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Lighting Simulation - An Effective Approach for Energy Efficiency

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ABSTRACT: Buildings as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and natural resources. Lighting simulation is a software based tool which helps to analyse various lighting design, orientation of fixtures, controllability and day lighting analysis for making energy efficient and climate responsive building design. Lighting Simulation provides flexibility to the Lighting engineers at the designing stage to deal with building geometry, geographic information, so that an Energy Efficient Lighting Design can be incorporated in a building. With the help of this tool the best design strategy can be worked out which is energy, causes minimum environmental problems and what will be the project design and operating energy expenses providing optimal visual comfort.

KEYWORDS:BEE, EPI, TR, LPD, ECBC, Green Building, Carbon footprint, GRIHA, IGBC, kW, LUX, Luminous efficacy.

I. INTRODUCTION

In commercial Buildings typically lighting is responsible for 20-40% of energy consumption (1). Lightingting is an area which provides huge opportunity for energy saving in existing as well as in new buildings. Visual comfort is the main aspect in any lighting design and as per NBC there are standard lux values for particular spaces. But as per the studies and various energy Audit (2) a huge amount of building are not following the lighting compliances and because of that lighting itself consumes a high portion of available energy (3) and not only limited to that lighting design is also responsible for excessive cooling load in a building. Different usage areas need different lighting and different lux values for their visual comfort. As required lux value is much higher in an operation theatre than an office space. Different light have different efficacy (2) and their respective life-span.

Type of lamp	Lumen/Watt	CRI	Application	Life(hours)
Incandescent	8-14	Excellent	Home, restaurant	1000
Fluorescent lamps	46-60	Good	Office, homes, hospitals	5000
CFL	40-70	Very good	Office, homes, hospitals	8000-10000
HPMV	44-57	Fair	Factories, car parking	5000
Halogen	18-24	Excellent	Display, flood lighting	2000-4000
High pressure sodium	67-121	Fair	General lighting	6000-12000
Low pressure sodium	101-175	Poor	Roadways, tunnels	6000-12000

Table I: Performance characteristic of Luminaries

Sunlight is free and uses no electricity. By simply adding a large number of windows to let the sunshine enter can create excessive glare, and unwanted heat gain. Proper distribution of lights as per the required lux (5) values and with amalgamation of daylight by taking in control measures regarding glare and excessive heat gain lighting simulation will

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give energy efficient results. Lighting software help designers to compare lighting alternatives and make sure that ultimate design choice will provide quality light.

II. KEY TECHNICAL TERMS

Ballast: All fluorescent lamps need ballast to operate. The primary function of lamp are to provide cathode heating, where necessary, initiate the lamp arc with high voltage, provide lamp operating power and then stabilize the arc by limiting the electrical current.

Candela: It is a measure of the intensity of light (brightness) of light source in a given direction.

Color Rendering Index: Measured on a scale of 0 to 100. The higher the average CRI value betters its light. A cool white fluorescent lamp has CRI of 62 to 70, while standard sodium lamps have CRI of only 27.

Correlated Colour Temperature: A measurement on the Kelvin scale that indicates the warmth or coolness of lamp colour appearance. The higher the color temperature the cooler or blue the light. Typically below 3200 K light is considered as warm and above 4000 K it is considered cool.

I luminance: The amount of light that reaches a surface. It is measured in candles (lumen/ft^2) or lux (lumen/m^2).

Lighting Power allowance: It is the maximum lighting power allowed in watts for interior and exterior.

Lighting Power Density: It is the lighting power drawn per unit area. It is generally expressed in Watt/m^2 or Watt/ft^2.

Lux: It is the unit of luminance and indicates the density of light that falls on a surface.1 lux is equal to 1 lumen per square meter.

Lamp Efficacy: It is the measure of the output of lamp in lumens divided by the power drawn by lamp. Its unit is lumen/watt.

III. ECBC COMPLIANT DESIGN STRATEGY

Many things can go wrong when designing lighting design such as:

i. Specifying the amount of light without considering the need of specific task.
ii. Designing a daylight strategy without enabling the system to dim or turn off.
iii. Adding large windows to allow daylight but not considering the effect of excessive heat gain and glare.
iv. Designing HVAC (3) system on thumb rule not considering the effect of energy efficient lighting design.

ECBC (Energy Conservation Building Codes) set mandatory and prescriptive requirements for lighting controls and lighting power density (4).For interior lighting power requirement there are two methods for deigning efficient lighting system which are building area method and space function method.

Building Area Method:

i. Determine the allowed lighting power density for particular building area.
ii. Calculate the gross floor area.
iii. The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed LPD for that building area types.

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Space Function Method:

i. Determine the building type and allowed LPD.
ii. Determine the gross floor area.
iii. The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed LPD for that building area types.

Building Area Method	LPD(Watt/m²)	Space Function Method	LPD(Watt/m²)
Office	10.8	Office enclosed/open plan	11.8
Library	14	Classroom	15.8
Retail Mall	16.1	Family dining	22.6
Cafeteria/fast food	15.1	Hospital (Emergency)	29
Parking garage	3.2	Corridor	5.4

Table II: Sample LPD Values as per ECBC

IV. METHHODOLOGY

For making the effective Energy Efficient lighting design various cases has been analysed with the help of lighting simulation software:
Case 1: Analysed the base case proposed by architect.
Case 2: Modification in the proposed case to met visual comfort.
Case 3: Select the luminaries with a twin fitting of T5.
Case 4: Select the luminaries with a twin CFL 36 W.
Area of office: 114.8 m², Project maintenance factor=0.8, reflectance of ceiling=0.7, wall=0.5, wall=0.3, floor=0.3.
Existing lighting design with a 40W fluorescent tube.

Case 1 Analysis:
Lamp type: 40 Watt fluorescent type.
Lumen output: 2450 lumen/lamp
Ballast Power loss: 15 W
Total power consumption: 55 W

Result:

Area (m²)	No of fixture	Average lux	LPD (W/m²)	Uniformity ratio
114.8	8	84	3.85	0.49

Table III: Simulation Analysis of case 1

In this case average illumination is 84 while as per NBC recommended lux level should be 300 and LPD limit as per ECBC is 11.8 W/m².

Case 2 Analysis:
Lamp type: 40 Watt fluorescent type.
Lumen output: 2450 lumen/lamp
Ballast Power loss: 15 W
Total power consumption: 55 W

Result:

Area (m²)	No of fixture	Average lux	LPD (W/m²)	Uniformity ratio
114.8	21	403	13.42	0.74

Table IV: Simulation Analysis of case 2

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Vol. 1, Issue 3, October 2014

In this case average illumination is 403 which is complying NBC compliance but higher than LPD limit as per ECBC is 11.8 W/m².

Case 3 Analysis:
Lamp type: 2*28W T5 lamp.
Lumen output: 2900 lumen/lamp
Ballast Power loss: 2 W
Total power consumption: 30 W

Result:

Area (m²)	No of fixture	Average lux	LPD (W/m²)	Uniformity ratio
114.8	18	412	6.7	0.48

Table V: Simulation Analysis of case 3

In this case average illumination is 412 which is complying NBC compliance and also complying the LPD limit as per ECBC is 11.8 W/m².

Case 4 Analysis:
Lamp type: 2*36W CFL lamp.
Lumen output: 2900 lumen/lamp
Ballast Power loss: 4 W
Total power consumption: 40 W

Result:

Area (m²)	No of fixture	Average lux	LPD (W/m²)	Uniformity ratio
114.8	20	464	11.8	0.53

Table VI: Simulation Analysis of case 4

In this case average illumination is 412 which is complying NBC compliance and also complying the LPD limit as per ECBC is 11.8 W/m²

V. CONCLUSION

- In case 1 the illumination level is very low, which leads to visual comfort i.e. this case is not acceptable.
- In case 2 visual comforts has been achieved but the LPD limit is higher which will lead to excess energy consumption.
- In case 3 & 4 visual comfort has been achieved and LPD value is also under the limits.
- In case 3 & 4 it has been proved with the help of lighting simulation that case 3 has lower LPD limits than case 4 which will save 586 Watt.

With the aid of these software proper lighting distribution, visual comfort and energy efficiency can be easily achieved. As in case 3 & case 4 which both are complying NBC and ECBC even though case 3 can save 5.86 kW.

Parameter	Value	Unit
Energy Saved	5.86	kW
Operating hours	8	Hr
Operating days	320	Days/year
Energy Saved	15002	kWh
Energy charge	5	Rs/kWh
Amount saved	75010	Rs/year

Table VII: Simulation Analysis of case 1

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Above mentioned results shows that case 3 will not only provide visual comfort but also lead to save 15,002 kWh/annum and on the base of 5 Rs/kWh an annual saving of Rs 75,010. In case 3 T5 lamps have been used which has life of around 12000-15000 hrs.

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