Performance and Energy Consumption Analysis of Artificial Lighting in a Classroom Using DIALux Simulation

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Abstract: Energy crisis is a major problem faced today. Lighting system consumes a significant amount of world energy resources. In an office building, major portion of power is consumed in lighting system. Continuous increase in energy cost also forces us to look for a possible minimisation of energy in this area. Adequate lighting is essential for the visual comfort of humans. But it needs to be efficient as well. Therefore it is very essential to analyze the lighting factors and energy consumption of the building to provide comfortable lighting environment. 3D model of a classroom in Energy Centre, MANIT Bhopal with the existing lighting installations was designed. Actual illuminance level at different points inside the class room were estimated and simulated by lighting design software DIALux evo 3. Energy consumption based calculations are also carried out using the DIALux. The advantage of using energy saving sensor in class room lighting was also proposed. The power consumptions and efficiency of existing lighting system were simulated and analyzed. Finally; it is shown that with the use of the energy saving senor, a reduction of 33% in lighting energy numeric indicator (LENI) is obtained. In addition to that, 13 % reduction in the energy cost can also be achieved.

Keywords: DIALux, Efficiency, Energy sensor, Illuminance

1. INTRODUCTION

Lighting or illumination is an essential part for every day to day purpose. Whether it is an office, educational institutions or household, lighting consumes a major portion of electric power consumption (about 20 to 50 %) in world [1, 2]. Thus it is very important that lighting in a workplace should be proper, adequate and efficient. There are several techniques to minimise energy in a building. It can be analysis of lighting quality, proper design of buildings and lighting systems, selection of proper lamp types and their fixtures, maintenance of lighting system, maximise the daylight to reduce artificial light consumption, load shedding or automation of lighting system. Artificial illumination is required to supplement daylight as daylight cannot be always available. Lighting system is categorized as Direct Lighting, Indirect Lighting and Direct/Indirect Lighting [3]. Light quality affects how well people can see to do visual tasks. Especially in a Classroom, Lighting should be very proper because visual tasks like reading and screen based work are done. Also, it is important to energy efficiency because high quality lighting will have high illumination with minimum power consumption. The objectives of the study are as follows: (i) to visualize the class lighting in a 3D model using DIALux software (ii) to simulate the illuminance and energy consumption of the classroom and (iii) to propose the use of energy sensor for energy conservation.

2. 2. METHODOLOGY

2.1. Selection of location

A classroom in Energy Centre, MANIT, Bhopal, is selected for the lighting analysis. The room is darker as compared to other rooms in the department. The orientation of the room is in such a way that it is free from natural daylight [4]. Figure 1 shows the actual classroom. In the simulation and calculations, only indirect light or artificial light is taken into account and no daylight is considered.

Figure 1: Classroom of Energy Centre, MANIT, Bhopal

2.2. Software introduction

DIALux is computer software for simulation and visualization of lighting in an environment. It is a famous lighting design tool. It helps a user to create a virtual environment [5, 6]. It can be a building, a room or even a workplace. It can simulate and analyse the performance of lighting system in that environment. The present study used parameters for conditions where there is no room for daylight. It completely simulates the artificial lighting [7].

2.3. Design of 3D model of the classroom

A 3D model of the classroom is designed with the help of DIALux evo 3. Actual room dimensions (length, breadth and height) were provided to the software. Around 10 benches in the classroom were also designed. Figure 2 and 3 shows the 2D floor plan view and 3 D top view of the classroom respectively.

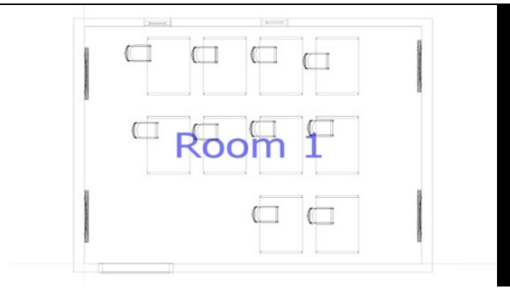

Figure 2: Floor plan View

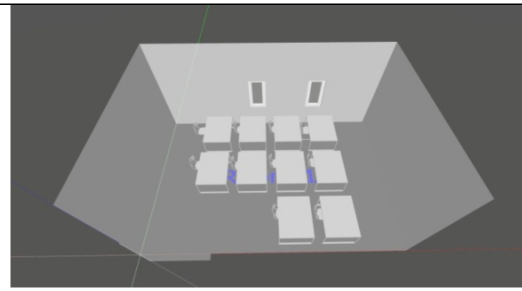

Figure 3: 3D top view

It should be noted that the door and windows are designed in the simulation model but are considered as closed. Only Indirect light is considered in the calculations. The walls and ceiling of the classroom are white painted and the floor is yellowish in colour. Thus, in the simulation, corresponding colouring for the surfaces was provided. There are four tube lights (Phillips 40 W) which are installed in the classroom at the same mounting height.

Figure 4 shows the room view after wall colouring and light fittings**.** Figure 5 shows the final room view after lights are turned on.

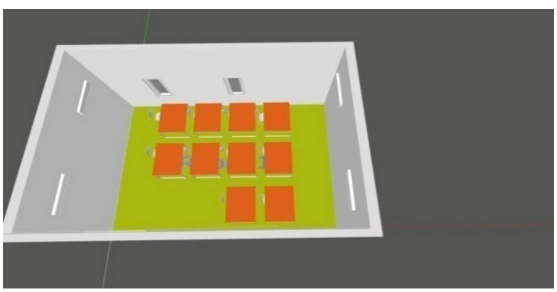

Figure 4: Room top view after wall colouring & light fittings

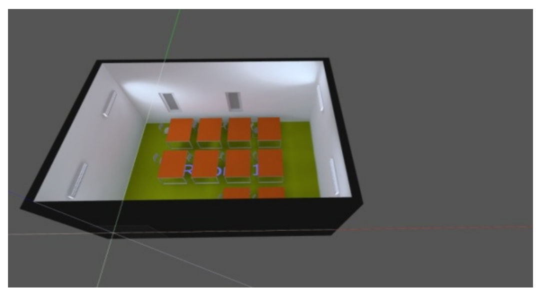

Figure 5: Final room view after lights on.

3. RESULTS & DISCUSSION

Luminary parameters, illuminance pattern in the classroom and energy performance analysis of the classroom with and without sensor are discussed in this section.

3.1. Luminary details

The existing lighting system in the classroom includes 4*36 W Phillips tube lights. It should be noted that the ballast output is not included in the total circuit watts of the classroom. Figure 6 shows the luminary detail of a single Phillips TL-D36W/840 tube light in the classroom. Light output ratio is around 68%. Total luminous flux is around 13400 lumens and the total load excluding ballasts is 144 W.

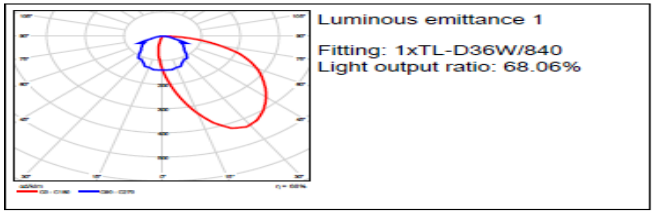

Figure 6: Luminary detail of a single Phillips TL-D36W/840 tube light

3.2. Illuminance pattern

The software also calculates the perpendicular illuminance (adaptive) on 128 relevant points on the working plane or surface of the room. Relevant points are points that are within the respective surface and are not covered by furniture or other elements. The summarized results are based exclusively on these points, as all other points would falsify the results, in some cases significantly. It also calculates the average, minimum and maximum illuminance as 159 lux, 68 lux and 218 lux respectively. It should be noted that the working plane height is given as 0.80 metres. Reflection factors of the walls, ceiling and floor are 82.1%, 80.7% and 29.4 % respectively. It is a factor which decides the reflection of light from a particular surface and depends on the colour of that surface. Figure 7 shows the perpendicular illuminance on 128 relevant points of the classroom.

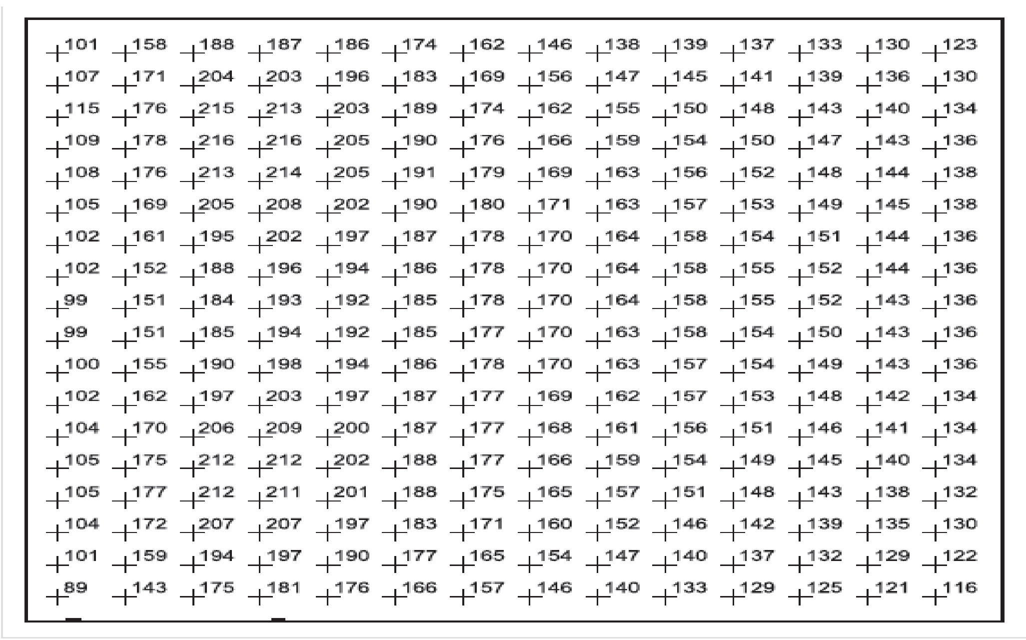

Figure 7: Perpendicular illuminance on 128 relevant points of the classroom.

3.3. Energy performance analysis

Case 1: Electric consumption of the classroom

The electrical consumption of the classroom with the existing lighting system was also calculated. All these calculations are of daytime only and there is no night time use of the lighting because classrooms are open in daytime only. Assuming 120 working days in a year and 8 hours of daily use i.e. 960 hours per year, the consumption was calculated as 100 Kwh/annum. Energy cost was calculated as Rs 530. The currency unit in Rupees and price per Kwh is set by the user according to the local tariff. The lighting energy numeric indicator (LENI) was calculated as 3 $Kwh/a/m^2$. It is the total amount of energy used by a lighting system per square meter, per year [(LENI=W/A) in $Kwh/m^2/a$, where W= total power consumption and A=total area]. The absence factor is 0.5 in this case. It is the factor relating to the period of absence of occupants. For standard calculations it is 0.50. Some other parameters which were defined or calculated are shown in Table 1.

Table 1: Various parameters used in energy consumption calculation

Assessment zone	Educational Buildings
Application	Classroom
Illumination value for visual task	300 [lux] (standard for classroom)
Use time per year	9600 [hours]
Colour rendering index R_a	80
Height of working plane	0.80 [metres]
Maintenance interval	1 year
Ambient conditions	clean
Maintenance interval for luminaries	1 year
Replacement interval of lamps	1 year

It should be noted that if all parameters are kept same and only absence factor is changed to zero i.e. there is no period of absence and light is completely occupied, the energy consumption, cost and LENI is changed to 150 Kwh/a, Rs 760 and 4 $Kwh/a/m^2$ respectively. It means on decreasing absence factor, energy consumption is increased. Thus absence factor in a standard condition is taken as 0.50.

Case 2: Electric consumption of the classroom after inserting energy sensor

In this case, electrical energy consumption is calculated considering an energy sensor in the classroom. Figure 8 and 9 show classroom with and without energy sensor respectively. The pink coloured sensor can be seen in the middle of the classroom in Figure 9.

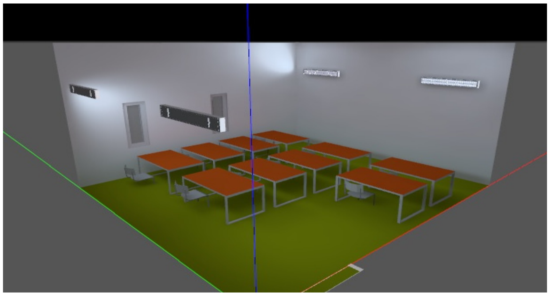

Figure 8: Classroom without energy sensor

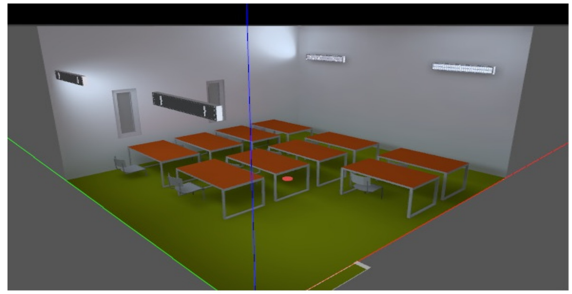

Figure 9: Classroom with energy sensor

In this case also, all the parameters are same as above case. The difference comes only due to the energy sensor. It has different modes of working. It has a presence check sensing element which can switch on and switch off the lights either manually or automatically or both according to the need of the user. Different modes of sensor and respective energy consumption are shown in Table 2.

Table 2: Different modes of sensor and corresponding energy consumption

Mode	Energy consumption [Kwh/a]	Cost [Rs]	Cost savings [%]	LENI [Kwh/a/m^2]
Switching on/off manually (no sensor)	100	530	nil	3
Automatic switching on/Dimming	100	490	7.54	2
Automatic switching on and off	100	460	13.20	2
Switching on manually/Dimming	100	460	13.20	2
Switching on manually/Switching off Automatically	50	380	28.30	2

It is observed that when sensor works under mode switching on manually/switching off automatically, about 50% reduction is possible in the energy consumption and a cost saving of around 30 % is possible. Thus 50 % energy efficiency is seen in this mode. Also the LENI is reduced from 3 to 2. In the case of automatic switching on/off, energy consumption is same but a cost reduction of 13% is possible. LENI also reduces to 2. Similarly with every case of using an energy sensor there is a reduction in energy consumption, cost as well as LENI.

4. CONCLUSION

The existing classroom of Energy Centre MANIT Bhopal is designed and simulated with the lighting system installed. The luminary details and its parameters are discussed. Also the illuminance pattern at various relevant points is observed and average lux is calculated. The energy performance analysis of the lighting system in the classroom is also studied. The energy consumption, cost and LENI are calculated for some defined parameters. It is seen that with decrease of absence factor, the energy consumption is increased. Different cases are compared and the use of energy sensor is justified. It is clearly shown that the energy consumption, the cost and the LENI are reduced with the use of energy sensor. The automatic switching on/off of the lighting system, which is the best use of energy sensor, reduces the LENI to 33% and the cost to about 13 %. Thus it leads to energy efficiency and proper management.

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