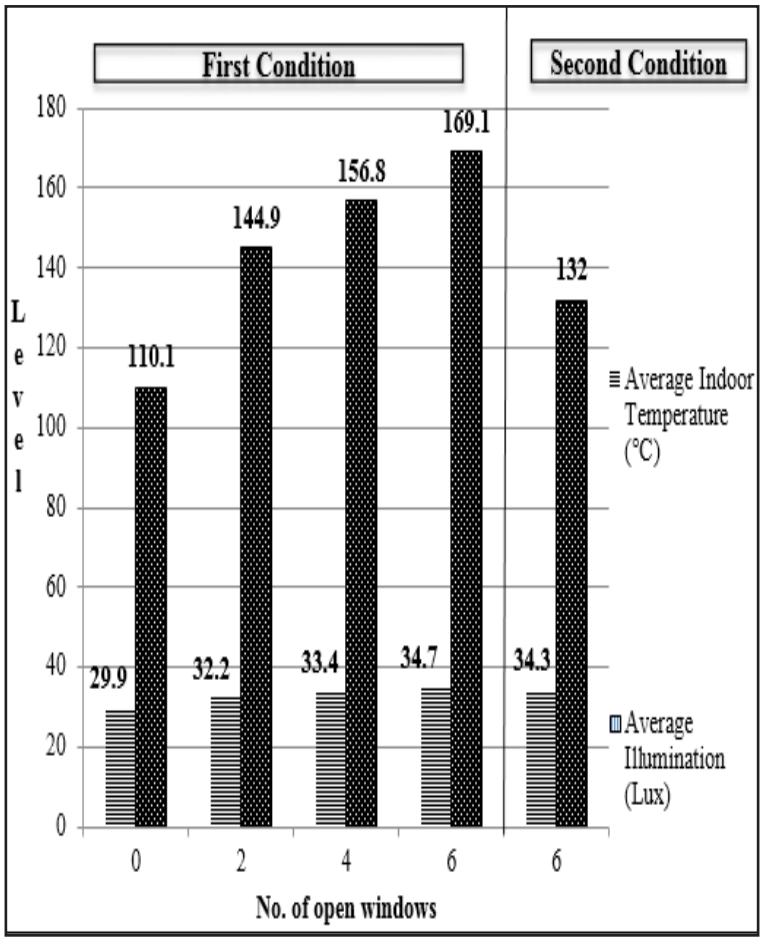

Figure 3. Influence of opening the windows on illuminance and temperature in the laboratories

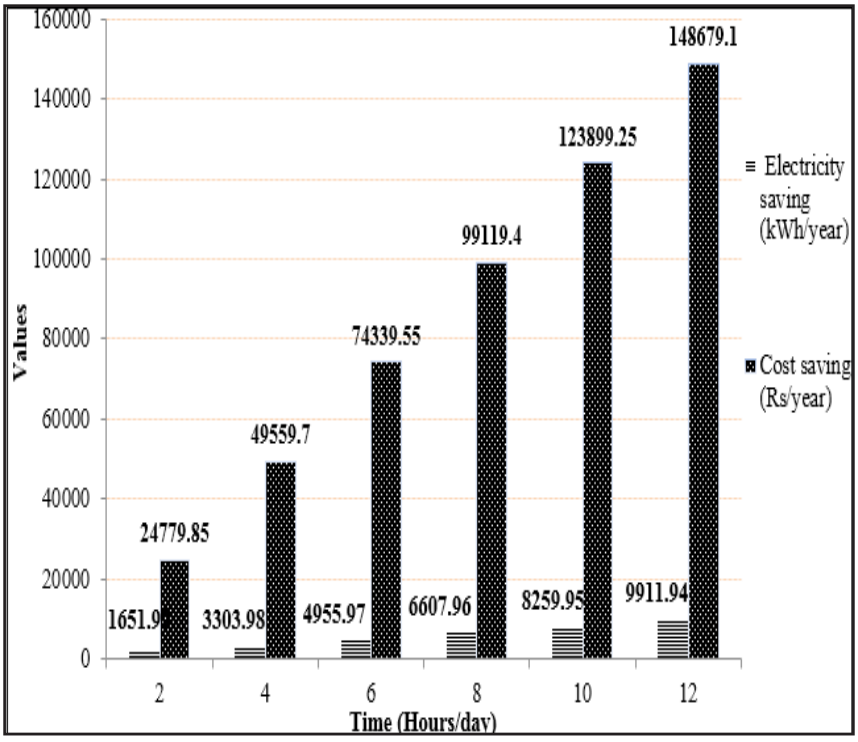

Figure 4. Influence of opening the windows on electricity and cost saving

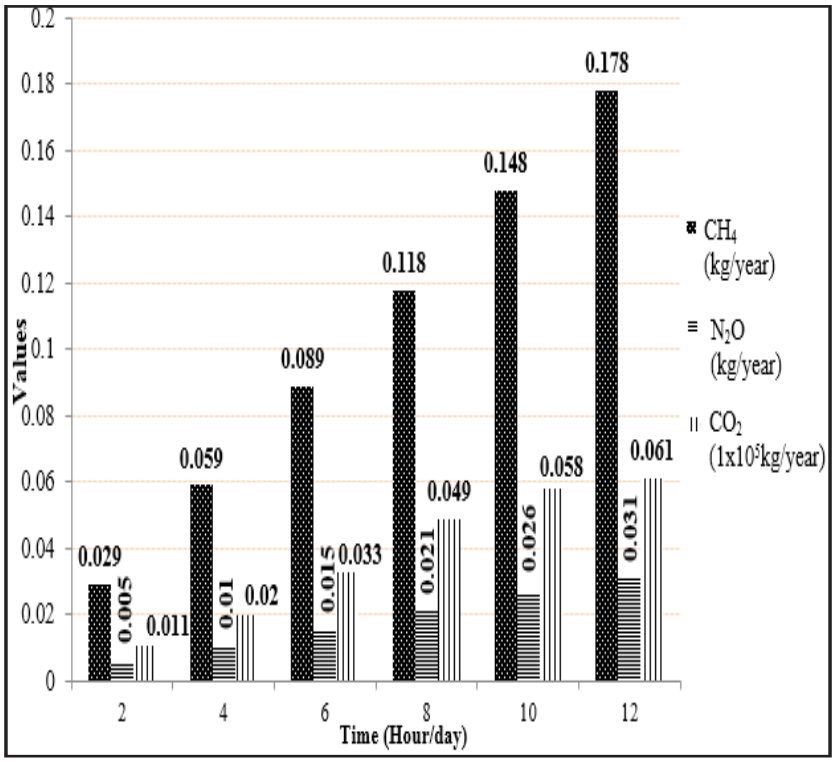

Figure 5. Influence of opening the windows on gases reduction