STUDIES ON ENERGY SAVING POTENTIAL OF DAYLIGHT INTEGRATION IN CLASSROOM LIGHTING SYSTEM

A Thesis Submitted Towards Partial Fulfillment of the requirement for the Degree of

MASTER OF ENGINEERING

IN

ILLUMINATION ENGINEERING

Submitted By

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Studies on Energy Saving Potential of Daylight Integration in Classroom Lighting System",** is a bonafied work and carried out by **S DIVYANSHU DEO** (Examnation Roll No :- **M4ILN22010**, Registration No**. 154033** of **2020-2021**) under my supervision and guidance for partial fulfilment of the requirement for the award of degree of **Master of Engineering illumination Engineering,** Department of Electrical Engineering, during the academic session 2021-22.

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This foregoing Thesis is hereby approved as a credible study of an engineering subject carried out and presented by **S DIVYANSHU DEO** (Examnation Roll No :- **M4ILN22010**) in a manner satisfactorily to warranty its acceptance as a pre – requisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn there in but approve the thesis only for purpose for which it has been submitted.

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DECLARATION OF ORIGINALITY AND OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of the thesis for the degree of Master of Engineering in illumination Engineering studies during academic session 2021 – 22.

All information in this document have obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have cited and referred all materials and results are not original to this work.

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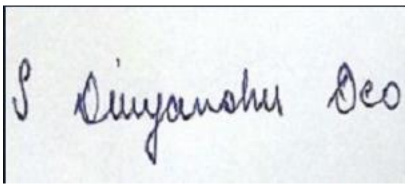

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TABLE OF CONTENTS

ABSTRACT

Electric lighting consumes a considerable amount of energy. Using energy efficient luminaires, effective controls and careful design can result in reduced consumption of energy. Reducing the unnecessary electric lighting decreases heat gain, thus saving air-conditioning energy and improving thermal comfort. Proper electric lighting design improves visual performance and visual comfort by maintaining adequate and appropriate illuminance while controlling reflection and glare.

Now a days most conventional luminaires are being replaced by LED luminaires owing to their high efficacy. These luminaires when incorporated with occupancy and daylight sensors can generate large amount of energy savings.

In this thesis work we have made an attempt to give a solution towards the energy saving potential of the daylight integration in classroom Lighting System. In this thesis work we had first taken energy with full dim light and then again with 50% dim and at last with no dim light and then compared all three energy in a big classroom . All Simulations are run using lighting design software DIALux 4.13.

CHAPTER – 1

INTRODUCTION

1.1 INTRODUCTION

Energy is the ability to do work. So, to perform any work, be it simply walking or sending astronauts to space, energy is required. Different sources of energy may be used for the work to be done. In order to light up a bulb in our home, electricity is needed which is generated by burning Coal or Natural Gas or maybe by a nuclear reaction or probably by a hydroelectric plant set up on a river. These energy sources can be divided into two groups: Renewable (which can be easily replenished) and Non-renewable (that cannot be easily replenished). Most of the energy sources that are used, are non-renewable in nature and hence it is necessary to use energy more efficiently. It is estimated that the electric lighting consumes about 20% of the total electric load [6]. So, it is the responsibility of lighting professionals to reduce electric lighting energy consumption. This not only will preserve the planet but also will reduce the electricity cost.

Over the last few years, technologies in electric lighting has developed considerably. For indoors, incandescent lamps having luminous efficacy of around 15-20 lumens per watt were replaced by Fluorescent Lamps (FLs) or Compact Fluorescent Lamps (CFLs) that have an efficacy of around 60-70 lumens per watt. These Fluorescents or CFLs are now being replaced by Light Emitting Diodes (LEDs). LED based light sources are much more energy efficient than most of the other lighting sources with a luminaire efficacy of around 100-130 lumens per watt. Moreover, with LEDs, the illuminance level can be altered much easily for different activities. So, sensors can be used more conveniently with LEDs to save energy. The total electric energy consumed by the lighting load is affected by the duration over which the lights are switched on and the consumption can be reduced with a suitable lighting control, which may be manual or automatic or a combination between the two to ensure optimum lighting conditions without lighting being left on unnecessarily.

Optimum usage of daylight can also help in conserving energy. It is the most preferred light source but it is necessary to keep in check glare and overheating due to daylight. A balance between the illuminance level and the thermal environment has to be maintained so as to achieve a satisfactory design solution.

1.2 Literature Survey

Electric lighting is a major energy consumer. Enormous energy savings are possible using energy efficient equipment, effective controls, and careful design. Using less electric lighting reduces heat gain, thus saving air-conditioning energy and improving thermal comfort. Therefore, the balance must be ensured against the need for well-lit environments to ensure the productivity, well-being, safety and health of the people it serves. Both visual function and visual amenity for the particular application and for the architecture must be provided by a well-lit environment, together with an efficient use of energy.[6]

Lighting technology based on light-emitting diodes (LEDs) is developing rapidly and is paving the way for different applications of LED lighting in the lighting sector. With the advent of new technologies, the lighting products are becoming more energy-efficient and eco-friendly. Along with energy saving, the illuminance, brightness, lamp spectrum and colour rendering index (CRI) should also be accepted by the user. For office lighting scenarios, users preferred Light Emitting Diodes (LEDs) over conventional Fluorescent lamps such as Compact Fluorescent Lamps (CFLs). [2,3]

A smart lighting control system can reduce energy usage and money and can significantly contribute to a comfortable working environment, making it an essential component in modern commercial buildings. It is possible to dim the LED luminaires easily in order to save energy. Light sensors can be used to monitor illumination levels. Using this sensing information as feedback input, a lighting controller can change the artificial light output so that desired illumination levels are maintained. [4,5]

In the working environment, glare is a major occupational risk. It is very important to predict and limit glare. The assessment of discomfort glare is difficult owing to the involvement of subjective sensation. The International Commission on Illumination (CIE) recommends the formula for the Unified Glare Rating (UGR) in predicting glare, which is standardised and represents a technical approach to this glare rating scale. The UGR can also be estimated through subjective analysis with an experiment involving 65 subjects. Subjective glare rating is always a few units lower than the glare predicted by UGR formula.[2]

Occupancy sensors reliably deliver significant savings in infrequently or unpredictably occupied spaces, such as washrooms, stairwells, corridors, storage areas and mail carrier sorting stations. The practical problem is determining the best location for the sensors and the type of sensor that is to be used. Number of sensors should be optimised so as to increase accuracy and shorten the applicable time delay without increasing the cost much.[7]

Lighting has traditionally considered visual performance like horizontal illuminance on the work plane, then focussing on energy efficiency, while only recently paying particular regard to human health outcomes. Light is the primary stimulus for resetting the biological clock. Every morning the sleep–wake cycle is reset by light to be in sync with the night–day cycle. The characteristics of light stimuli are also central to this process, specifically in respect to the amount (or level) of light received at the cornea, its spectral properties, the timing of the light.

exposure and the duration of that exposure. Light also exerts an acute alerting effect on humans that is similar to that provided by a cup of coffee. It has been found that a Circadian Stimulus (CS) of at least 0.3 for a minimum of 2 hours during the daytime is beneficial for circadian entrainment and for increasing alertness and energy levels Supplementing common overhead lighting with a desktop luminaire delivering light directly to the simulated office occupants' eyes provided a greater amount of CS at a lower lighting power density (LPD) than overhead luminaires that were capable of delivering the criterion CS of 0.3. Exposure to blue light can affect the body's production of the hormone melatonin (a well-established circadian system marker). Red light can also deliver a similar alerting effect without suppressing melatonin and disrupting circadian rhythms. [8]

1.3 Problem Defination

Poor lighting at work can lead to eye-strain, fatigue, headaches, stress and accidents. On the other hand, too much light can also cause safety and health problems such as "glare" headaches and stress. Both can lead to mistakes at classrooms, poor quality and low productivity. Various studies suggest that good lighting at the classrooms pays dividends in terms of improved productivity, and a reduction in errors. So, a proper lighting design for classrooms should be made so that these factors can be taken into account.

Moreover, suitable type of sensor should be selected and their placement should be optimised for energy saving without increasing installation cost.

1.4 Objective

The objectives of this thesis work are:

- To determine an optimum lighting solution for a classrooms
- To save electrical energy in the classrooms without compromising on the lighting design parameters and also without neglecting the effect on children health or mood.

1.5 Organization of the Thesis

The thesis is divided into six chapters.

In **chapter 1**, an introduction to the thesis work has been given. It also includes Literature survey, problem definition, objective and organisation of the thesis.

In **chapter 2**, the lighting design fundamentals, parameters, procedure, various types of lamps conventional lamps that can be used in classroom areas and LED light source have been discussed.

In **chapter 3**, a general overview of an classroom lighting is discussed along with basics of classroom lighting and its effect on learning along with the LED light fixtures for schools and educational facilities have been discussed in this chapter

In **chapter 4**, details of case study for a typical classroom have been given. The lighting design requirements like the input data, design considerations, types of lamps, luminaires and lighting control to be used have been briefed along with the DIALux 4.13 simulation report using conventional and LED light sources. Lighting Design of a Typical classroom is also discussed.

In **chapter 5**, Results are analysed and compared in terms of Average Illuminance, Lighting Power Density (LPD) comparision , evalution of LPD , Cost and Glare.

In **chapter 6**, Conclusion of the thesis work is drawn and future scope of this work is highlighted.

At last, all the references have been given

CHAPTER - 2

LIGHTING DESIGN

2.1 Introduction

Lighting is an essential service for all.. According to the international agency lighting accounts for 19 percent of the world's total energy output depending on type of use[1]. Continuous design and improvement in the field of lighting has given rise to greater potential for energy saving in this area. Lighting design offers great scope of obtaining energy efficiency in the design phase, by combining modern power efficient lamps, lamps and gears, functional controls, and careful design without any fuss in operating procedures.

India is facing urban growth faster than expected. Disobedience building codes and inefficient lighting designs have transformed the construction industry to the top of an energy-intensive sector. Energy consumption in buildings represents approximately 14% of the total delivered power in India in 2019[2]. Although the US Energy Information Association expects India's commercial growth rate to be higher than its residential capacity growth, the residential sector remains the largest consumer of real estate, representative more than 70% of the total property during the speculative period[2] . Most of this power used for active lighting, cooling, and ventilation for fans.

Lighting is not just a priority when considering office construction design but it is also a high return, low risk investment. By introducing new lighting technology, offices can reduce the cost of electricity used and energy costs associated with lighting. Lighting is required in order the appearance of objects in a place or in dark conditions.. Newly energy-efficient lighting fixtures as the Light Emitting Diode (LED) can be used to reduce lighting operating costs from 30% to 60% while improving lighting quality, reducing environmental impacts, and improving health and work productivity[3].

2.2 Fundamentals of lighting design

The following design ideas should be considered generally when designing lighting solution for indoor or outdoor applications:

• Whether the lamps and luminaires will be installed in a safe or dangerous place.

• The required level of lighting for local activities.

• Operational level where the recommended light level should be

achieved.

• Types of lamps and luminaires to be used and their lumen output.

• Elevation height available.

• Illumination similarity will be achieved.

• The color rendering needed for the work to be done locally.

• Total energy consumption

• Light Pollution Limit.

2.2.1 CLOSED VS. OPEN PLACES

The amount of protection required for lighting in areas such as the weather, corrosion and infiltration of water or dust depends on whether lamp is installed in indoor spaces or not.

- **Working Plane Height**

The Working plane in a study area or meeting place is usually on a desk level (750 to 900 mm from the ground level) whereas, on a corridor or stadium, it may be at a lower level.

- **Mounting Height**

The mounting height of the lamps determines the illuminance of the working plane. Indoor lighting affects the cavity above the input height, (ceiling cavity) and below the working plane, and the walls around the work area as shown in Figure 2.1.

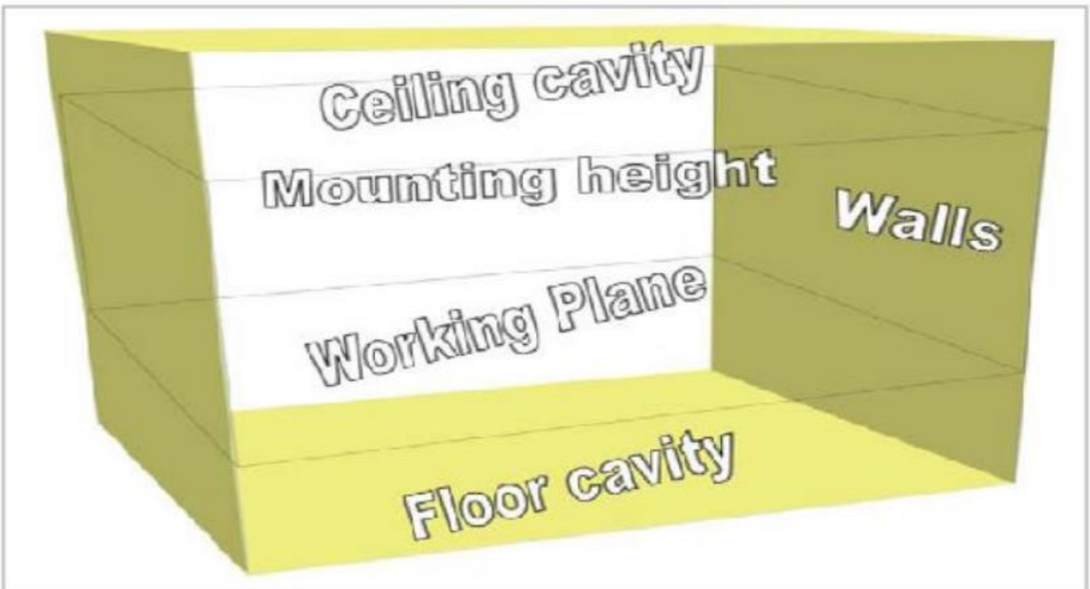


Fig 2.1 : Working plane and Mounting Heights

- **Reflectance Factor**

  Reflectance is classified into three types – Light, Medium and Dark. The average value of these factors for ceiling, walls and floor can be obtained from the following table 1.1

Table 1.1 : The average value of the reflectance for ceiling, wall and floor

Surface reflectance	Light	Med	Dark
Ceiling cavity	0.70	0.50	0.30
Walls	0.50	0.30	0.10
Floor cavity	0.30	0.20	0.10

- ## COEFFICIENT OF UTILISATION

This is a ratio of the luminous flux that reaches the working plane to the total flux emitted by the mounting lamps, considering the floor and roof holes, as well reflectances. In a closed room, the CoU (Coefficient of Utilization) is based inside the room internal dimensions (length, width and luminaire height) and is governed by the formula:

Room Index = (**Length** × **Width**) / **Mounting Height** × (**Length** + **width**).

CoU features are provided by luminaire manufacturers for each different type of luminaire. Room indicators and reflectance factors are also used in lighting calculations to determine number of lights required.

- ## MAINTENANCE/ DEPRECIATION FACTOR

Luminaire depreciation factor refers to a decrease in the amount of light output of the luminaire as it ages and due to the accumulation of impurities, degradation of materials etc. The lamp output also gradually decreases with age due to factors such as filament evaporation. This is called the lamp depreciation factor. Maintenance factor (MF) can also be assumed to cater for reduced light output by the luminaires or lamps. The MF of 0.7 - 0.8 is which is often considered in design statistics in which information about the maintenance system or the luminaire or type of lamp to be used is not available.

2.3 Lighting Design Parameters

- **Average Illuminance(E_{avg})**

Illuminance usually refers to the amount of luminous flux falling in per unit area of a given surface.

Lightning should be such that:

• A good balance should be maintained between the horizontal Illuminance in the work area (especially where computer-related work is being studied) and the surrounding area.

• It provides the appropriate vertical illuminance as it is essential for presenting the truth as well a pleasing interior and exterior look.

- **Overall Uniformity(U_o)**

The operating code recommends that light similarity be measured as ratio of minimum illuminance to average illuminance over an area, which may be all internal or specific areas of work.

$$\textbf{Uniformity}(U_o) = E_{min}/E_{avg}$$

It is important for the following reasons:

• Excessive light variation means that some parts receive less light than desired.

• The constant change of different segments with bright and bright lights creates a larger eye discomfort, which leads to depression and fatigue.

- **Unified Glare Rating (UGR)**

Glare is a condition of vision where there is discomfort or reduction in the ability to see important items, or both, due to improper distribution of light or due to excess differences in space or time.

UGR (Unified Glare Rating) is a method of calculating the brightness from luminaire, light through windows and bright light sources. It helps to determine if the luminaire is likely to cause discomfort for those around her. This category is from 5 to 40, with low numbers which reflects low light.

- **Lighting Power Density(LPD)**

  Lighting power density is a measure that shows energy saving opportunities of any space . It is defined as the maximum lighting power installed per unit area of space as per its function or structure as its subdivision. LPD can be determined in two ways:

  • Common Area Method - This method provides a total calculation process of the whole building based on its type.

  • Space Function Method - In this way the LPD varies depending on the function of location based on type of building.

2.4 Objective Of Lighting Design

- ***Modelling***

This lighting feature allows the designer to help emphasize the dimension of the object or person. Some items may appear "flat" and uninteresting. This is usually due to the lack of angle light which creates shadows on objects. Light contrast once and the shadow creates a keen interest and allows us to see things clearly, especially the human face. The same is true of three-dimensional objects and the technique used on stage. Correct angles for light should be used to create a texture look in the audience.

- ***Visiblity***

Physically something appears when light emanates from it along with us. We have seen that light with our own eyes. However, just because something reflects light does not make it clearly visible. Appearance is closely related to modeling and durability. For example, if there is a high level of light on the stage, it may be difficult to see people clearly when there is no modeling or comparison. Thus, visibility is a "clear" way in which the user see something. Good looks are comfortable in the eyes and enhanced by all the qualities of light.

- ***Selective Focus***

Selected focus means that objects and people are highlighted either dark to control user attention (or focus). The user is free to view anywhere in the office. It is the designer's job of lighting to direct the audience’s attention to important moments .

- **Mood**

Creating a situation occurs when the designer brings life to light emotional situations in the office. The creation of emotions can use all the attributes of light, but very effective color, angle, and movement. The color change will affect the users view.

- **Appearance and Comfort**

Illumination system of any area can affect the luxury and landscape.
Apart from these main objectives, modern light has a few other purposes also: -
I. Visual resources
II. Integration of Buildings or Ambience
III. Energy efficiency and stability
IV. Nutrition.
V. Expenses.

2.5 Lighting Design Procedure

- Step I : For any designer, the best step is to have a formal conversation with the designer, the client or end user and other members of the design team and assess whether design is required for a new building or an existing building, what function the space that can work and therefore have an idea about what it should be done.

- Step II : In an existing building the scope of the lighting design is as small as a luminaire positions are highly adjusted. Only energy saving can be achieved through equal use LED retrofitting solutions instead of conventional sources and by adding more controls. In a new type of construction project, the AutoCAD file is read completely. The size of the rooms is assessed and the client is asked for any missing details.

- Step III : Lighting and other relevant Codes and guidelines should be read in detail.

- Step IV : Different possibilities for lamps and lanterns, which can be used for lighting up in a given area are being checked. E.g - will it be postponed, mounted or fixed, direct or indirect lighting or both direct indirect light will be used.

- Step V : The AutoCAD file is imported with lighting design software, here DIALux version 4.13. A 3-dimensional model of all the rooms is manufactured using a design software. Different lighting conditions are modeled and the lights work very well is selected which must be compatible with the appropriate standards.

- Step VI : The type of sensor is determined by the areas in which the sensor will be used. The sensor positions are determined in AutoCAD Drawing for proper installation and overlapping hearing areas.

- Step VII : If the imitation does not comply with the standards or if the client requests it to a certain requirement, reviews are made on that and redesign is done until standards are met and client is satisfied.

2.6 Criteria for Lighting Design

Lighting requirements are based on the following lighting design frameworks : -

I. Illuminance Level (Average Illuminance)
II. Luminance Distribution and Similarity
III. Glare
IV. Incident guide for light effect and shadow
V. Color appearance and color rendering.

- **Illuminance level**

Illuminance is the amount of luminous flux falling on unit area of a surface.. The SI unit is lux (lx) and is a derived unit of Illuminance. One lux is equal to one lumen per square meter (lm / m^2). The level of lighting produced by the installation of lighting in any area is usually measured in terms of light produced in a specified plane.. The surface may be horizontal, vertical or inclined. The light provided for installation affects both functional performance and landscape appearance.

Average illuminance (E) provided by the Lumen Method is provided by:

$$E = (\phi * n * N * UF * MF) / A,$$

where

- ϕ = Initials bare lamp luminous flux (lumens).
- n = Number of lamps per luminaire
- N = Number of Luminaire
- UF = Utilisation feature
- MF = Maintenance feature
- A = Area of the surface(m^2).

• Illuminance Ranges

Circumstances may vary significantly different for different interiors used for the same system or different situations of the same type. Therefore, the Illumination range recommended for each type of interior or activity intended, instead of a single amount of illuminance. Each range consist three steps of recommended light scale. Internal equipment, in the middle of each range represents the recommended service light that will be used unless one or more the following suggestions apply. The maximum width range should be used when:

- Lower exposure or unusually low brightness is present in the work,
- Most expensive to fix errors,
- Visible work is important,
- High accuracy or high productivity is also very important
- Observation capacity makes it necessary.

A minimum range of width can be used where display or brightness is not normal, high, speed and accuracy are not important; and the work is done only occasionally.

- ## Luminance Distribution

In large rooms, light distributed should be considered in accordance with the design of the light inside. It should take into account the following factors : -

- The luminance of the task and its immediate surrounding area; Ceiling luminance, walls, and floor;

- Avoid limitation of luminance of lamps and windows.

Luminance Distribution of Light in the Workplace and the illuminance of the work environment should, if possible, be lower than the work light, preferably not less than l / 3 of this, value. This means that the rate of the reflection of the immediate vicinity of the work in that work itself is best suited be in the range of 0.3 to 0.5.

- ## Restriction of Glare

Glare may be caused by lights, lamps, and windows (direct light) or with the appearance of light sources from bright sources (light reflected). In the interior light, discomfort glare from the lamps and luminaire it may be more of a problem than a stroke.

Restriction of direct glare : Direct glare is considered limited enough, if light sources at a critical width of 45 degree < Y <85 degree, where Y is the ratio of horizontal distance from viewer and light to direct distance between viewers ’ eye and luminaire leading. Pressed scales for glare G measurement are based on the following is an explanation of the appearance of the spectators: 0 = No glare, 2 = Visible, 4 = Uncomfortable and 6 = Intolerable light

- ## Shadows and Modelling

The appearance of the interiors improved when their structural features, the objects and the people inside are lighted. shapes are revealed clearly and happily and the shadows formed without confusion. This happens when the light flows noticabally more in one direction than in any other. The word modeling is used to explain how the conditions of three-dimensional objects are expressed in light. The requirements for displaying the shape and texture of certain types of work can be special and testing may be necessary in these cases to find the best solution

- ## Colour Appearance and Colour Rendering

This can be provided with additional lights placed a short distance from the visible work, which only illuminates limited space. In industrial situations, this is often referred to as additional lighting. The color of the light emitted by the ‘near white’ source can be indicated by its corelated color temperature (CCT). Each type of lamp has a specific color temperature relative to it, but due to practical use related color temperatures are grouped into three classes.
the choice of the appropriate visible color of the light source in the room is largely determined by the skin function. This may involve psychological aspects of color such as a view given by warmth, relaxation, clarity, etc., and other such common assumptions . As a need to have a

color appearance that matches the daylight but yet to give white color at night. Unlike CCT, CRI refers to how a light source gives the colors of other objects and places. CRI can reach a maximum of 100, that is the light source mentioned has the same ability to give color as natural daylight. The supply is increasingly distorted as the CRI becomes lower, and there is no lower limit: incorrect CRI values indicate very poor light sources that completely distort color understanding. Groups to give color to the various lamps that will be used for lighting. The interior is described in Fig. No.2.2 below. CIE 1931 x, y chromaticity space, also shows chromaticity of black light sources of various temperatures (Planckian locus), and the corresponding color temperature lines are always shown in Fig. No-2.3.

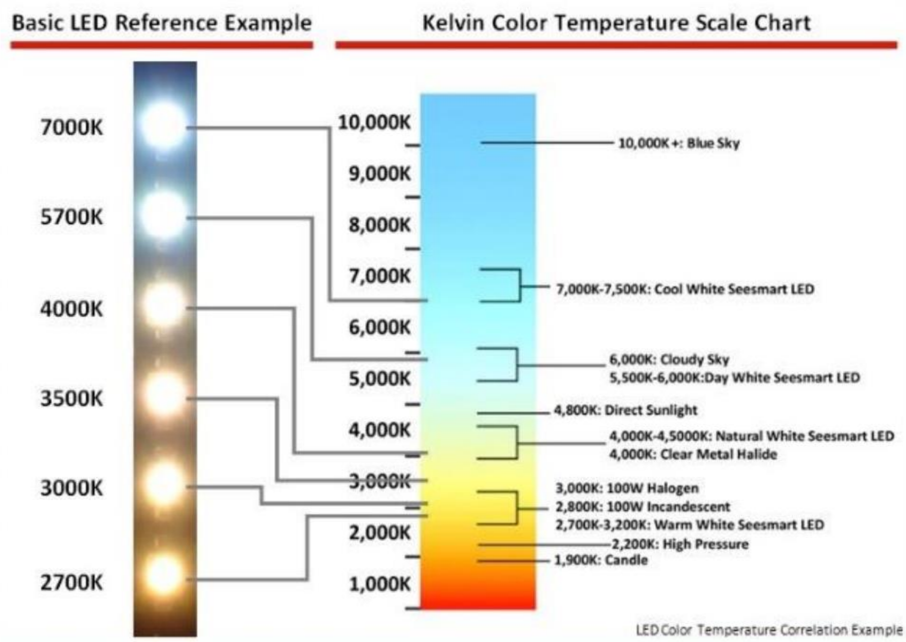


Fig 2.2 : Corelated Colour Temperature for LED

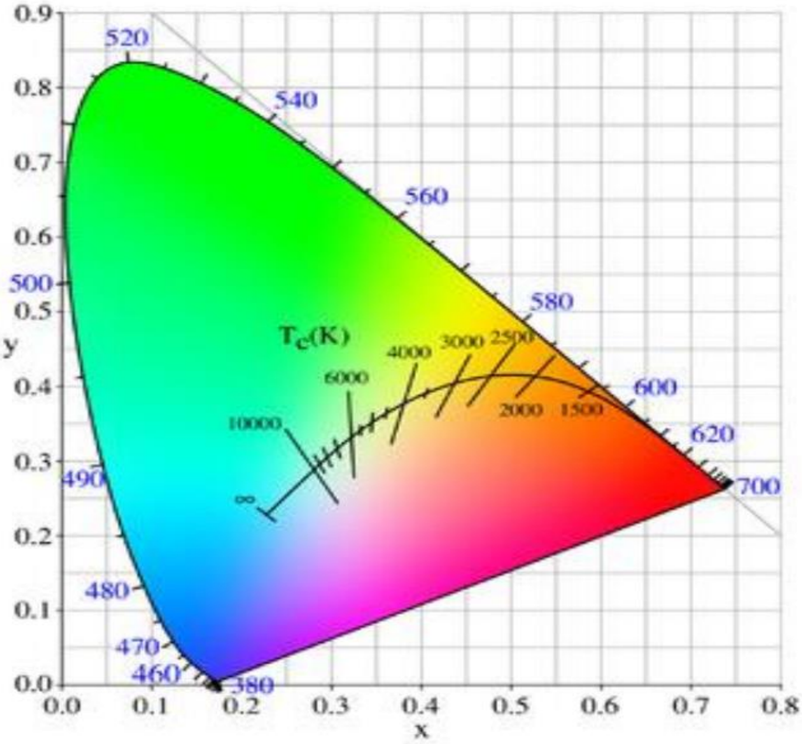


Fig 2.3 : CIE 1931 x,y Chromaticity Diagram

Table 1 – Corelated Colour Temperature & Colour Rendering Index

Type of lamp	CCT (K)	CRI
General Lighting Service lamp	2500 – 2700	100
Tungsten Halogen Lamp	2700 – 3200	100
Florescent Tube Light	3000 – 6500	60 - 90
Compact Fluorescent Lamp	2700 – 6500	> 80
High Pressure Mercury Vapour Lamp	3200 – 3900	40 - 50
Quartz tube Metal Halide Lamp	3000 – 5000	60 -90
Ceramic tube Metal Halide Lamp	3000 – 4400	78 - 93
SOX (Low Pressure sodium vapour lamp)	2100	19
SON (High Pressure sodium vapour lamp)	1900 – 2500	40
Induction Lamp	2500 – 4000	80
Light Emitting Diode	2700 – 6500	> 70

2.7 Conventional Light Source

Traditional light bulbs or incandescent lamps, also known as General Lighting Service (GLS) lamps such as tungsten filament and tungsten halogen consume excessive energy. Their efficacy is within the range of 10-25 lumen / watt as only about 5% of the electricity they use is converted to visible light. The filament is heated until it glows and turns a white-yellowish light. The bulbs do not last long because the filament evaporates slowly.

With the advent of low-pressure mercury emission lamps such as fluorescent lamps (FLs) and compact fluorescent lamps (CFLs), GLS lamps are gradually replaced and almost disappeared from the office lighting today. The main reason for this is high efficiency (up to 100 lumen / watt) and longer of fluorescent lamps compared to GLS lamps. The conventional lamps of office space is still used today below:

2.7.1 FLUORESCENT TUBE LAMP (FTL)

Fluorescent lamps are known as gaseous discharge lamps that produce light by emitting an electric arc with a tube filled with argon gas with low pressure and mercury atoms. Some of the electrons in the arc collide with the electrons in the mercury atoms. As a result, mercury electrons are released in orbit and jump to a higher level of energy and return to the normal course by stopping the absorbed energy. Primary emission is in ultraviolet range and therefore invisible to human eyes. Ultraviolet light also interacts with it special compounds of phosphors attached to the inner surface of the fluorescent lamp tube it effectively converts invisible light into useful white light

Fig 2.4 T5, T8, and T12 Fluorescent Tube Lamp

- **Classification**

Fluorescent Tube lamps are available in a variety of styles as shown in Figure 2.4. The letter "T" designates the tubular shape and is followed by a number that indicates its width by eight inches.

• Fluorescent T12 tubes

The earliest fluorescent lamps have a maximum width of 12/8 inches. They are quite less efficient compared to T5 and T8 lamps and lasts up to 8,000 hours.

• Fluorescent T8 tubes

These second-generation fluorescent lamps have a minimum width of 1 inch. They are one of the most widely used and energy-efficient lamps compared to T12 lamps, which last up to 15,000 hours, and even longer in some cases. It is usually available in 4 Feet lengths 36W giving a output of about 2500 lumens.

• T5 Fluorescent tubes

These third generation light bulbs with a minimum diameter of 5/8 inch are the most effective and it usually lasts about 20,000 hours. This is the first type of line light that should be provided only by electronic ballasts. They can work very well at about 90 to 100 lumens per watt. The CRI of T5 lamps can be specified from the 70s to the mid-90s. Generally, 28W 4 Feet tubes are available offering a output of about 2500 Lumens.

2.7.2 COMPACT FLUORESCENT LAMP (CFL)

CFL can be seen as an improved version of the usually premium fluorescent lamp phosphors and ballasts can be connected directly to a lamp, or they may be remotely connected. The operating principle of the CFL bulb remains the same as in another fluorescent light: electrons bound to mercury atoms rejoice when they emit ultraviolet light as they return to low energy levels; this ultraviolet light emission is converted to visible light as it strikes a fluorescent coating on the bulb. They end up from 8,000 to 12,000 hours and available in different wattages of 9W, 10W, 11W, 13W, 18W, 20W, 26W, 36W, 40W and 55W.

- ## Classification

• Non-Integrated CFL

Non-integrated CFLs have ballast installed elsewhere, usually in the luminaire and usually only the fluorescent tube is replaced at the end of its life. These ballasts last larger than combined. The types of lights that are not included are as follows:

i. **Bi-pin tube**, which can be used with both magnetic and electronic ballasts but is available not dimmable.

ii. A quad-pin tube, which is usually paired with electronic ballasts and can be dimmable.

Fig 2.5: Bi-pin tube CFL Lamp

Fig 2.6: Quad-pin tube CFL

- ## Integrated/ Retrofit CFL

Integrated lamps combine the tube and ballast in a single unit. This allows in easy replacement of incandescent lamps with CFLs.

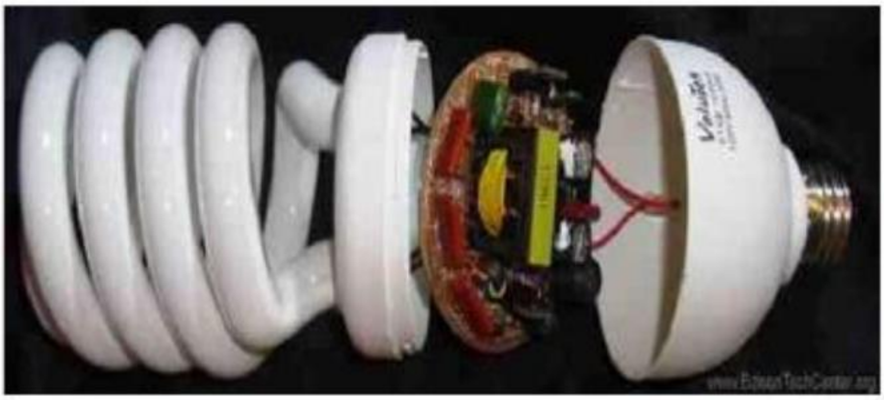


Fig 2.7: Integrated CFL lamp showing the position of Ballast Inside

2.7.3 Types Of Ballast

There are two types of ballasts used with a fluorescent lamp: electromagnetic and electronic.

• Electromagnetic Ballast

Most electromagnetic ballast transformers are limited current as shown in Fig.2.8. In this ballast, enamelled copper magnet wire coils are wound on the back of the transformer distance iron. Power consumption on these ballasts is approximately 15 to 25 percent estimated of the rated power of the lamp which is dispersed like heat. And they are responsible for both generation and limitation of harmonic limit.

Fig 2.8: Electromagnetic Ballast

• Electronic Ballast

Electric ballasts as shown in Fig.2.9 use the oscillator circuit to make waves 20 to 40 kHz range. Fluorescent lamps like to work at high frequencies. Internal power loss is much lower than that of electromagnetic ballast.

Fig 2.9 : ***Electronic Ballast***

2.8 LED Light Source

Light-Emitting Diodes (LED) light sources use light emitting diodes when connected to a circuit. The effect is a kind of electro luminescence in which the LEDs release a large amount photon. LEDs consist of p and n regions with interlocking as normal diode. When sufficient voltage is applied to the semi-conductor chip, the electrons can move easily across the street where they are immediately attracted to the positive energy in p region. When the electron moves close enough to a positive charge in the area of p region, the two charges "reunite". When an electron meets a positive ion, electricity potential energy is converted into magnetic field and this results in the release of a light photon. This photon has a frequency determined by the features of semiconductor material (usually a combination of chemical substances gallium, arsenic, and phosphorus). LEDs emit different colour made of different semiconductor materials.

2.8.1 Advantages of LED

• They are very efficient, over 100 lumens per watt.

• Energy losses are lower for LEDs compared to conventional sources.

• They have a very long life, about 50000 hours.

• LEDs are eco friendly as they do not have Lead or Mercury.

• LEDs can be very easily controlled. Blurring can occur from 0.1% to 100% without changing the lamp Co-related Color Temperature (CCT) and Colour Rendering Index (CRI).

• LED chips are small in size so luminaires of any shape and size can be created.

• LEDs emit light in a certain area, thus reducing the need for indicators.

• LEDs reach full light quickly without any delay.

2.8.2 WHITE LEDS

LEDs cannot emit naturally white light. However, the use of certain technologies makes the LED emitting white light. There are two main ways to produce white LEDs (WLEDs), namely:

• Wavelength conversion

In this wavelength conversion method, an LED emitting blue rays is used sweeten the yellow colour phosphor (Yttrium Aluminium Garnet) as shown in Fig.2.10 and 2.11. This causes the emission of yellow and green light and this resulting mixture of blue and yellow light gives the appearance of white light. The performance of this type of LED is higher than that of RGB but it has a cool color temperature.

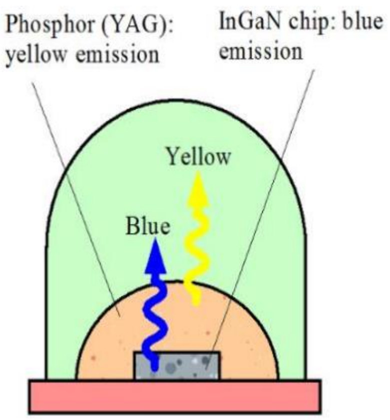


Fig 2.10 : white LED using Wavelength Conversion

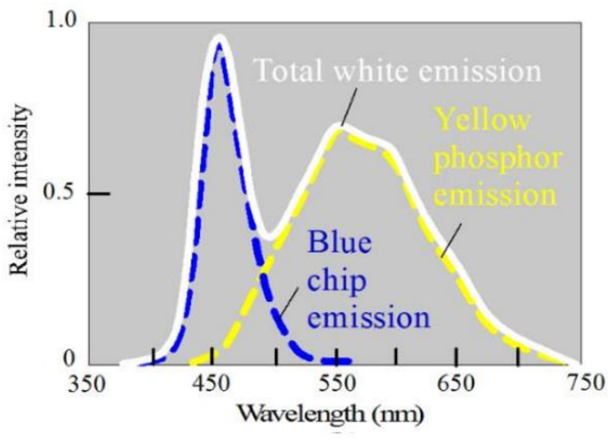
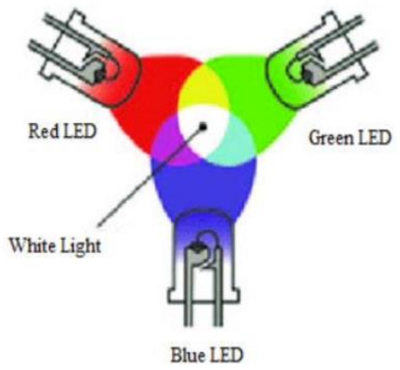


Fig 2.11 : SPD of phosphor coated Blue LED

- **Colour Mixing**

The LEDs that emit the primary colours red, blue and green are embedded in the lamp and the intensity of each LED is evenly tuned to obtain white light as shown in Fig.2.12 and 2.13. This method has many applications due to the flexibility of mixing different colour and thus the temperature of the white light colour can be easily adjusted



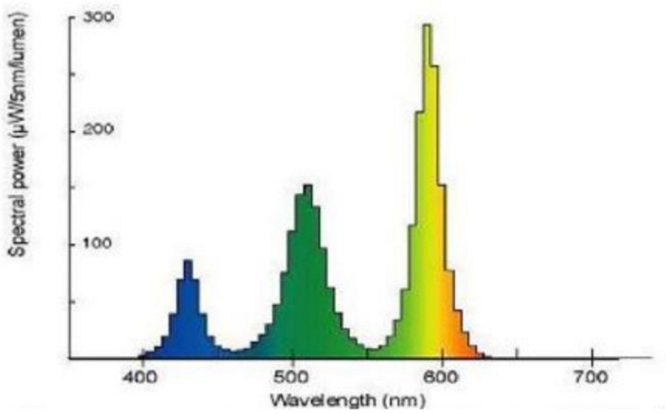


Fig 2.12 : Mixing of RGB to White Light

Fig 2.13 : Spectral Power Produce Distribution(SPD) of white light RGB

2.8.3 LED Driver

LEDs require drivers for two purposes:

• LEDs designed to operate at low voltage (12-24V), direct current. However, in many places provide high voltage (120-277V),alternating current. The LED driver rectifies high voltage, current alternating to low voltage, direct current.

• LED drivers, shown in Fig. 2.14, also protect the LEDs from voltage or current fluctuations. A change in voltage can cause a change in the current supplied to the LEDs. LED output light corresponds to your current availability and the LEDs are rated to operate within a certain current range (measured in amps). Therefore, the current strength is too much or too little current cause the output light to vary or decrease rapidly due to the high temperatures inside the LED.

Fig 2.14 : LED Driver

TYPES OF LED DRIVER

• Current Continuous Type

A feature of the current drive is that the current output is constant. The Output voltage is adjusted at one point.

Fig 2.15 : Constant Current Driver

• Continuous Voltage Type

Power LEDs require a constant output voltage with a large output current. For LEDs, the current is already controlled, either by simple resistors or internal constant-current driver, inside the LED module. These LEDs require a single stable voltage, usually 12V DC or 24V DC

Fig 2.16 : Constant Voltage Driver

CHAPTER – 3
CLASSROOM LIGHTING

Classrooms need good lighting to make learning easier. From a practical point of view, it needs to have enough light and the right kind of lighting to do homework. Finally, lighting has been shown to improve character and increase productivity in the workplace. That may extend to learning areas such as schools. Classroom lighting influences students' circadian rhythm. Of course, the quality of student sleep that they receive has a direct bearing on the schools' assessment, behaviour, and presence.

Fluorescent lighting systems are the most widely used in schools today. The main focus of lighting design is on energy and cost savings rather than job preparation.

3.1 Basics of classroom lighting

Lighting in the classroom is very important in the lives of students. Lack of exposure to light has a negative effect on sleep cycles. These rhythms promote the production of hormones, the sleep cycle and the major body cycles. The short wavelength of blue light in the daylight spectrum has positive effects especially on the human circadian rhythm. When these rhythms are disturbed, people are at greater risk for insomnia, emotional disorders and other health problems.

Fluorescent lighting fixtures are very common in modern schools and classrooms. The main reasons for the high availability of fluorescent bulb are low cost, good color and low levels of blinking and noise. There are not enough schools, however, that have developed different lighting levels in their classrooms. Many different functions are performed in these spaces, and there is usually a single level of illumination.

A good lighting designer and lighting test are important tools for determining the best lights for the best areas of school work such as reading, writing, and presentations. Each function has a different lighting consideration.

According to a survey of 20 primary schools, about 60 percent of schools with fluorescent lamps are fitted with more than 500 Watt power. These programs are in many cases based on needs dating back to about 1980. Since then many things have changed. For example, computers have become part of classroom education. The vast majority of children with physical and mental disabilities attend traditional schools. These features and advanced lighting technology are forcing re-imagining of school lighting that includes receiving LEDs in schools and using functional lighting.

The role of enlightenment in the acquisition of knowledge and learning process is fundamental. Allows visual exploration of visual cues for research studies and the acquisition of concepts in written and pictorial representations on paper, computer, and speculation. Enlightenment also sets the stage for listening, verbal communication, community skills development, and understanding situations. As an important design element that greatly influences how space meets the needs of students and faculty, classroom lighting should support health, well-being, and functionality by providing a comfortable, attractive environment for students and faculty. In addition to enhancing community satisfaction and supporting educational experience within the enlightened environment, enlightenment in schools and educational institutions should be brought within the confines of the affirmative code.

3.2 Classroom lightning and Its effect on Learning

There are different types of lighting in the classroom, but it is not known that there are actually measurable differences in the way the students read. Fluorescent lights are fashionable in many schools, offices, and other commercial areas, but this is not the best type of lighting to encourage reading.

Studies have shown that fluorescent light can cause headaches and migraines, increase anxiety, reduce concentration and create a general feeling of discomfort after prolonged exposure.

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3.2.1 Does Classroom Light Affect Learning?

The answer is yes. The human body is not designed to be subject to artificial light and to desire natural light where it is available. Therefore, if students are only exposed to fluorescent light, they may experience concentration problems, anxiety, and more while in school. Fluorescent lamps adversely affect human natural circulation rhythm, leading to sleep problems. Students who do not get enough rest will face many problems because they do not feel awake during the day. All of these factors affect the performance of learning, learning, production, and more in the school.

While there are techniques that can be used to help combat this in classrooms, providing limited exposure to even daylight, full light, or blue light like LED lights can help improve the study environment, provide measurable results for classroom assessment scores and more.

3.2.2 What Is the Impact of Fluorescent Light?

The traditional ceiling lights, which are very white are used in the offices, in shopping malls, in classrooms, and in some cases, in homes. This is because fluorescent lighting is cheap, provides energy efficiency, and is easy to install in any room. But just because it does not take much time to install it does not mean it is a good solution for the job.

In fact, it could even harm human health and the health of the students. Studies have shown that it can cause migraines, headaches, eye fatigue, sleep problems, depression, anxiety, and more[3]. The body prefers to be under natural sunlight, and if not, an impact on the student's behaviour can be seen.

3.2.3 What kind of lighting is better than Fluorescent lamps?

Not all teachers can choose which light to use in classroom, but one should get something full of spectrum or blue light. This includes LED lighting. This type of classroom lighting is better than fluorescent lamps for many reasons. Lights save energy so they do not touch bottom line. LED do not blink, which means that those light headaches and migraines, eye fatigue, and sleep problems will be a thing of the past. These lamps do not contain mercury, so there is no risk of exposure to this harmful substance. As children spend a lot of time in front of screens these days, too much blue light can be just as dangerous.

3.2.4 What Are the Recommended Light Levels ?

Different areas of classroom should have different levels of light or luxury. For example, the front of the classroom near the board should be brighter, while one can dim the lights in some areas to help reduce exposure to strong light. To promote good conditions in classroom, consider using at least 150 lux[4]. Wall lighting should be more than 75 lux, and ceiling lux should be more than 50 lux.

- **How Can the Light of the Universe be limited?**
  If natural light is used in the classroom, this is optional, though shadesare required Even a combination of natural light like windows and artificial lighting will help the class more than fluorescent light bulbs. If there is no access to sunlight for the floors underground or in the middle of a building, the designers can design strategies to surround the negative fluorescent light in the light of the classroom.

  There are light filters that will reduce the negative impact of a fluorescent lamp by emitting light rays in classroom. Students in the class will notice improved performance when it is measured over bulbs and panels.. These are available in a different color or with a different design, helping the designer to change the shape of the room.

Proper lighting is beneficial, it plays an important role in improving learning in the years to come.

3.3 LED light Fixtures for schools and Educational Facilities

The role of enlightenment in the acquisition of knowledge and learning process is fundamental. It enables visual exploration of physical characteristics for research studies and the acquisition of concepts in written and pictorial representations on paper, computer, and speculation. Enlightenment also sets the stage for listening, verbal communication, community skills development, and understanding situations. As an important design element that greatly influences how space meets the needs of students and faculty, classroom lighting should support health, well-being, and functionality by providing a comfortable, attractive environment for students and faculty. In addition to enhancing community satisfaction and supporting educational experience within the enlightened environment, enlightenment in schools and educational institutions should be brought within the confines of the affirmative code.

3.3.1 Learning Environment

Educational institutions range from primary (elementary), middle schools, high schools, universities and colleges. Although these institutions have different types of facilities, they are all the same in that most of the learning and learning activities take place in the classroom. The standard classroom has a rectangular floor plan that allows for better viewing than a square plan. The teaching area is designed with visual cues attached to windows that provide daylight (sky) to enter space and provide sensory stimulation and visual contact with the outside world. Control media such as shades or curtains are used to reduce outdoor light to match the interior light, or to eliminate daylight when needed. Side lighting using daylight through the windows provides natural light most of the time during the school day. However, the light produced plays an important role in the need for a balanced, consistent, and manageable viewing environment.

The classroom structure is usually divided into a student area and a teacher's area. The student area always needs regular light, while the teacher's area needs extra light to bring direct light to the teaching boards and provide good modelling of the personal aspects of the teacher. A very common teaching tool for classroom boards, which includes grey and green chalk boards (black boards) and dry wipe boards such as white boards and grey boards. Video screens for the proposed media presentation are often used for computer-based teaching. This requires a light screen display to be minimized while sufficient ambient light should be provided in the reader area to take note. The classroom may be a computer space where reducing the screen display of video display terminals (VDTs) will be a major concern. Screen reading may be reduced by exposure to images produced by lights, windows and high bright areas around it.

3.3.2 Lighting Design considerations

Classroom lighting can be considered as high quality if it allows students and teachers to perform visual tasks accurately and comfortably. The basis of the lighting design is to integrate the needs of people, buildings, and the economy and the environment. The key to classroom lighting is to satisfy individual needs such as appearance, work performance, visual comfort, social media, health, safety, and well-being. These different human needs must be properly balanced in order to develop a stimulating learning environment, while taking into account economic, environmental and physical considerations. Achieving quality lighting involves more than just providing the right lighting to make a given task stand out. There are many factors that affect people's ability to see and perform tasks, the seven most important of which are gloss, light similarity, light contrast, blinking, colour appearance, facial modelling and objects, and veil visibility.

3.3.2 Luminance Contrast

Lighting is the amount of light that comes from a location or area. It is a function of higher light and higher visibility, which means that light can be increased by increasing the amount of light hitting the work surface or increasing the light intensity. Walls and ceilings often come with a matte finish in a bright colour. They create inter-reflections of light that can ensure optimal use of light in horizontal and vertical light enhanced while reducing illumination. The human eye responds to light, not to light. Light that leads to the harmony of light. The ability to see details is greatly influenced by the relationship between the light of an object and its immediate background. Proper differences between job descriptions and background information can create significant interest and provide tangible indicators. However, too much light variation will create difficulty with adjustment and blurred vision. The maximum light intensity between work and the surrounding area is 3: 1 (dark environment) or 1: 3 (light environment).

3.3.3 Colour appearance

Colour is an important part of lighting. It has an important relationship with light in terms of visual effects, emotions and biological effects. The degree to which visual activity, heart rate, mood, health, and well-being are affected depends on the spectral energy distribution (SPD) emitted by the light source. The light source can be determined by the temperature of its colour and its colour rendering function, both of which are determined by the SPD. The colour rendering of the non-illuminated objects themselves is a product of the interaction between the light source SPD and the visual function of the material. Some classes may require light that accurately renders colours. Colour rendering is one part of lighting. It is very important to look at the distribution of light energy and understand exactly how the colour of light will affect behaviour, satisfaction, psychological responses, and health. The colour of light sources — whether "warm" or "cool" in appearance has a profound effect on human health, productivity, and well-being.

3.3.5 Glare

Gloss occurs when illuminances, or illuminances ratios, are higher than illuminances or illuminances levels in which the eyes are adapted. The effects of glossing include paralysis (decreased visual acuity and visual function) as well as discomfort (unpleasant sensation of light that does not actually interfere with visual function or visual acuity). The glare may be caused by direct contact with the light from the light source (direct light) or by the reflection of high-intensity light from the bright spot (reflected light). Extra light correction may be assigned to the Unified Glare Rate (UGR) or Visual Comfort Probablity (VCP) to predict the glare of discomfort in internal operating systems. A maximum of 19 UGR or a minimum of 70 VCP is considered acceptable for reading, writing, and computer-based activities. If a high level of visual comfort is required, lights with 16 UGR or 80 VCP should be selected.

3.3.6 Flicker

Flicker is an amplitude modulation of light that is distracting and has several negative effects. Both fluorescent light bulbs and LEDs using low-power power can produce twice as much powerline frequency (i.e., 120 Hz or 100 Hz). Flicker is most commonly seen at frequencies above 70 Hz. However, blinking invisible to human eyes can trigger the nervous system's response. Both visible and invisible blinking are disturbing. Varying from person to person, blurred vision may cause eye strain, allergies, nausea, loss of vision, panic attacks, headaches, headaches, epilepsy, and evidence of worsening autistic conditions. In educational institutions where children or young people stay longer each day, stronger control should be exercised.

Vision display

Display of high light leaflets (bright images of light source) displayed on special areas such as computer screens or glittering reading materials. Exposure of the veil from primary light sources (widows or lamps) or secondary light sources (reflected) diminishes the brightness of the work and obscures the details. To ensure that no light sources create a special or diffused effect on the human eye, set up computer screens directly on the light source, or specify a light bulb with a small amount of light emitted from problem angles.

Face modeling and objects

Face-to-face modeling is an important light consideration in educational institutions. The interaction of light and shadow on the face can aid in teacher-student communication by making the lips easily readable and the touch of the face easier to interpret. Lighting can add shape and depth to a visual space, reveal textures and details of objects, create a desirable pattern and highlight highlights and tangible interests. Strong direct light may cause a deep shadow that does not fade, whereas diffused light makes the face or objects appear flat or unattractive. Therefore, the right combination of direct and diffused light is desirable.

3.4 General Lightning

General lighting is the main source of Illuminance in the classroom. It provides space with perfect light at the same time and serves as the main source of lighting function. Ordinary lighting in the classroom can be achieved by using ceiling-mounted lighting systems with direct, indirect or direct / indirect distribution. Direct lighting provides uninterrupted light from the luminaire to the horizontal work plane. Indirect lighting transmits light to the ceiling, which also reflects light to the floor. Direct / indirect lighting provides both low and high light distribution. Straight lighting systems work well for delivering light, but can create harsh shadows, veil light, and unpleasant visual effects such as black ceiling and scallops in the upper areas of the wall. With ceiling-directed lighting, indirect lighting systems distribute light evenly over excessive light in the viewing field. Indirect lighting, however, makes the space appear dim and blank for highlights and tangible interests. Direct / indirect lighting incorporates the benefits of direct and indirect lighting to provide a balanced light distribution to achieve optimal visual comfort, uniform brightness in the horizontal workspace, and enhanced visibility of visibility, visual acuity and clarity.

Despite the concerns of producing glare and the effect of the cave, direct light is probably a universal option in the classroom simply because most educational areas have low roof heights. Direct lighting is usually provided in the form of recessed lighting, flush light or suspended lighting. Specific lighting fixtures can be designed in a variety of shapes and sizes. In educational institutions, the most commonly used rectangles are rectangular cords designed for grid roofing and line lights designed for retreat, mounting and mounting mounting brackets. Troffer is available in the form of volumetric troffers, parabolic troffers, diffused / lens troffers, and LED panels with light at the edge. Line light adjustment comes in sections of standard length, such as 4, 8 or 12 meters, or in continuous configuration.

Lighting Technology

Over the past few decades lighting classrooms and other educational spaces has become a specialized state of fluorescent lighting technology. A fluorescent lamp uses electricity to cool mercury vapor inside a glass tube. Mercury vapor is released to release ultraviolet (UV) light which in turn causes the absorption of phosphorus into fluoresce, producing light in the visible spectrum. Fluorescent lamps have gained widespread use due to their high brightness performance, widespread light distribution, and long service life. However, the use of fluorescent lamps is controversial. Fluorescent lamps have many disadvantages such as ultraviolet emission, long start time, radio interference, high vulnerability, harmonic distortion, limited range of operating temperatures, and reduced life expectancy due to frequent changes. However, the worst effect of fluorescent lighting is that it greatly reduces the level of internal light and poses health risks. Excessive concentrations of light efficiency have caused many fluorescent light sources to malfunction in colour production and bring about high colour temperatures (6000 K - 6500 K) which can have a detrimental effect on human circulation rhythm and raise anxiety. danger of blue light. Because a fluorescent lamp requires a ballast to control the current brought by the lamp electrodes, a blinking problem arises. When it comes to lighting quality, fluorescent lighting is a bad start especially in the history of lighting done in indoor areas.

Solid lighting based on light emitting diode (LED) technology is gaining momentum. LEDs have become the leading light source for every illumination imaginable. LED is a semiconductor device that converts electrical energy into photons. A semiconductor device has a p-n junction formed by opposite layers of semiconductor material such as indium gallium nitride (InGaN). When the p-n junction is biased in direction, electrons and holes are inserted into the active surface and reconnected to produce light. LED technology has faced many challenges of conventional technology and offers the promise of high efficiency, long life, high spectral flexibility, special controls (opening / closing / dimming), high flexibility in optical construction, and high resistance to shock and vibration. LEDs produce only radiant energy in the visible spectrum (frequency from 400 to 700 nm). The absence of ultraviolet (UV) and infrared (IR) radiation makes this technology suitable for use in sensitive individuals or in situations where radiation from normal light sources can be harmful to humans.

3.4.1 LED Light Fixtures

Long service life and high energy efficiency are significant advantages of LEDs. This leads to the common misconception that long lifespan and the high brightness of LED lighting systems is a fact. Fluorescent luminaire uses a set of lamps, e.g., T5 line (5/8 inch width), T8 (1 inch width), and T12 (11/2 inch width), which are standard for the whole industry and for all manufacturers with the same lifespan. , light output and lumen retention. The fixture acts as a lamp frame and provides limited light distribution. In contrast, LED lighting is generally a highly designed system that integrates LEDs with low temperature, electrical, and optical systems to provide an acceptable product. System performance and operating life of an LED lamp are highly dependent on system design and construction. The life expectancy of an LED lamp is based on the initial time the light needs to be adjusted, which may be due to lumen retraction, color change, malfunction or sudden failure of the LED drivers.

LEDs are the most efficient light source available today. However, more than half of the electricity supplied to LEDs is converted into heat. Unlike incandescent and halogen lamps that emit heat without lamps in the form of infrared energy, the heat generated by LEDs is trapped inside semiconductor packages and must be dispersed by the luminaire itself. Excessive heat inside LEDs can speed up the deterioration of chip, phosphorus, and packaging materials. High junction temperatures have been shown to cause multiple failures such as nucleation and separation of the diode in the active part of the diode, degradation of phosphor quantum efficiency, and discoloration of encapsulant and plastic housing. Therefore, effective thermal management is essential for the performance of LEDs in their limited service life. Hot design is a very important part of luminaire design. All building materials and components of the thermal line from the semiconductor die through a printed circuit board (PCB) to the surrounding area must have low temperature resistance. The performance of a thermal design is highly dependent on the ability of the thermal sink to dissipate heat through thermal conduction and convection. Extra light fixtures such as troffer and line pendants usually provide sufficient volume to create an overhead space that transmits heat exchange.

More often than not, the point of failure or malfunction in the LED system is the LED driver. Since LEDs are sensitive to even the smallest current and voltage fluctuations, LED circuit breakers should be configured to control output at constant intensity under voltage or load variability. Active LEDs with proper current drive are also part of the heat management. Excessive driving what the LED is limited to will increase the mixing temperature and reduce the efficiency of the internal quantum of the LEDs. Driver key performance metrics focus on their ability to control the power of the LED or LED unit (or cords) efficiently and effectively, while bringing the element of high power and complete harmonic distortion (THD) over a wide range of input power. The driver should also provide protection features for overloading, open and short conditions, as well as temporary power outages and smart overheating protection. However, some lighting manufacturers are constantly reducing costs by designing drivers' circuits. This not only makes the driver's circuit reliability vulnerable, but also makes the problem worse because low-cost drivers often provide incomplete ripple pressure. It is generally not accepted that the current ripple value of the output is more than ± 10%.

Visual design is a key factor in the development of LED systems. The same brightness in a large area or work plane calls for the use of a large number of central power LEDs. Extracting the high energy of these small light sources makes the reduction of glare a precursor. LED lights come in a variety of distribution features that are achieved using visual aids such as diffusers, lenses, displays, and louvers. Direct light from LEDs can be reduced by distributing light to large areas. Lenses covering a series of small prisms can reduce the luminaire brightness at viewing angles near the horizontal surface. Reflection is a commonly used method of controlling the flow of light from LEDs. Volumetric lamps are a type of "straight" light that reflects light on the interior of a recessed house, while LED modules that emit light up are protected or hidden in metal baskets supported by split acrylic. Edge-lit LED panel lights inject light into the light guide (LGP) plate and then distribute the light evenly to the diffuser using a full indoor light (TIR). The ability to deliver uniform illuminated without creating excessively high luminance makes these recessed lumainaires a workhorse in educational facilities.

3.4.2 Color Rendering

Like fluorescent light, the trade off between color quality and brightness efficiency lies in the era of LED lighting. White LEDs are usually phosphor-converted LEDs that use a short wavelength light emitted from LED dies to pump phosphors (luminescent material). Many phosphor-converted LEDs LED blue pumps slightly alter electroluminescence. The high color that gives the LED pump a blue pump requires a very large portion of the short output light wavelength to be turned down. This process of converting pump light into phosphorus light (photoluminescence) involves a large amount of Stokes energy loss. Transmission of light-emitting light (LER) with optical sensitivity may not work well despite the apparent scattering of light wavelengths. When combined with these effects, the brightness of the high-density LEDs that provide LEDs with an evenly distributed SPD across the visible field is low compared to high-density LEDs that are extremely saturated with blue and green waves.

As a result of planning for high efficiency and low cost, most LED lights used in educational institutions include LEDs with a color rendering (CRI) indicator of 80, acceptable (but far from ideal). In particular, the light emanating from these lamps is limited by the wavelength of the wave that gives full color. For the classroom to have a pleasant feel and colors to appear naturally, the light source must be able to initiate a visible reaction to all wavelengths in the visible spectrum. Educational institutions deserve to be illuminated with high quality color, e.g. 90 CRI. Although green pump LEDs can be designed to provide high color translation, violet pump LEDs are specially designed to produce a wide white light that delivers radiant energy in a wide range across the visible spectrum.

Science behind the Color of Light

The corelated color temperature (CCT) of a light source is intended to reflect the color of light (e.g., warm or cool). White light showing a warmer tone than CCT in the range 2700 K to 3200 K. White light with CCT in the range 3500 K to 4100 K is often referred to as having a "medium white" appearance. White light with CCT over 4100 K is referred to as a "cool white" appearance. Not all white light is equal, whether the appearance of white light warm or cool not only affects our vision and affects our emotions, but also has effects on the list of neuroendocrine and neurobehavioral responses. Generally, cool white is associated with a higher percentage of blue light in the spectrum and warmer white indicates a lower blue component in the spectrum.

Studies have found that blue light can stimulate photoreceptors in the retinal ganglion cell (ipRGC) of the retinal ganglion cell layer. IpRGCs transmit light into the sensory signals of a biological clock. The biological clock found in the suprachiasmatic nuclei (SCN) then regulates body temperature and releases endocrine hormones, such as melatonin and cortisol. A large enough amount of green bioactive light will activate the main biological clock to set the human body to get the day mode. Exposure to blue radiation was found to promote the production of hormones such as cortisol for stress response and awareness; serotonin to control stress and cravings for carbohydrates; and dopamine for relaxation, monitoring and muscle communication. Although it mimics the body's response to daytime exposure, exposure to green bioactive light also results in the suppression of sleep hormone melatonin. As it supports concentration, alertness and performance, the bright white light with high blue components is therefore often used during study hours.

Generally, cool white light with a CCT of about 4100 K is preferred for daytime lighting in educational areas. The maximum CCT of indoor light usually should not exceed 5400 K, which is the apparent temperature of the sunlight color that shines directly from the surface. However, the introduction of fluorescent lighting is accompanied by a sharp rise in the temperature of the color of the interior lighting. Light sources that produce high wavelength white light collected at the end of the blue spectrum have very high light intensity due to the small photoluminescence involved and high sensitivity of the spectrum over this spectral band. This makes CCT at 6000 K to 6500 K a common choice for educational lighting. However, high-resolution CCT visual acuity appears to be harsh and often causes color distortion due to the length of the illusion. Most importantly, exposure to blue rays at high doses throughout the day can depress the human body and make it difficult to maintain a smooth circulation rhythm.

Students often continue to experience intense blue rays during night training hours, leading to improper suppression of melatonin in the evening. The nightly release of melatonin from 9 PM to 7:30 AM is an important defense mechanism that supports vital regeneration and suppresses cancer cells in our body. In the evening, at least two hours before bedtime, high CCT and high lighting should be avoided. Moderate levels of warm white light, defined as 60 lux, are sufficient for small visible functions without circadian disturbances.

3.4.3 Tunable White Lighting

The effects of light on human health, well-being and performance have enabled the lighting industry to create a solution that can stimulate certain biological responses to focus on improved mindfulness, alertness, and function, while supporting circadian rhythm. The tuneble white light allows for a change in the temperature of the white light color, with the intensity of the light being controlled independently. This technology allows a flexible lighting system to be delivered throughout the day and allows you to adapt the lighting to the needs of the various target groups. Tuneble white lighting based on LED technology is a force that drives the rapid transmission of human centric lighting (HCL). Intermediate human lighting is designed to enhance the rhythm of body rotation and the natural cycle of biological activities. It provides careful control of hormonal processes and learning environment throughout the complete design of visual, biological and emotional light effects. The intensity and intensity of indoor light can be adjusted to reflect the characteristics of natural daylight during the day.

Photobiological Safety

Armchair experts have been making noise with the danger of the green light of LED lighting. They say that green pump LEDs contain higher concentrations of green waves and are more powerful than other types of light sources to pose a risk of blue light exposure. Risk of blue light damage to the retinal image caused by chemical exposure to radiation in the wavelengths between 400 nm and 500 nm. Because white LEDs use green emitters to pump phosphorus down-n converters and there may be a high blue value in their SPDs, it does not mean that LEDs have the potential to cause photochemical damage to the retina. The white light of the appearance of different colors is basically the result of different combinations of long and short waves. There is a strong correlation between CCT and blue light regardless of where white light is emitted. The function of measuring the risk of blue light extends over a range of wavelengths. It is important to consider the extent of harmful radiation, rather than any altitude. The sum of the number of blue waves in the composition of the light emitted by LEDs is usually the same as the light emitted by any other light source at the same color temperature.

To reiterate: LEDs are not very different from light sources using traditional technology when it comes to photobiological safety. To blame for the use of CCT is too high in internal light. White light with a CCT over 6000 K contains a significant amount of blue light and is more likely to cause photochemical damage to the retina than white light emitted by low CCT light sources. The light limit for the risk group division as RG2 or higher is 1000 lux light source with CCT 6000 K, 1600 lux light source with 4000 K CC, and 3200 lux light source with 2700 CC CC, however, light risk separation the blue Risk Group 2 and 3 are less likely to be in all types of white light sources simply because the maximum brightness of educational applications rarely exceeds 300 lux.

CHAPTER – 4

COMPUTER-AIDED LIGHTING DESIGN OF A TYPICAL CLASSROOM

4.1 Introduction:

The primary activity in a classroom is reading and writing. So sufficient illuminance must be provided at desk level to satisfy the visual requirements of the occupant as well as visual comfort is provided at the same time. Generally an average illuminance of 300lux is considered adequate in teaching areas.

4.2 Design Parameters:

1. Illuminance (E) : It is the amount of luminous flux incident on a unit of a surface. The SI unit is lux.

2. Overall Uniformity (Uo) : It is the ratio of the minimum Horizontal Illuminance(Emin) to the average Horizontal Illuminance(Eavg) on the area under consideration. A good overall uniformity ensures that all surfaces on the area is sufficiently visible.

4.3 Lighting Design of a Typical Classroom:

Lighting design of a typical classroom has been carried out for 3 different light scenes.

- Daylight with 50% dimming of artificial luminaires.
- Daylight with 100% dimming of artificial luminaires.
- Daylight with 0% dimming of artificial luminaires.

4.3.1 Lighting Design of a Typical Classroom – Daylight with 50% dimming of artificial luminaires:

DESIGN INPUTS:

A 10m X 8m classroom is considered for design. Room height of the room is considered as 3m (False ceiling ht.) and also mounting height of the lighting fixtures is considered 3m.

REFLECTION PROPERTIES OF THE SURROUNDINGS:

This data helps in deciding the reflectance of the walls, floor and ceiling. According to National Lighting Code 2010, the reflectance values for major interior surfaces are considered as follows:

Ceiling: 0.6 to 0.9

Walls: 0.3 to 0.8

Working Planes: 0.2 to 0.6

Floor: 0.1 to 0.5

DESIGN CONSIDERATIONS:

For Classroom Lighting Design, following are the design considerations:

- Maintenance Factor is considered as 0.85.
- Room Surface Reflectance is considered as 80% (Ceiling), 50% (Walls) and 20% (Floor).
- Room orientation: North alignment is 0 degress from y-axis.
- Sky Type: Clear Sky.
- Daytime: 10:28 am

- Date: 05-06-2022
- Position of Window: 1) Distance from left-1m and distance from below-1m. 2) Distance from left-4.534m and distance from below-1m. 3)Distance from left-3.5m and distance from below-1m.
- Window Orientation: 1st is West facing,2nd is also West facing and third is North facing.

Considering all the above requirements and considerations, lighting design is carried out using Lighting Simulation Software like DIALux 4.13. 3D Rendering of a typical classroom is shown below with integration of daylight and dimming the artificial luminaires to 50%:

Room / Light scene_with_daylight_50%_dim / 3D Rendering

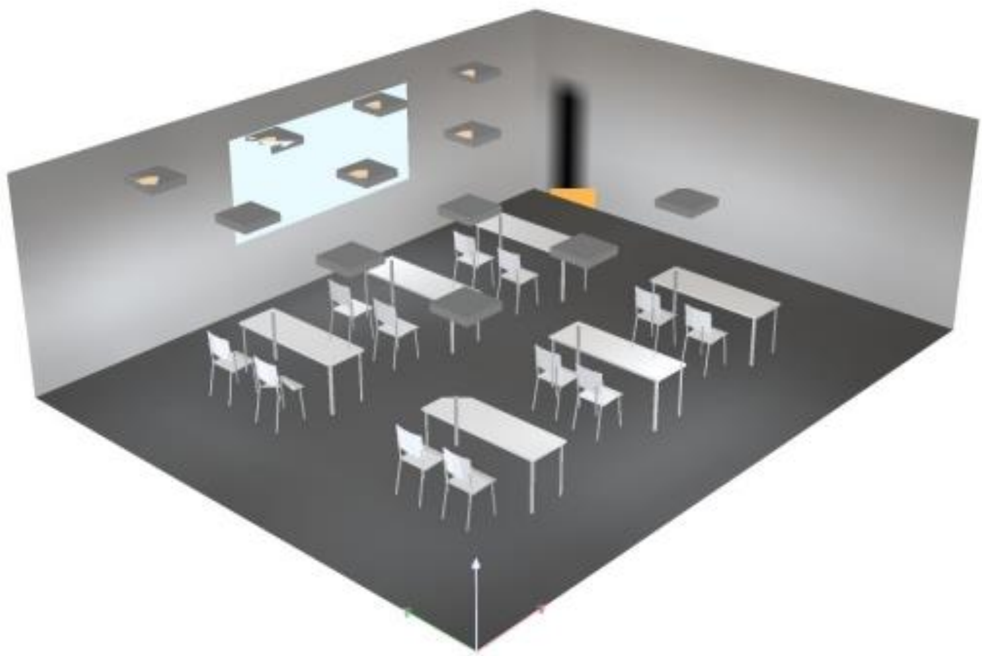
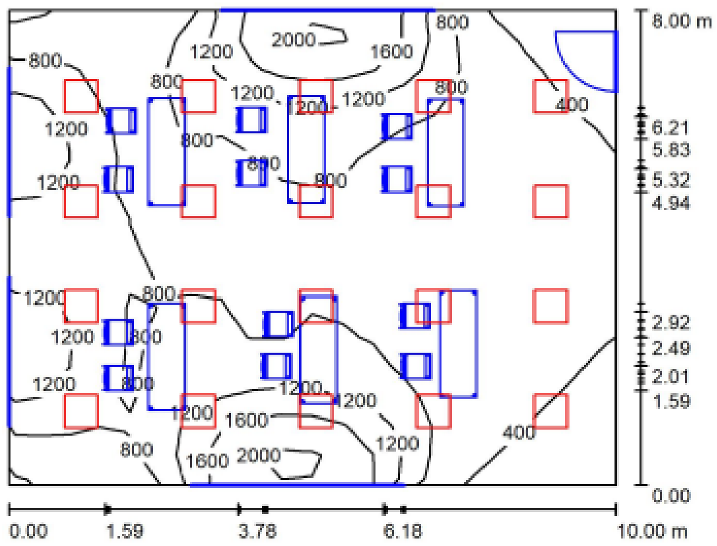


Fig 4.1 Typical Classroom-Daylight Integration with 50% dimming of artificial luminaires 3D Rendering

Room / Light scene_with_daylight_50%_dim / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.85 — Values in Lux, Scale 1:103

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	856	284	2119	0.332
Floor	20	668	306	1374	0.458
Ceiling	80	157	96	205	0.613
Walls (4)	50	391	154	799	/

Workplane:
Height: 0.760 m
Grid: 20 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.417, Ceiling / Working Plane: 0.184.

Fig 4.2 Typical Classroom-Daylight Integration with 50% dimming of artificial luminaires Summary

The DIALux summary page for the simulation has been shown in fig. 4.2.Workplane height has been considered as 0.76m from floor level.

Technical Details of Luminaires Used:

Lamp: 26W LED
Ingress Protection: IP20

Luminous flux (Luminaire): 2700 lm
Luminous flux (Lamps): 4100 lm
Efficacy: >100Lm/W
Dimension: 600mm X 600 mm
CCT: 5300K
Type: Suitable for plaster recessing.

4.3.2 Lighting Design of a Typical Classroom – Daylight with 100% dimming of artificial luminaires:

DESIGN INPUTS:

A 10m X 8m classroom is considered for design. Room height of the room is considered as 3m (False ceiling ht.) and also mounting height of the lighting fixtures is considered 3m.

DESIGN CONSIDERATIONS:

For Classroom Lighting Design, following are the design considerations:

- Maintenance Factor is considered as 0.85.
- Room Surface Reflectance is considered as 80% (Ceiling), 50% (Walls) and 20% (Floor).
- Room orientation: North alignment is 0 degress from y-axis.
- Sky Type: Clear Sky.
- Daytime: 10:28 am
- Date: 05-06-2022

- Position of Window: 1) Distance from left-1m and distance from below-1m. 2) Distance from left-4.534m and distance from below-1m. 3) Distance from left-3.5m and distance from below-1m.
- Window Orientation: 1st is West facing, 2nd is also West facing and third is North facing.

Considering all the above requirements and considerations, lighting design is carried out using Lighting Simulation Software like DIALux 4.13. 3D Rendering of a typical classroom is shown below with integration of daylight and dimming the artificial luminaires to 100%:

Room / Light scene_with_daylight_100%_dim / 3D Rendering

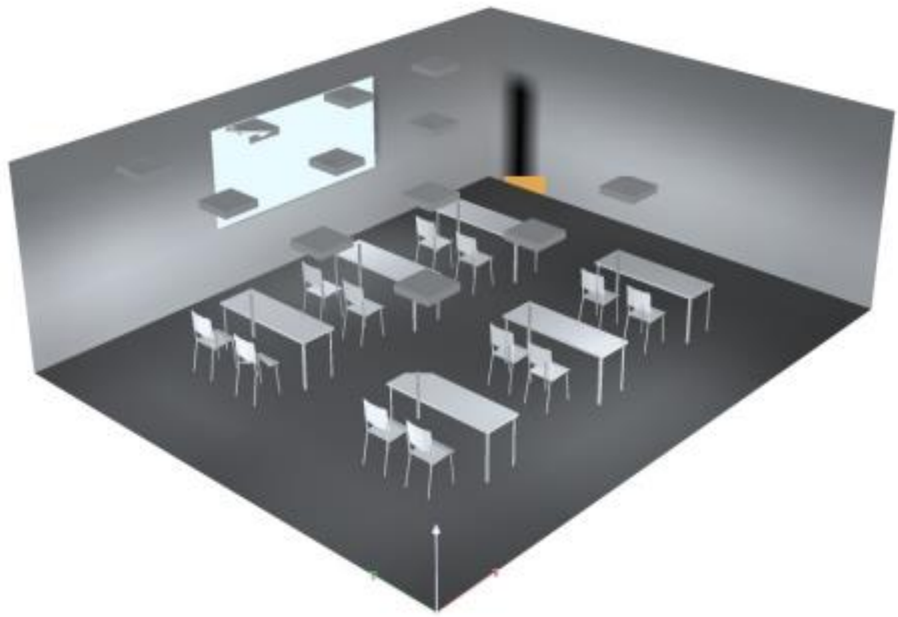
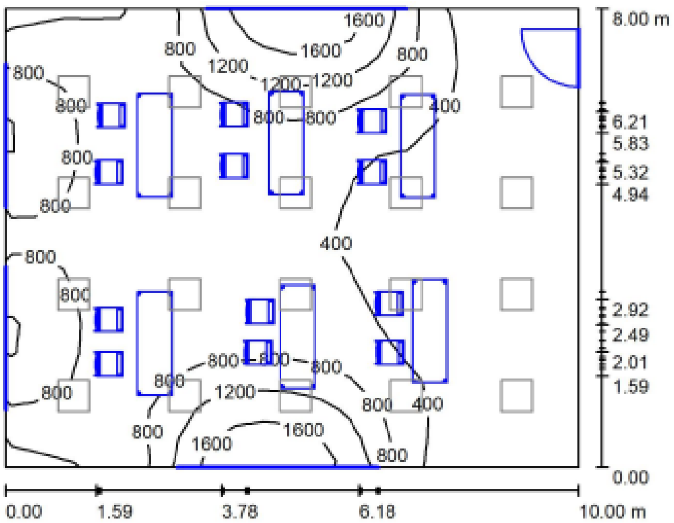


Fig 4.3 Typical Classroom-Daylight Integration with 100% dimming of artificial luminaires 3D Rendering

Room / Light scene_with_daylight_100%_dim / Summary



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:103

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	619	150	1901	0.243
Floor	20	489	153	1212	0.313
Ceiling	80	123	90	164	0.729
Walls (4)	50	278	92	680	/

Workplane:
Height: 0.760 m
Grid: 20 x 16 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.388, Ceiling / Working Plane: 0.199.

Fig 4.4 Typical Classroom-Daylight Integration with 100% dimming of artificial luminaires Summary

The DIALux summary page for the simulation has been shown in fig. 4.4.Workplane height has been considered as 0.76m from floor level.

Technical Details of Luminaires Used:

Lamp: 26W LED
Ingress Protection: IP20
Luminous flux (Luminaire): 2700 lm
Luminous flux (Lamps): 4100 lm
Efficacy: >100Lm/W
Dimension: 600mm X 600 mm

CCT: 5300K
Type: Suitable for plaster recessing.

4.3.3 Lighting Design of a Typical Classroom – Without Daylight:

DESIGN INPUTS:

A 10m X 8m classroom is considered for design. Room height of the room is considered as 3m (False ceiling ht.) and also mounting height of the lighting fixtures is considered 3m.

DESIGN CONSIDERATIONS:

For Classroom Lighting Design, following are the design considerations:

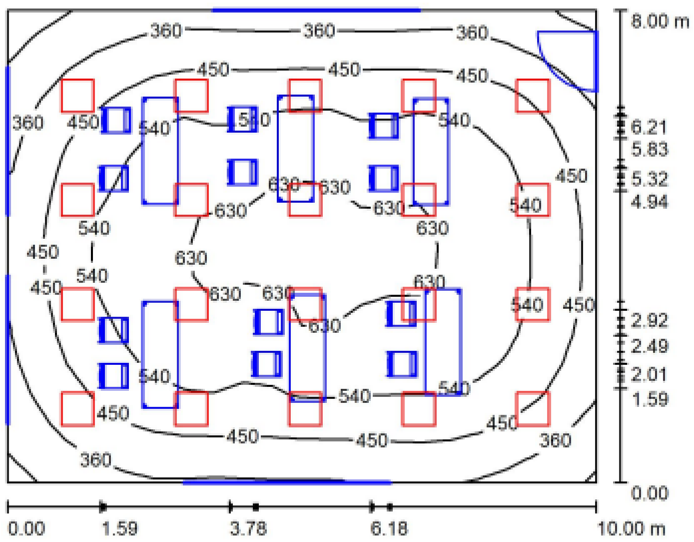
- Maintenance Factor is considered as 0.85.
- Room Surface Reflectance is considered as 80% (Ceiling), 50% (Walls) and 20% (Floor).

Considering all the above requirements and considerations, lighting design is carried out using Lighting Simulation Software like DIALux 4.13. 3D Rendering of a typical classroom is shown below without daylight:

Room / Light scene_without_daylight / 3D Rendering

Fig 4.5 Typical Classroom-Without Daylight 3D Rendering

Room / Light scene_without_daylight / **Summary**



Height of Room: 3.000 m, Mounting Height: 3.000 m, Light loss factor: 0.85 Values in Lux, Scale 1:103

Surface	ρ [%]	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0
Workplane	/	502	247	656	0.492
Floor	20	381	156	575	0.409
Ceiling	80	109	82	140	0.748
Walls (4)	50	254	99	395	/

Workplane:

Height: 0.760 m
Grid: 20 x 16 Points
Boundary Zone: 0.000 m

Illuminance Quotient (according to LG7): Walls / Working Plane: 0.520, Ceiling / Working Plane: 0.220.

Fig 4.6 Typical Classroom-Without Daylight Summary

The DIALux summary page for the simulation has been shown in fig. 4.6.Workplane height has been considered as 0.76m from floor level.

Technical Details of Luminaires Used:

Lamp: 26W LED
Ingress Protection: IP20
Luminous flux (Luminaire): 2700 lm
Luminous flux (Lamps): 4100 lm
Efficacy: >100Lm/W

Dimension: 600mm X 600 mm
CCT: 5300K
Type: Suitable for plaster recessing.

CHAPTER – 5

RESULT ANALYSIS

5.1 Introduction:

The Lighting Design carried out in the previous chapter should fulfil the visual requirements as well as it should be an energy efficient design. No conventional type of fixtures has been used in design. LED luminaires have been used in the design because of its advantages over conventional light fixtures.
Lighting Design has been carried out for average **500 lux** for classroom area which is in accordance to **IS 3634**.
Energy efficiency can be shown by evaluation of Lighting Power Density (LPD) values for different light scenes. Integration of Daylight in the classroom area further leads to energy savings.

5.2 EVALUATION OF LPD:

Lighting power density is a measurement that indicates whether a certain space offers scope for energy savings. “Lighting Power Density” (LPD) is defined as watts of lighting per square foot of room floor area (W/f^2) or as watts of lighting per square meter (W/m^2) of room floor area. LPD values are given in Energy Conservation Building Code (ECBC 2017) for an energy efficient building design. So recommended LPD values can be referred from ECBC.

5.3 LPD Comparison:

LPD value for the classroom area without daylight has come out to be 6.50 W/m^2 which is less than the limiting value of 9 W/m^2 for Classroom areas as per ECBC 2017.LPD value for the light scene with integration of daylight with 50% dimming has also come out to be 6.50 W/m^2.Therefore we can conclude that the design has fulfilled the visual requirements as per IS 3646 as well as it is an **energy efficient design.**

CHAPTER - 6

CONCLUSION

6.1 Conclusion

The thorough analysis of the proposed designs discussed in the previous chapter clearly shows that just by using LED luminaires instead of conventional fixtures, energy saving as high as 60% can be achieved. This when accompanied with proper lighting control implemented using occupancy sensors and daylight sensors, can achieve a further saving in energy which in turn reduces carbon foot prints and also the electricity bill.

The high cost for new installation or extra cost for replacement is generally returned within 6 to 7 years of installation/replacement through savings in energy. As LED lasts more than that it can be easily concluded that the LED lighting solution is completely viable for both the cases.

In the design shown in the previous chapters, the ECBC+ building ratings are achieved in all areas and superECBC building ratings are also achieved in some spaces indicating that LED luminaires can be used to easily satisfy the ECBC standards. Whereas, the conventional luminaires are having trouble in achieving the basic ECBC rating.

All the luminaires used in the design help in satisfying the illuminance criteria as per the IS 3646:1992 but in many areas, they fail to limit the maximum glare as per the standard suggesting that a more careful design of the luminaires should be considered so as to limit the maximum glare. Moreover, the intensity distribution of the luminaires can also be worked with, like using direct and indirect intensity distribution or using better diffusers, in order to reduce glare.

6.2 Challenges Faced

Most of the inputs for lighting simulations are dimensional data that are generally obtained from the CAD drawings. Some Important data like the colour of walls and floors or materials for walls, windows and doors etc are decided only after lighting design is done. Thus, some assumptions in values are required to carry out the lighting simulation which may result in variation from the actual measured values. Approximate input data used such as room dimensions, reflectance, light loss factor, furniture and architectural elements significantly affect the lighting calculations. If the actual site condition does not match the input data, differences occur between measured values and simulated values.

In many areas, the luminaire positions are already fixed owing to some constraints like AC ducts, smoke detectors, sprinklers. It is sometimes quite challenging for a lighting designer to achieve the standard values of illuminances and uniformity in those spaces using the given luminaire layout.

6.3 Future Scope of Work

As it is seen from the glare comparison of the simulation result obtained for LED and conventional light sources, the UGR values obtained with LED light source is higher than that obtained with CFL/FTL. In some cases, it is even higher than the recommended value. Work can be done to improve the intensity distribution of the LED luminaires so that the glare can be reduced. This can be done by using more suitable optics.

In this case only direct intensity distribution type of luminaires have been used. Further study with indirect and direct as well as only indirect distribution type of luminaires can be done. Those distributions can even help to reduce glare values.

Other newer methods for glare evaluation can be used to check the glare and then a comparison study can be done between these methods of glare evaluation and the UGR method.

Field evaluation of energy saving using the sensors can also be done so as to properly verify the cost savings.

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