I dedicate this thesis to my mother *Late* ***Lalita Bera*** whose love, unselfish support and example over many years laid the foundation for the discipline and application necessary to complete this work.

— Manjulika Bera

STUDIES ON EDUCATIONAL FACILITY LIGHTING SYSTEM

A thesis submitted towards partial fulfilment

of the requirements for the degree of

Master of Technology in

Illumination Technology and Design

Jadavpur University

Submitted by

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2019

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"STUDIES ON EDUCATIONAL FACILITY LIGHTING SYSTEM"** is a bonafide work carried out by **MANJULIKA BERA, Exam Roll No.: M6ILT19007** under my supervision and guidance for partial fulfilment of the requirement of **M.Tech. in Illumination Technology and Design** in School of Illumination Science, Engineering and Design during the academic session 2018 -2019.

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite 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 therein but approve the thesis only for purpose for which it has been submitted.

Committee of final examination for evaluation of Thesis ----------

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of her **M.Tech. in Illumination Technology and Design** studies during academic session 2018-2019.

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

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

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Date:

Place:

(Manjulika Bera)

Contents

Page No.

Page No.

Page No.

Chapter 1:
Introduction

1.1 General Overview

This Thesis work is a partial study of methodology and procedure adapted and involved in a proposed lighting design of an Educational Facility. In this study, the lighting design of the Educational Facility has been accomplished with the use of artificial lighting and in order to conserve energy, sensor is used to adjust the lighting to the optimum. The design has been proposed with LED light fixtures on the product catalogue of Indiabulls LED with whom the author worked as an internee while working at Mumbai Head Office and Kolkata Regional Office in the internship period from 9th July 2018 to 15th June 2019.

1.2 Objectives

The purpose of penning down the Thesis Work is to provide each step depiction of how seamlessly the framework built up by the architect in a computer readable CAD format which is culminated into actual light fixtures being installed in the existing Educational Facility which is being created and developed in lighting software to achieve the entire needs of lighting design.

1.3 Literature Review

Some paper studies established the concept of lighting design of Educational Facility lighting design.

1.3.1 Earlier Studies-[1]

'Studies of Lighting Vision in Schools'

by author R. G. Hopkinson, B.Sc. (Eng.), Ph.D. Fellow, Volume: 14 issue: 8_IEStrans, page(s): 244-268, Issue published: September 1, 1949.

Objectives of the Paper:

The distribution of visual acuity in a random sample of London school children in relation to the influence of illumination level and chalkboard reflection factor is described in this paper. This paper also presents the effect of illumination and contrast on visual acuity respect to ease and speed of reading which had varied from good to poor. This paper presents the influence of glare on reading along with the above mentioned objectives.

1.3.1 Earlier Studies-[2]

'Lighting affects students' concentration positively: Findings from three Dutch studies'

by PJC Sleegers PhD, Department of Educational Sciences, University of Twente, Enschede, The Netherlands; NM Moolenaar PhD, Department of Educational Sciences, University of Twente, Enschede, The Netherlands; M Galetzka PhD, Department of Marketing Communication and Consumer Psychology, University of Twente, Enschede, The Netherlands; A Pruyn PhD, Department of Marketing Communication and Consumer Psychology, University of Twente, Enschede, The Netherlands; BE Sarroukh PhD and B van der Zande, Philips Lighting, Eindhoven, The Netherlands,Lighting Res. Technol. 2013; 45: 159–175.

Objectives of the Paper:

This paper evaluates the effect of lighting conditions (with vertical illuminances between 350 lx and 1000 lx and correlated colour temperatures between 3000 and 12000 K) on the concentration of elementary school children in three experiments. In the first two experiments, a flexible and dynamic lighting system is used in quasi-experimental field studies using data from 89 pupils from two schools (Study 1) and 37 pupils from two classrooms (Study 2). The third experiment evaluated two lighting settings within a school-simulating, windowless laboratory setting (n 1⁄4 55). The results indicate a positive influence of the lighting system on pupils' concentration. The findings underline the importance of lighting for learning.

1.4 Organisation of the Thesis Work

The Thesis Work is reported sequentially as depicting general introduction which is included in Chapter: 1 , followed by mechanism of light generation from Light Emitting Diodes and its effect on human being in Chapter: 2.Chapter: 3 tells about lighting design requirements in designing of Educational Facility with associated National and International standards and recommendation that is specified in Chapter: 4 which describes about the Work-Place ,taken in this Thesis Work ,followed by methodology adapted and softwares taken in implementing the proposed lighting design in Chapter: 5.

Chapter: 6 describes about the detailed technical specification of the luminaires and lighting controls, used in designing the Educational Facility. The Chapter: 7 tells about the complete software simulation to achieve to the recommended values of the design parameters considered, as per National and International standards for each type of room ,taken inside the Educational Facility. The last section of this work that is Chapter: 8 consists of future aspect and scope of the lighting design accomplished here.

Chapter 2:
LED Technology and Human Factors

2.1 Electromagnetic Radiation

The name itself implies that the radiation which is created by the synchronized oscillations of electric charges in a generation of waves which incorporates electric field and magnetic field, moving orthogonal to each other at a velocity of $3 * 10^8$ m/s, shown in **Figure-2.1** [1].

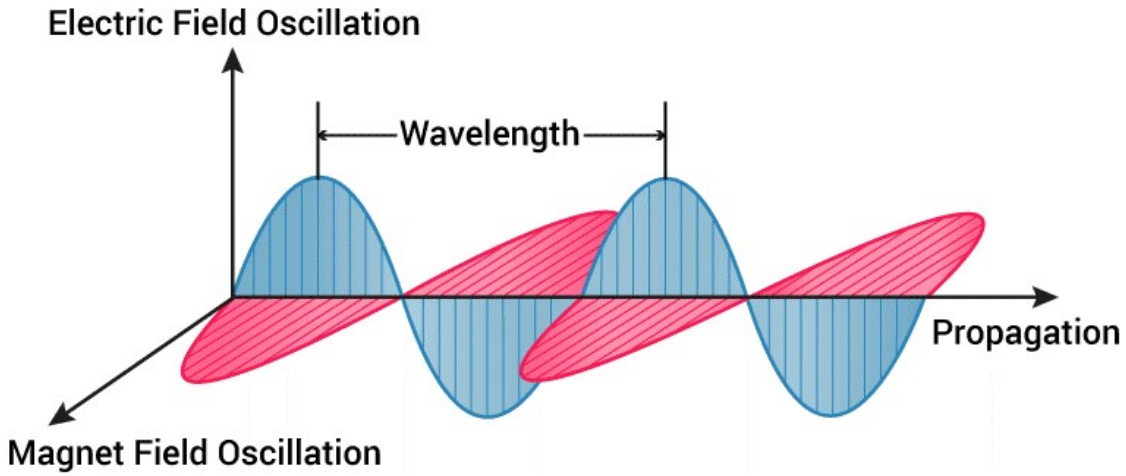


Figure-2.1: Electromagnetic Field

It includes Radio waves, Microwaves, Infrared waves, Visible light, Ultraviolet rays, X-rays and Gamma-rays, illustrated in **Figure-2.2** [1].They are omnipresent in wireless communication networks, infrared remote controllers for wireless local area network (popularly called 'Wi-Fi'), solar radiations, satellite radio and television networks, electrical devices and wires and many more.

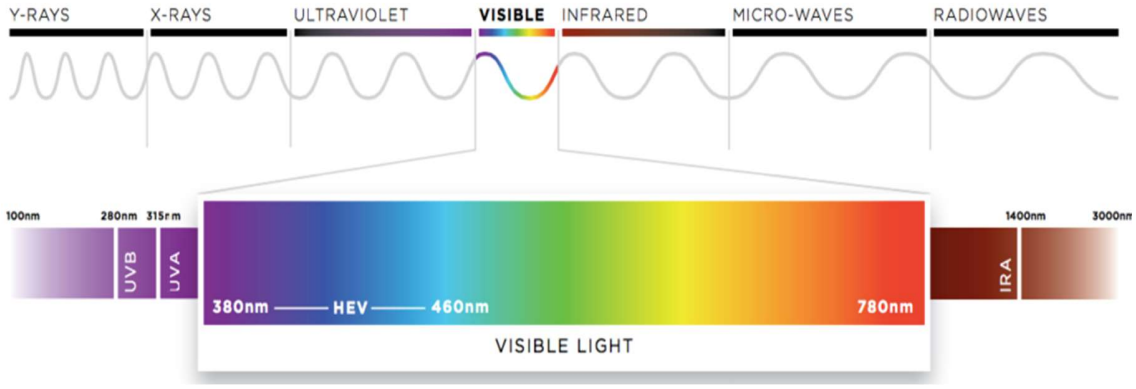


Figure-2.2: Spectrum of Electromagnetic Radiation

Electromagnetic radiation at wavelengths between the region of transition to X-rays (λ=l nm) and the region of transition to radio waves (λ=l mm) [1].The visible light refers to any optical radiation capable of causing a visual sensation directly, ranged between 380 nm to 780 nm. There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer.

Infrared Radiation refers to optical radiation for which the wavelengths are longer than those for visible radiation. For infrared radiation, the range between 780 nm to 1400 nm refers to IR-A, the range between 1.4 nm to 3 nm refers to IR-B, the range between 3 nm to 1 mm refers to IR-C. For ultraviolet radiation, the range between 100 nm and 400 nm [2] is commonly subdivided into:

IR-A: 780 nm - 1400 nm
IR-B: 1.4 nm – 3 nm
IR-C: 3 nm – 1 mm

Ultraviolet Radiation refers to optical radiation for which the wavelengths are shorter than those for visible radiation. For ultraviolet radiation, the range between 100 nm and 400 nm is commonly subdivided into:

UV-A: 315 nm - 400 nm
UV-B: 280 nm - 315 nm
UV-C: 100 nm - 280 nm

2.2 LED Technology

Light plays a central role in our everyday lives. While natural sources of light enable biological processes such as photosynthesis, cellular reactions, and other key life-sustaining processes, artificial sources of light have changed human lives in many ways by allowing us to be productive beyond sunrise and sunset. This section deals the process of light generation from Light Emitting Diode (LED) which in now a days, enhances the pace of technological and commercial growth in illumination field.

2.2.1 Physics of Light Generation from Light Emitting Diode (LED)

Light emitting diode is nothing but a specialized PN junction diode which emits light following the electroluminescence phenomenon. It is made from a very thin layer of fairly heavily doped semiconductor material. In an LED, similar to a diode, current easily flows from the p-side to the n-side of the semiconductor material when voltage applied to it in a forward-bias condition, but not in the reverse direction. When an electron crosses the barrier and meets a hole, it falls into a lower energy level and releases energy in the form of a photon. The photon is a carrier of electromagnetic radiation of all wavelengths. The actual wavelength of light generated and its colour is dependent on the band gap energy of the materials used to form the p-n junction, shown in **Figure-2.3** [3].

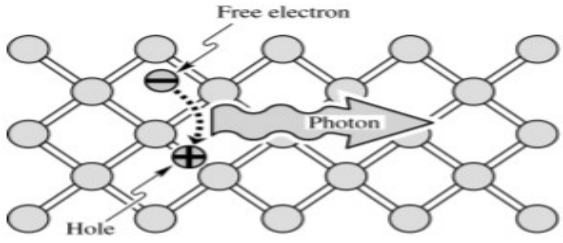


Figure-2.3: Mechanism of Light Generation in Light Emitting Diode (LED)

In the fabricated LED there are two legs connected with the diode, the longer leg is for applying positive voltage, called anode and negative potential is applied on the shorter leg or cathode to create the forward bias condition, is shown in **Figure-2.4** [3].

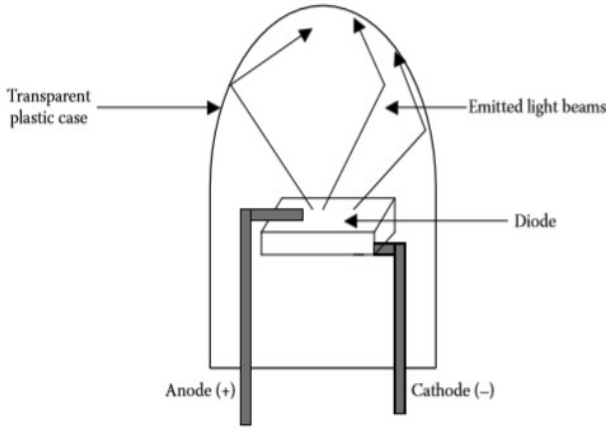


Figure-2.4: Fabricated LED

In earlier days, the LEDs were used to be monochromatic that is it could emit only single colour. Then it was very popular in traffic signals and other applications where single coloured light was required. In now a days, there are many different ways to convert monochromatic LEDs into white LEDs. These include:

a) Wavelength Conversion: Popular methods which are used for white light generation are blue LED and yellow phosphor; blue LED and several phosphors; ultraviolet LED and blue, green, and red phosphors. When light falls on the phosphor material, it gets excited and when the phosphor molecules comes into lower energy state it radiates energy in visible band. Sometimes mixing of single coloured light with the phosphor converted wavelength makes it appear as white light.

b) Colour Mixing: Minimum two colours are required for this technique. Blue and yellow light can be mixed in a suitable intensity which will give white light. Red, green and blue LEDs or sometime red, blue, green and yellow LEDs is also used to create white light.

c) Homoepitaxial ZnSe: In this method white LED is produced by growing a blue LED on a zinc selenide (ZnSe) substrate, which results in the simultaneous emission of blue light from the active region and yellow from the substrate and this two colours when come out of the hemispherical dome appeared as white light.

2.2.2 Effects of Light on Humans

Light has a great effect on human being. Light helps us to see, stimulates us and influences our moods and activity levels. Because our physiological response to light depends on the light's characteristics such as colour spectrum, intensity and timing, the characteristics of the artificial light in our surroundings will be of significance if we spend a lot of time in indoors. In Lighting Technology recent innovations of LEDs, tuneable white light can be achieved in an energy-

efficient manner which is easy to control with advanced control systems to meet human needs in many work areas. New smart connected lighting systems create endless possibilities with better user control. On this perspective, a new innovation in lighting field is Human Centric Lighting for people which is needed in an optimum manner to light control intelligently and it contributes to healthy biorhythms and satisfied workers in offices or in work areas that are optimally supported in their daily work. Light helps in maintaining the circadian rhythms, increased visual acuity, energy savings & sustainability and improved productivity, shown in **Figure-2.5** [4].

Figure-2.5: Light and Human Factors

Chapter 3:
Educational Facility Lighting

3.1 General Requirements

It consists of Visual Task Requirements and Visual Environment Requirements which follows:

3.1.1 Visual Task Requirements

The primary activity for a student is reading and writing. These may range from easy tasks of reading clear and bold printed matter to more difficult ones like maps or graph sheet work. They may also be fine and detailed work such as art work, analytical activity in laboratory etc. The difficult tasks also includes IC testing, simulation work or signal processing work. The difficult tasks would need higher levels of illumination.

The students may have to look up at the board from a distance while the teacher will be required to have a general surveillance of the whole class while teaching. Such distant viewing calls for a good level of illumination, considering also that the illuminance requirement increases with age.

The illuminance required is governed by the size of the object to be seen, contrast and period of viewing. Generally an illuminance level of 300 lx (horizontal) is considered adequate for teaching areas, 100 lx in corridors and 200 lx in gymnasiums. Higher illuminance should be provided for more exacting visual tasks by supplementary localized lighting. Where tasks with different requirements are to be performed at the same time in a space, the level of illuminance should satisfy the most demanding task. If this is defined for excessive levels, then levels lower than those may be adopted, with localized supplementary lighting for specific tasks which require higher levels such as drafting tables, chalk board etc.

Illumination in the vertical plane is required for good viewing conditions, especially on chalk boards, display charts, etc. In many applications, this requirement is automatically satisfied by the source meant for general (horizontal plane) lighting. Supplementary local lighting will however be needed in certain cases. For example, corridors, which not only serve as passage areas ,but may also be used for display of bulletins, charts, posters and notices and local lighting has to supplement the general corridor lighting.

In areas where colour rendition is an important parameter (for example, art rooms and chemistry laboratories the source should be selected for a high CRI).Fluorescent lamps are most commonly used for indoor applications. HID lamps can be used in gymnasium halls where colour is not that important.

In rooms where VDTs are in place, consideration for such areas should be given for good visual comfort, free from reflected glare.

3.1.2 Visual Environment Requirements

A student has to look at various objects with close attention for a long duration. There would be requirements of both nearby and far off viewing alternately. Where the eyes are required to adapt to vastly different luminance values for short durations at frequent intervals one is likely to experience discomfort and fatigue. In order that such viewing is without discomfort, the visual environment should be good.

3.2 Aspects of Good Educational Facilities

For a good visual adaptation, the lighting system and the environment should be coordinated so as to achieve the following end results:

a) Luminance of desk top, immediately adjacent to the task must not exceed the task luminance, or be below one third of the same.

b) No surface in view should have a luminance lower than one third of the task luminance.

c) Luminance of any surface in view should not exceed 5 times the task luminance.

d) Walls should have a reflectance of 40 to 60 percent, ceiling 70 to 90 percent and flooring is over 25 percent, so as to provide a comfortable luminance pattern [2].

e) Direct glare from the lighting should be avoided, as students will often have to look across the room, shifting their view from their desks at frequent intervals. Luminaires should have limited brightness from normal angles of viewing. The ceiling should be bright enough to allow the luminaires to be seen against a comfortably bright background environment.

f) Objects in critical view, namely, boards, paper (books) etc. need special attention for visual comfort. While chalk over black boards and dark marking pens over white boards, ensure a high contrast. Paper used in book, notebooks are opaque and matt, shiny sheet surfaces should be avoided. Printed matter should have liberal spacing between lines and print size should not be very small. All these aspects contribute to good seeing conditions.

g) Most of the classrooms have windows, bringing in substantial daylight. Direct sunlight should be prevented inside the classrooms. Glare should be avoided from the windows while getting the benefit of daylighting. These requirements are met through suitable provision of exterior appendages such as shades, blinds, louvers or baffles and roof overhangs and also by proper orientation of building. Daylight itself is a variable source and needs to be supplemented with an electric lighting system with necessary switching arrangements.

h) In lecture theatres in colleges, (where the room sizes are larger compared to schools) attention should be given for unobstructed viewing and dimming of lights for the use of various visual aids. This dimming facility may be needed in large halls where visual aids are likely to be used and also where practical experiments are conducted.

While designing for educational facility, lighting designer should have to identify some following information:

a) Indoor ambience

b) Type of visual task

c) Age group who are doing work in task area

d) Making area glare free

e) Maintenance Schedule

f) Type of lighting arrangement (i.e. general lighting, local lighting and localized lighting)

g) Daylight utilization

h) Dimming system is necessary or not

3.3 Design of Educational Facility Lighting

Design of the Educational facility lighting depends on two factors:

a) Quality Based
b) Quantity Based

a) Quality Based Lighting Design

Light quality effects on visibility of people to do visual tasks and how visually comfortable people feel. Quality based lighting design should be uniform in brightness and has no glare. The light sources should provide correct colour balance, directional control. Thus light source should be chosen with high CRI (> 70) and cool white to enhance the visual comfort in task areas of indoor based lighting system.

Good indoor based lighting design depends on three factors:

- Human needs
- Architecture
- Economics and Environment, shown in **Figure -3.1**.

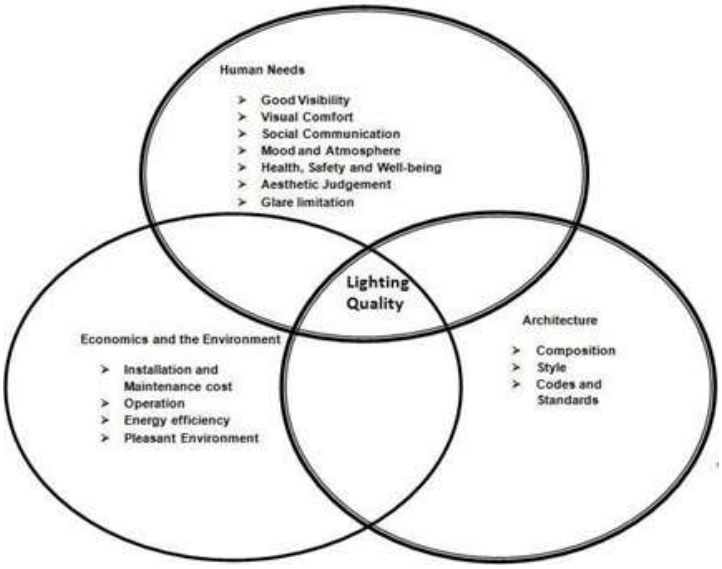


Figure -3.1: Quality Based Lighting Design Factors

b) Quantity Based Lighting Design

The quantity of light required to perform a specific visual task by selecting the proper illuminance value for indoor Educational lighting which is dependent on

- Age of the Workers
- Speed and accuracy of work in a visual task
- Visual size of object, brightness and contrast of object within task area
- Room surface reflectance

Older occupants need more light than young occupants. The need of light for visual task performance increases with age. Also to improve speed and accuracy of work desired lx level is required at a task area.

3.4 National and International Standards

There are many lighting design criteria and parameters based on which lighting designs are carried out. The lighting design parameters are guided and recommended by different International and Indian Standards. These recommendations give the concept for lighting design parameters. The mostly followed recommendations for indoor Educational Lighting Facility designs are given by Indian Standard IS 3646 Part-1:1992, ECBC 2017 and European Standard is EN 12464-1:2002(E) [2].

3.4.1 IS 3646 (Part 1):1992

The IS3646 Part I: 1992 was adopted by the Bureau of Indian Standards in 1992, after the draft was finalized by the Illuminating Engineering and Luminaires Sectional Committee that had been approved by the Electrotechnical Division Council. This standard is referred to the lighting design of those rooms in an Educational Facility which along with other building designs. This standard provides three illuminance values for every space. The lowest value is used where the contrast and reflectances of the task area high, the speed of the task is not very important and the task is seldom performed. The highest values are used where the contrasts and reflectances of the task are unusually low, visual accuracy or speed of task is of great importance with critical visual work. Sometimes, the visual capacities of the occupants require more light. The middle value is used at all other places.

In clause 4.2.2.2 of IS 3646 (Part 1): 1992, the recommended illumination which includes Type of interior or Activity, Range of Service Illuminance in lx, Quality Class of Direct Glare Limitation and Remarks for Educational Facility have been stated which follows:

It is stated in SL No. 21 of clause 4.2.2.2 of IS 3646 (Part 1): 1992 that sets illumination for Assembly Halls, Teaching Spaces, Lecture Theatres, Seminar Rooms, Art Rooms, Needlework Rooms, Laboratories, Libraries, Music Rooms, Sport Halls, Workshops in an Educational Facility, shown in **Table-3.1** [2].

IS 3646 (Part 1) : 1992

Table 1 Recommended Illumination

(*Clause* 4.2.2.2)

Type of Interior or Activity	Range of Service Illuminance in Lux	Quality Class of Direct Glare Limitation	Remarks
21.1 Assembly Halls			
21.1.1 General	200-300-500	3	
22.1.2 Platform and stage	—	—	Special lighting to provide emphasis and to facilitate the use of the platform/ stage is desirable
21.2 Teaching Spaces			
General	200-300-500	1	
21.3 Lecture Theatres			
21.3.1 General	200-300-500	1	
21.3.2 Demonstration benches	300-500-750	1	Localized lighting may be appropriate
21.4 Seminar Rooms	300-500-750	1	
21.5 Art Rooms	300-500-750	1	
21.6 Needlework Rooms	300-500-750	1	
21.7 Laboratories	300-500-750	1	
21.8 Libraries	200-300-500	1	
21.9 Music Rooms	200-300-500	1	
21.10 Sports Halls	200-300-500	1	
21.11 Workshops	200-300-500	1	

Table-3.1: IS-3646(Part 1): 1992 Recommended Illumination

3.4.2 EN 12464-1:2009(E) and EN 12464-1:2011

To enable people to perform visual tasks efficiently and accurately, adequate and appropriate lighting should be provided. The illumination can be provided by daylight, artificial lighting or a combination of both. The degree of visibility and comfort which is required in a wide range of work places, is governed by the type and duration of activity. This standard specifies requirements for lighting systems for most indoor work places and their associated areas in terms of quantity and quality of illumination. In addition recommendations are given for good lighting practice. This European Standard specifies lighting requirements for indoor work places, which meet the needs for visual comfort and performance. All usual visual tasks are considered, including Display Screen Equipment (DSE). This standard neither provides specific solutions, nor restricts the designers' freedom from exploring new techniques nor restricts the use of innovative equipment.

In section 6.2 of Table 5.6 of EN 12464-1:2009(E), the Maintained Illuminance ($\overline{E_m}$), Unified Glare Rating Limit **UGR**$_L$, Colour Rendering Indices (Ra) have been specified which follows as:

6.2	Educational buildings			
Ref. no.	Type of interior, task or activity	$\bar{E}_m$ lx	UGR_L -	R_a -
6.2.1	Classrooms, tutorial rooms	300	19	80
6.2.2	Classroom for evening classes and adults education	500	19	80
6.2.3	Lecture hall	500	19	80
6.2.4	Black board	500	19	80
6.2.5	Demonstration table	500	19	80
6.2.6	Art rooms	500	19	80
6.2.7	Art rooms in art schools	750	19	90
6.2.8	Technical drawing rooms	750	16	80
6.2.9	Practical rooms and laboratories	500	19	80
6.2.10	Handicraft rooms	500	19	80
6.2.11	Teaching workshop	500	19	80
6.2.12	Music practice rooms	300	19	80
6.2.12	Music practice rooms	300	19	80
6.2.13	Computer practice rooms (menu driven)	300	19	80
6.2.14	Language laboratory	300	19	80
6.2.15	Preparation rooms and workshops	500	22	80
6.2.16	Entrance halls	200	22	80
6.2.17	Circulation areas, corridors	100	25	80
6.2.18	Stairs	150	25	80
6.2.19	Student common rooms and assembly halls	200	22	80
6.2.20	Teachers rooms	300	19	80
6.2.21	Library: bookshelves	200	19	80
6.2.22	Library: reading areas	500	19	80
6.2.23	Stock rooms for teaching materials	100	25	80
6.2.24	Sports halls, gymnasiums, swimming pools (general use)	300	22	80
6.2.25	School canteens	200	22	80
6.2.26	Kitchen	500	22	80

Table-3.2: Lighting Requirements for Interiors (Areas), Tasks and Activities as per EN 12464-1: 2009(E)

EN 12464-1:2011includes Mean Cylindrical Illuminance($\boldsymbol{E_{cy}}$) **,** Modelling Index**.** The Mean Cylindrical Illuminance(E_{cy}) , Modelling Index have been considered as design parameters in this case study, apart from Maintained Average Illuminance($\overline{E_m}$), Overall Uniformity (U_o), Lighting Power Density (LPD) and Unified Glare Rating (UGR_L).The recommended value for these two design parameters follows below as per EN 12464-1: 2011 in **Figure-3.2**:

Figure-3.2: Recommendation for Mean Cylindrical Illuminance(E_{cy}) and Modelling Index as per EN 12464-1:2011

3.4.3 ECBC 2017

The name ECBC 2017 implies Energy Conservation Building Code 2017. There are two methods defined by ECBC 2017 that define Lighting Power Density (LPD) for each building type. The methods are:

a) Building Area Method
b) Space Function Method

a) Building Area Method

Determination of interior lighting power specification (watt) by the Building Area method shall be in accordance with the following:

- Determine the allowed Lighting Power Density (LPD) from each appropriate building area type.
- Calculate the gross lighted floor area for each building area type of ECBC 2017.
- The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area.

The recommended Lighting Power Density (LPD) value for Workshop and Motion Picture Theatre for this case study taken as follows in **Table-3.2**:

Room Category	**LPD (W/m^2)**	**Room Category**	**LPD (W/m^2)**
Workshop	14.1	Motion Picture Theatre	9.43

Table-3.2: Recommended Lighting Power Density (LPD) as per Building Area Method

b) Space Function Method

Determination of interior lighting power allowance (watt) by the Space function method shall be in accordance with the following:

- Determine the appropriate building type and the allowed Lighting Power Density (LPD).
- For each space enclosed by partitions 80% or greater than the ceiling height, determine the gross interior floor area by measuring to the centre of the partition wall and include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80 % partition height requirements [2].
- The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting power allowance for a space is the product of the gross lighted floor area of the space times than that of allowed lighting power density for that space.

The recommended Lighting Power Density (LPD) value for Storage, Meeting Room, Radiology, Corridor, Workshop, Stairway, Class Room, Library, Food Preparation, Conference Room, Electrical Room, Imaging, Transition, Lobby, Laboratory, lecture, Seating Area (Theatre) and Motion Picture Theatre for this case study taken as follows in **Table-3.3**.

Room Category	LPD (W/m^2)	Room Category	LPD (W/m^2)
Storage	6.80	Conference Room	11.50
Meeting Room	11.50	Electrical Room	7.10
Radiology	9.10	Imaging	9.10
Corridor	9.10	Transition	9.10
Workshop	17.10	Lobby	9.10
Stairway	5.50	Laboratory	15.10
Classroom	13.70	Lecture	13.70
Reading Area/Library	10.00	Seating Area(Theatre)	22.60
Food Preparation	12.10	Motion Picture Theatre	9.60

Table-3.3: Recommended Lighting Power Density (LPD) as per Space Function Method

3.5 Lighting Design Parameters

These are Lighting Level, Luminance Distribution, Uniformity, Direction of incidence of Light and Shadow Effect, Correlated Colour temperature, Glare and Colour Rendering Index, considered as generalised Lighting Design Parameters for any kind of indoor based design.

a) Lighting Level ($\overline{E_m}$): The lighting level generated by a lighting installation is usually qualified by the illuminance produced on specific working plane. The lighting level is termed as Illuminance and the illuminance is supposed to fall by an installation, which effects the performance of the tasks and the colour appearance of the working plane. It is measured in Lux or lx.

b) Luminance Distribution: The luminance distribution should be regarded as complementary to the design on the illuminance in the Educational Facility interior. The luminance distribution in the field of view controls the adaptation level of the eyes, which is related to task visibility. Luminance distribution should be taken into account by avoiding the glare.

c) Uniformity (U_o): The term uniformity for indoor Educational Facility lighting design defines the ratio of minimum illuminance value measured under the different grid points. According to the standards the task shall be illuminated as uniformly as possible. The uniformity of the task area and the immediate surrounding areas shall not be less than the specified values as per EN 12464-1:2002 (E), shown in **Table-3.4.** It is the ratio of minimum illuminance level ($\overline{E_{min}}$) to average illuminance level ($\overline{E_m}$).

Task Illuminance(Lux)	Illuminance of Immediate Surrounding Area (Lux)
≥750	500
500	300
300	200
≤200	E_{task}
Uniformity: ≥ 0.7	Uniformity: ≥ 0.5

Table-3.4: Recommended Uniformity as per EN 12464-1:2002(E)

c) Direction of Incidence of Light and Shadow Effect: Directional lighting may be used to highlight objects, reveal texture and improve the appearance of people within the space. Directional light of a visual task may also effect its visibility. Veiling reflections and reflected glare should be avoided to reduce shadow effect.

d) Correlated Colour Temperature: The colour of the light source also plays an important role in determining its CRI. Light of an artificial electric light source, does not follow the black body radiation, or the Planckian Locus given in **Figure 3.3**. Such a light source is assigned a colour temperature which very closely traces the Planckian Locus [5]. This colour temperature is called Correlated Colour Temperature (CCT), shown in CCT Scale in **Figure-3.4**, illustrated in **Table-3.5.**

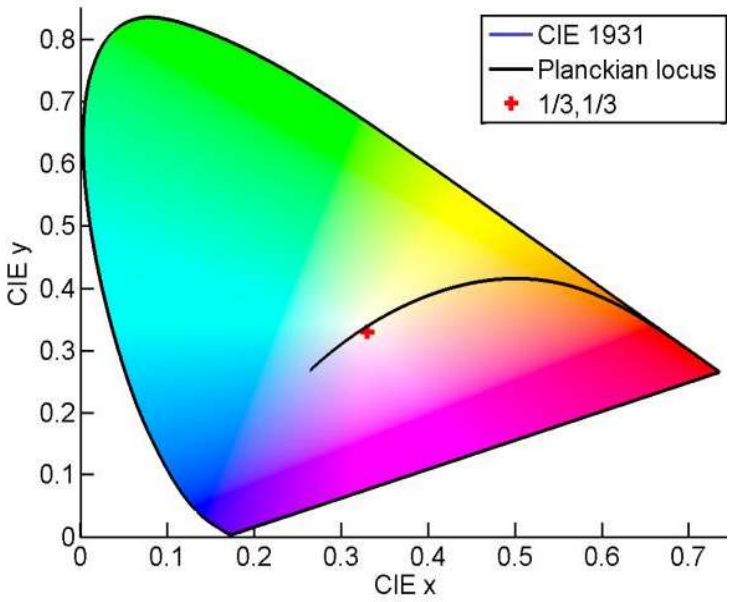


Figure 3.3: Planckian Locus

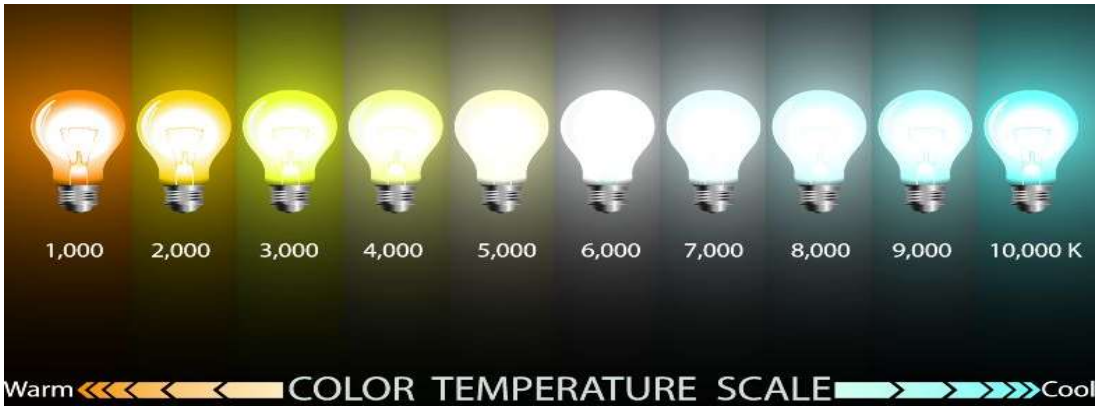


Figure 3.4: Correlated Colour Temperature (CCT)

Correlated Colour Temperature(CCT)	CCT Type
CCT≤3300K	Warm
3300K<CCT≤5300K	Intermediate
5300K<CCT	Cold

Table-3.5: Tabulation of CCT Range

f) Glare: Glare is very common term in lighting environment and possibly the most important lighting issue facing in Educational Facility lighting. Glare caused by relatively bright source than surrounding that makes it difficult to see or causes discomfort. Two types of glare that follows:

- **Disability Glare:** It is that type of glare which impairs one's visibility.
- **Discomfort Glare:** It does not necessarily prevent the viewer from the intended task, but constant adaptation of the eye to the varying light levels which in turn causes discomfort, and is generally measured by Unified Glare Rating (UGR_L), Glare Index etc. The mathematical expression as per EN 12464-1:2002(E) of Unified Glare Rating (UGR_L) is given in **Figure-3.5.**As per CIE the maximum allowable UGR values not only for various Educational Facility but also for any kind of indoor based design are given in the **Table-3.6.**

$$UGR = 8 \log_{10}\left(\frac{0,25}{L_b}\sum\frac{L^2\omega}{p^2}\right)$$

where:

L_b is the background luminance in cd × m^{-2}, calculated as $E_{ind} \times \pi^{-1}$, in which E_{ind} is the vertical indirect illuminance at the observer's eye,

L is the luminance of the luminous parts of each luminaire in the direction of the observer's eye in cd × m^{-2},

ω is the solid angle (steradian) of the luminous parts of each luminaire at the observer's eye,

p is the Guth position index for each individual luminaire which relates to its displacement from the line of sight.

All assumptions made in the determination of UGR shall be stated in the scheme documentation. The UGR value of the lighting installation shall not exceed the value given in clause 5.

Figure-3.5: Mathematical Expression as per EN 12464-1:2002(E) of Unified Glare Rating (UGRL)

UGR	Discomfort Glare Criterion
10	Imperceptible
13	Just perceptible
16	Perceptible
19	Just Acceptable
22	Unacceptable
25	Just Uncomfortable
28	Uncomfortable

Table-3.6: Unified Glare Rating (UGRL) Value

g) Colour Rendering Index (CRI): Colour rendering index (CRI) is the measure of the ability of a light source to render the exact colour of an object illuminated by the light source on a scale of 100. The low luminous-efficacy incandescent lamps have CRIs close to 100.With the advent of discharge lamps, the older filament lamps started to lose preference. This resulted in huge power savings, but the spectra of light produced were not continuous anymore. Their lights were seen to show distinct peaks at certain wavelengths, and very little energy in other parts of the spectrum. Colours with the wavelengths in which the spectral power distribution (SPD) was lower were not seen to show 'correct' colour under these lights. White light given by discharge lamps contains a greater proportion of its spectral energy in the blue region (380-495 nm). This resulted in lower CRIs. With the advancement in technology, this problem has been greatly taken care of. The Colour Rendering Index of various lamps to be used in Educational Facility is to be specified in below **Table-3.7.**

Colour Rendering Groups	CIE General Colour Rendering Index(R_a)	Typical Application
1A	$Ra \geq 40$	Wherever accurate colour matching is required.
1B	$80 \leq R_a < 90$	Whenever the accurate colour judgement is necessary and good colour rendering is required for reason purpose.
2	$60 \leq R_a < 80$	Wherever moderate colour rendering is required.
3	$40 \leq R_a < 60$	Wherever colour rendering is of little significance but marked distortion of colour is unacceptable
4	$20 \leq R_a < 40$	Wherever colour rendering is of no importance at all and marked distortion of colour is acceptable.

Table-3.7: Colour Rendering Index of Various Lamps

Chapter 4:
Case Studies

4.1 About the Work Place

This design report defines the brief description of various rooms which are proposed for computer science, electrical engineering block for the Educational Institute, situated in Hyderabad**.** All electrical installations will be carried out as per local codes, regulations and practices. Each type of room for the two Blocks of this Educational Institute AD-2 and AD-3 are included. Power supply for the proposed AD-2 Block and AD-3 Block will be obtained from existing LT panel (2 individual feeders required from substation for CS & EE blocks) through cable network at 433 V system voltages shall be done through underground LT cables from the source tapping point.

4.2 Detailing of the Floors and Rooms Considered in this Case Study

Room Name	Block	Floor	Length(m)	Width(m)	Height(m)
Auditorium	AD-3	First	24.74	18.83	8.9
H.O.D Room	AD-3	Fourth	5.6	3.0	4.2
Research Staff Room	AD-3	Fourth	6.1	5.920	4.2
Office Staff Room	AD-3	Fourth	15	14.10	4.2
Class Room	AD-3	Ground	10.910	8.1	4.2
Seminar Hall	AD-3	Ground	12.49	15.98	4.2
Teachers' Room	AD-3	Second	11.42	7.80	4.2
Power System Computation Workshop	AD-2	Second	36.33	10.13	4.2
VLSI CAD Workshop	AD-2	Second	11.00	17.13	4.2
Core Technician Workshop	AD-2	First	17.68	15.78	3.9
IC Testing and Characterization Workshop	AD-2	First	17.20	10.40	3.9
Dean’s Cabin	AD-2		8.71	7.44	4.2
Conference Hall	AD-2	First	11.45	8.80	4.2
Embedded System Laboratory	AD-2	Fifth	17.12	6.88	4.2
Speech Processing Laboratory	AD-2	Fifth	13.60	6.90	4.2
Power Electronics Laboratory	AD-2	Fifth	13.34	7.15	4.2

Room Name	Block	Floor	Length(m)	Width(m)	Height(m)
Signal Processing Demonstration Bench	AD-2	Fifth	17.13	6.9	4.2
Smart Grid Management System	AD-2	Fifth	8.74	6.6	4.2
Electric Drive Room	AD-2	Fifth	8.50	7.00	4.2
Server Room	AD-2	First	17.13	7.00	4.2
Library	AD-2	Fifth	17	11	4.2

Chapter 5:
Design Methodology Adapted

5.1 Introduction

This chapter is dedicated to the steps required in the designing the lighting of a given project. The architect prepares the building layout in a computer-readable format, preferably the CAD format. The layout contains all the intricate details, including the presence of doors, windows, fire hydrants, HVAC ducting, electrical wiring etc. It also provides the height of the floors and types of ceilings, whether true or false. The knowledge of the ceiling types is very important. This idea will be elaborated during the course of this chapter.

5.2 Softwares Used in this Case Study and Step by Step Lighting Design

Two softwares are used in this case study lighting design. These are:

- AUTOCAD 2019: CAD drawing software.
- DIALux 4.13: Lighting design software.

The CAD file is opened on the AUTOCAD software platform, shown in **Figure-5.1**.

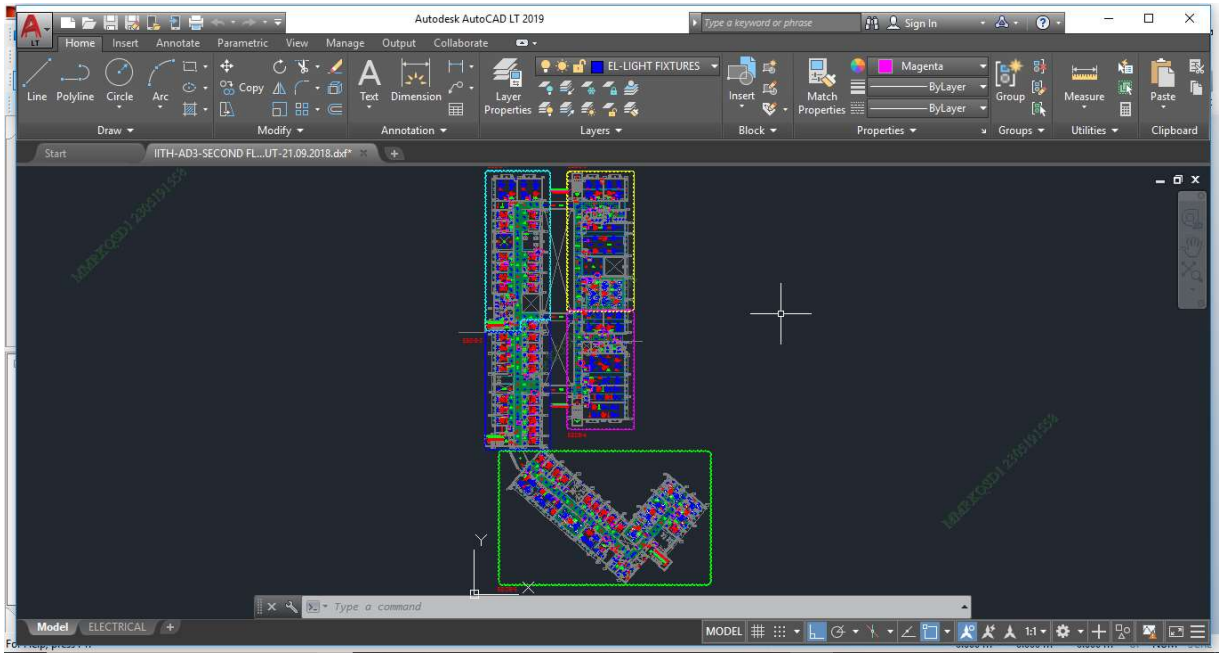


Figure-5.1: CAD drawing, opened in AUTOCAD 2019

It is carefully studied and necessary notes are made regarding the units of measurement (such as in millimetre, in feet etc.) and special information (sectional diagrams, objects), if any. The layers of CAD drawing may be turned on or turned off as per user's requirement. It is given in .dwg or .dxf format [12].

After this the CAD drawing file is imported by specifying respective unit of measurement (such as in millimetre, in feet etc.) into DIALux 4.13 going to the tab 'New Interior Project', which is shown in **Figure-5.2.**

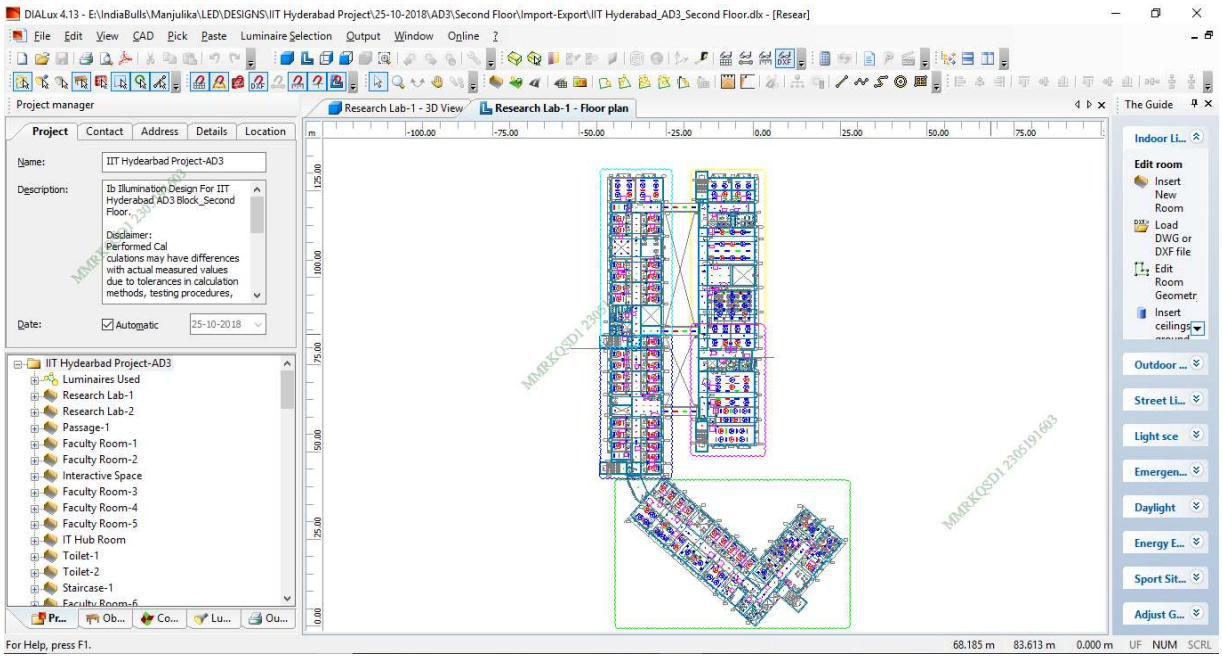


Figure-5.2: CAD drawing, imported into DIALux 4.13

Now, saving this DIALux 4.13 file will generate .dlx file format. The .ies files corresponding to the luminaires intended to be used in the simulation must be imported to DIALux 4.13 [13].The simulated result file is saved in .pdf format.

5.3 Design parameters to be achieved in this case study

a) Maintained Average Illuminance ($\overline{E_m}$)
b) Overall Uniformity (U_o)
c) Mean Cylindrical Illuminance (E_{cy})
d) Modelling Index
f) Lighting power Density (LPD)
g) Unified Glare Rating (UGR_L)

Chapter 6:
Luminaires Used

6.1 Introduction

In this Case Study, downlighter, 2x2 panel, linear fitting, linear batten type luminaire, and linear pendant type luminaire are used as per application area to meet lighting design parameters.

a) Glow Round

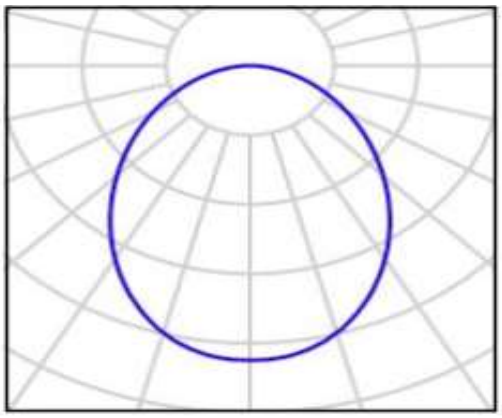


Figure-6.1(a): Physical Appearance **Figure-6.1 (b): Polar Diagram**

- Supply of lighting fixtures of recess mounted 6/9/12/15/18/24W edge lit LED round downlighter luminaire.
- The LED source used shall be complying with LM 80 standards and LED source efficacy >150 lm/W.
- Epoxy white powder coated die cast aluminium housing and efficient PMMA front visor.
- The system lumen output of the luminaire of a minimum of 90 lm/W system efficacy with colour temperature of 3000/4000/5700/6500 K and CRI>80.
- Integral driver with constant current constant voltage (CVCC), P.F >0.9, THD<20% and surge protection of at least 2.5kV**.**
- System lumen output is 540/810/1080/1350/1620/2160 for the respective Wattages.
- IbLED product catalogue no.IRDLR21RD-6XX/9XX/12XX/15XX/18XX/24XX [10], [11].

b) Sunglo

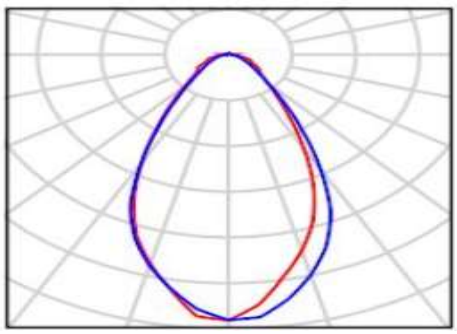


Figure-6.2(a): Physical Appearance **Figure-6.2 (b): Polar Diagram**

- Linear fitting.
- Epoxy Powder Coated CRCA MS housing.
- Safe operating voltage range - 140-270VAC.
- Power factor >0.95.
- Total current Harmonics <20%.
- Surge protection 2.5 kV.
- CRI >80.
- IP 54.
- Driver efficiency >0.85.
- CCT 5700K.
- Highly efficient LED having efficacy > 100 lm/W and 5000 Lumen.
- IbLED product catalogue no. IIBL01L-50WH.

c) Maxo

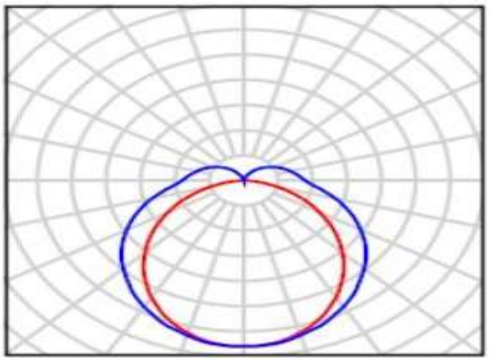


Figure-6.3(a): Physical Appearance **Figure-6.3(b): Polar Diagram**

- Epoxy white powder coated extruded aluminium housing.
- Efficient PMMA/PC front visor.
- High efficiency LED >120 lm/W.
- CRI >80.
- Life 50000 hrs.
- CCT available in 4000K/5700K/6500K.
- It is available in 18 W, 36 W.
- IP 20.
- IbLED product catalogue no.IIBN02-18XX/IIBN03-36XX [10], [11].

d) Quadglo

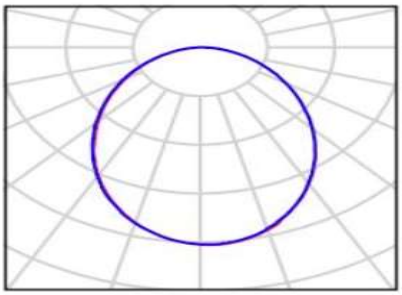


Figure-6.4(a): Physical Appearance **Figure-6.4(b): Polar Diagram**

- Supply of lighting fixtures of 30/36/42/60W.
- Recess mounted square LED luminaire with epoxy coated CRCA white powder coated housing, special translucent high transmitivity non yellowing (PMMA) diffuser.
- Colour temperature of 3000/4000/5700/6500 K and CRI>80.
- The LED source used shall be medium/high power complying with LM80 standards& LED source efficacy >150 lm/W.
- Non-integral 3 stage isolated Driver with constant current constant voltage (CVCC).
- P.F >0.95 and surge protection of at least >3 kV.
- System lumen output of the luminaire 3000/3600/4200/6000 Lumen.
- System luminous efficacy is of a minimum of 100 lm/W.
- IbLED product catalogue no.IMRC01-30WH/36WH/42WH/60WH [10]. [11].

e) Activ

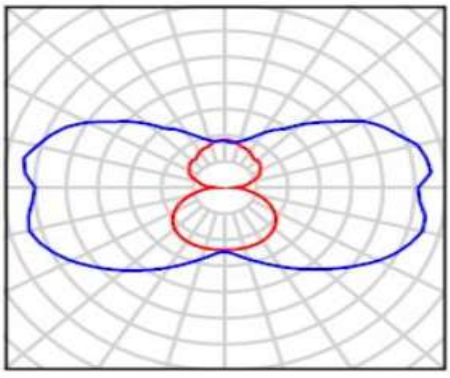


Figure-6.5(a): Physical AppearanceFigure-6.5(b): Polar Diagram

- Supply of linear suspended 28W downlight luminaire with epoxy grey powder coated aluminium extruded housing, special translucent high transmitivity non yellowing (PMMA) diffuser.
- Colour temperature of 5700 K and CRI>80.

- The LED source used shall be medium/high power complying with LM80 standards & LED source efficacy >150 lm/W.
- Integral 3 stage isolated driver with constant current constant voltage (CVCC).
- P.F >0.95 and surge protection of at least >3 kV.
- System lumen output of the luminaire 2800 Lumen.
- IbLED product catalogue no.IMSL04-28WH [10], [11].

Chapter 7:
Proposed Lighting Design

7.1 Lighting Simulation for Educational Facility

While designing in DIALux 4.13, certain parameters were set prior to design. These are followed as:

- Maintenance Factor has been considered to 0.8for the areas.
- Refection Factors for Ceiling, Wall and Floor has been considered as per standard office areas that is 0.8, 0.5 and 0.2.
- Height of the work plane has been taken at 0.76 m height from the floor.
- Due to the presence of false ceiling, some of the luminaires are recessed mounted, where needed.

7.2 Lighting Design of Types of Rooms in the Educational Facility taken as Case Study

An Educational Facility has a lot of different types of rooms. They can be divided broadly into following categories. Design of each category is presented below:

- Auditorium
- H.O.D Room
- Research Room
- Office Staff Room
- Class Room
- Seminar Hall
- Teachers' Room
- Power System Computation Workshop
- VLSI CAD Workshop
- Core Technician Workshop
- IC Testing and Characterization Workshop
- Deans' Cabin
- Conference Hall
- Embedded System Laboratory
- Speech Processing Laboratory
- Power Electronics Laboratory
- Signal Processing Demonstration Bench
- Smart Grid Management System
- Electric Drive Room
- Server Room
- Library

7.2.1 Lighting Design of Auditorium

a) Design Consideration: A modern functional and technologically equipped auditorium is vital for hosting wide range of event types. Higher universities require an independent auditorium due to the amount of time that the art department and athletic department need in order to meet their demanding curriculum requirements. Every university has their significant sized auditoriums. Popular events and guest speakers generate excitement and draw crowds. The design of this venue allows multiple uses and maximum flexibility.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Auditorium

- Maintained Average Illuminance ($\overline{E_m}$)=150lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =50 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

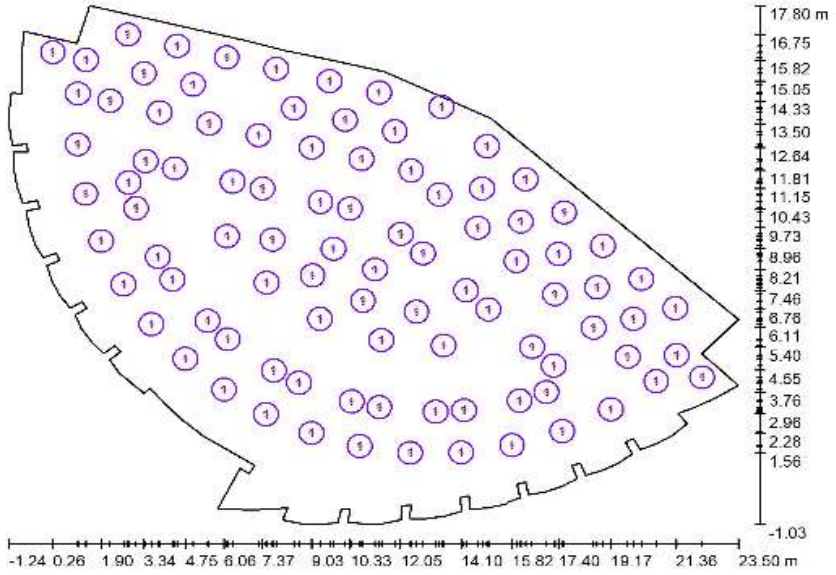
- Lighting Power Density (LPD) = 9.60 W/m^2.

In this section below the Floor Plan, Luminaire Layout, Lighting Report, 3D and False Colour Rendering, Simulated Output and Discussion are stated briefly.

b) Floor Plan:

Figure-7.1: Floor Plan View of Auditorium

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	95	lbLED IRDLR21RD-12XX (4000/5700/6500 degK) Recess Mounted LED Downlighter-Glow Round

Figure-7.2: Luminaire Layout of Auditorium

Luminaire Layout depicts luminaire arrangement inside the Auditorium, marked in Figure-7.2.Specifications on luminaire mounting height of the Auditorium, Light Loss Factor (LLF) and reflectance values, considered in the lighting design, mentioned below:

- Height of the room=8.9 m
- Light Loss Factor(LLF)=0.70
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

As the height of the auditorium is 8.9 m from floor level, Light Loss Factor is considered as 0.70, only for the lighting design of the Auditorium as the height is more compared to that of other rooms, the possibility of reaching illuminance on working plane after a certain period of time shall reduce for the time being. Apart from the lighting design of Auditorium, 0.80 is considered as Light Loss Factor (LLF) for other rooms, in this Educational Facility.

d) Lighting Report:

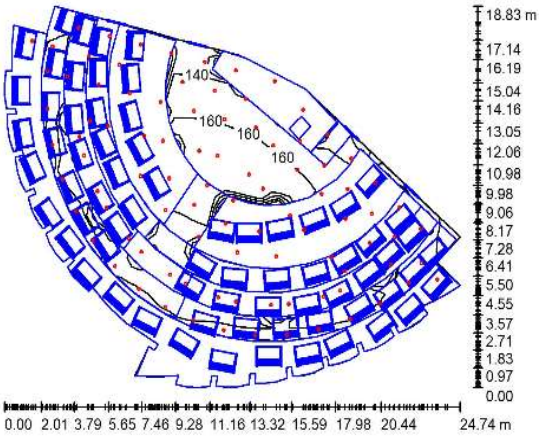


Figure-7.3(a): Isolines on Work-Plane

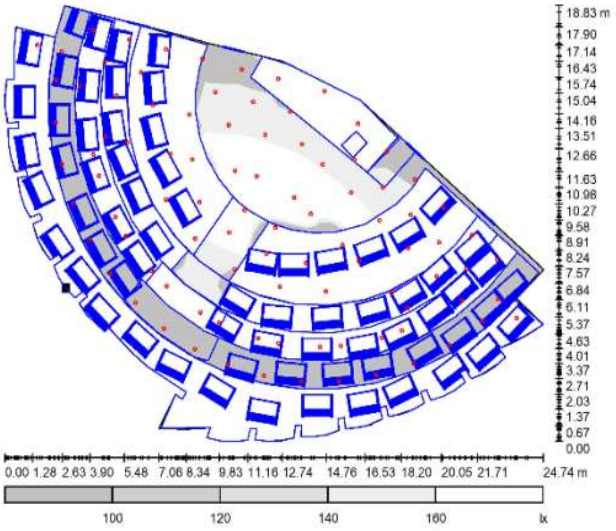


Figure-7.3(b): Greyscale on Work-Plane

e) 3D Standard View of Auditorium

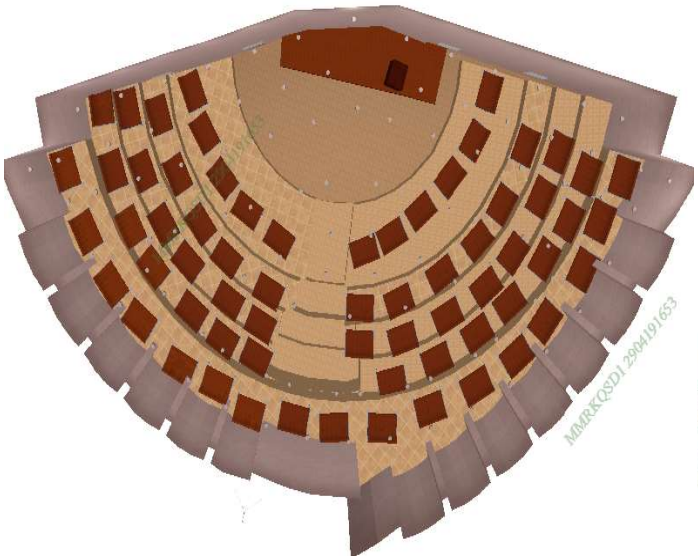


Figure-7.4(a): 3D Standard View of Auditorium

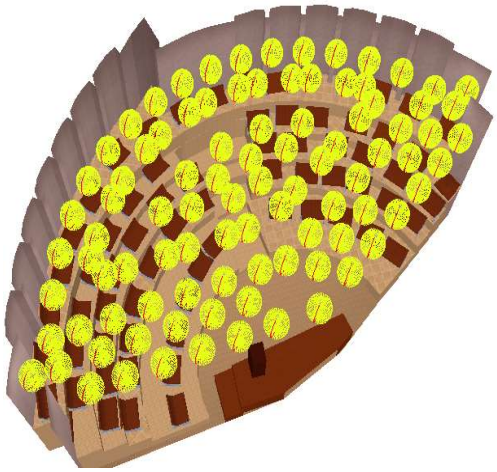
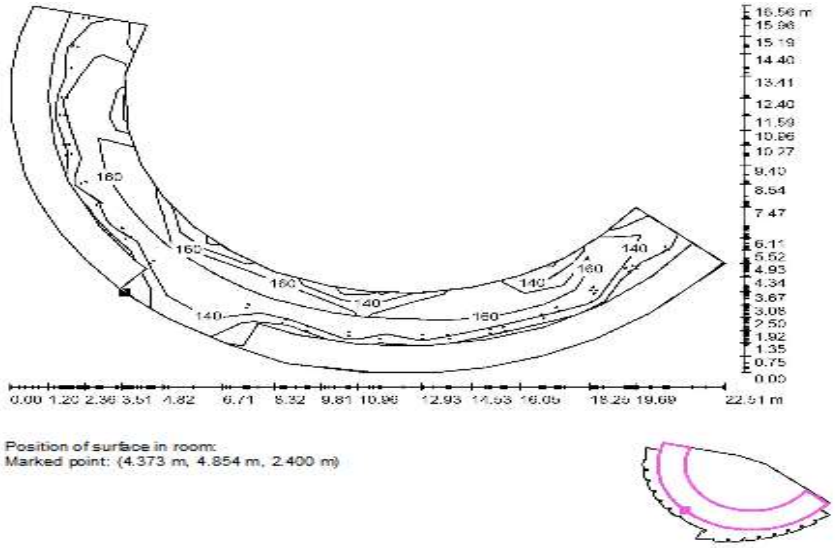


Figure-7.4(b): 3D Light Distribution Display

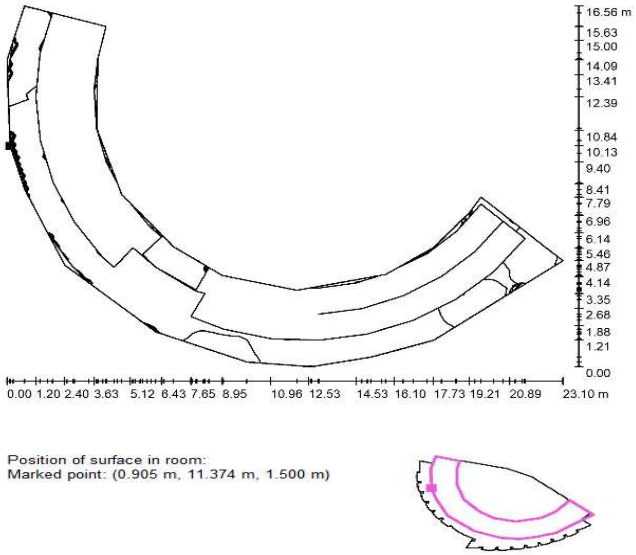
The central portion of the auditorium where audience can sit has been taken as calculation surface in the lighting design and the lighting design parameters obtained in the simulation stated below:

f) Simulated Output:



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min}/E_{max}
154	116	174	0.752	0.667

Figure-7.5: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min}/E_{max}
50	34	56	0.683	0.609

Figure-7.6: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

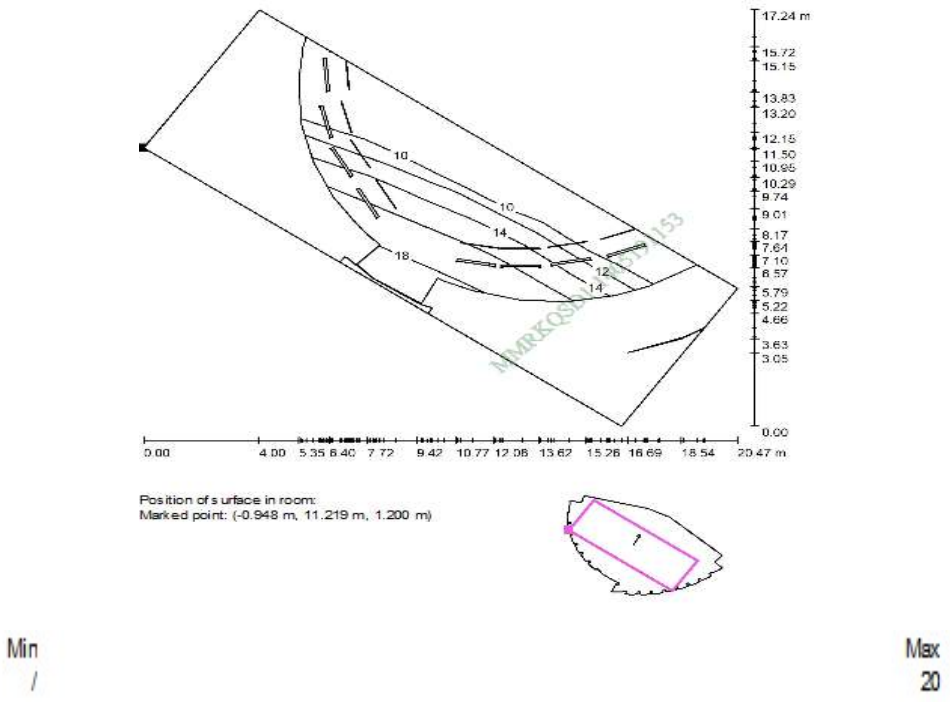


Figure-7.7: UGRL on UGR Calculation Area

g) Discussions

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	150 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	9.60 W/m^2 As per ECBC-2017	50 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	22 As per EN-12464-1:2011
Achieved Value	154	0.752	2.74 W/m^2/100 lx or 3.81W/m^2	50	0.32	20

Table-7.1: Comparison Table for Calculation Surface

7.2.2 Lighting Design of H.O.D Room

a) Design Consideration: The H.O.D Room is a room where head of any department study in his or her recess period, reads, writes or meets with staff members and students. This room should have general illumination for performing visual tasks like reading, writing, correcting papers and notebooks.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in H.O.D Room,

- Maintained Average Illuminance ($\overline{E_m}$)=300 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =50 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

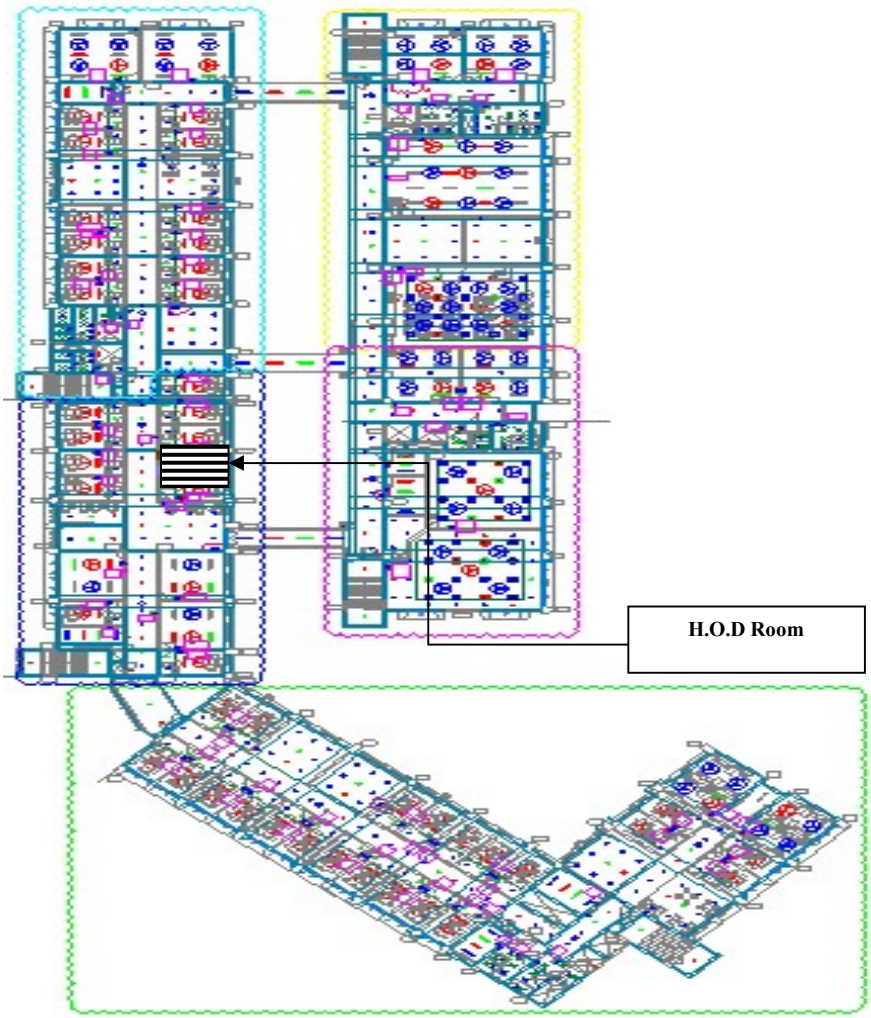
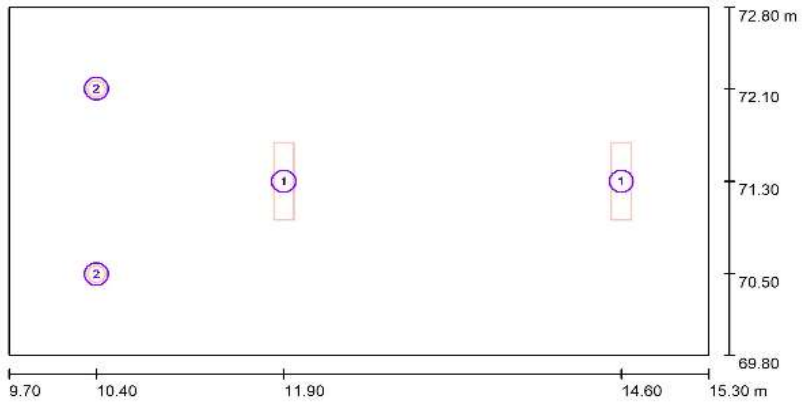


Figure-7.8: Floor Plan View of H.O.D Room

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	2	IbLED IIBL01L-50WH LED Linear Highbay 50W
2	2	IbLED IRDLR21RD-15XX (4000/5700/6500 degK) Recess Mounted LED Downlighter-Glow Round

Figure-7.9: Luminaire Layout of H.O.D Room

Luminaire Layout depicts luminaire arrangement inside the H.O.D Room, marked in Figure-7.9.Specifications on luminaire mounting height of the H.O.D Room, Light Loss Factor (LLF) and reflectance values, considered in the lighting design, mentioned below:

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

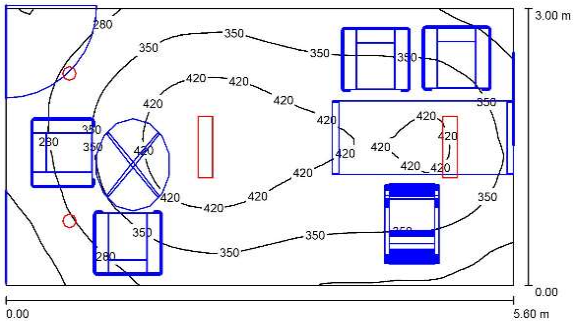


Figure-7.10(a): Isolines on Work-Plane

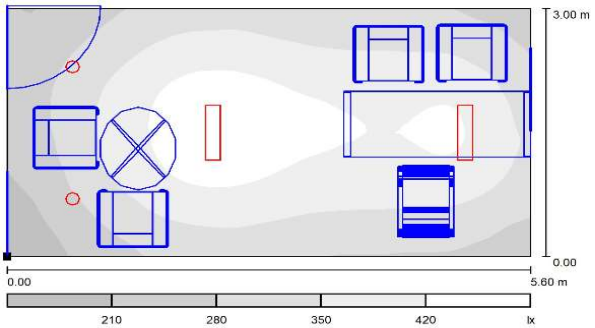


Figure-7.10(b): Greyscale on Work-Plane

e) 3D Standard View of H.O.D Room

Figure-7.11(a): 3D Standard View of H.O.D Room

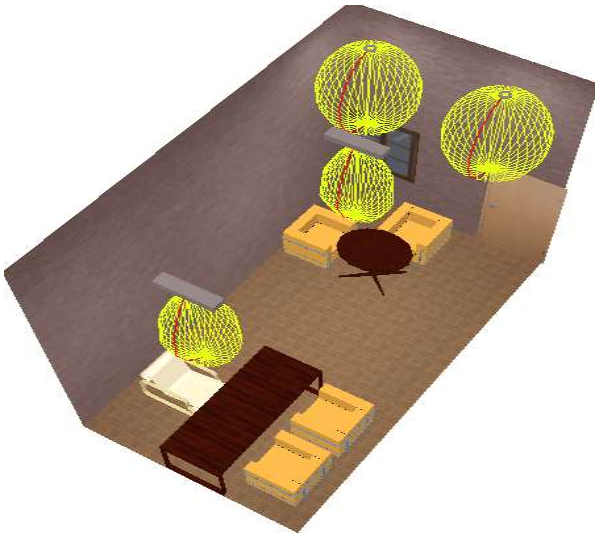
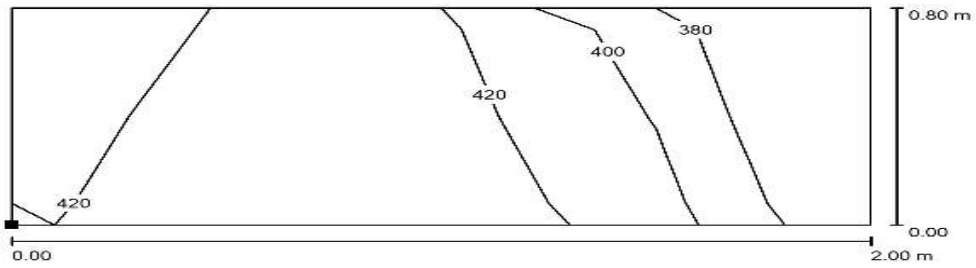


Figure-7.11(b): 3D Light Distribution Display

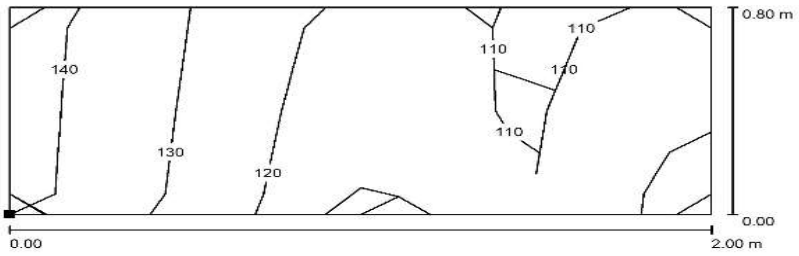
f) Simulated Output:



Position of surface in room:
Marked point: (13.296 m, 71.000 m, 0.800 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
416	374	435	0.899	0.860

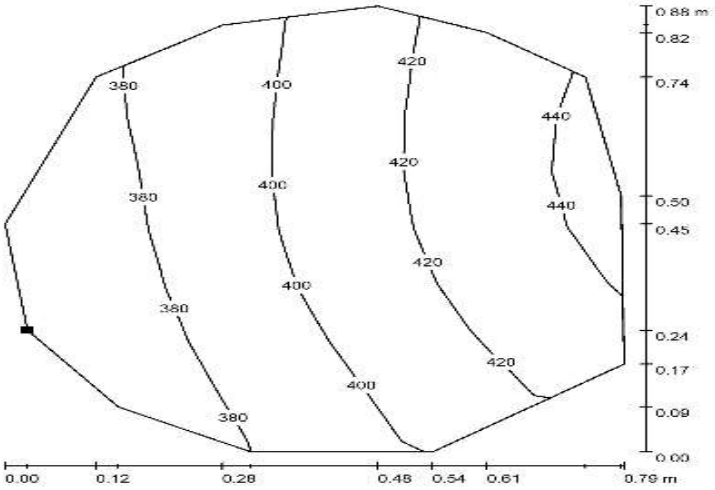
Figure-7.12: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1



Position of surface in room:
Marked point: (13.299 m, 71.000 m, 1.500 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
117	103	136	0.875	0.757

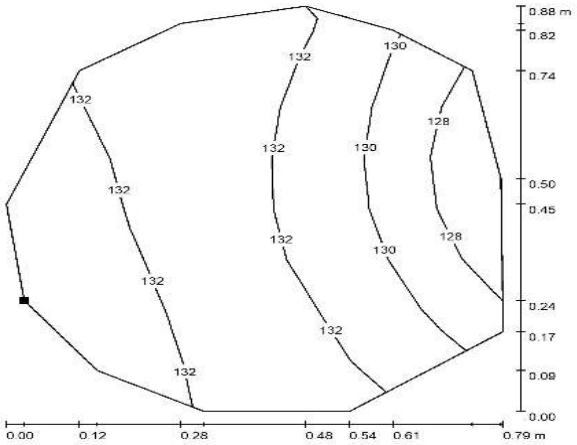
Figure-7.13: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1



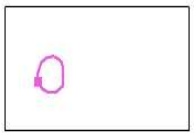
Position of surface in room:
Marked point: (10.729 m, 70.972 m, 0.760 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
404	362	447	0.894	0.809

Figure-7.14: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2



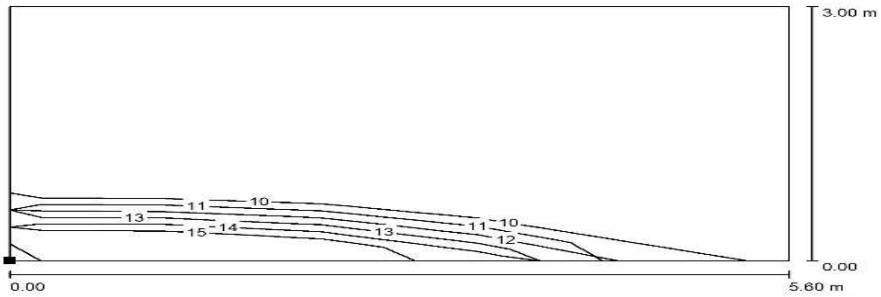
Position of surface in room:
Marked point: (10.717 m, 70.971 m, 1.500 m)



Grid: 8 x 8 Points

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
131	126	133	0.960	0.946

Figure-7.15: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



Position of surface in room:
Marked point: (9.700 m, 69.800 m, 1.200 m)

Min	Max
/	13

Figure-7.16: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	50 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	416	0.899	3.24 W/m^2/100 lx or 11.31W/m^2	117	0.28	13

Table-7.2: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	50 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	404	0.894	3.24 W/m^2/100 lx or 11.31W/m^2	131	0.324	13

Table-7.3: Comparison Table for Calculation Surface 2

7.2.3 Lighting Design of Research Room

a) Design Consideration: The Research Room is a room where a researcher has to look at various objects with close attention for a long duration. There would be requirements of both nearby and far off viewing alternately. Where the eyes are required to adapt to vastly different luminances for short durations at frequent intervals one is likely to experience discomfort and fatigue. In order that such viewing is without discomfort, the visual environment should be good.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Research Room,

- Maintained Average Illuminance ($\overline{E_m}$)=300 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

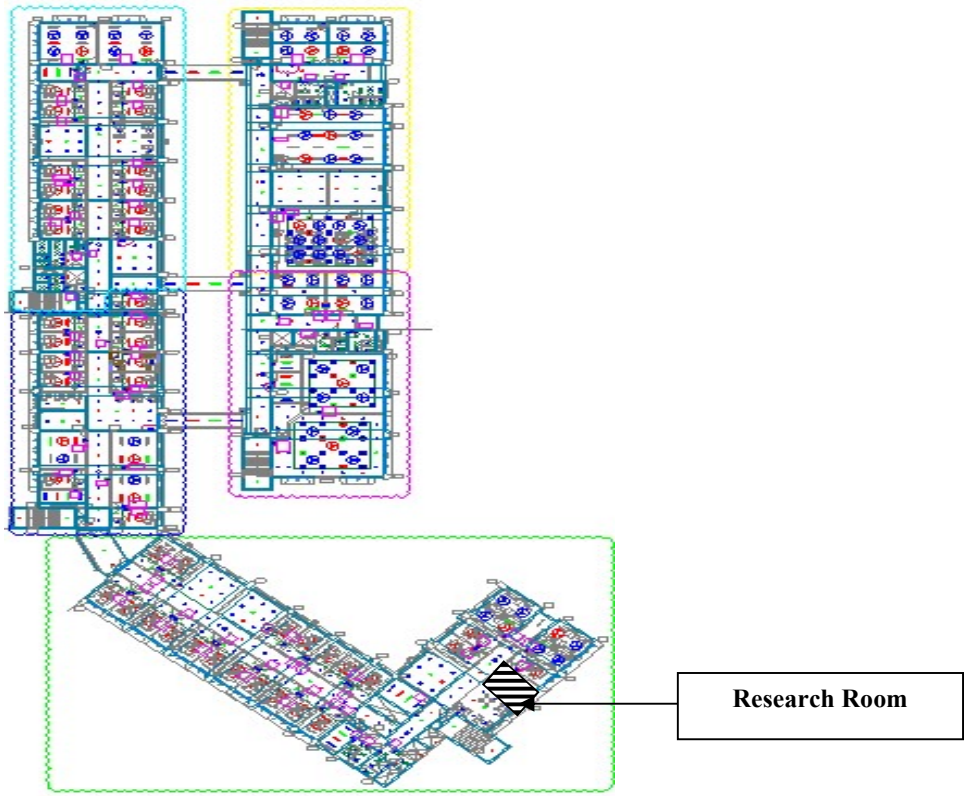
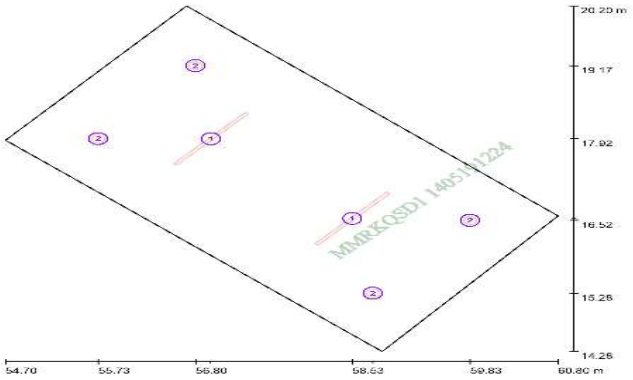


Figure-7.17: Floor Plan View of Research Room

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	2	IbLED IIBNXX-36XX Maxo-4FT LED Aluminium Batten (4000/5700/6500)degK
2	4	IbLED IRDLR21RD-24XX(4000/5700/6500 degK) Recess Mounted LED Downlighter-Glow Round

Figure-7.18: Luminaire Layout of Research Room

Luminaire Layout depicts luminaire arrangement inside the H.O.D Room, marked in Figure-7.18.Specifications on luminaire mounting height of the H.O.D Room, Light Loss Factor (LLF) and reflectance values, considered in the lighting design, mentioned below:

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

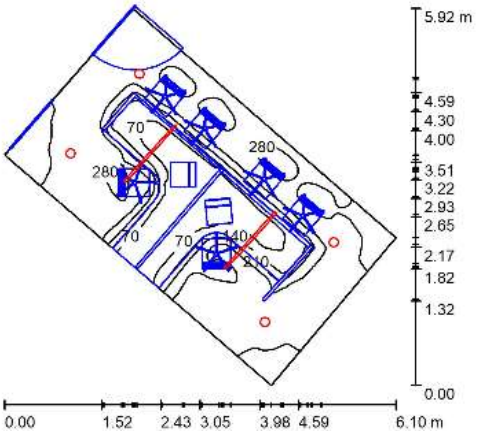


Figure-7.19(a): Isolines on Work-Plane

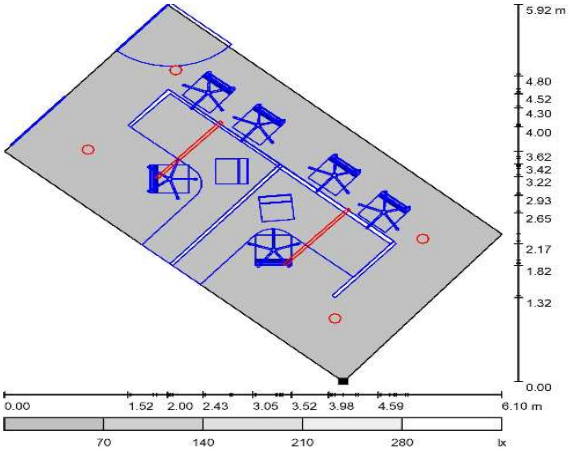


Figure-7.19(b): Greyscale on Work-Plane

e) 3D Standard View of Research Room:

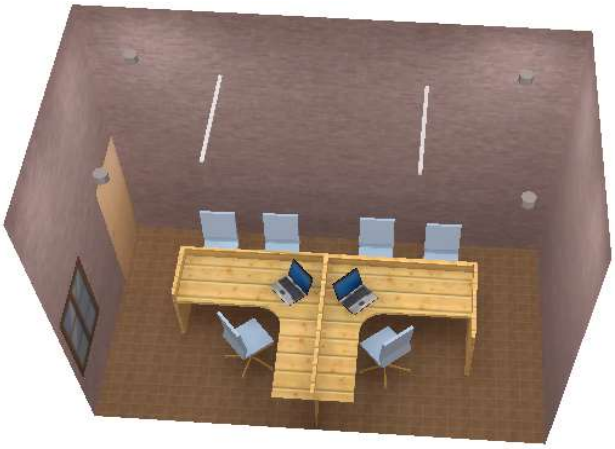


Figure-7.20(a): 3D Standard View of Research Room

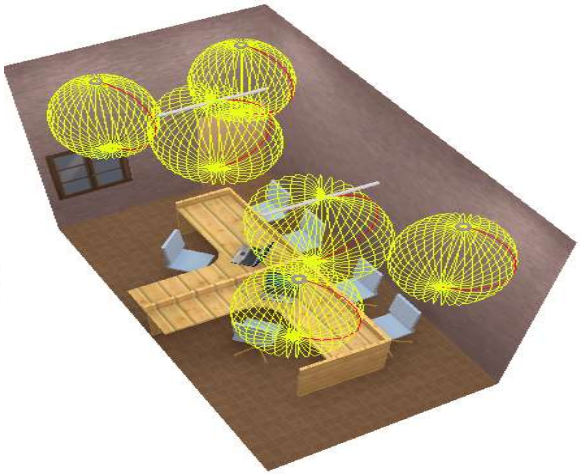
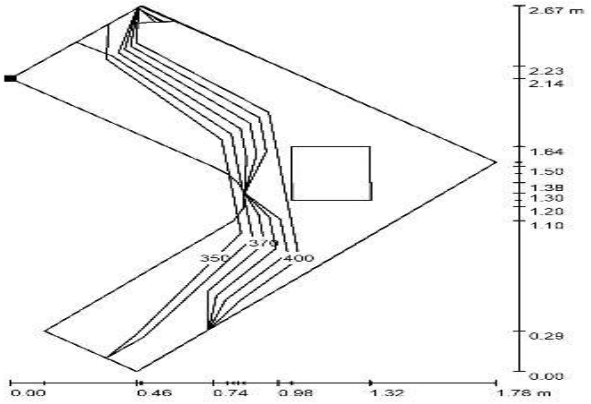
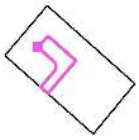


Figure-7.20(b): 3D Light Distribution Display

f) Simulated Output:

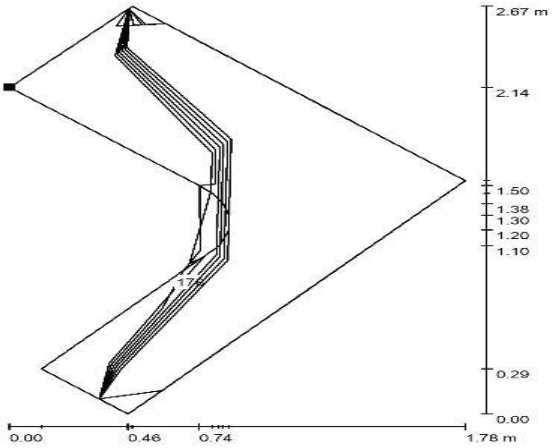


Position of surface in room:
Marked point: (56.258 m, 18.277 m, 0.860 m)

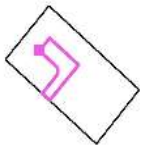


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
356	342	369	0.961	0.925

Figure-7.21: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1

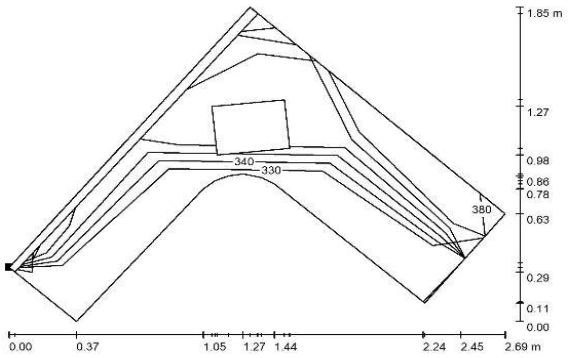


Position of surface in room:
Marked point: (56.258 m, 18.279 m, 1.500 m)

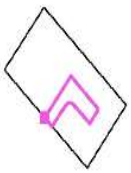


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
174	172	177	0.990	0.971

Figure-7.22: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1

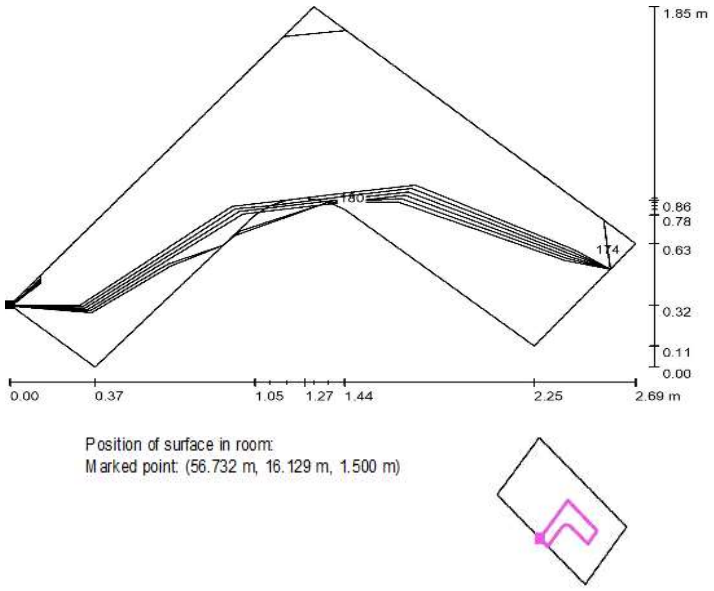


Position of surface in room:
Marked point: (56.732 m, 16.131 m, 0.860 m)



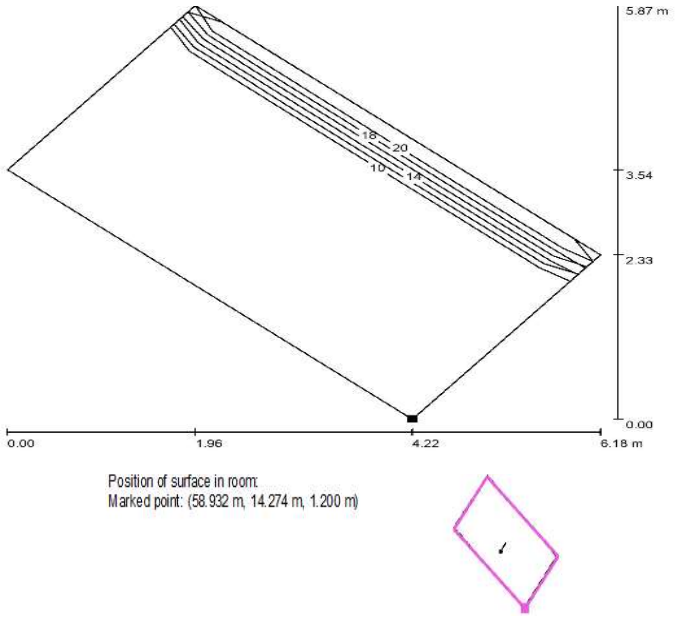
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
345	327	363	0.949	0.902

Figure-7.23: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
175	173	178	0.989	0.970

Figure-7.24: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



Min	Max
/	17

Figure-7.25: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	356	0.961	4.28 W/m^2/100 lx or 10.09W/m^2	174	0.48	17

Table-7.4: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.3 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	345	0.949	4.28 W/m^2/100 lx or 10.09W/m^2	175	0.50	17

Table-7.5: Comparison Table for Calculation Surface 2

7.2.4 Lighting Design of Office Staff Room

a) Design Consideration: The Office Staff Room is a room where variety of work from data base oriented task such as keyboard work to paper work are performed. For these areas the lighting criteria and system shall be chosen in accordance with activity area and task type. In some circumstances, the keyboard may suffer from reflections causing disability and discomfort glare. It is therefore necessary to select, locate and arrange the luminaires to avoid high brightness reflections.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Office Staff Room,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 9.5 W/m^2.

b) Floor Plan:

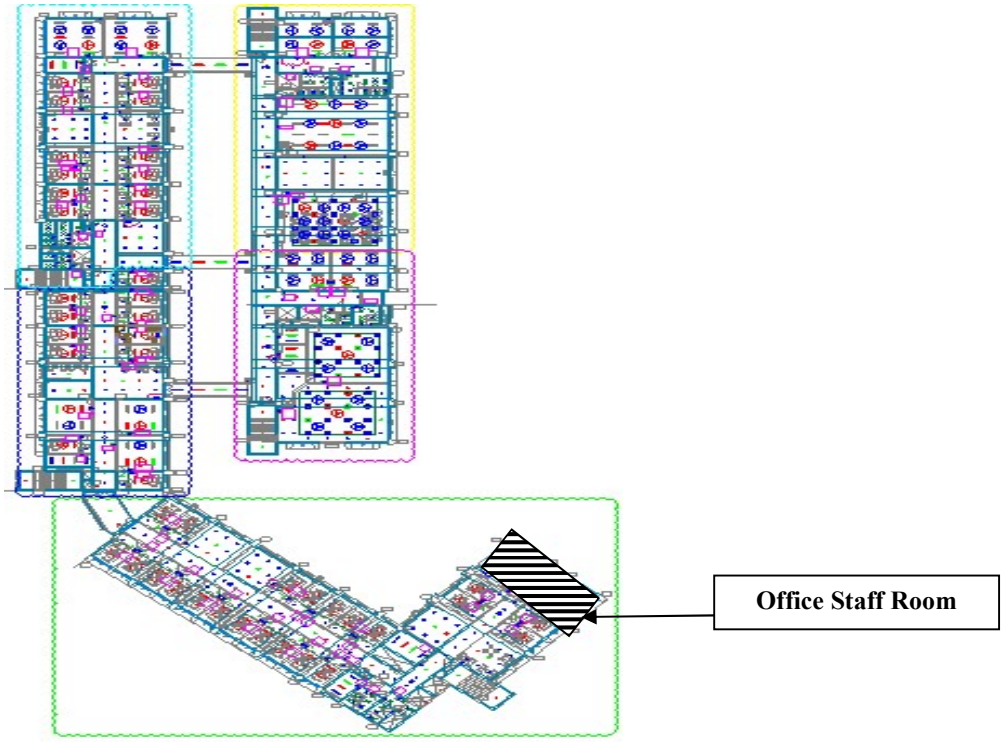
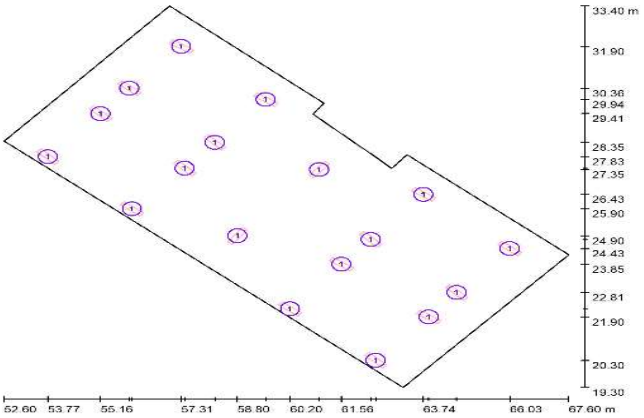


Figure-7.26: Floor Plan View of Office Staff Room

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	18	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.27: Luminaire Layout of Office Staff Room

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

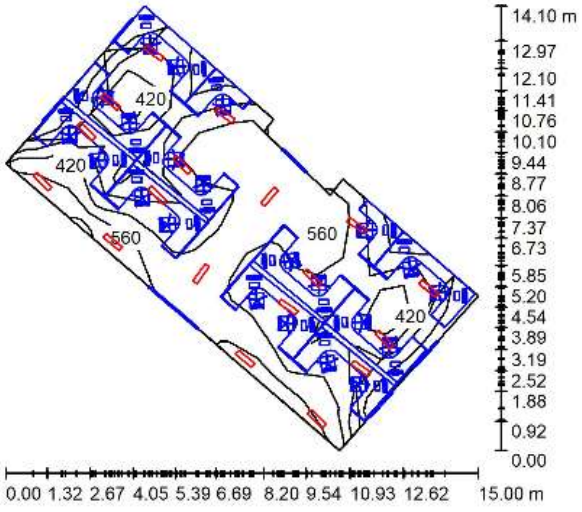


Figure-7.28(a): Isolines on Work-Plane

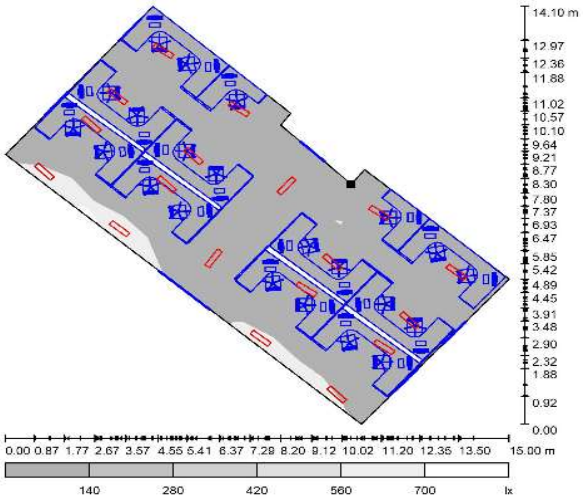


Figure-7.28(b): Greyscale on Work-Plane

e) 3D Standard View of Office Staff Room:

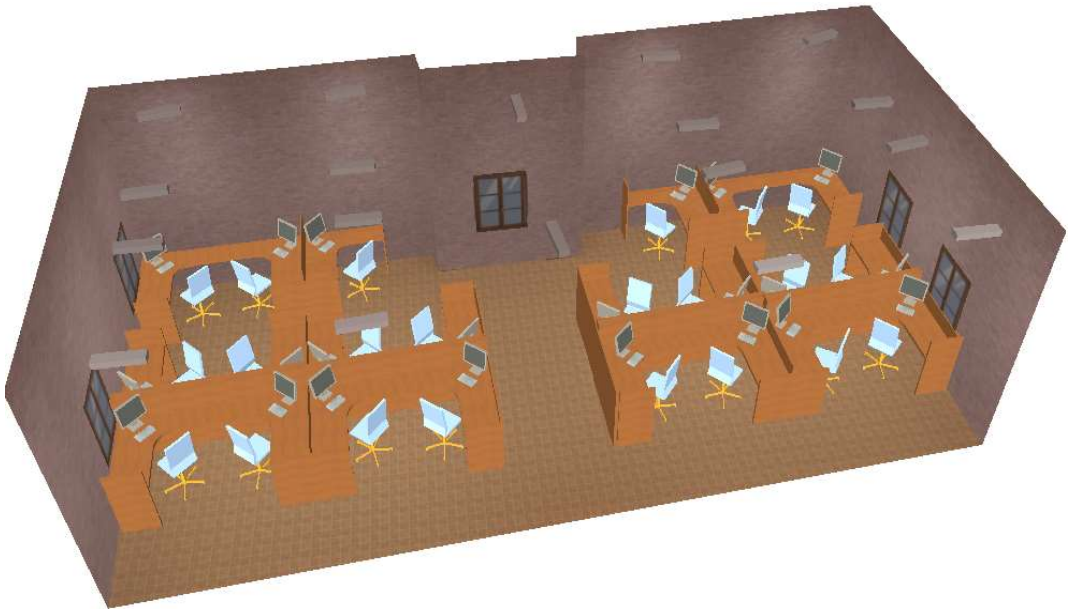


Figure-7.29(a): 3D Standard View of Office Staff Room

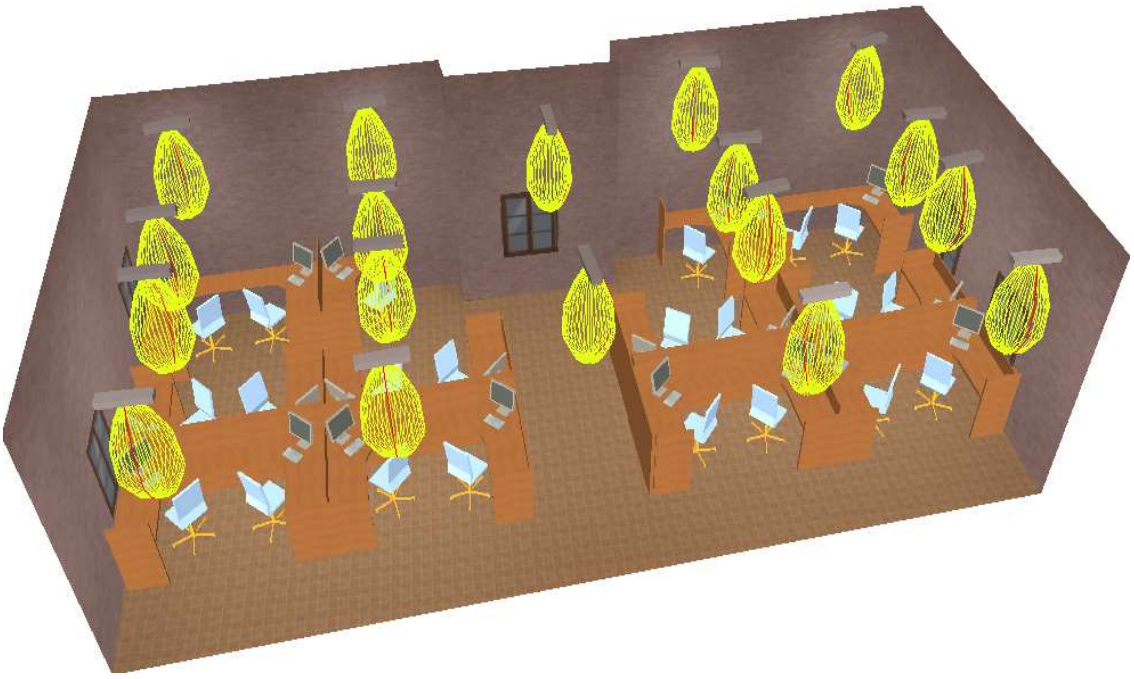
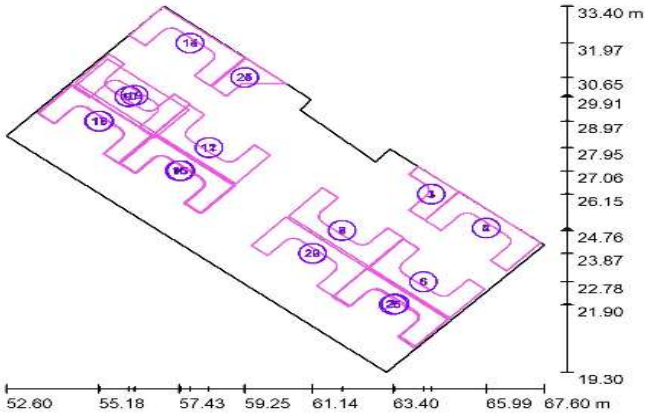


Figure-7.29(b): 3D Light Distribution Display

f) Simulated Output:



Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	13	676	422	860	0.62	0.49
cyl.	13	236	178	270	0.76	0.66

Figure-7.30: Maintained Average Illuminance ($\overline{E_m}$) and Mean Cylindrical Illuminance (E_{cy}) on Calculation Surfaces

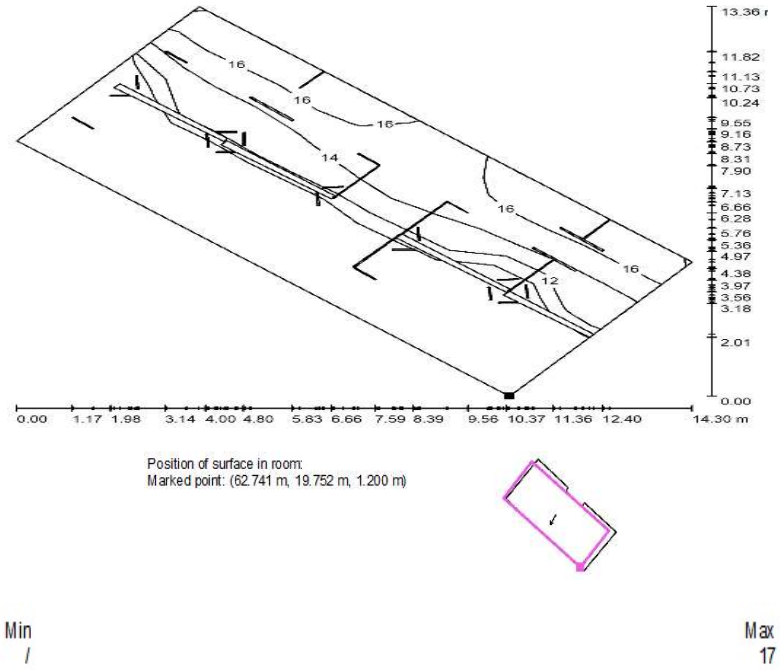


Figure-7.31: UGRL on UGR Calculation Area 1

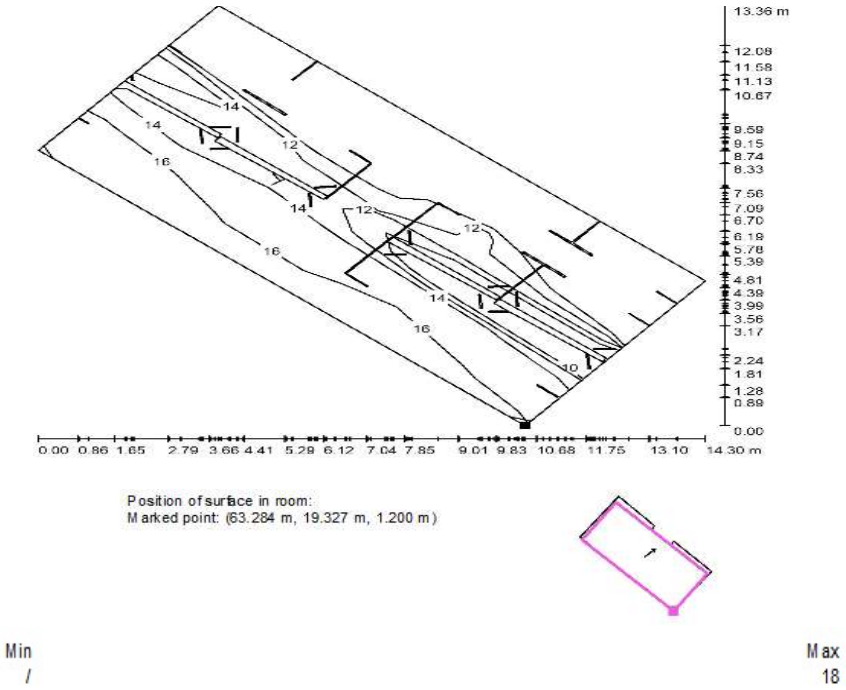


Figure-7.32: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN 12464-1:2011	9.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	676	0.62	1.97 W/m^2/100 lx or 7.13W/m^2	236	0.34	18

Table-7.6: Comparison Table for Calculation Surface

7.2.5 Lighting Design of Class Room

a) Design Consideration: The Class Room is a room where students write notes during the lecture, study, read, write in recess period. This room should have general illumination for performing visual tasks like reading.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Research Room,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 13.7 W/m^2.

b) Floor Plan:

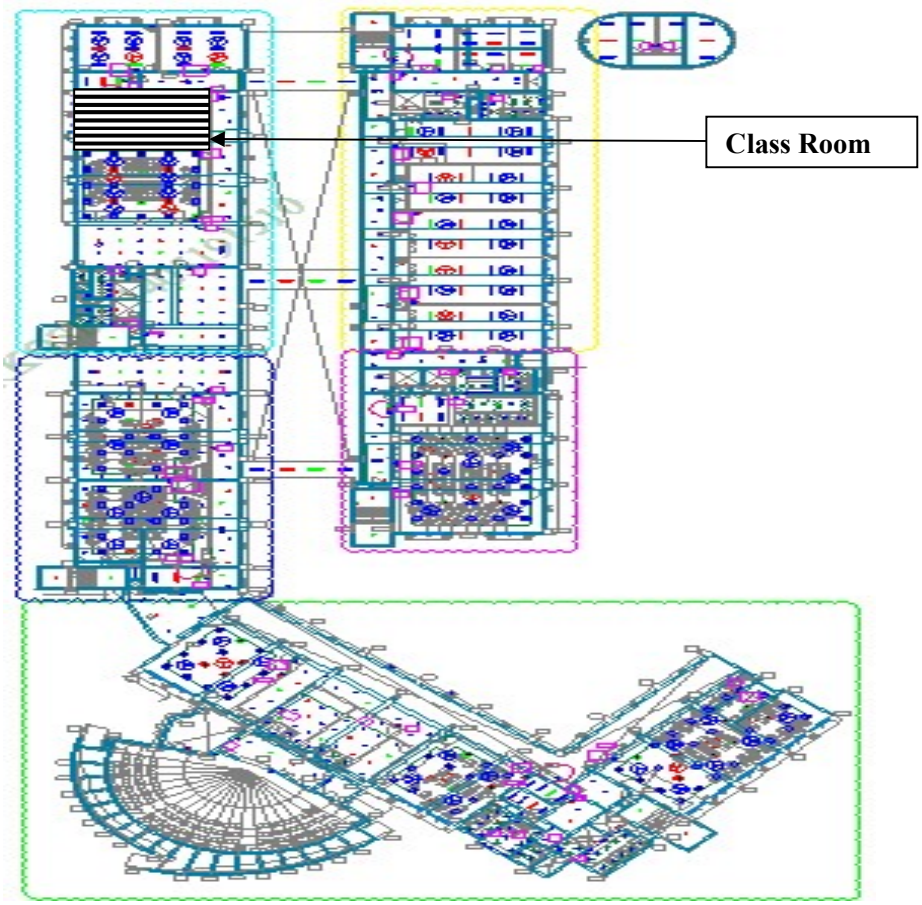


Figure-7.33: Floor Plan View of Class Room

c) Luminaire Layout:

Luminaire Parts List

No.	Pieces	Designation
1	15	IB LEDS IMRC01-42WH (5700degK) Recessed Mounted 2x2 LED with Diffuser-Quadglo
2	10	IbLED IRDLR21RD-15XX (4000/5700/6500 degK) Recess Mounted LED Downlighter-Glow Round

Figure-7.34: Luminaire Layout of Class Room

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

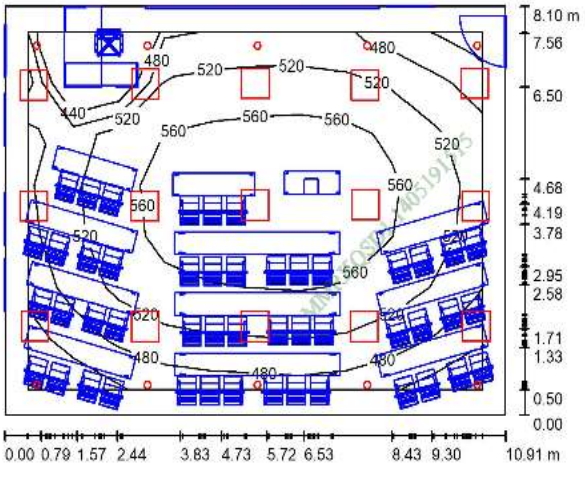


Figure-7.35(a): Isolines on Work-Plane

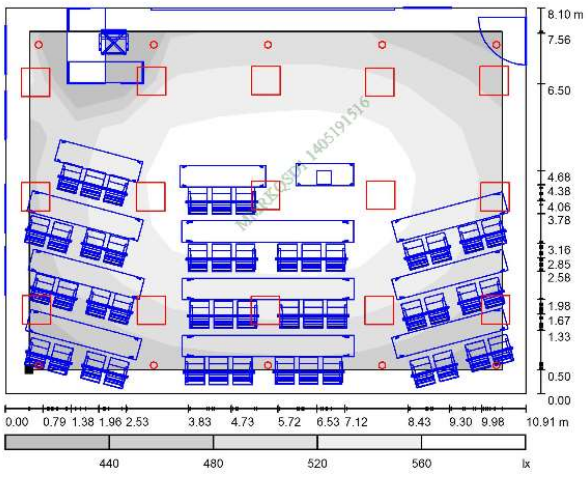


Figure-7.35(b): Greyscale on Work-Plane

e) 3D Standard View of Class Room:

Figure-7.36(a): 3D Standard View of Class Room

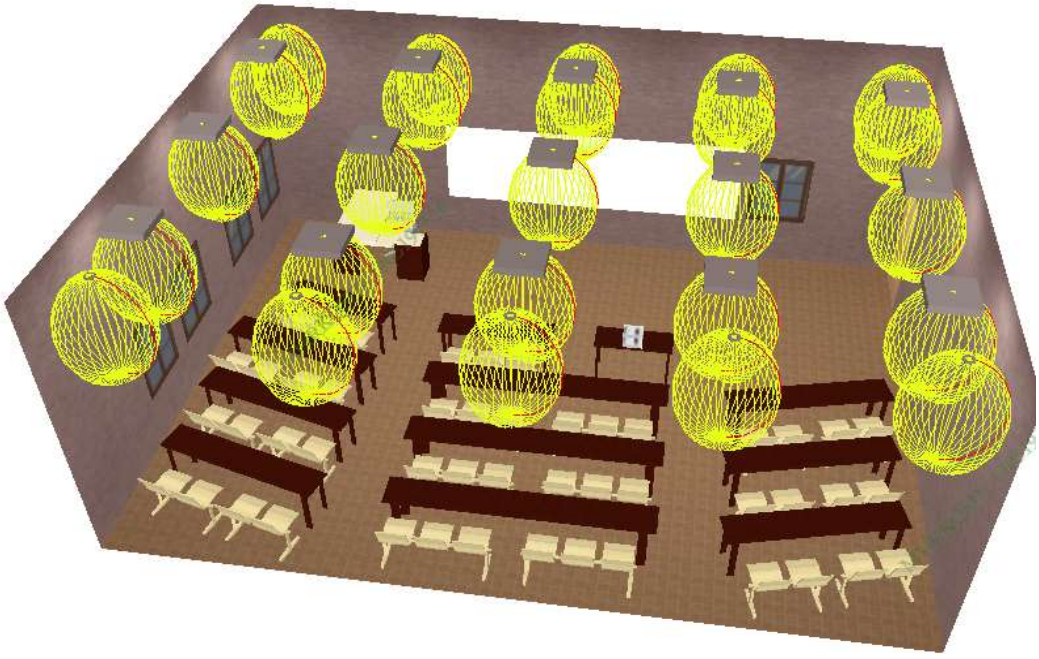
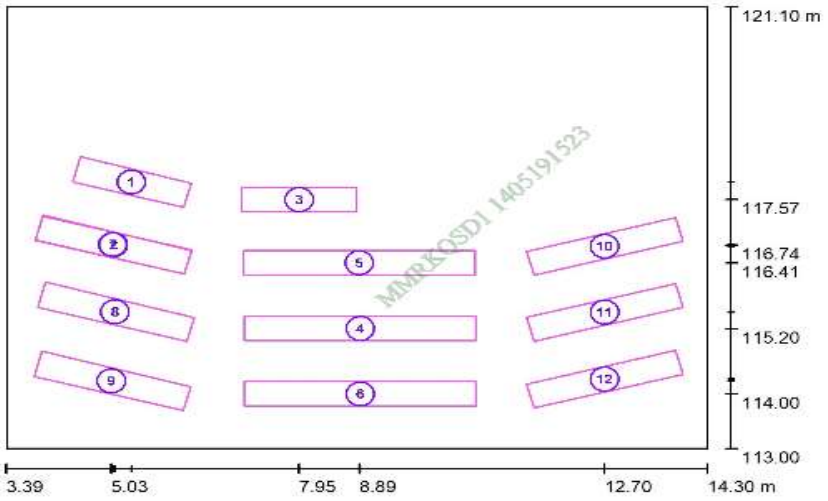


Figure-7.36(b): 3D Light Distribution Display

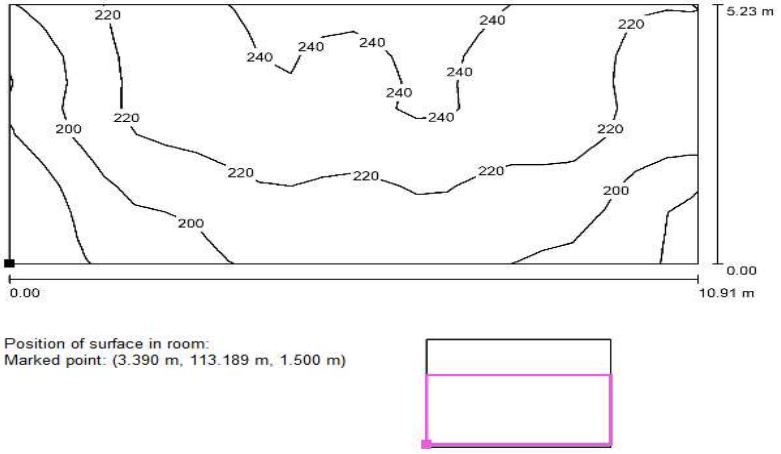
f) Simulated Output:



Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	12	530	452	585	0.85	0.77

Figure-7.37: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
216	167	245	0.775	0.684

Figure-7.38: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

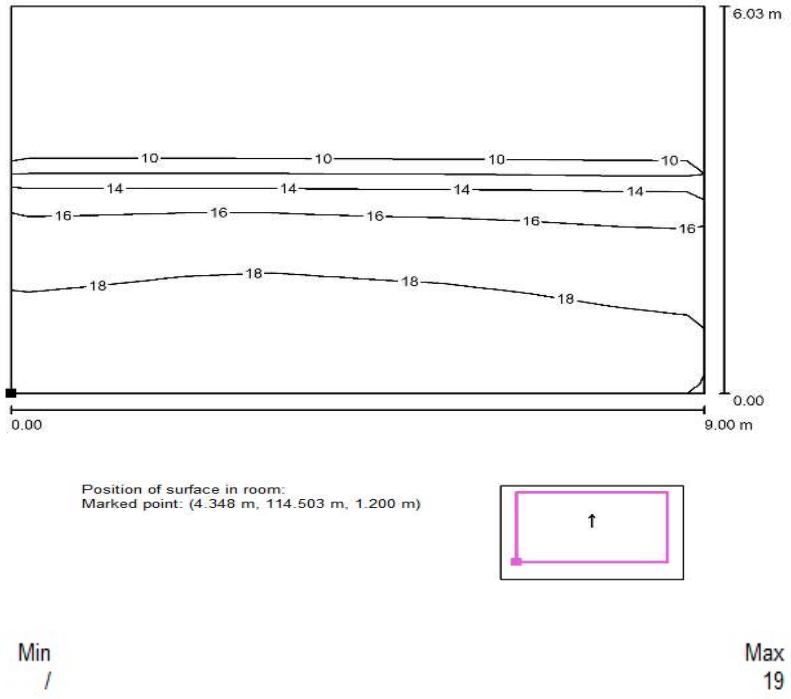


Figure-7.39: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	13.70 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	530	0.85	1.67 W/m^2/100 lx or 8.83W/m^2	216	0.40	19

Table-7.7: Comparison Table for Calculation Surface

7.2.6 Lighting Design of Seminar Hall

a) Design Consideration: The Seminar Hall in an institution is equipped with latest audio and visual equipment where presentations on various aspects such as, on latest technological aspect, personality development aspect, on any workshops etc. can take place.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Seminar Hall,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

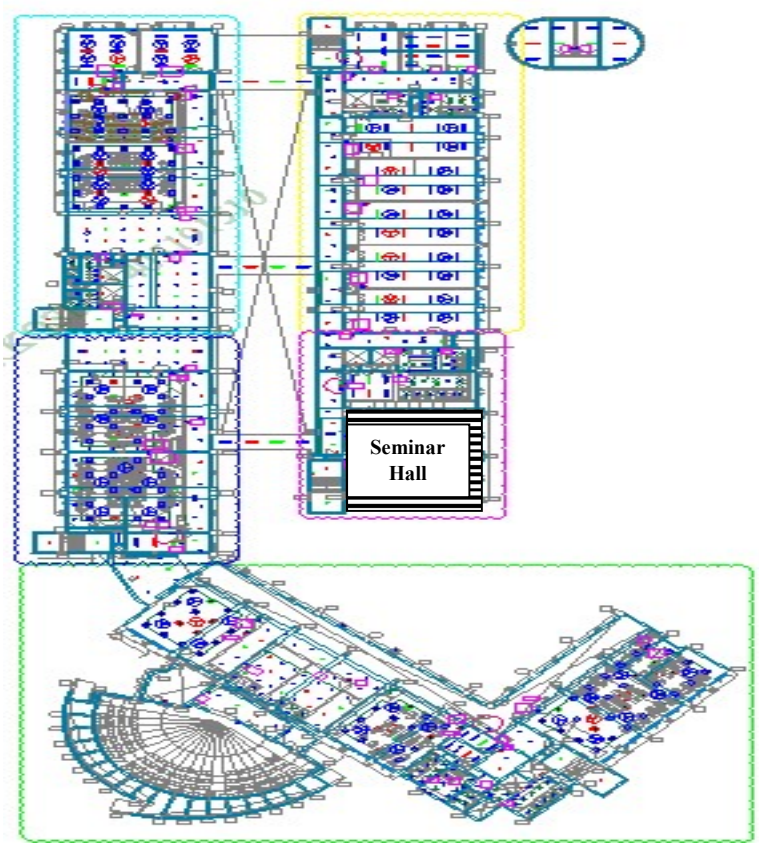


Figure-7.40: Floor Plan View of Seminar Hall

c) Luminaire Layout:

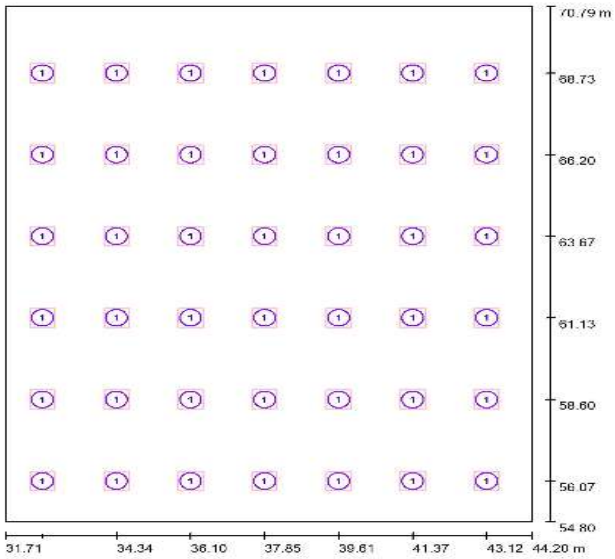


Figure-7.41: Luminaire Layout of Seminar Hall

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

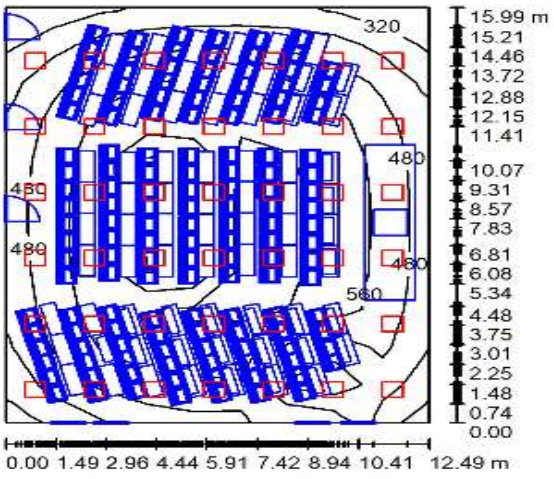


Figure-7.42(a): Isolines on Work-Plane

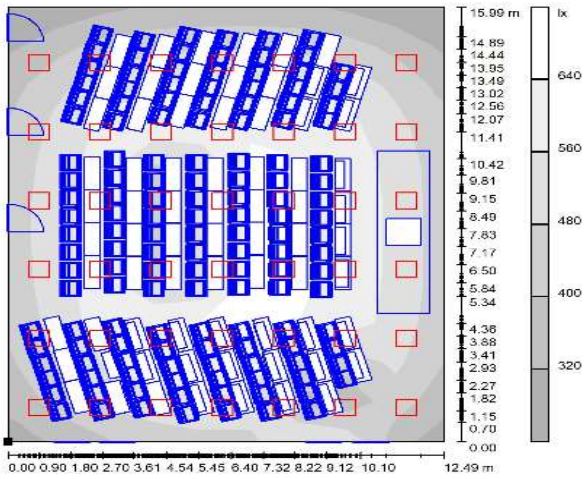


Figure-7.42(b): Greyscale on Work-Plane

e) 3D Standard View of Seminar Hall:

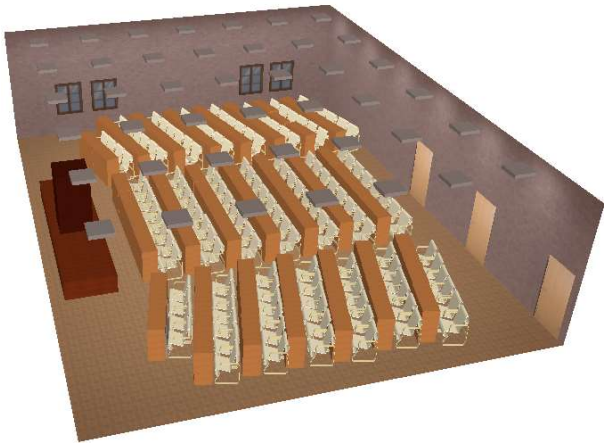


Figure-7.43(a): 3D Standard View of Seminar Hall

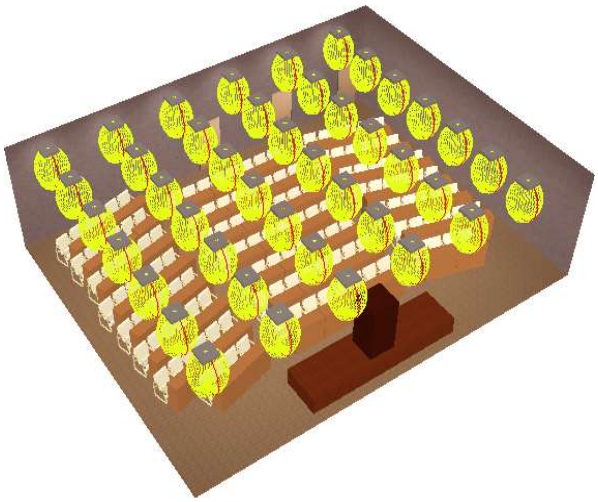
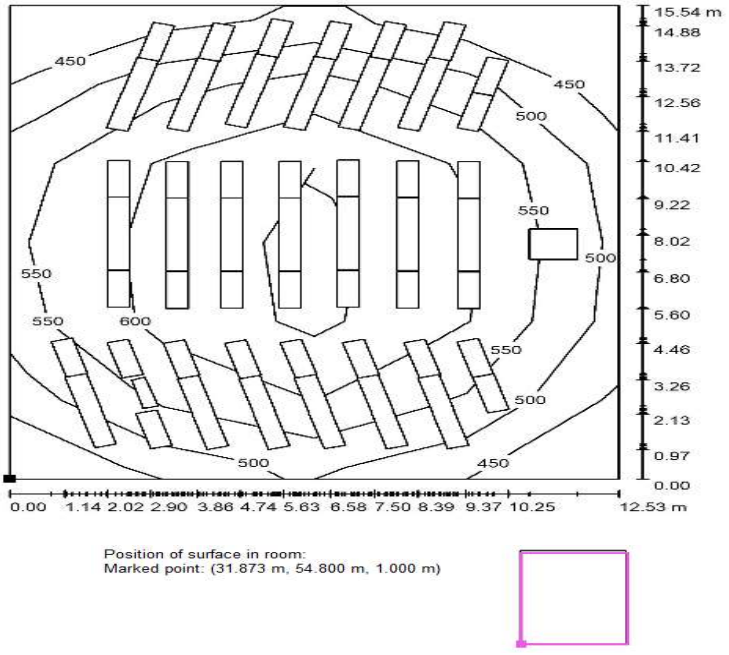


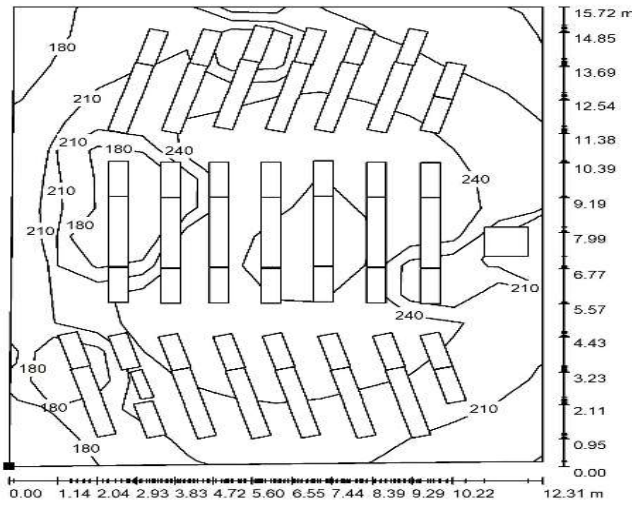
Figure-7.43(b): 3D Light Distribution Display

f) Simulated Output:



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
560	425	674	0.760	0.632

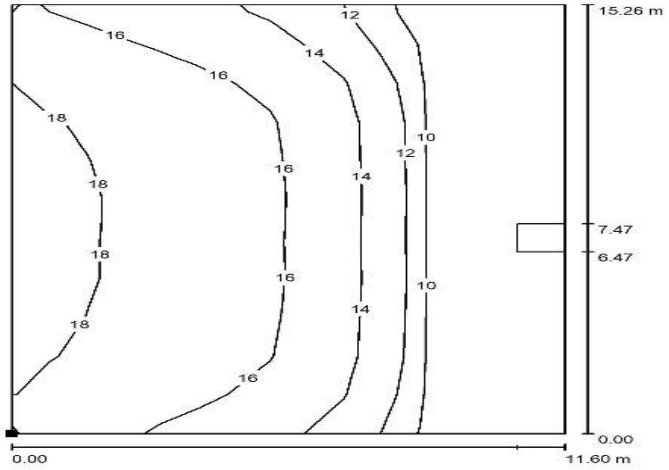
Figure-7.44: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface



Position of surface in room:
Marked point: (31.586 m, 54.824 m, 0.920 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
230	157	276	0.681	0.567

Figure-7.45: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface



Position of surface in room:
Marked point: (31.955 m, 55.534 m, 1.200 m)

Min	Max
/	19

Figure-7.46: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	560	0.76	1.44 W/m^2/100 lx or 7.57W/m^2	230	0.41	19

Table-7.8: Comparison Table for Calculation Surface

7.2.7 Lighting Design of Teachers' Room

a) Design Consideration: The Teachers' Room is a place where teachers assemble for discussions, study or rest during recess periods. These rooms should have general illumination for performing visual tasks like reading and writing (correcting papers and notebooks). Supplementary local lighting may be provided at the side of the user in the form of a table lamp or wall lamp so that an individual could continue with his/her work without disturbing the others who may relax at the same time.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Teachers' Room,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

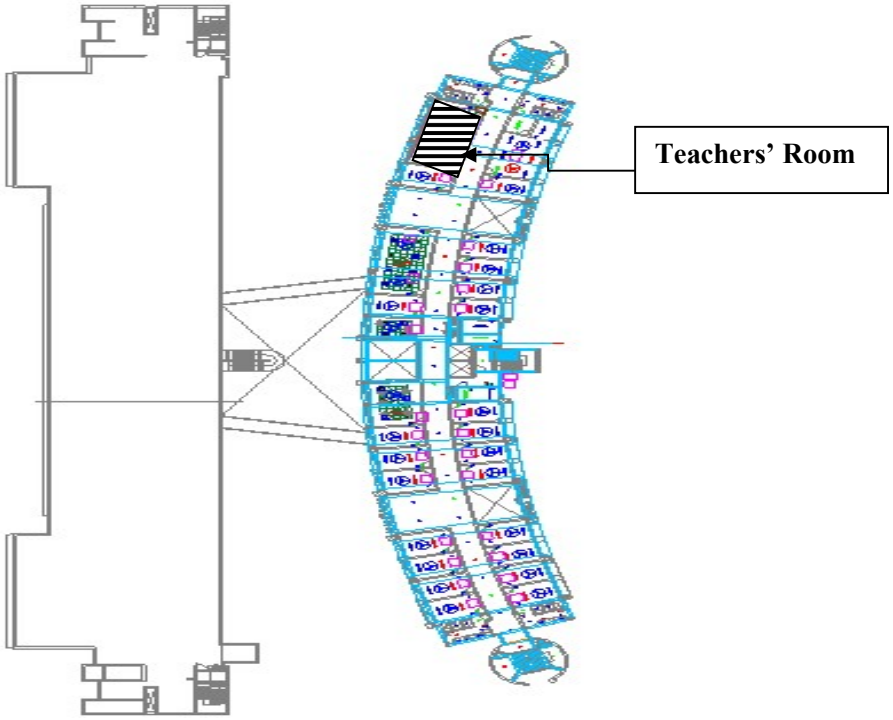
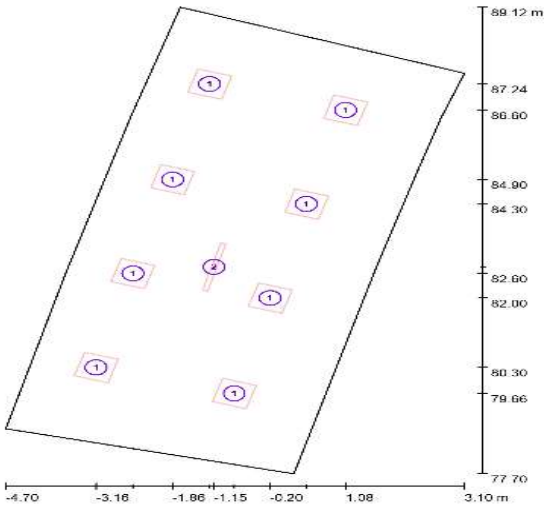


Figure-7.47: Floor Plan View of Teachers' Room

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	8	IB LEDS IMRC01-42WH (5700degK) Recessed Mounted 2x2 LED with Diffuser-Quadglo
2	1	IbLED IMSL08-28WH (5700degK) ActivPro-Suspended LED Luminaire with Diffuser

Figure-7.48: Luminaire Layout of Teachers' Room

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

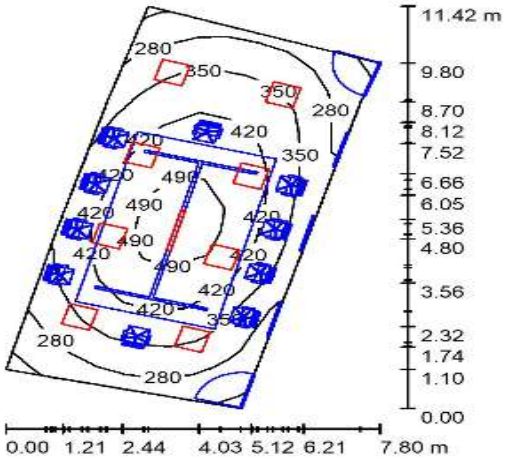


Figure-7.49(a): Isolines on Work-Plane

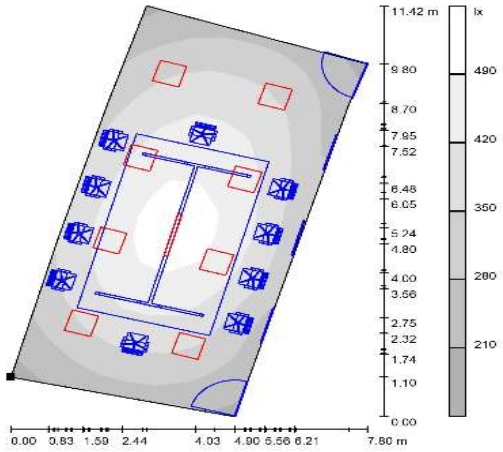


Figure-7.49(b): Greyscale on Work-Plane

e) 3D Standard View of Teachers' Room:

Figure-7.50(a): 3D Standard View of Teachers' Room

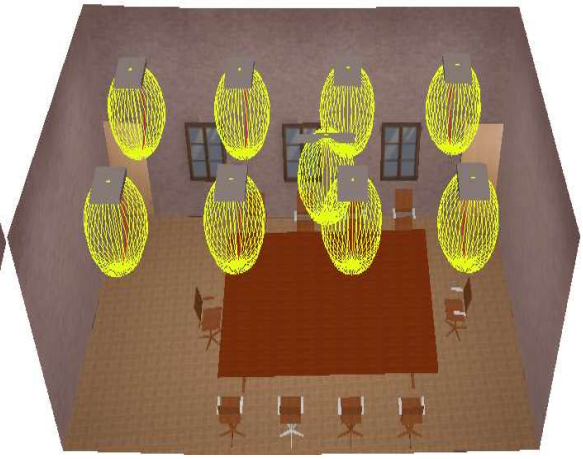
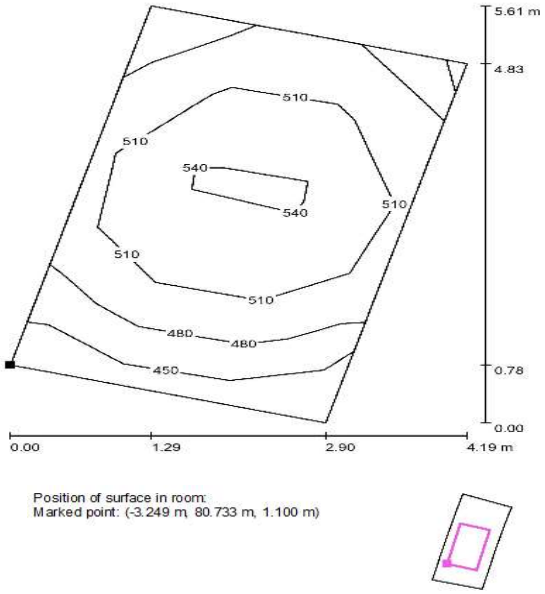


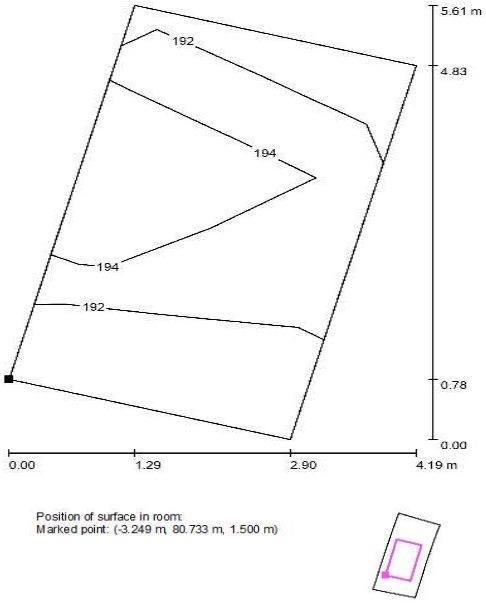
Figure-7.50(b): 3D Light Distribution Display

f) Simulated Output:



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
506	448	572	0.885	0.783

Figure-7.51: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
194	191	198	0.982	0.961

Figure-7.52: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

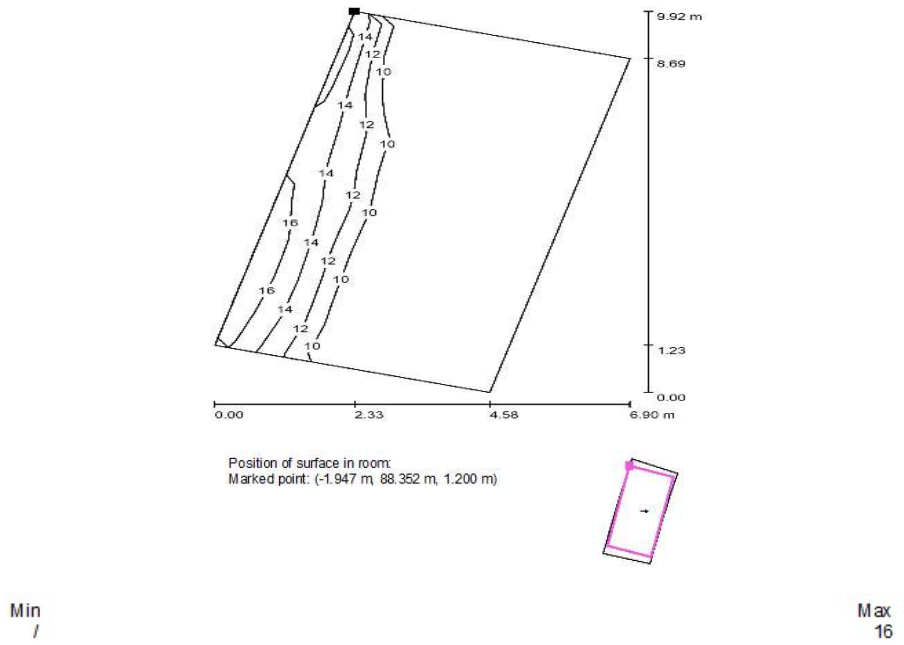


Figure-7.53: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	506	0.885	1.86 W/m^2/100 lx or 6.88W/m^2	194	0.38	16

Table-7.9: Comparison Table for Calculation Surface

7.2.8 Lighting Design of Workshop

Workshop is a room which provides both the area and tools that is required in development and production aspect in an Educational Facility. In this case study, some workshops are:

- Power System Computation Workshop
- VLSI CAD Workshop
- Core Technician Workshop
- IC Testing and Characterization Workshop

7.2.8.1 Power System Computation Workshop

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Power System Computation Workshop,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 17.1 W/m^2.

b) Floor Plan:

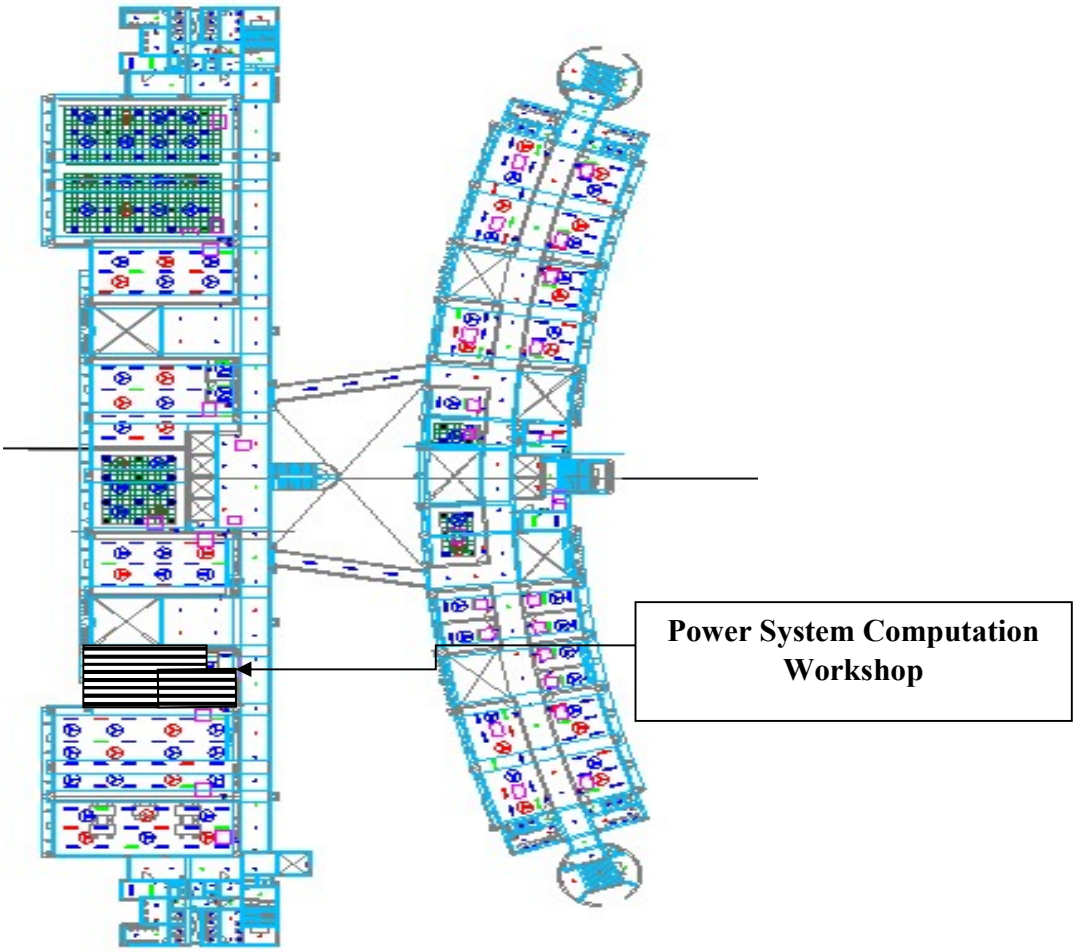
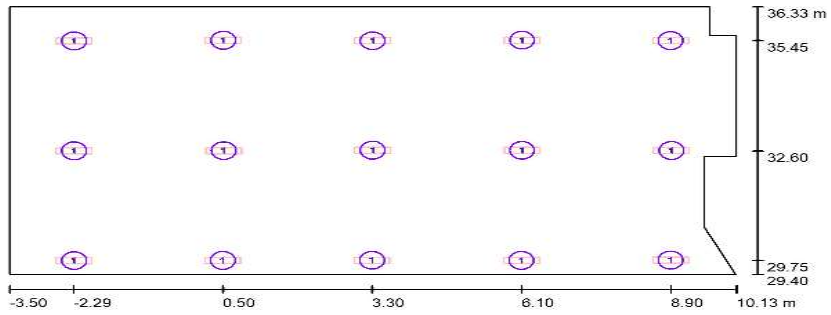


Figure-7.54: Floor Plan View of Power System Computation Workshop

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	15	IbLED IIBL01L-50WH LED Linear 50W

Figure-7.55: Luminaire Layout of Power System Computation Workshop

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

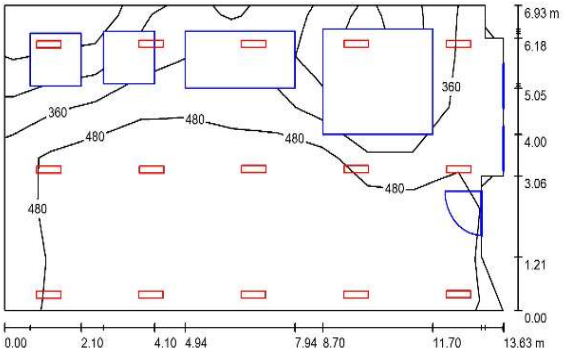


Figure-7.56(a): Isolines on Work-Plane

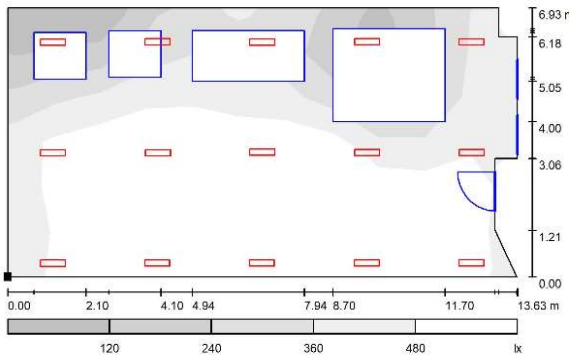


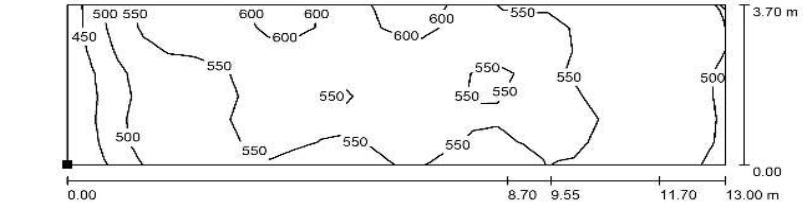
Figure-7.56(b): Greyscale on Work-Plane

e) 3D Standard View of Power System Computation Workshop:

Figure-7.57(a): 3D Standard View of Power System Computation Workshop

Figure-7.57(b): 3D Light Distribution Display

f) Simulated Output:



Position of surface in room:
Marked point: (-3.500 m, 29.400 m, 0.760 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
545	410	620	0.752	0.661

Figure-7.58: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface

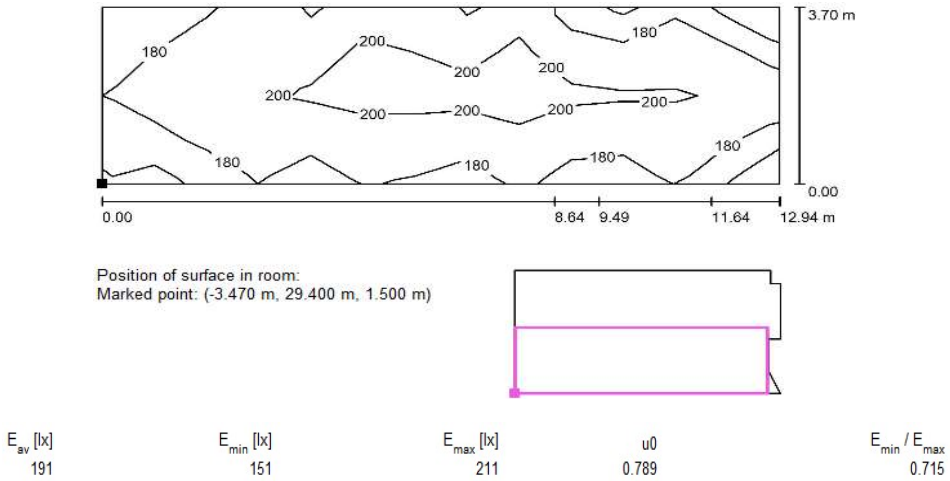


Figure-7.59: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

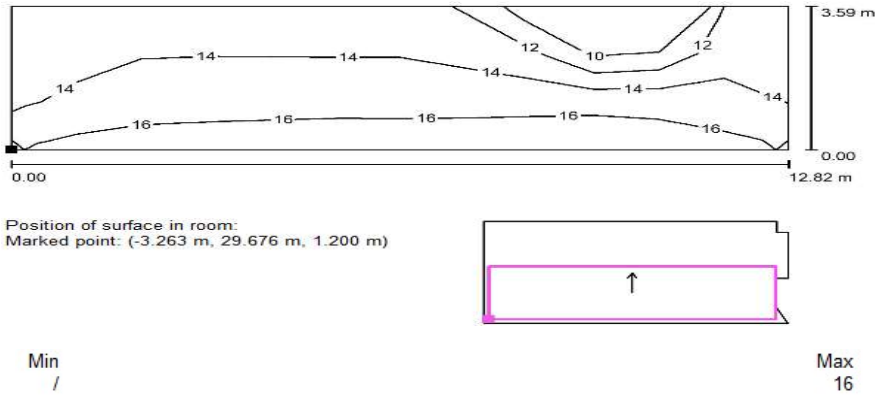


Figure-7.60: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	545	0.752	2.77 W/m^2/100 lx or 12.95W/m^2	191	0.35	16

Table-7.10: Comparison Table for Calculation Surface

7.2.8.2 VLSI CAD Workshop

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in VLSI CAD Workshop,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 17.1 W/m^2.

b) Floor Plan:

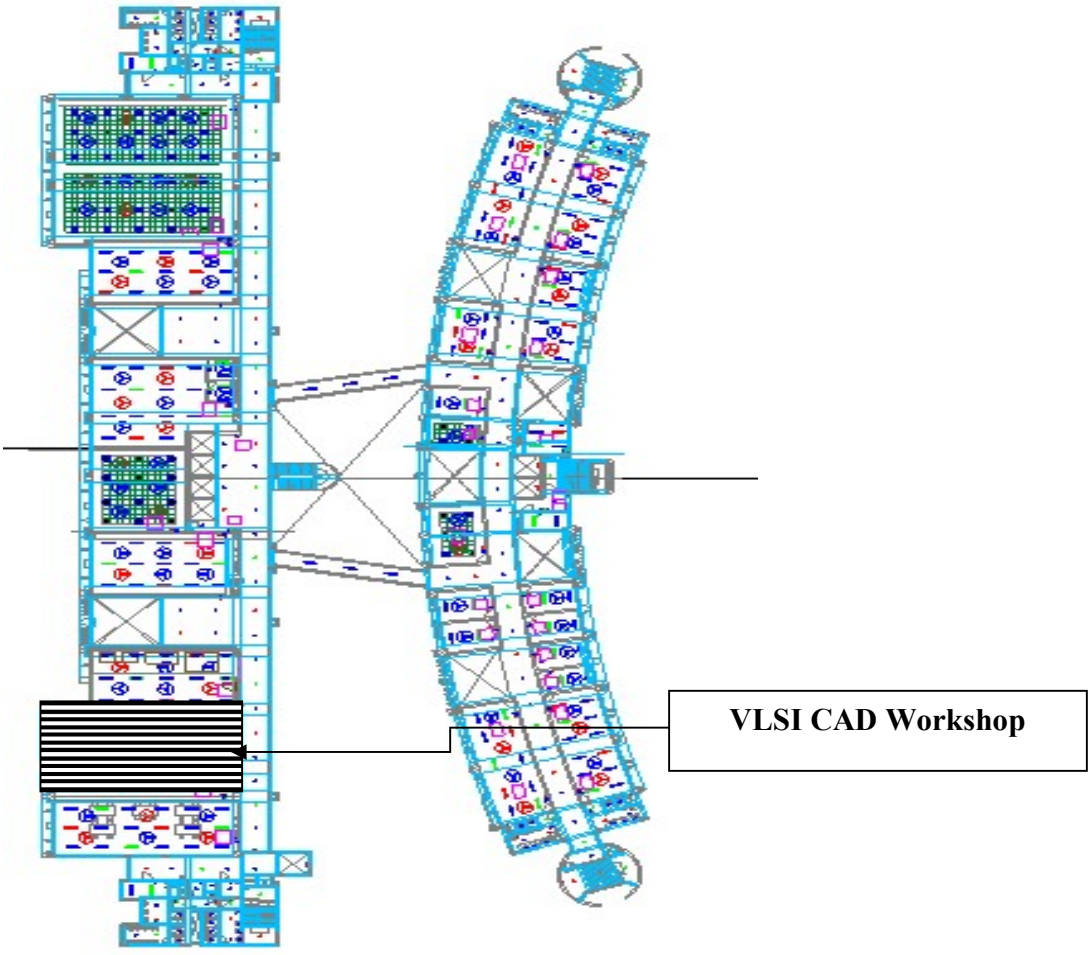
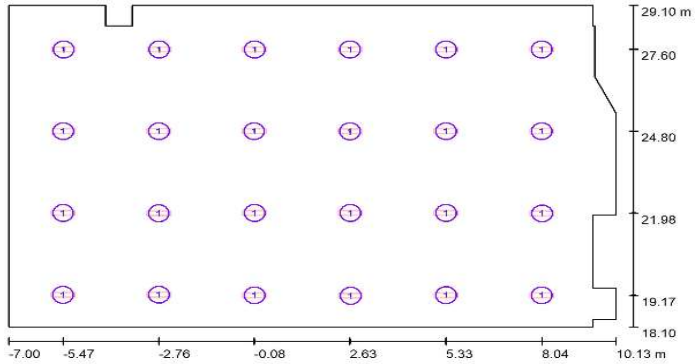


Figure-7.61: Floor Plan View of VLSI CAD Workshop

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	24	IbLED IIBL01L-50WH LED Linear 50W

Figure-7.62: Luminaire Layout of VLSI CAD Workshop

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

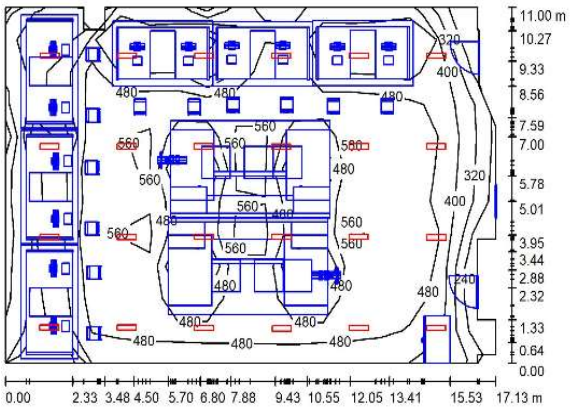


Figure-7.63(a): Isolines on Work-Plane

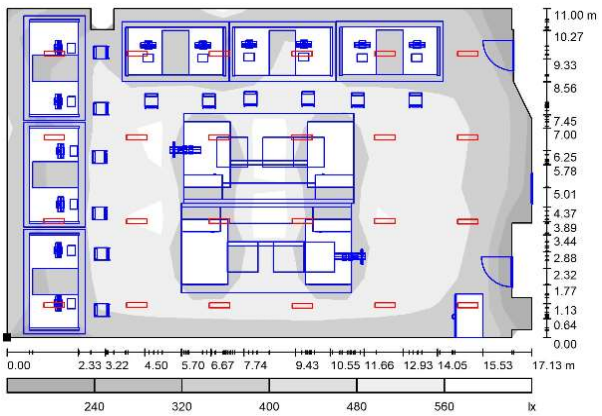


Figure-7.63(b): Greyscale on Work-Plane

e) 3D Standard View of VLSI CAD Workshop:

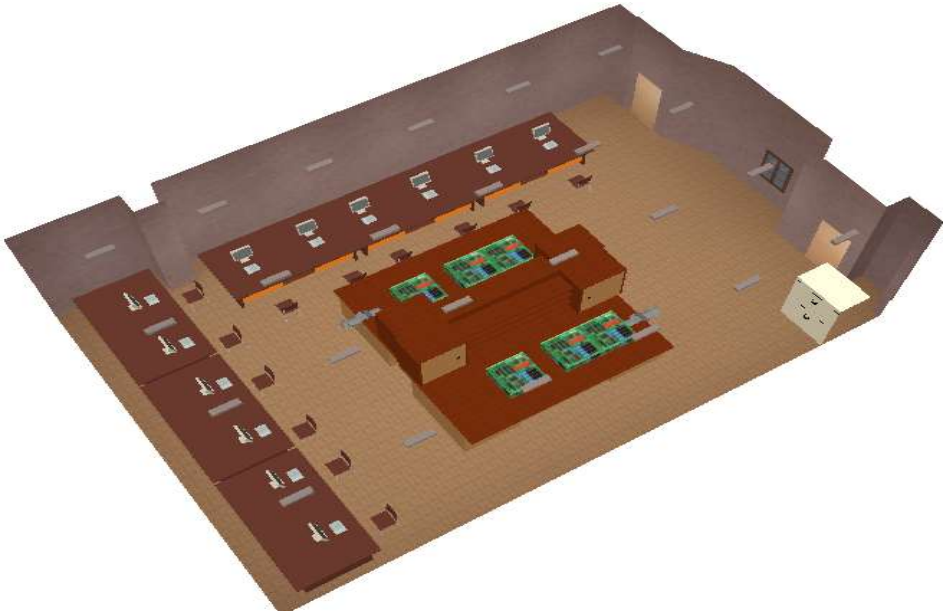


Figure-7.64(a): 3D Standard View of VLSI CAD Workshop

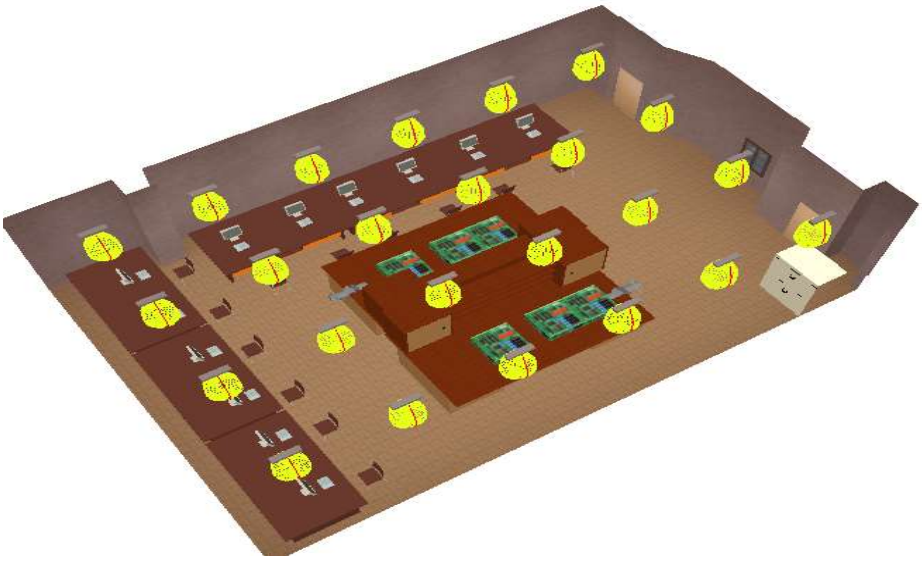
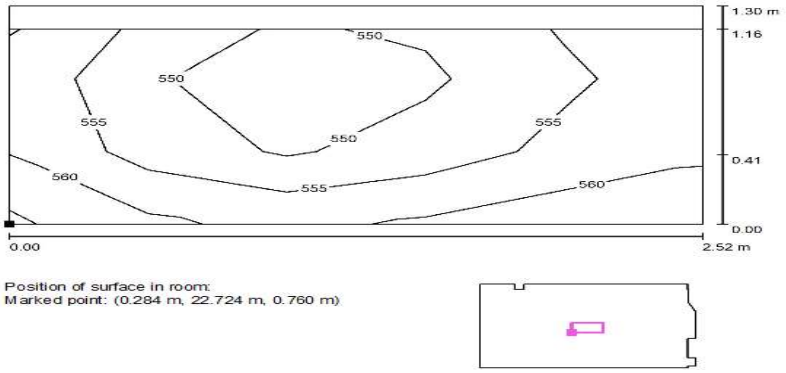


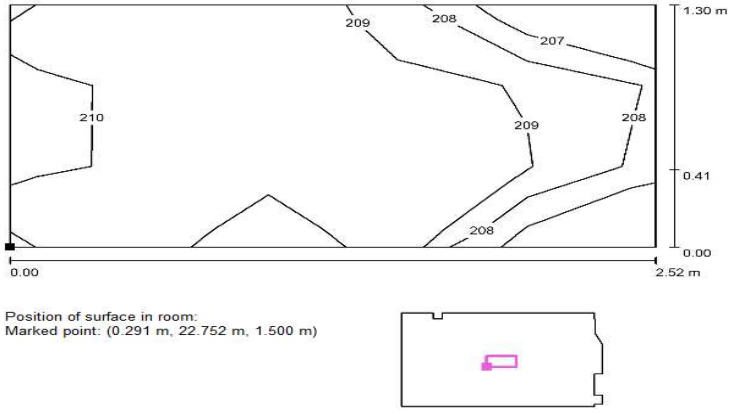
Figure-7.64(b): 3D Light Distribution Display

f) Simulated Output:



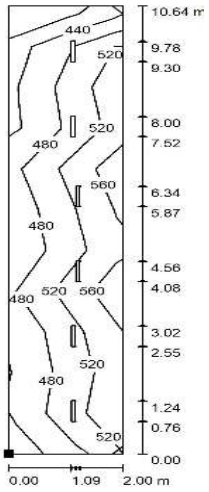
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
553	544	560	0.983	0.970

Figure-7.65: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1

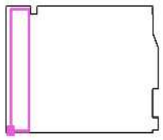


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
209	206	211	0.987	0.977

Figure-7.66: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1

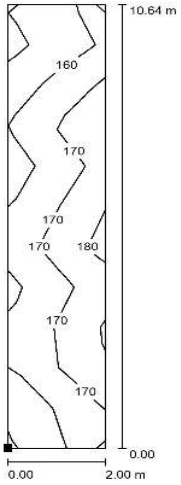


Position of surface in room:
Marked point: (-6.452 m, 18.229 m, 1.200 m)

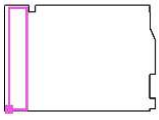


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
501	396	575	0.791	0.689

Figure-7.67: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2

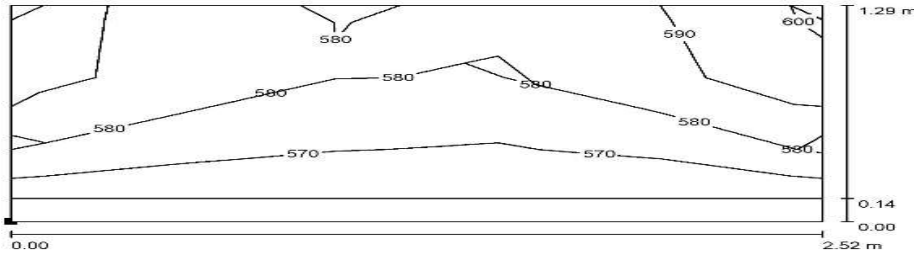


Position of surface in room:
Marked point: (-6.482 m, 18.229 m, 1.500 m)

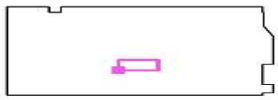


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
165	148	181	0.896	0.814

Figure-7.68: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2

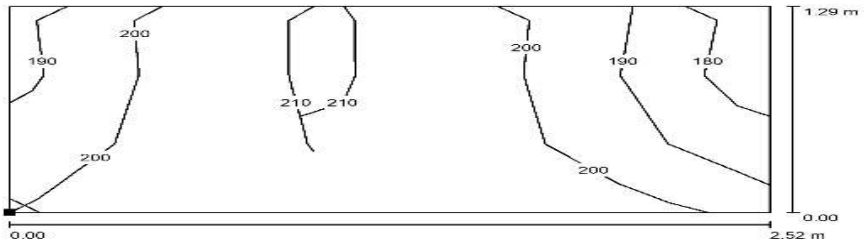


Position of surface in room:
Marked point: (0.214 m, 21.172 m, 0.760 m)

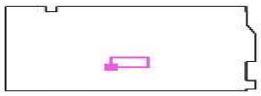


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
580	561	599	0.967	0.936

Figure-7.69: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 3

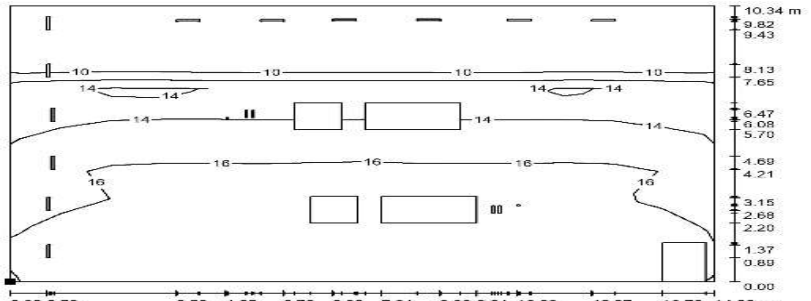


Position of surface in room:
Marked point: (0.213 m, 21.160 m, 1.500 m)



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
200	176	212	0.881	0.830

Figure-7.70: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 3



Position of surface in room:
Marked point: (-6.138 m, 18.100 m, 1.200 m)

Min
/

Max
18

Figure-7.71: UGRL on UGR Calculation Area 1

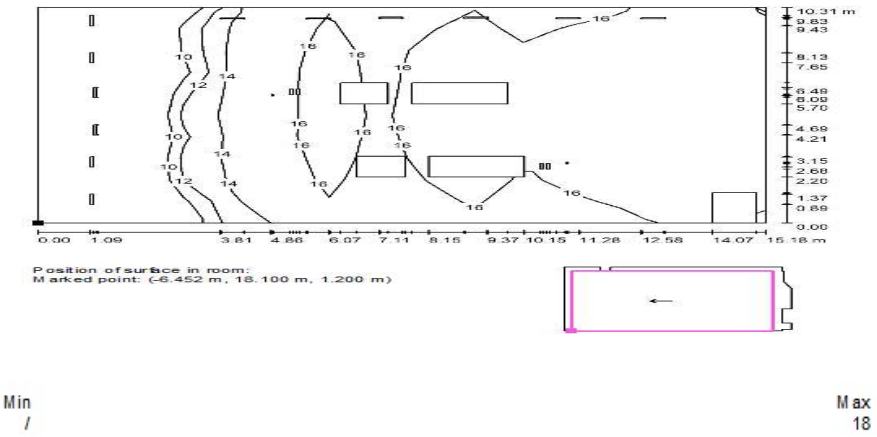


Figure-7.72: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	553	0.983	2.14 W/m^2/100 lx or 10.42W/m^2	209	0.37	18

Table-7.11: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	501	0.896	2.14 W/m^2/100 lx or 10.42W/m^2	165	0.32	18

Table-7.12: Comparison Table for Calculation Surface 2

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	580	0.967	2.14 W/m^2/100 lx or 10.42W/m^2	200	0.34	18

Table-7.13: Comparison Table for Calculation Surface 3

7.2.8.3 Core Technician Workshop

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Core Technician Workshop,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 17.1 W/m^2.

b) Floor Plan:

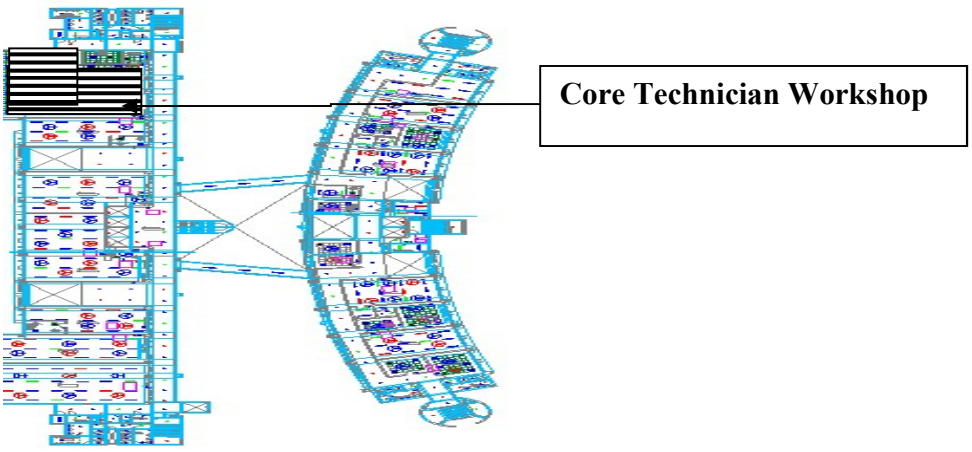
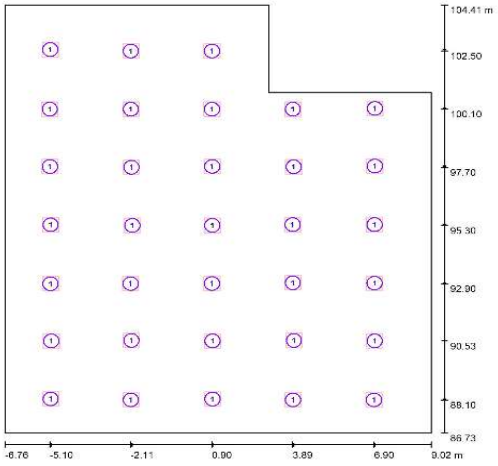


Figure-7.73: Floor Plan View of Core Technician Workshop

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	35	IB LEDS IMRC01-42WH (5700degK) Recessed Mounted 2x2 LED with Diffuser-Quadglo

Figure-7.74: Luminaire Layout of Core Technician Workshop

- Height of the room=3.9 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

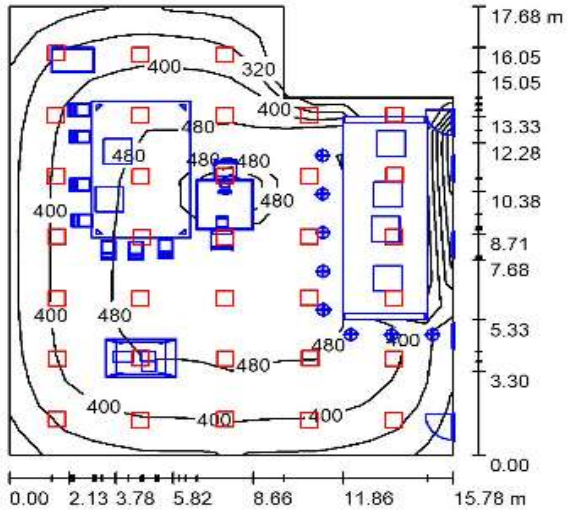


Figure-7.75(a): Isolines on Work-Plane

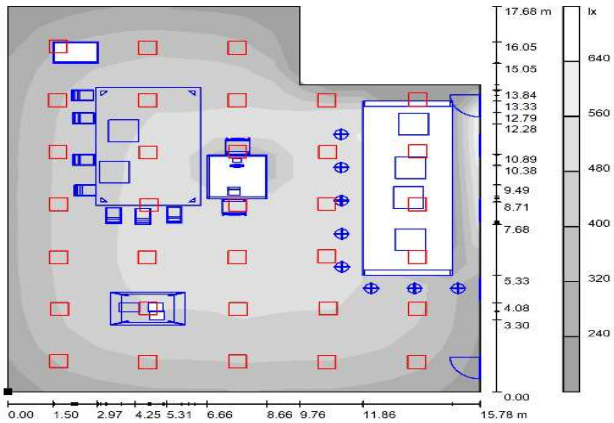


Figure-7.75(b): Greyscale on Work-Plane

e) 3D Standard View of Core Technician Workshop:

Figure-7.76(a): 3D Standard View of Core Technician Workshop

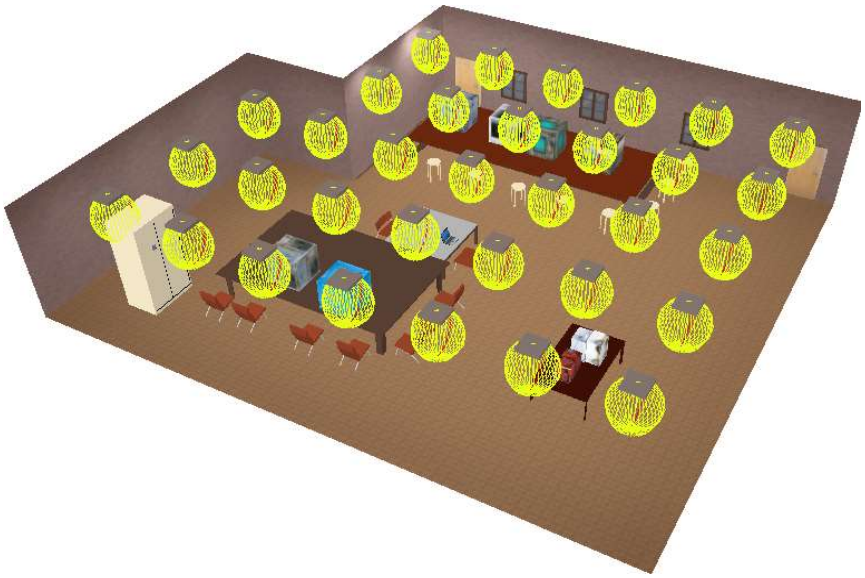
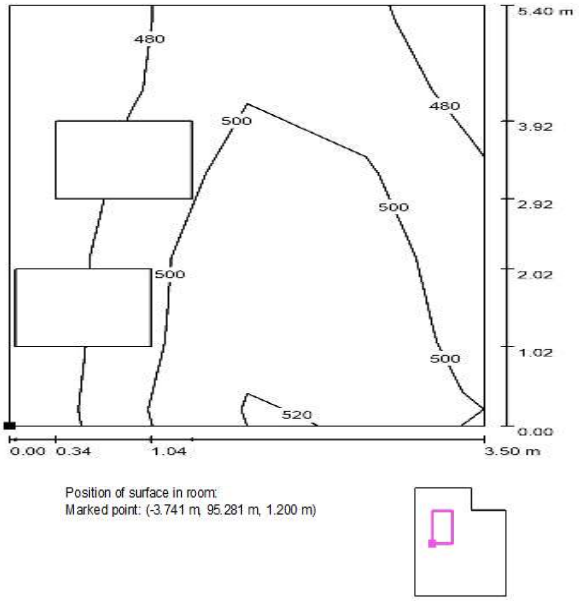
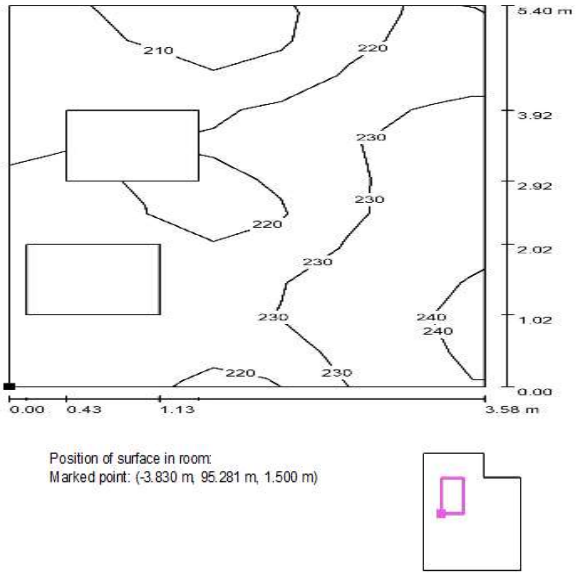


Figure-7.76(b): 3D Light Distribution Display



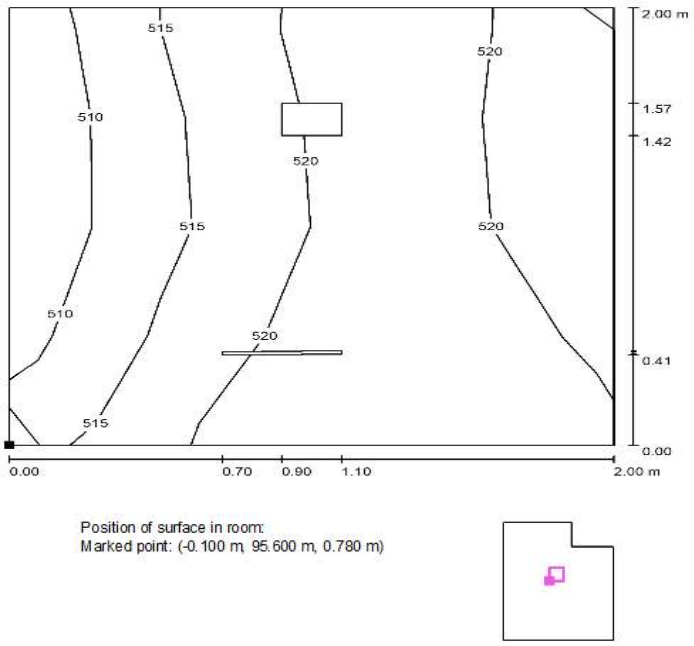
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
500	462	528	0.924	0.874

Figure-7.77: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1



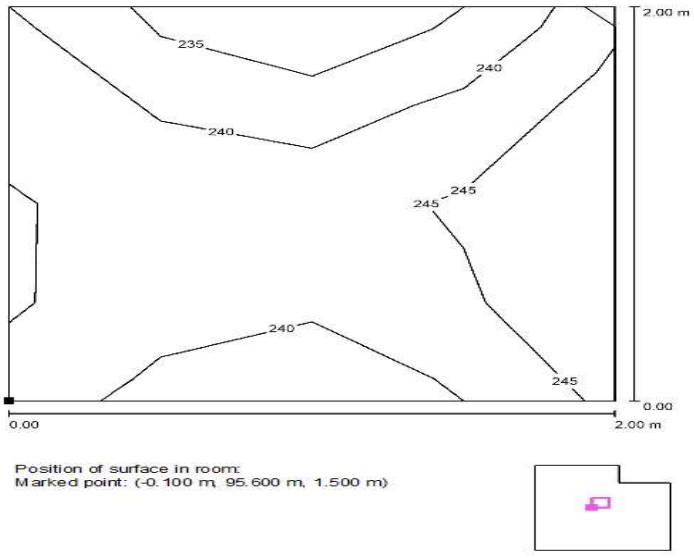
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
225	207	242	0.922	0.858

Figure-7.78: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1



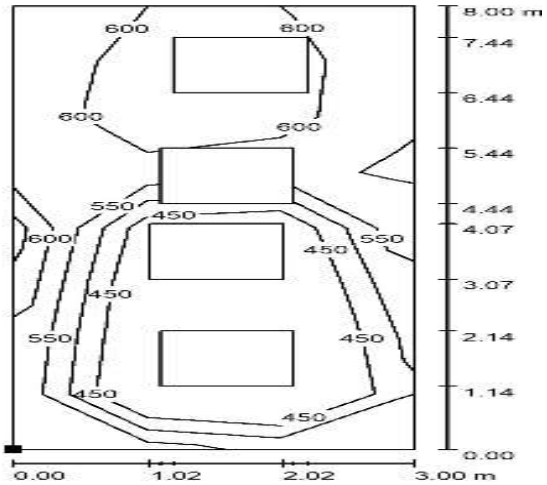
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
517	509	525	0.984	0.970

Figure-7.79: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
243	235	249	0.967	0.944

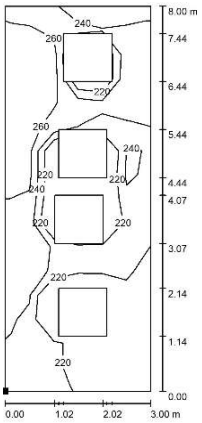
Figure-7.80: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



Position of surface in room:
Marked point: (5.100 m, 92.061 m, 0.780 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
531	412	641	0.776	0.643

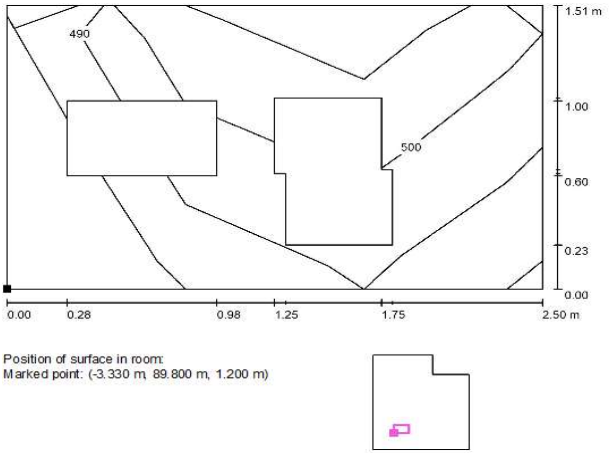
Figure-7.81: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 3



Position of surface in room:
Marked point: (5.100 m, 92.061 m, 1.500 m)

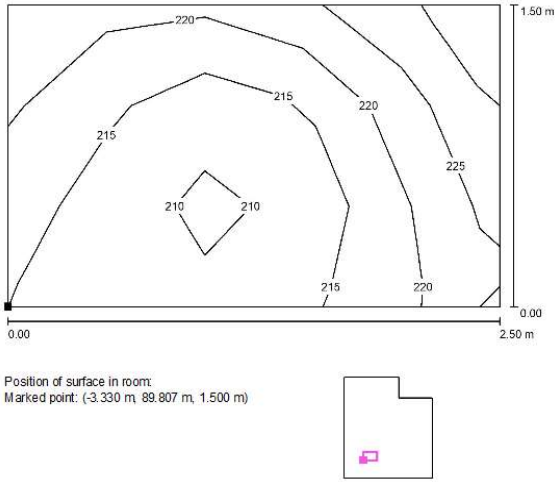
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
240	202	279	0.842	0.725

Figure-7.82: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 3



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
500	478	525	0.957	0.911

Figure-7.83: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 4



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
217	208	229	0.959	0.907

Figure-7.84: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 4

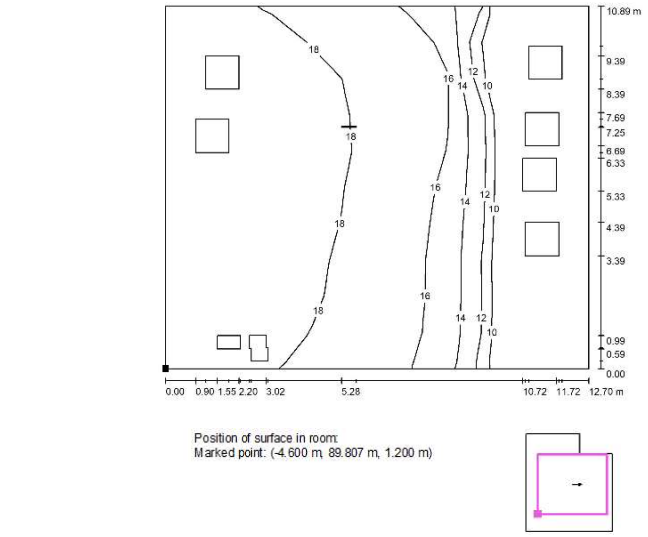


Figure-7.85: UGRL on UGR Calculation Area 1

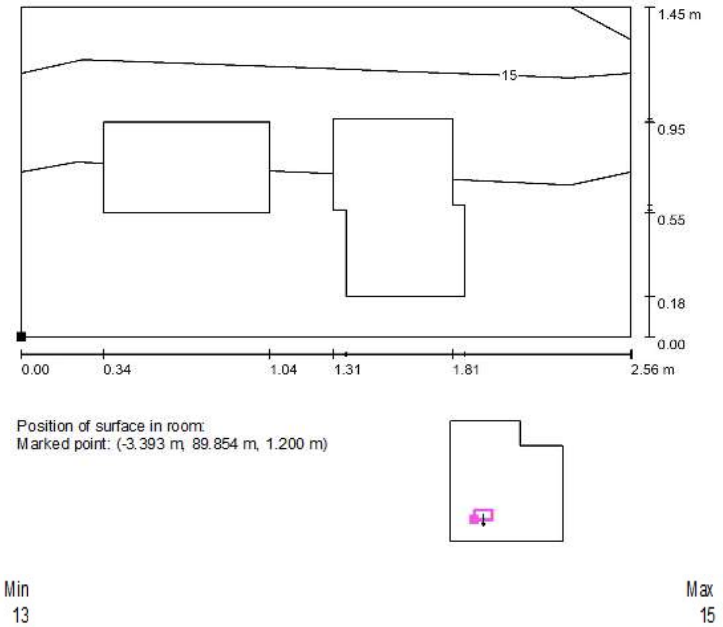


Figure-7.86: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	500	0.924	1.35W/m^2/100 lx or 5.72W/m^2	225	0.45	19

Table-7.14: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	517	0.984	1.35W/m^2/100 lx or 5.72W/m^2	243	0.47	19

Table-7.15: Comparison Table for Calculation Surface 2

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	531	0.776	1.35W/m^2/100 lx or 5.72W/m^2	240	0.45	19

Table-7.16: Comparison Table for Calculation Surface 3

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	500	0.957	1.35W/m^2/100 lx or 5.72W/m^2	217	0.43	19

Table-7.17: Comparison Table for Calculation Surface 4

7.2.8.4 IC Testing and Characterization Workshop

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in IC Testing and Characterization Workshop,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 17.1 W/m^2.

b) Floor Plan:

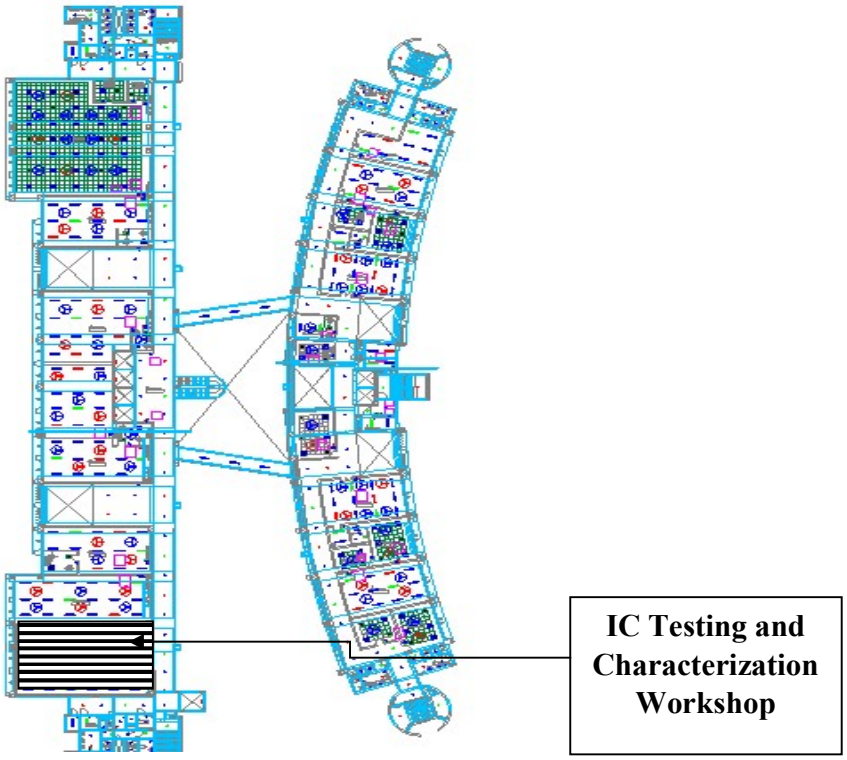
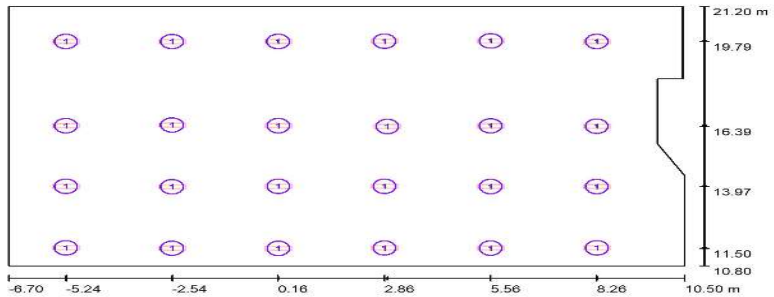


Figure-7.87: Floor Plan View of IC Testing and Characterization Workshop

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	24	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.88: Luminaire Layout of IC Testing and Characterization Workshop

- Height of the room=3.9 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

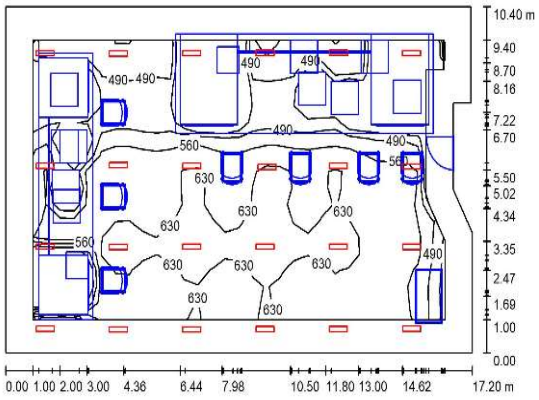


Figure-7.89(a): Isolines on Work-Plane

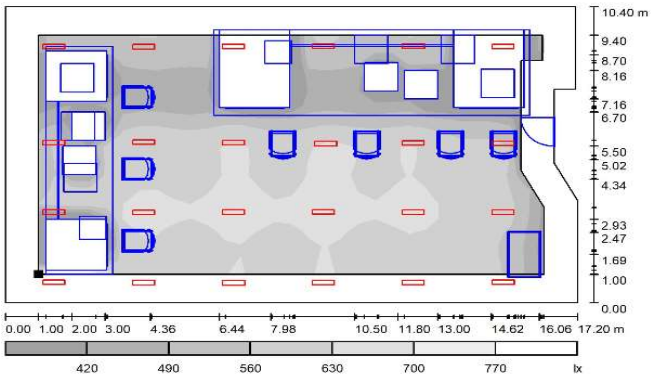


Figure-7.89(b): Greyscale on Work-Plane

e) 3D Standard View IC Testing and Characterization Workshop:

Figure-7.90(a): 3D Standard View of IC Testing and Characterization Workshop

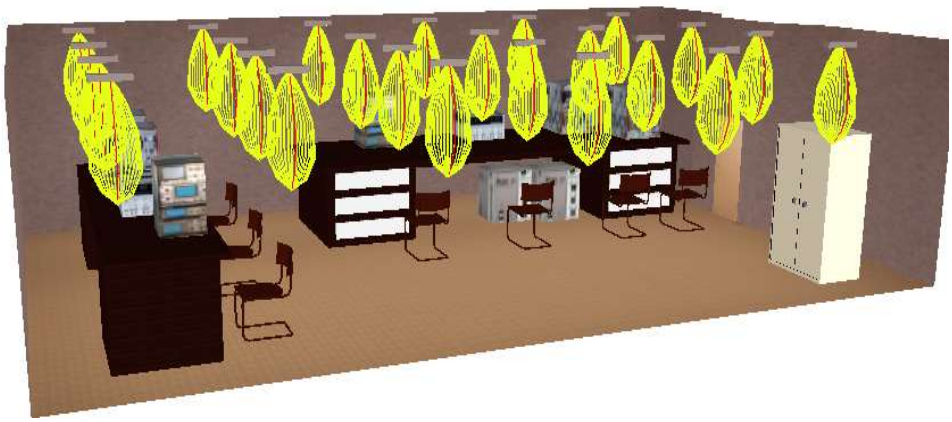
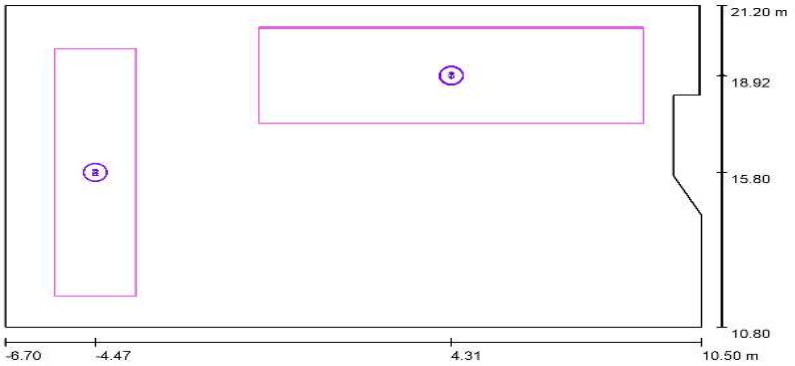


Figure-7.90(b): 3D Light Distribution Display

f) Simulated Output:



Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	2	531	272	964	0.51	0.28
cyl.	2	180	165	189	0.92	0.87

Figure-7.91: Maintained Average Illuminance ($\overline{E_m}$) and Mean Cylindrical Illuminance on Calculation Surfaces

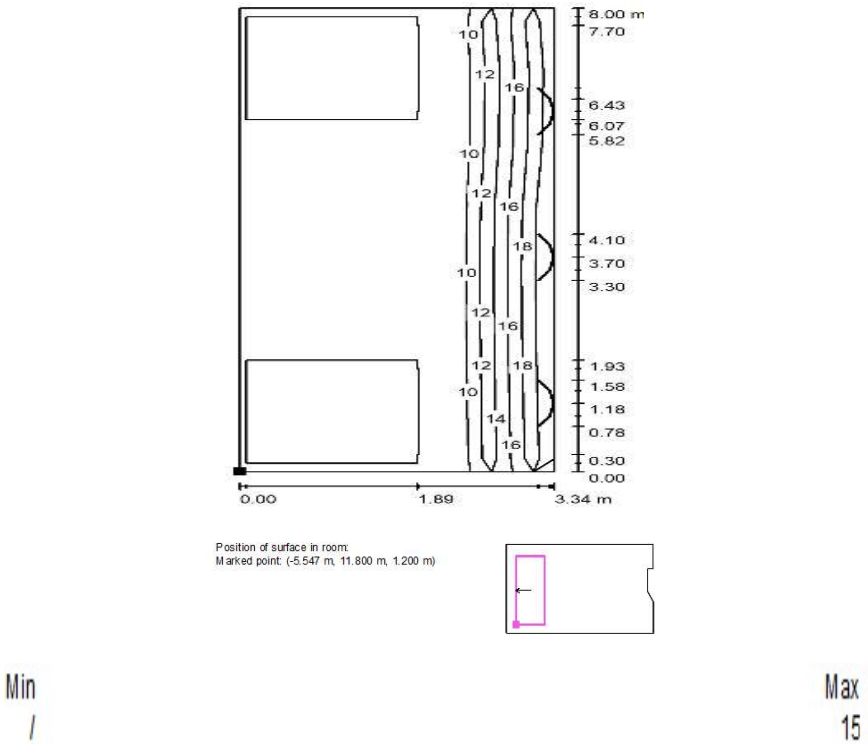


Figure-7.92: UGRL on UGR Calculation Area 1

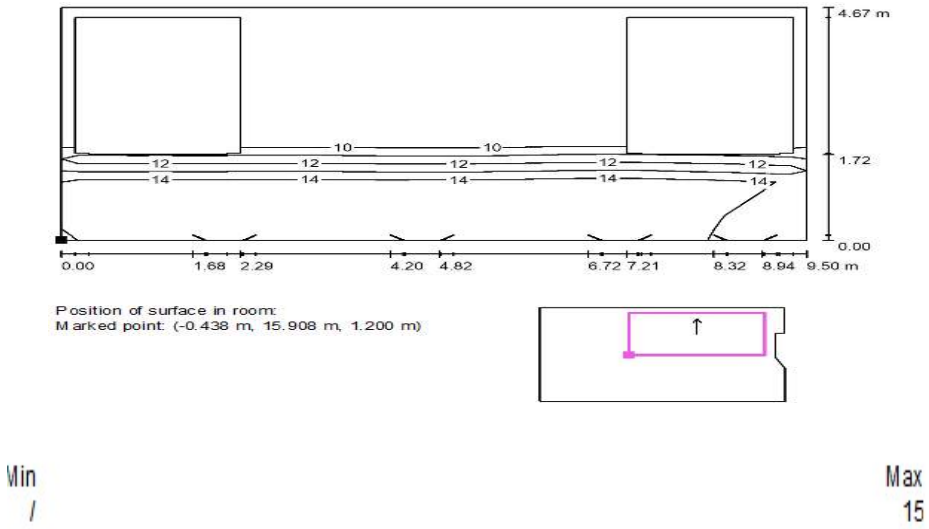


Figure-7.93: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	17.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	531	0.51	2.14 W/m^2/100 lx or 10.42W/m^2	180	0.33	15

Table-7.18: Comparison Table for Calculation Surface

7.2.9 Lighting Design of Dean's Cabin

a) Design Consideration: The Dean's Cabin is a place where he or she organizes assembly for discussions, study or rest during recess periods. This room should have general illumination for performing visual tasks like reading and writing (correcting papers and notebooks).

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Dean's Cabin,

- Maintained Average Illuminance ($\overline{E_m}$)=300 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

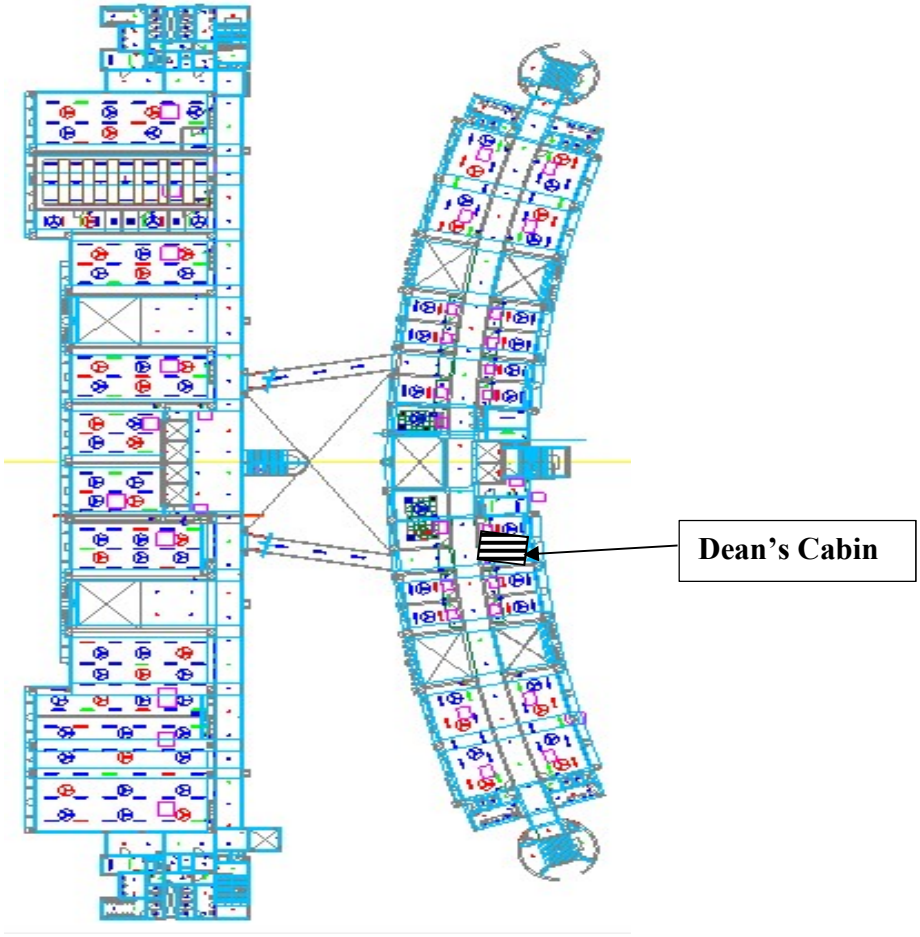
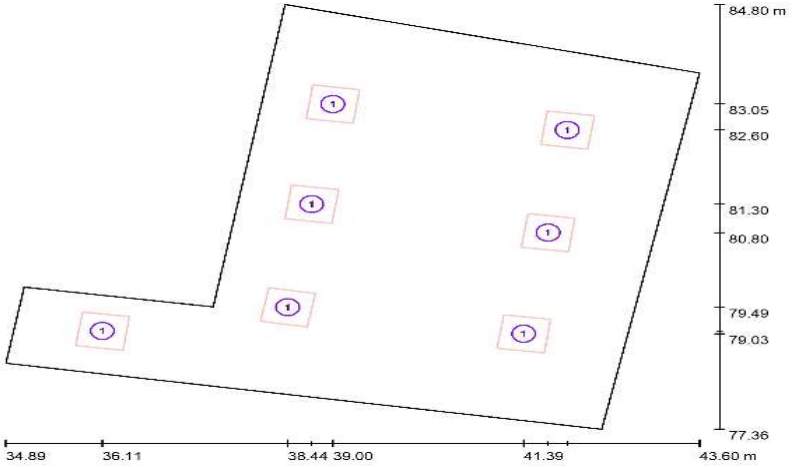


Figure-7.94: Floor Plan View of Dean's Cabin

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	7	IB LEDS IM RC01-36WH (5700degK) Recessed M ounted 2x2 LED with Diffuser-Quadglo

Figure-7.95: Luminaire Layout of Dean's Cabin

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

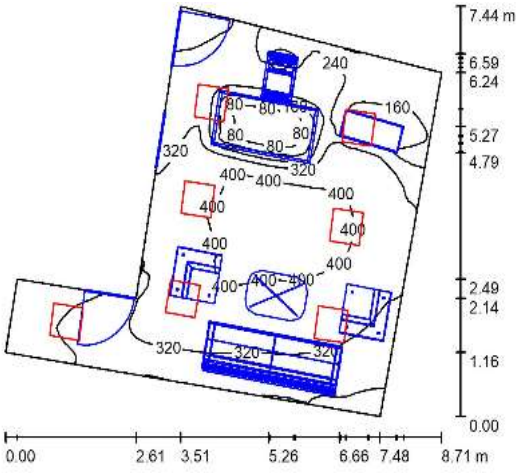


Figure-7.96(a): Isolines on Work-Plane

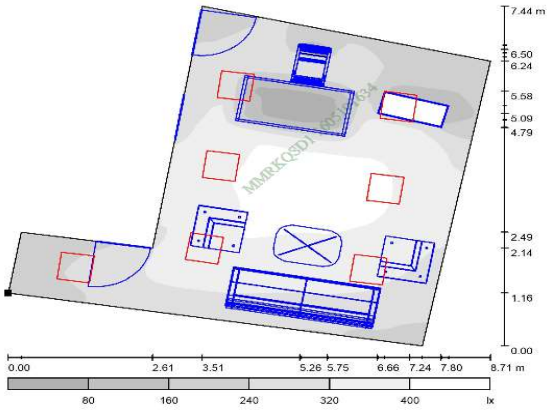


Figure-7.96(b): Greyscale on Work-Plane

e) 3D Standard View of Dean's Cabin:

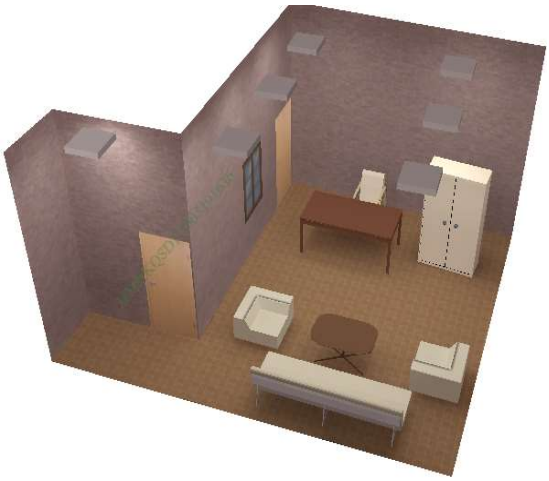


Figure-7.97(a): 3D Standard View of Dean's Cabin

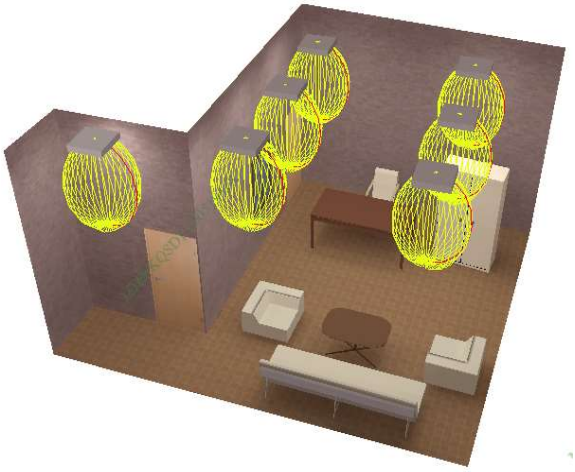
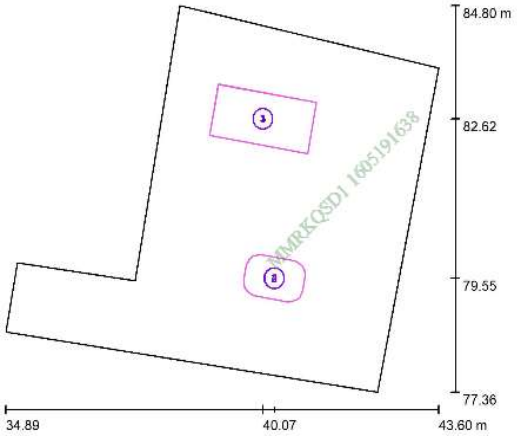


Figure-7.97(b): 3D Light Distribution Display

f) Simulated Output:



Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	2	378	368	391	0.97	0.94
cyl.	2	173	156	191	0.90	0.82

Figure-98: Maintained Average Illuminance ($\overline{E_m}$) and Mean Cylindrical Illuminance on Calculation Surfaces

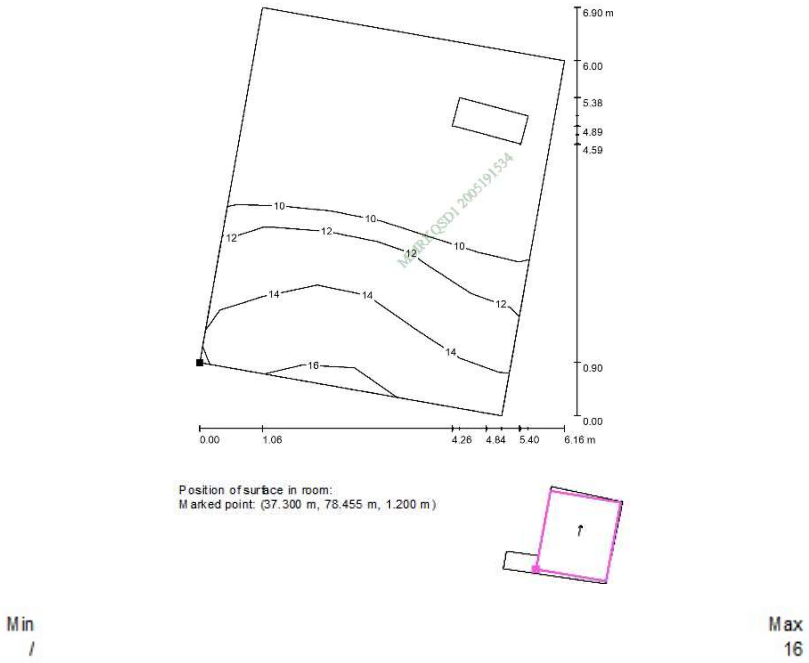


Figure-7.99: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	378	0.97	2.22 W/m^2/100 lx or 6.69W/m^2	173	0.45	16

Table-7.19: Comparison Table for Calculation Surface

7.2.10 Lighting Design of Conference Hall

a) Design Consideration: The Conference Hall provides scopes and facilities not only for academic presentations, academic meetings, academic exhibitions but also conducts corporate presentations and many more.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Conference Hall,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 11.5 W/m^2.

b) Floor Plan:

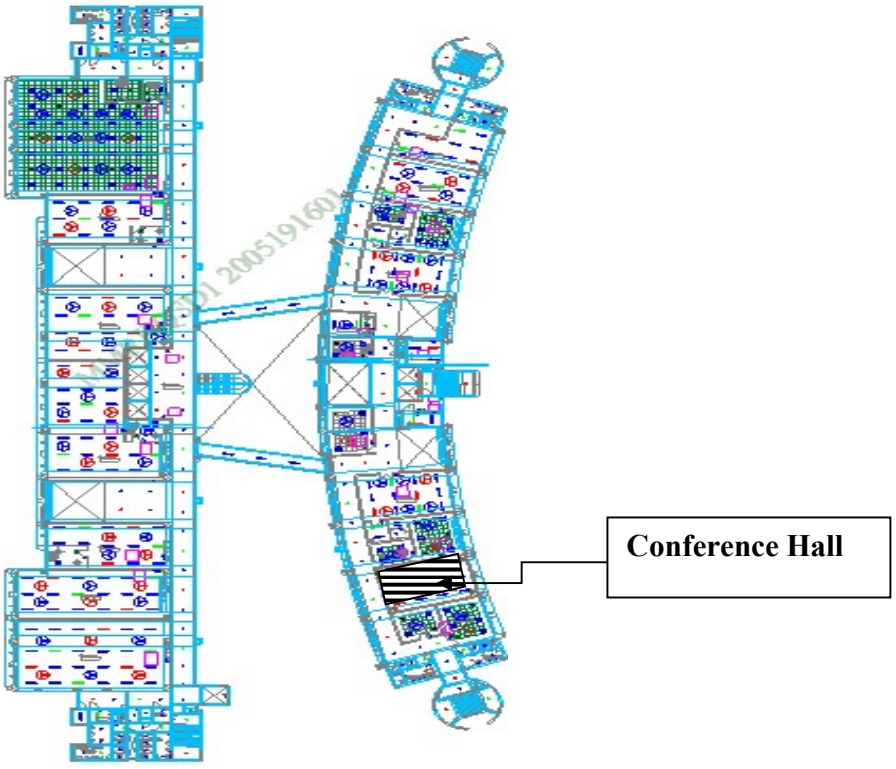
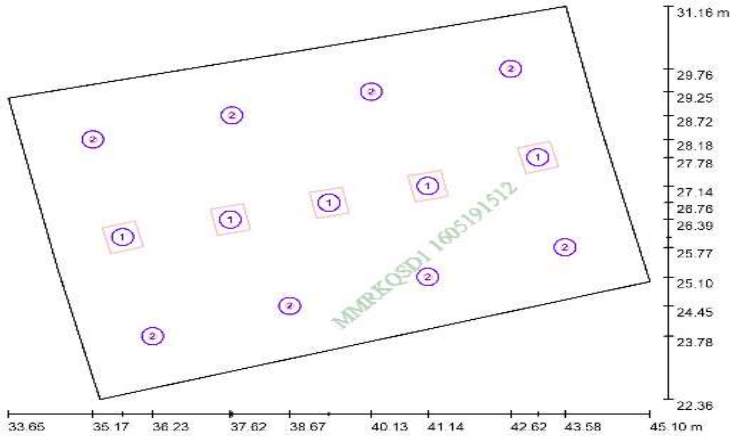


Figure-7.100: Floor Plan View of Conference Hall

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	5	IB LEDS IMRC01-42WH (5700degK) Recessed Mounted 2x2 LED with Diffuser-Quadglo
2	8	IbLED IRDLR21RD-24XX (4000/5700/6500 degK) Recess Mounted LED Downlighter-GlowRound

Figure-7.101: Luminaire Layout of Conference Hall

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

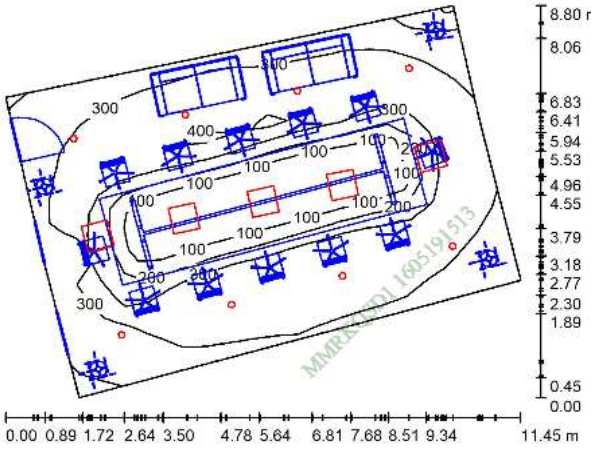


Figure-7.102(a): Isolines on Work-Plane

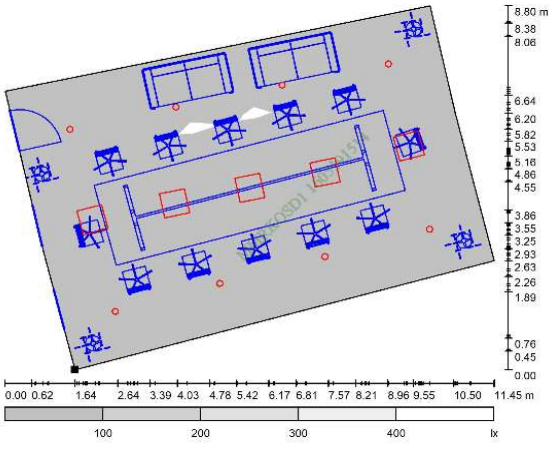


Figure-7.102(b): Greyscale on Work-Plane

e) 3D Standard View of Conference Hall:

Figure-7.103(a): 3D Standard View of Conference Hall

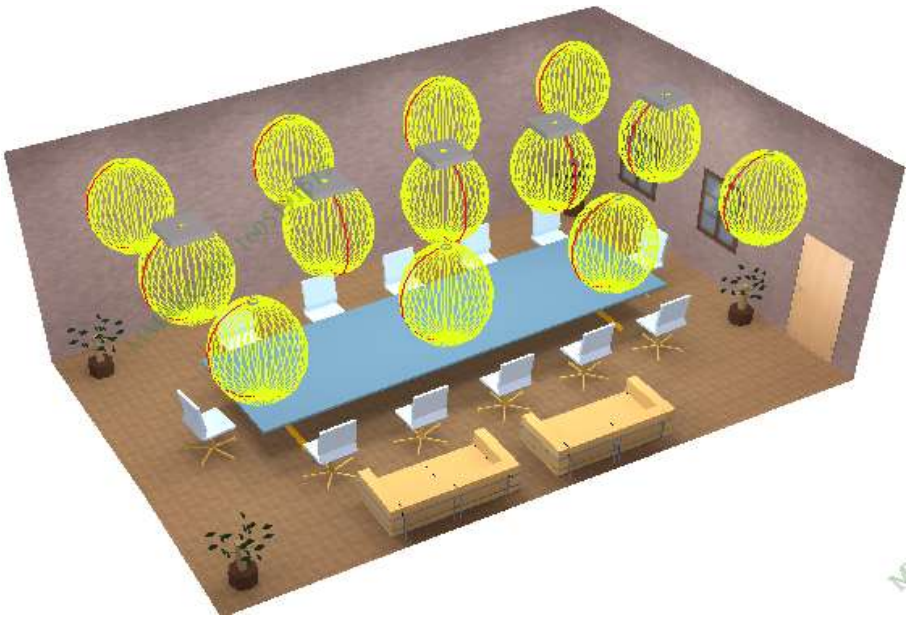
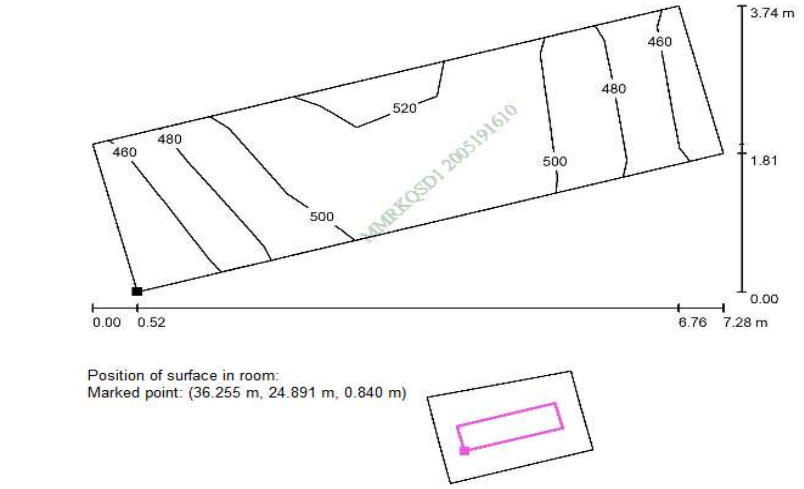


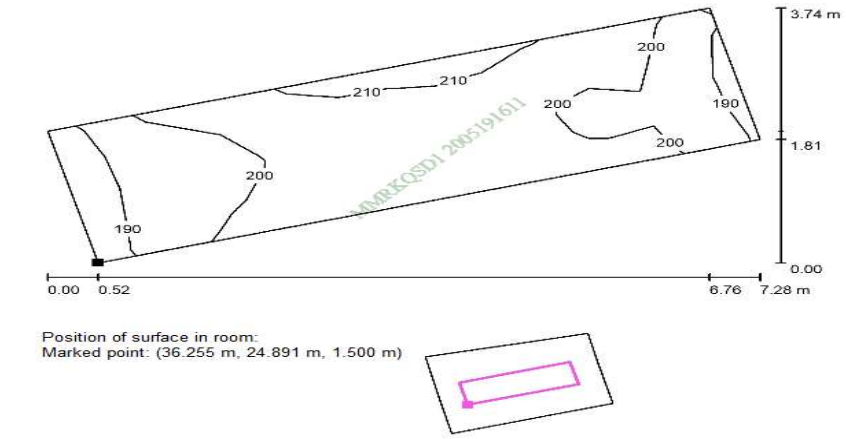
Figure-7.103(b): 3D Light Distribution Display

f) Simulated Output:



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
505	478	532	0.945	0.897

Figure-7.104: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
201	185	212	0.921	0.874

Figure-7.105: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

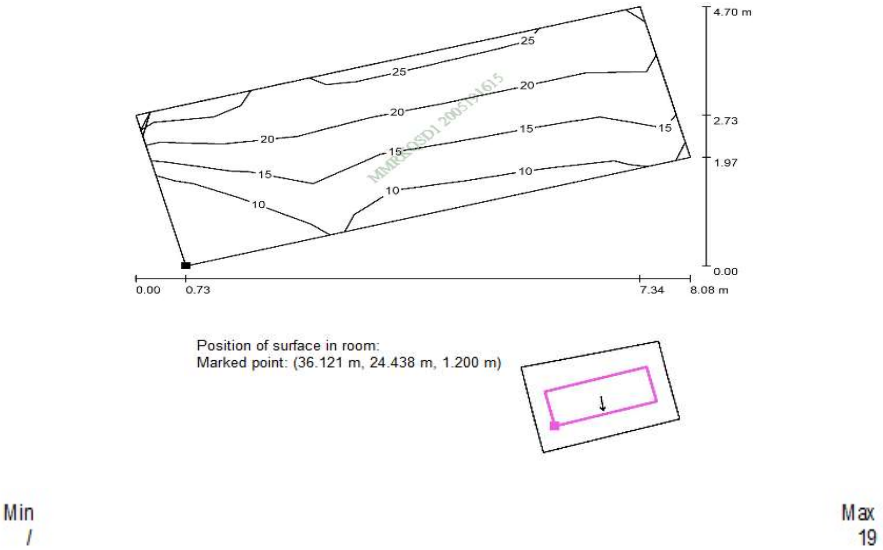


Figure-7.106: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	11.50 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	505	0.945	2.14 W/m^2/100 lx or 10.42W/m^2	201	0.39	19

Table-7.20: Comparison Table for Calculation Surface

7.2.11 Lighting Design of Laboratories

A technical Laboratory is a room where the laboratory instructors, teachers teach students to develop technological growth in students. A laboratory is a consortium that develops and provides technical standards, softwares and services to drive the technological growth in an effective and sustainable way. The laboratory may involve tables and benches at which very detailed work is carried out in dissection, inspection, instrumentation and measurement. Good diffusion with some directional component and appropriate colour quality is required. In this case study some laboratory designs include:

- Embedded System Laboratory
- Speech Processing Laboratory
- Power Electronics Laboratory

7.2.11.1 Lighting Design of Embedded System Laboratory

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Embedded System Laboratory,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 15.1 W/m^2.

b) Floor Plan:

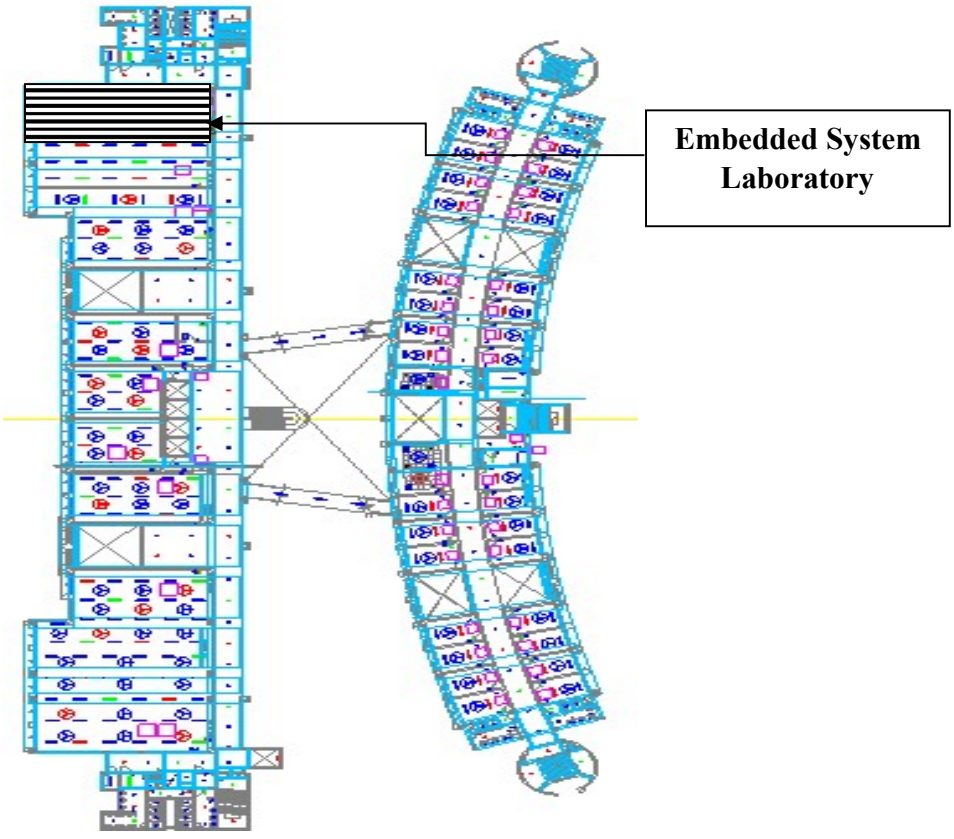
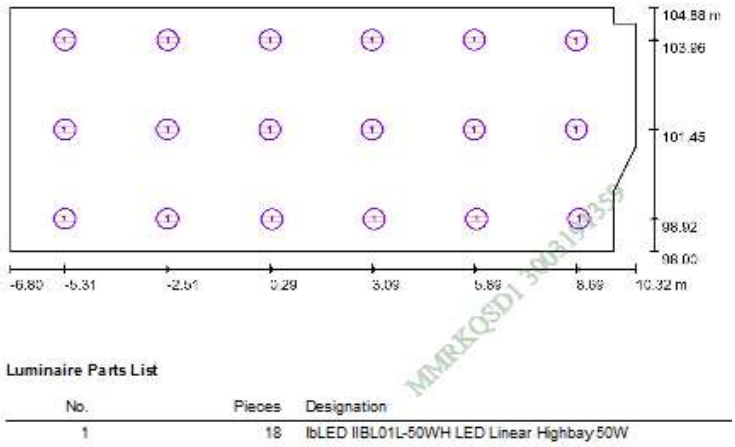


Figure-7.107: Floor Plan View of Embedded System Laboratory

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	18	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.108: Luminaire Layout of Embedded System Laboratory

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

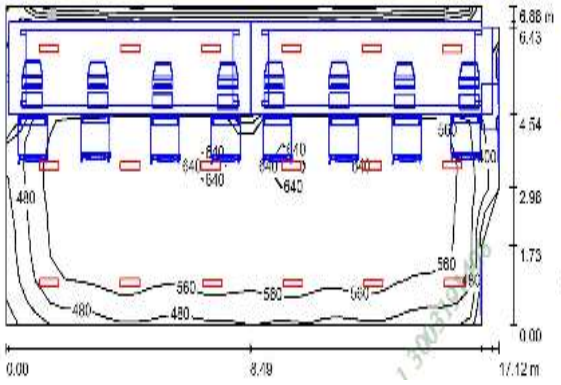


Figure-7.109(a): Isolines on Work-Plane

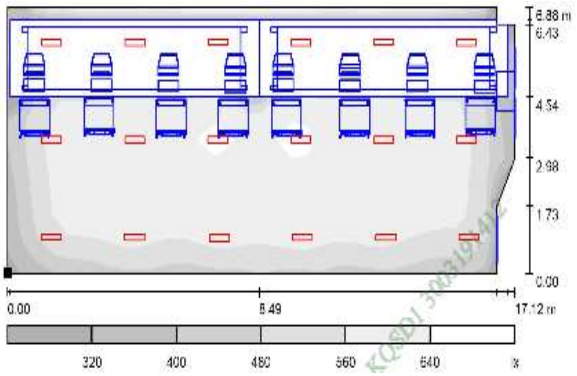


Figure-7.109(b): Greyscale on Work-Plane

e) 3D Standard View of Embedded System Laboratory:

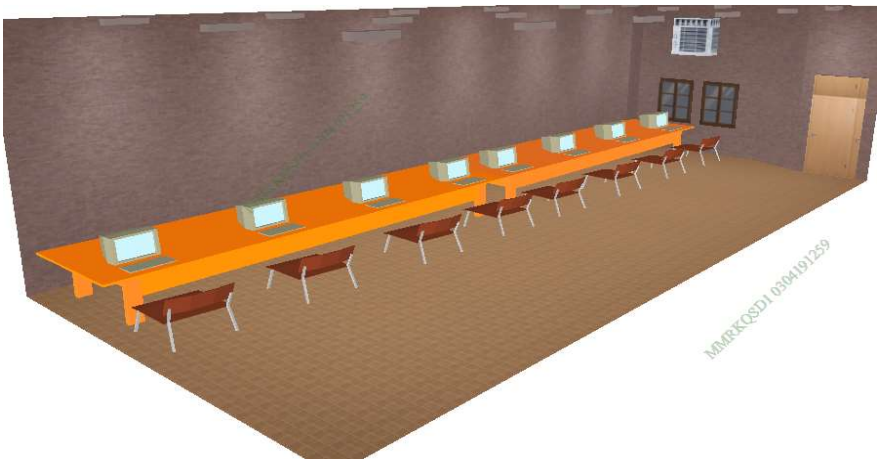


Figure-7.110(a): 3D Standard View of Embedded System Laboratory

Figure-7.110(b): 3D Light Distribution Display

f) Simulated Output:

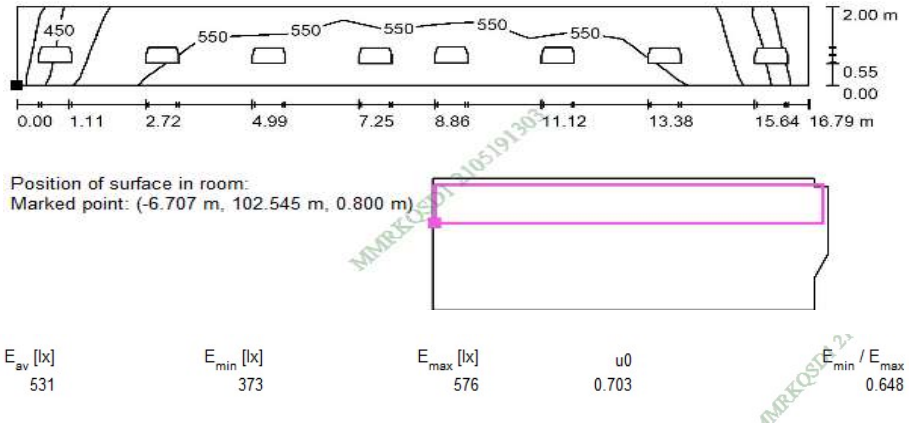


Figure-7.111: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface

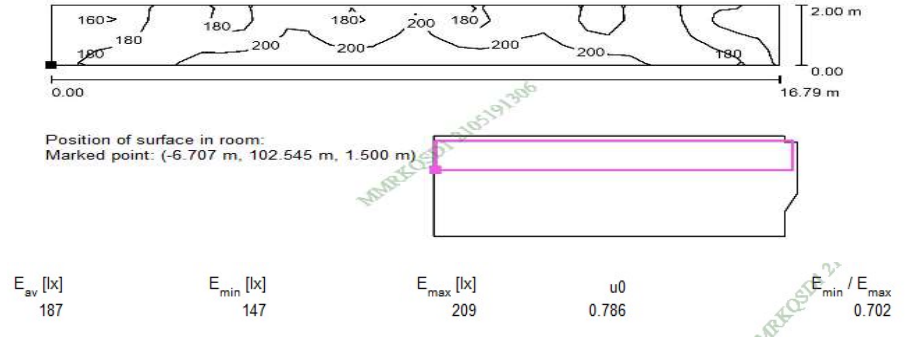


Figure-7.111: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

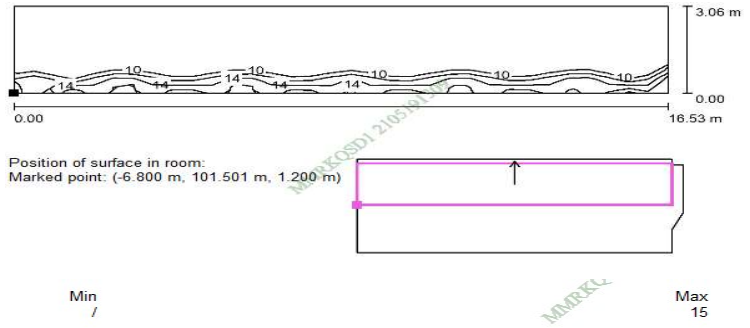


Figure-7.112: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	531	0.703	2.36W/m^2/100 lx or 12.41 W/m^2	187	0.35	15

Table-7.21: Comparison Table for Calculation Surface

7.2.11.2 Lighting Design of Speech Processing Laboratory

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Speech Processing Laboratory,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 15.1 W/m^2.

b) Floor Plan:

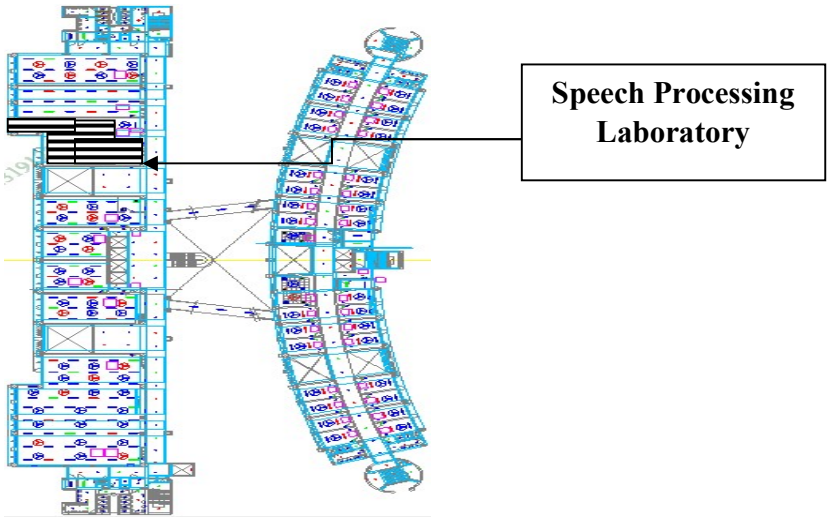
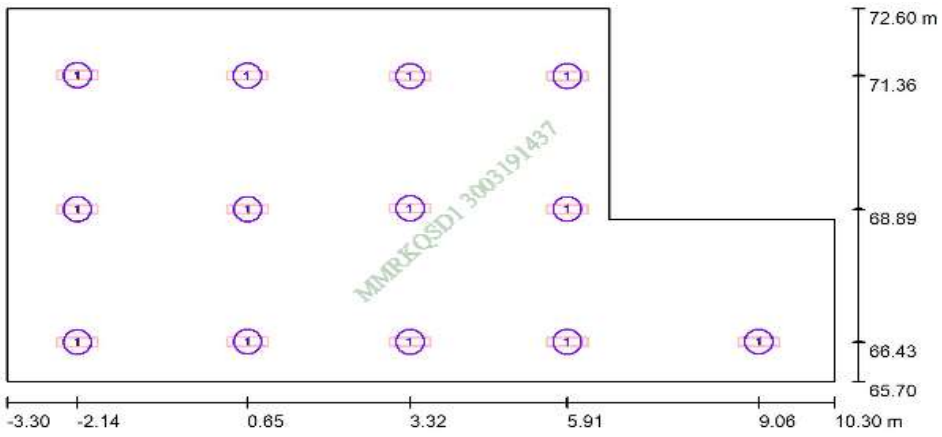


Figure-7.113: Floor Plan View of Speech Processing Laboratory

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	13	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.114: Luminaire Layout of Speech Processing Laboratory

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

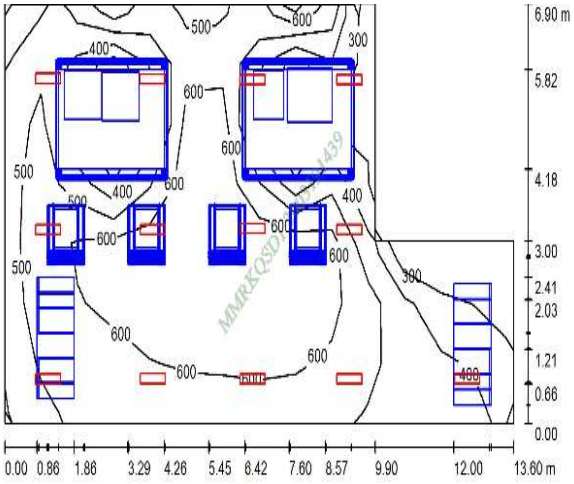


Figure-7.115(a): Isolines on Work-Plane

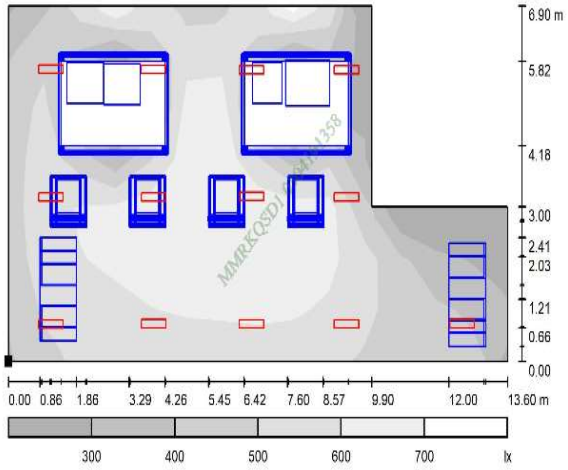


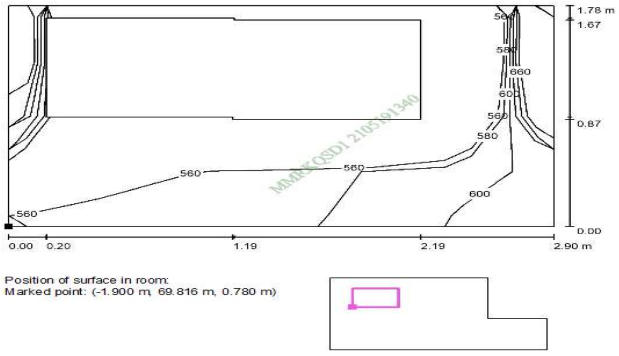
Figure-7.115(b): Greyscale on Work-Plane

e) 3D Standard View of Speech Processing Laboratory:

Figure-7.116(a): 3D Standard View of Speech Processing Laboratory

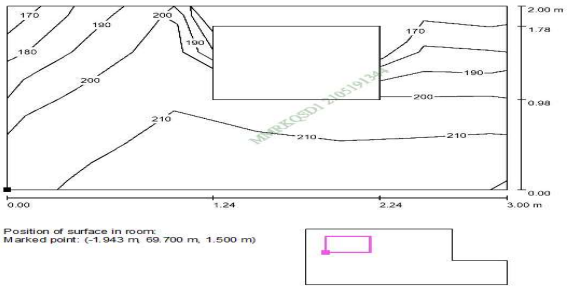
Figure-7.116(b): 3D Light Distribution Display

f) Simulated Output:



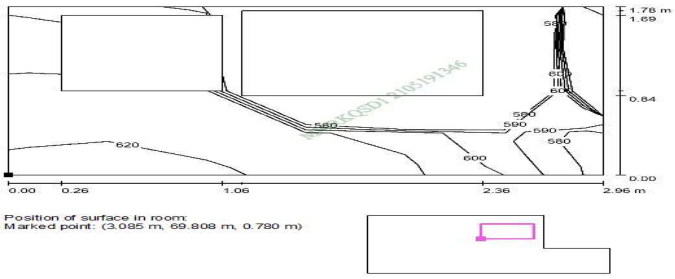
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
575	552	604	0.959	0.914

Figure-7.117: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1



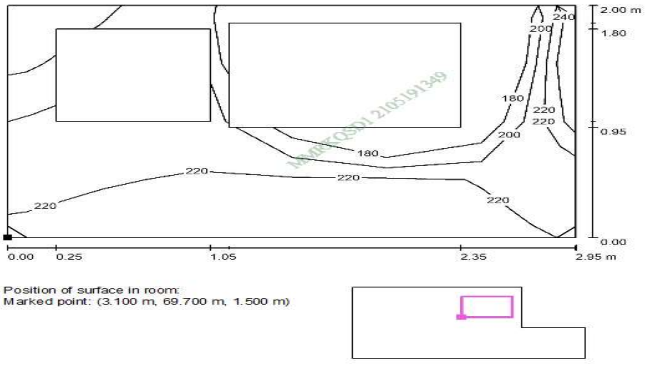
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
202	168	215	0.832	0.783

Figure-7.118: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1



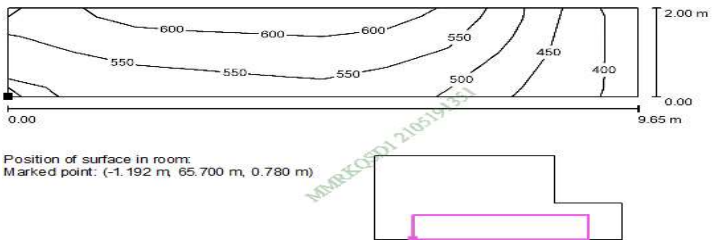
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
603	575	622	0.954	0.925

Figure-7.119: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2



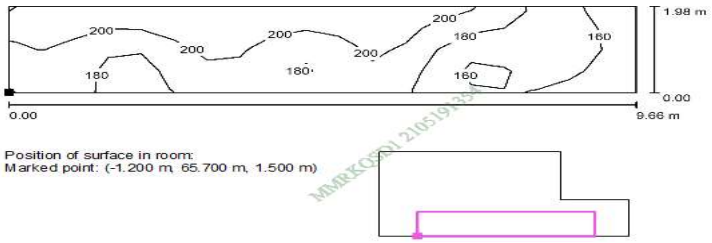
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
211	171	225	0.812	0.760

Figure-7.120: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



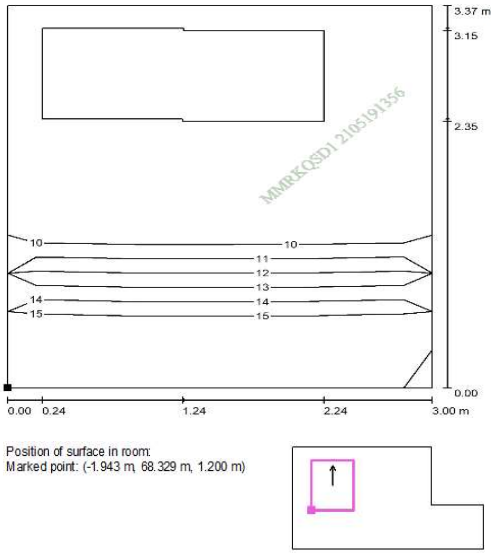
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
539	399	607	0.739	0.657

Figure-7.121: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 3



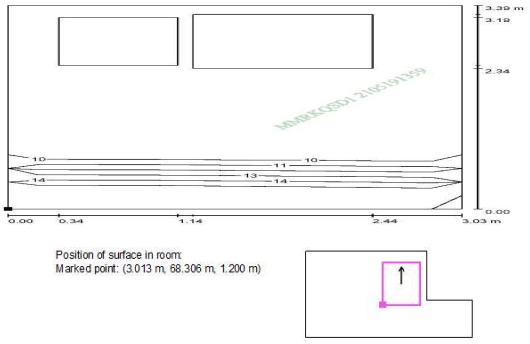
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
186	149	213	0.798	0.698

Figure-7.122: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 3



Min	Max
/	13

Figure-7.123: UGRL on UGR Calculation Area 1



Min	Max
/	13

Figure-7.124: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	575	0.959	2.53W/m^2/100 lx or 13.10 W/m^2	202	0.351	13

Table-7.22: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	603	0.954	2.53W/m^2/100 lx or 13.10 W/m^2	211	0.34	13

Table-7.23: Comparison Table for Calculation Surface

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	539	0.739	2.53W/m^2/100 lx or 13.10 W/m^2	185	0.34	13

Table-7.24: Comparison Table for Calculation Surface 3

7.2.11.3 Lighting Design of Power Electronics Laboratory

a) Design Consideration: According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Power Electronics Laboratory,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 15.1 W/m^2.

b) Floor Plan:

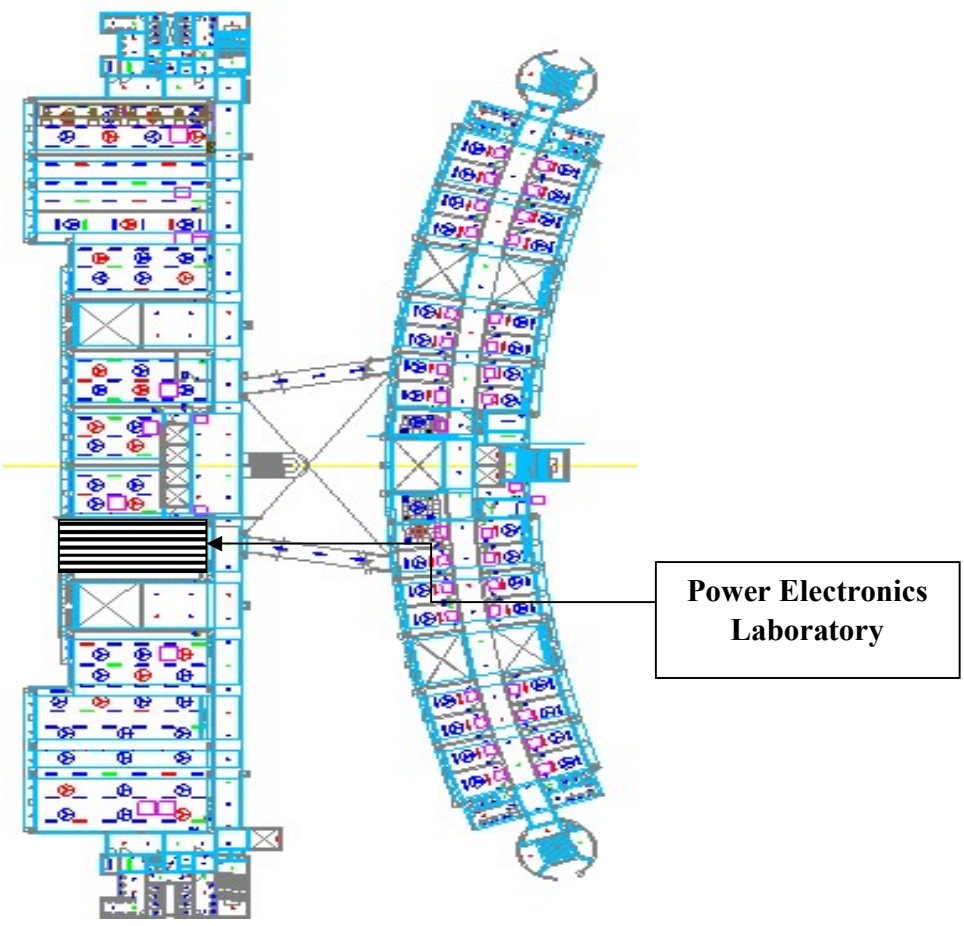
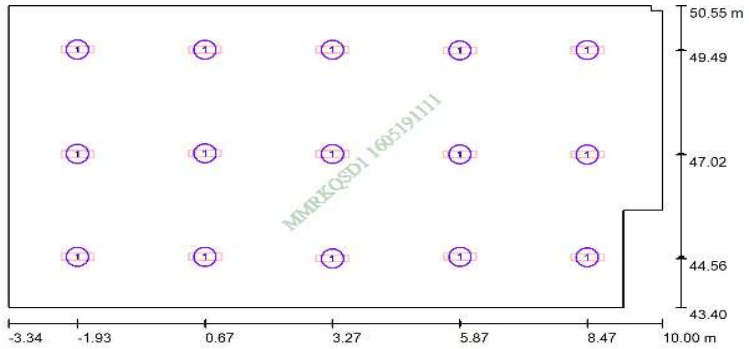


Figure-7.125: Floor Plan View of Power Electronics Laboratory

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	15	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.126: Luminaire Layout of Power Electronics Laboratory

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

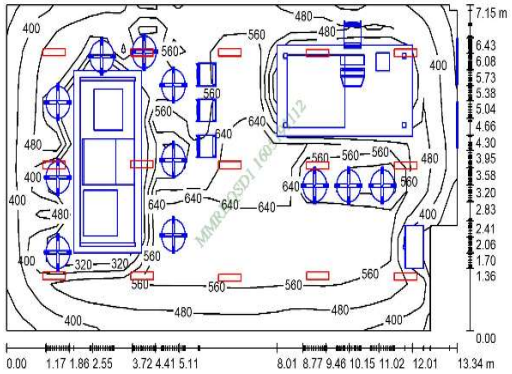


Figure-7.127(a): Isolines on Work-Plane

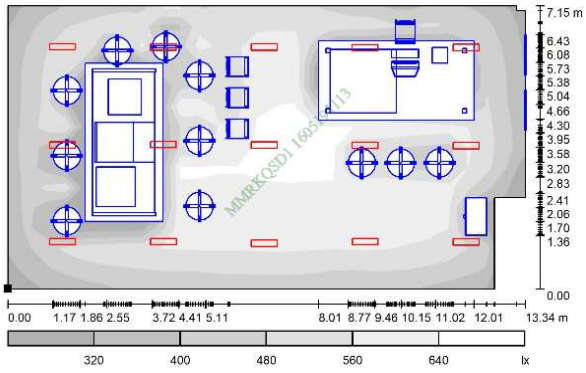


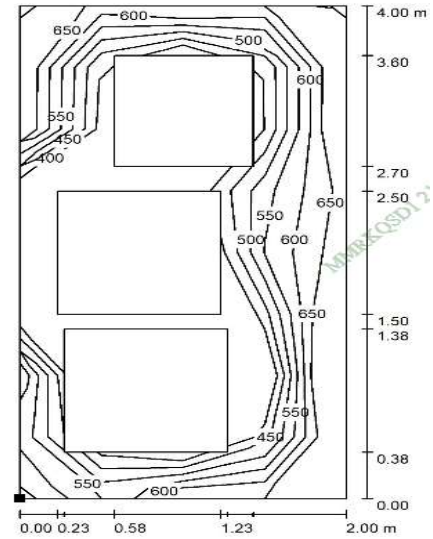
Figure-7.127(b): Greyscale on Work-Plane

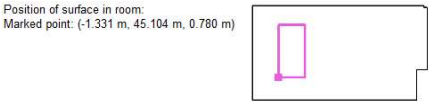
e) 3D Standard View of Power Electronics Laboratory:

Figure-7.128(a): 3D Standard View of Power Electronics Laboratory

Figure-7.128(b): 3D Light Distribution Display

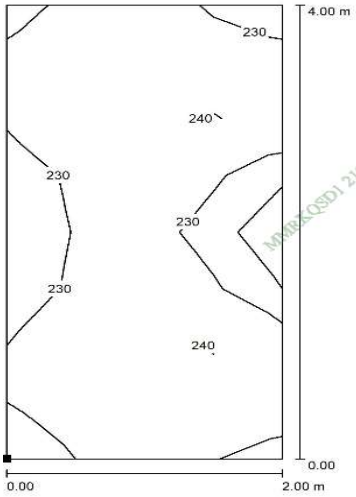
f) Simulated Output:



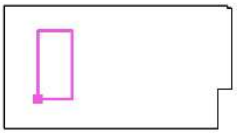


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
511	390	614	0.762	0.635

Figure-7.129: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1

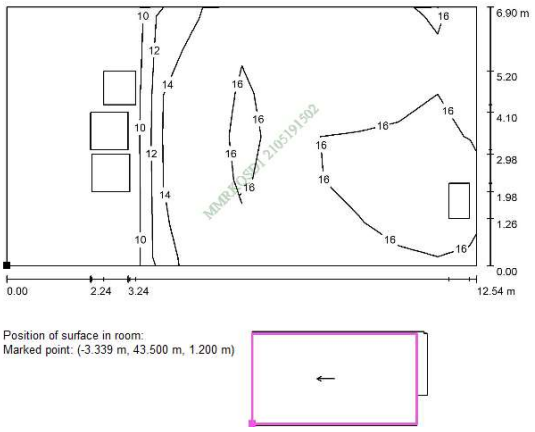


Position of surface in room:
Marked point: (-1.341 m, 45.104 m, 1.500 m)



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
236	218	244	0.923	0.890

Figure-7.130: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



Position of surface in room:
Marked point: (-3.339 m, 43.500 m, 1.200 m)

Min	Max
/	19

Figure-7.131: UGRL on UGR Calculation Area 1

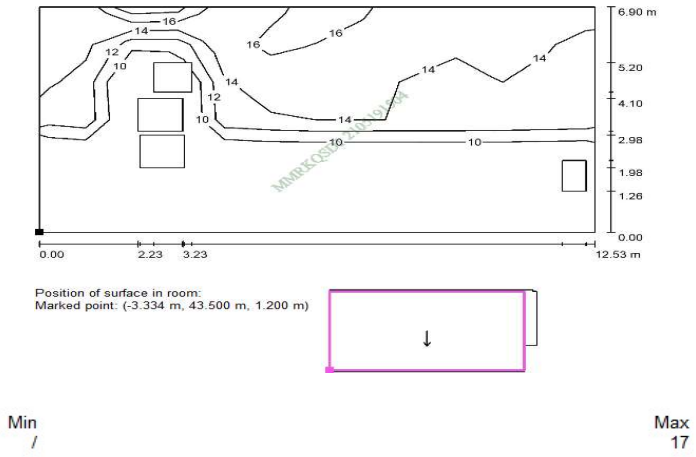


Figure-7.132: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	511	0.762	2.39W/m^2/100 lx or 12.84W/m^2	236	0.46	19

Table-7.25: Comparison Table for Calculation Surface

7.2.12 Lighting Design of Signal Processing Demonstration Bench

a) Design Consideration: This is a room which provides many facilities for pursuing research and development work in the areas of signal processing and digital communication.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Signal Processing Demonstration Bench,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 15.1 W/m^2.

b) Floor Plan:

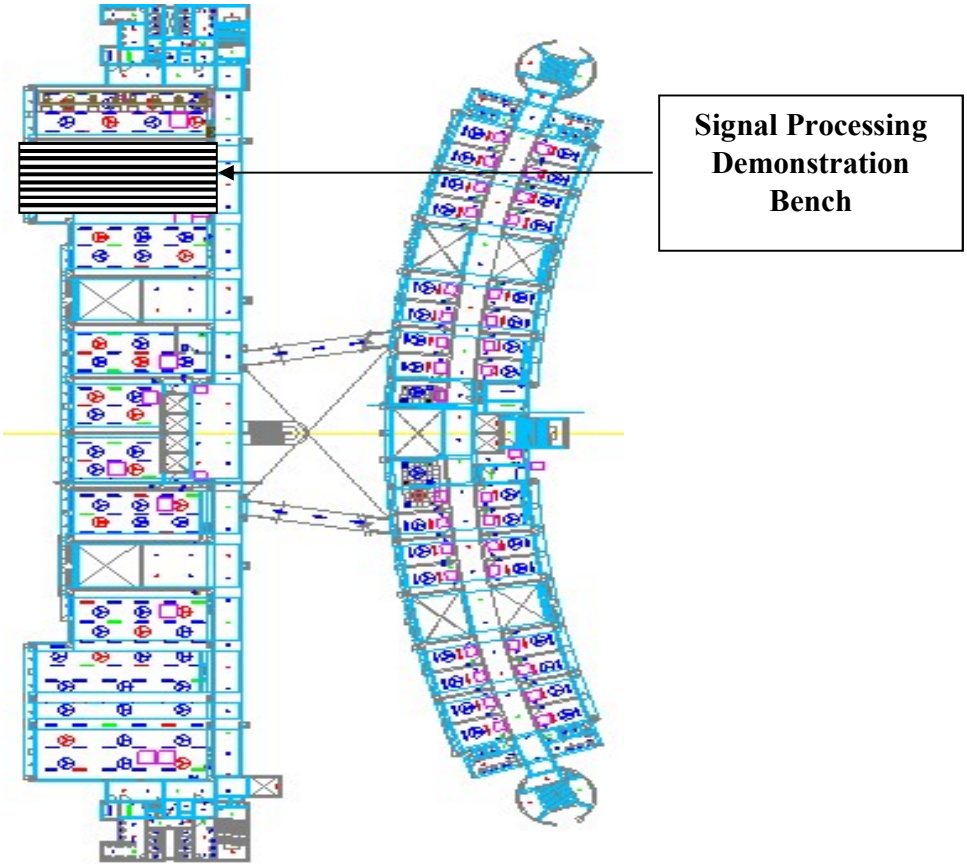
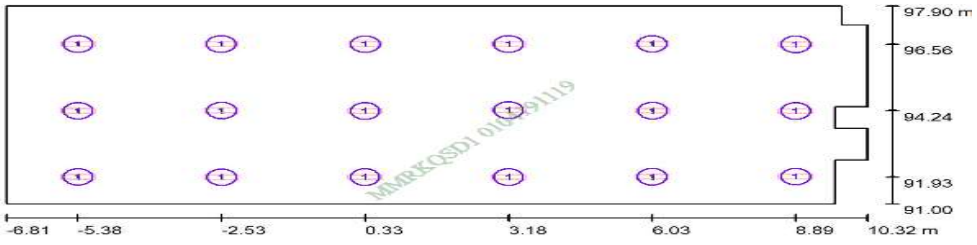


Figure-7.133: Floor Plan View of Signal Processing Demonstration Bench

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	18	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.134: Luminaire Layout of Signal Processing Demonstration Bench

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

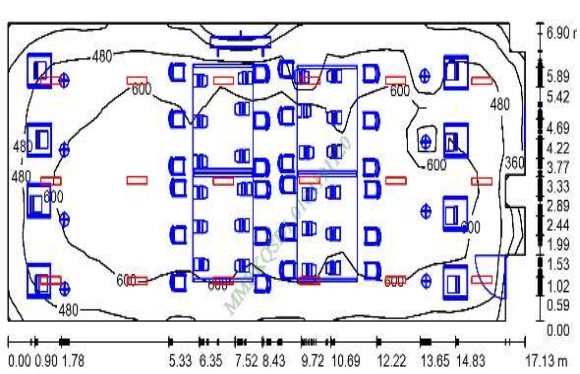


Figure-7.135(a): Isolines on Work-Plane

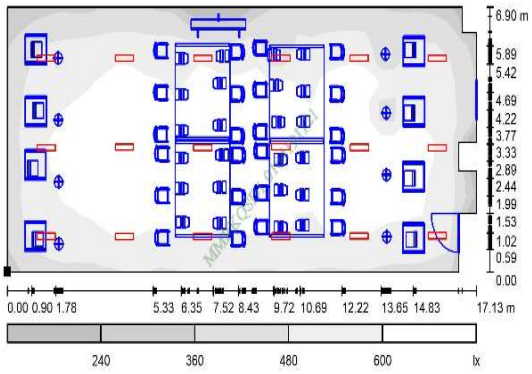


Figure-7.135(b): Greyscale on Work-Plane

e) 3D Standard View of Signal Processing Demonstration Bench:

Figure-7.136(a): 3D Standard View of Signal Processing Demonstration Bench

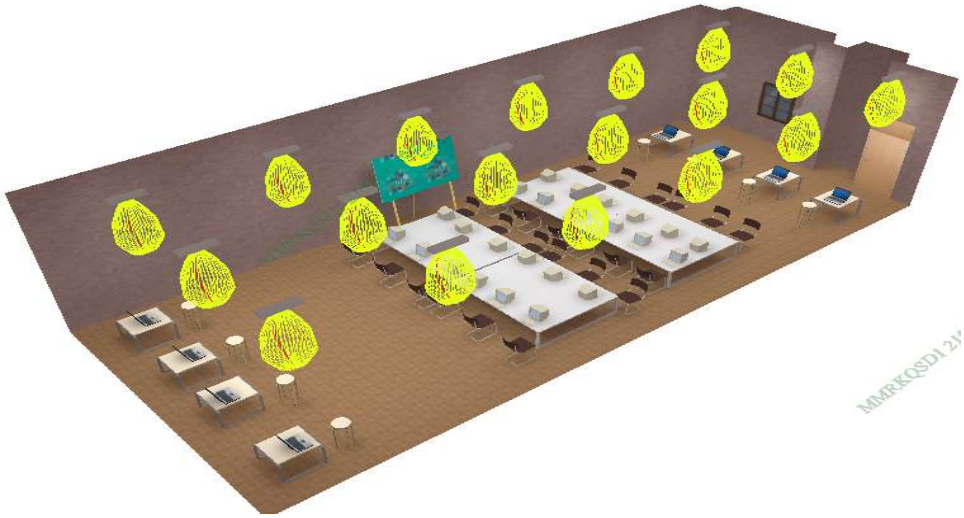


Figure-7.136(b): 3D Light Distribution Display

f) Simulated Output:

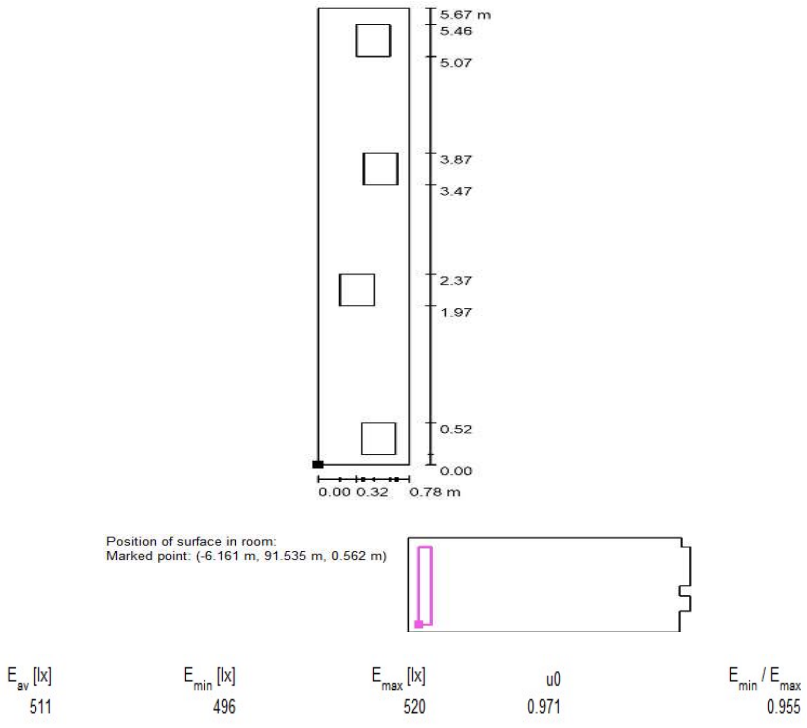
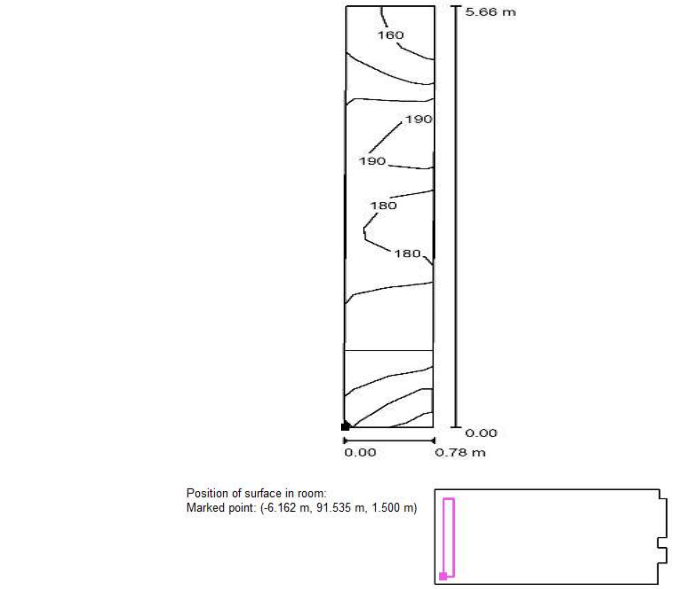
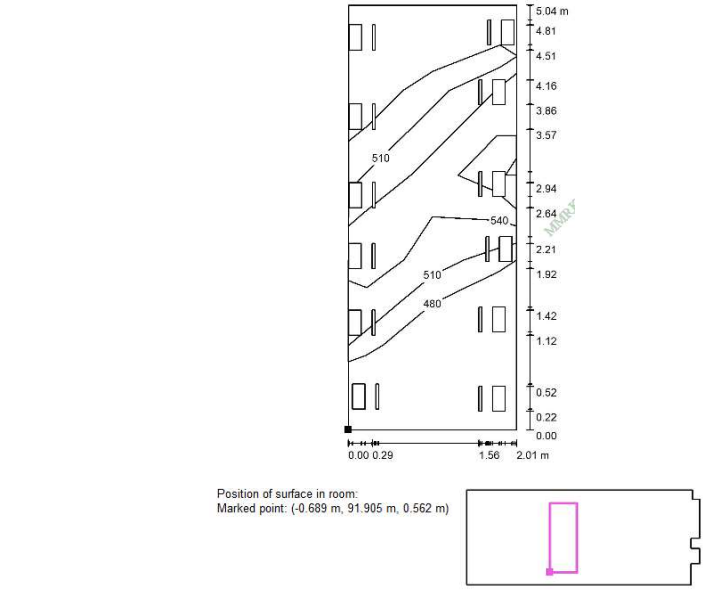


Figure-7.137: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1



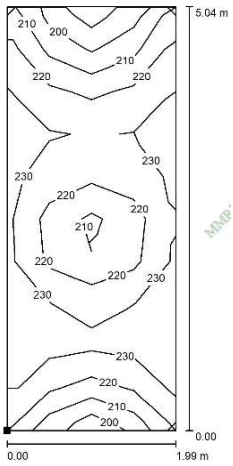
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
180	157	203	0.874	0.776

Figure-7.138: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1

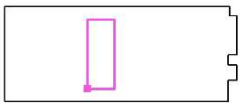


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
542	476	589	0.878	0.809

Figure-7.139: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2

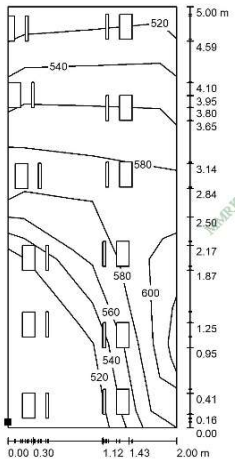


Position of surface in room:
Marked point: (-0.680 m, 91.905 m, 1.500 m)

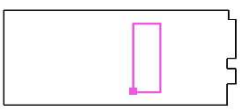


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
219	187	234	0.853	0.798

Figure-7.140: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2

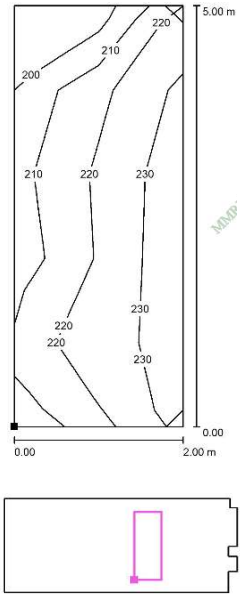


Position of surface in room:
Marked point: (2.764 m, 91.980 m, 0.562 m)



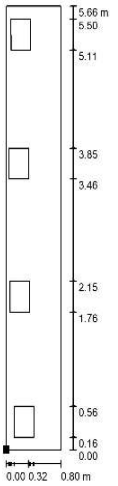
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
566	515	599	0.910	0.860

Figure-7.141: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 3



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
220	192	231	0.870	0.832

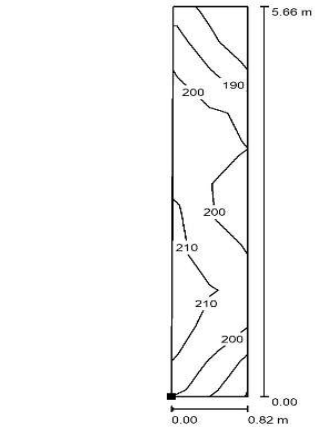
Figure-7.142: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 3

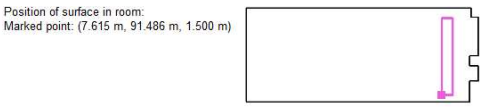


Position of surface in room:
Marked point: (7.635 m, 91.486 m, 0.562 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
519	366	569	0.705	0.643

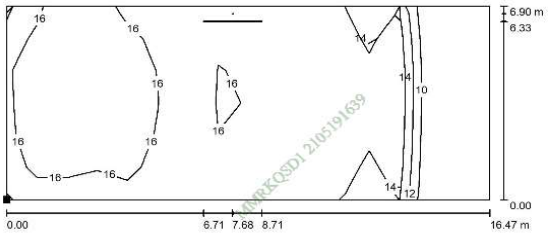
Figure-7.143: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 4

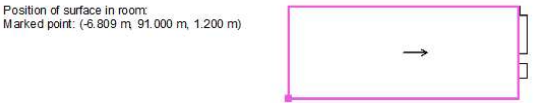




E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
200	175	213	0.876	0.822

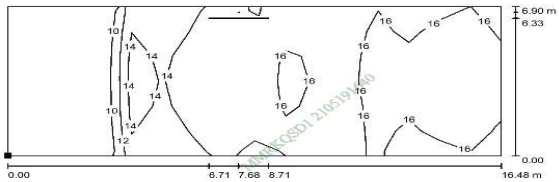
Figure-7.144: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 4

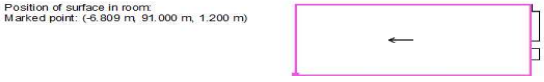




Min	Max
/	18

Figure-7.145: UGRL on UGR Calculation Area 1





Min	Max
/	18

Figure-7.146: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	511	0.971	2.35W/m^2/100 lx or 12.38W/m^2	180	0.35	18

Table-7.26: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	542	0.878	2.35W/m^2/100 lx or 12.38W/m^2	219	0.40	18

Table-7.27: Comparison Table for Calculation Surface 2

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	566	0.910	2.35W/m^2/100 lx or 12.38W/m^2	220	0.38	18

Table-7.28: Comparison Table for Calculation Surface 3

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	519	0.705	2.35W/m^2/100 lx or 12.38W/m^2	200	0.38	18

Table-7.29: Comparison Table for Calculation Surface 4

7.2.13 Lighting Design of Smart Grid Management System

a) Design Consideration: It has specific real time digital simulators, testing equipment, transmission systems (AC/DC), distribution systems, generation (Large Scale, DG, wind farms, PV etc.), AC/DC Converters, electrical Panels Grid emulator (200kVA amplifier, DC to 5 kHz) etc.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Smart Grid Management System,

- Maintained Average Illuminance ($\overline{E_m}$)=300 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 7.10 W/m^2.

b) Floor Plan:

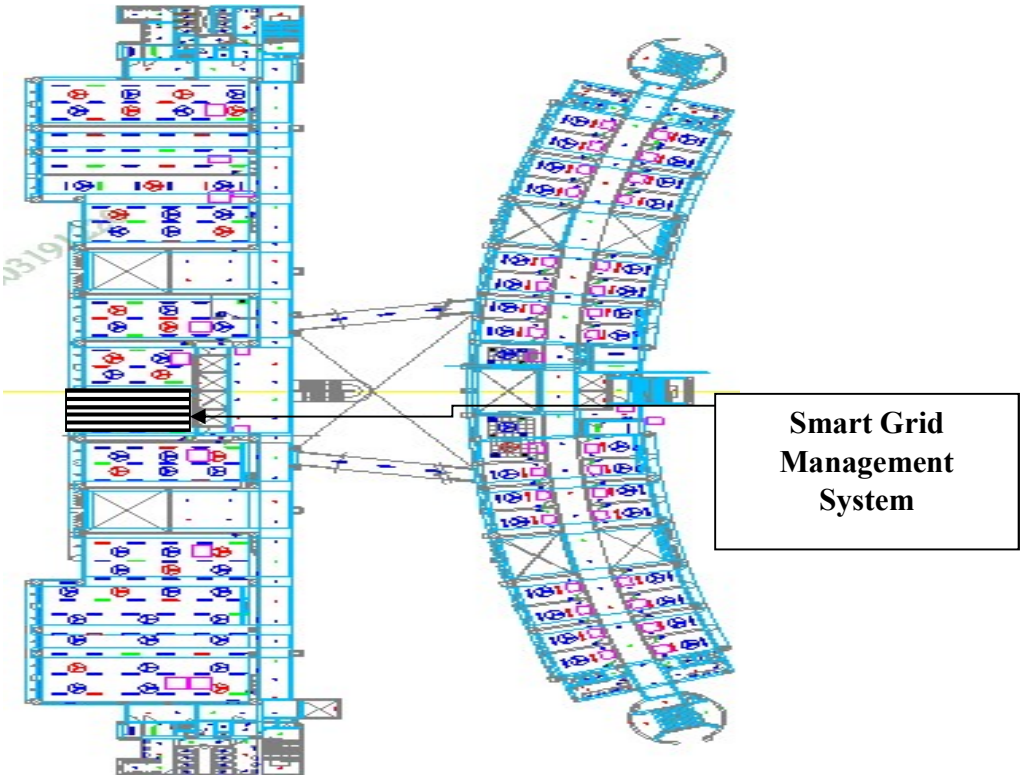
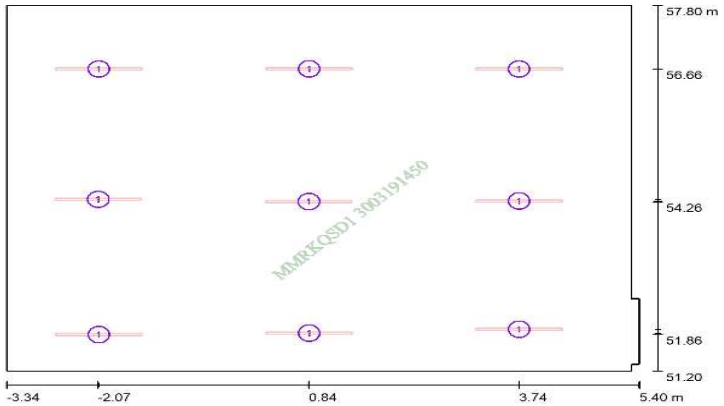


Figure-7.147: Floor Plan View of Smart Grid Management System

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	9	IbLED IIBNXX-36XX Maxo-4FT LED Aluminium Batten (4000/5700/6500)degK

Figure-7.148: Luminaire Layout of Smart Grid Management System

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

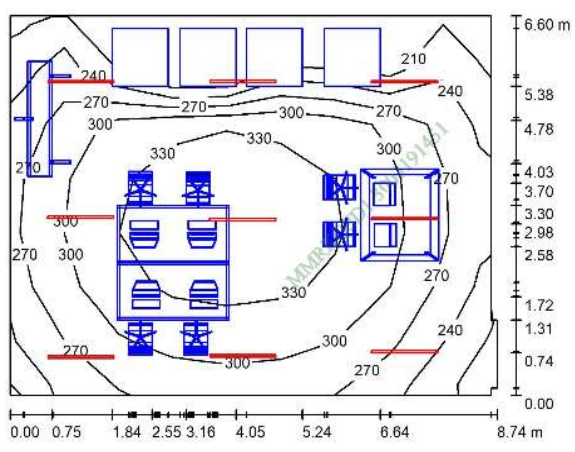


Figure-7.149(a): Isolines on Work-Plane

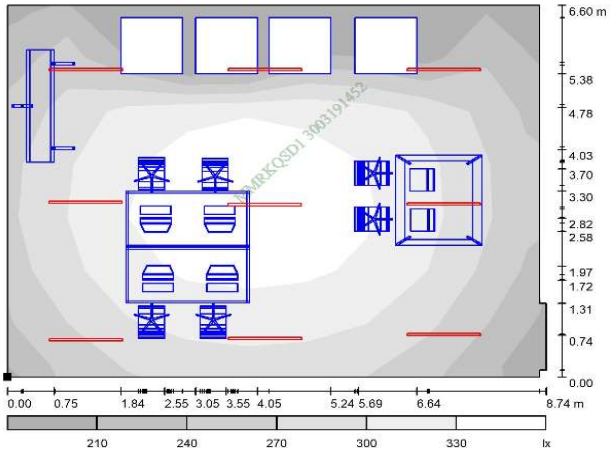


Figure-7.149(b): Greyscale on Work-Plane

e) 3D Standard View of Smart Grid Management System:

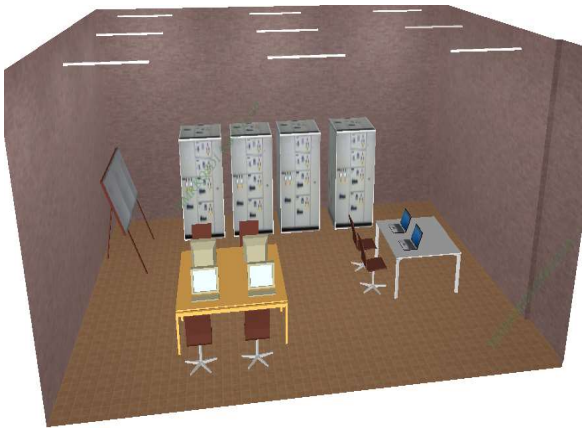
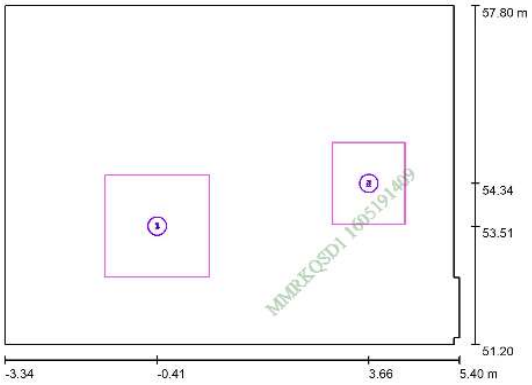


Figure-7.150(a): 3D Standard View of Smart Grid Management System

Figure-7.150(b): 3D Light Distribution Display

f) Simulated Output:



Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	2	315	287	331	0.91	0.87
cyl.	2	149	134	158	0.90	0.85

Figure-7.151: Maintained Average Illuminance ($\overline{E_m}$) and Mean Cylindrical Illuminance (E_{cy}) on Calculation Surfaces

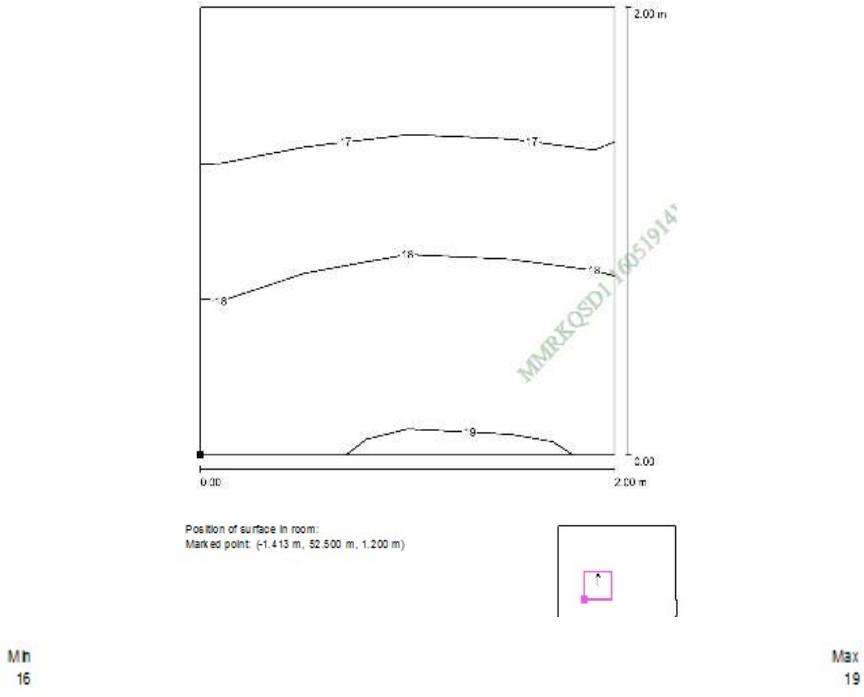


Figure-7.152: UGRL on UGR Calculation Area 1

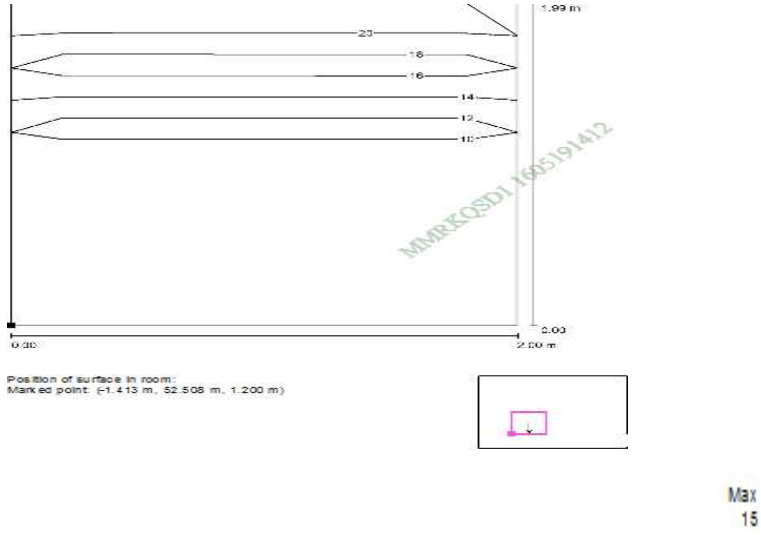


Figure-7.153: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	300 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	7.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	315	0.91	2.06W/m^2/100 lx or 5.68W/m^2	149	0.47	19

Table-7.30: Comparison Table for Calculation Surface

7.2.14 Lighting Design of Electric Drive Room

a) Design Consideration: This room is mainly equipped with electrical motors.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Electrical Drive Room,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 7.10 W/m^2.

b) Floor Plan:

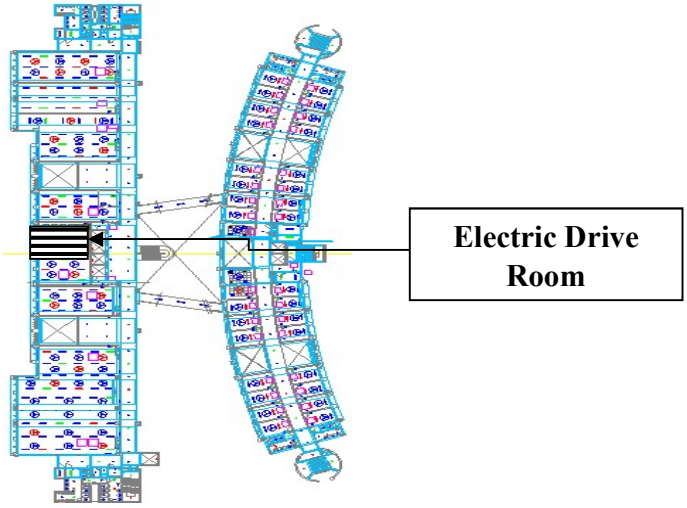


Figure-7.154: Floor Plan View of Electric Drive Room

c) Luminaire Layout:

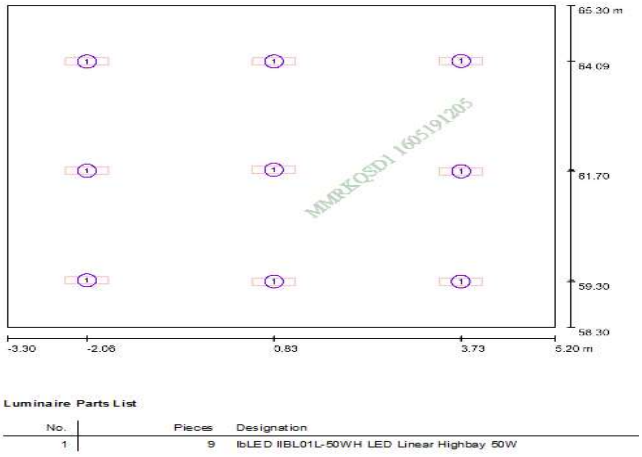


Figure-7.155: Luminaire Layout of Electric Drive Room

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

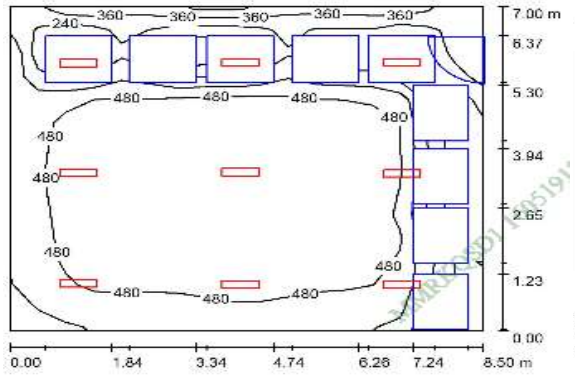


Figure-7.156(a): Isolines on Work-Plane

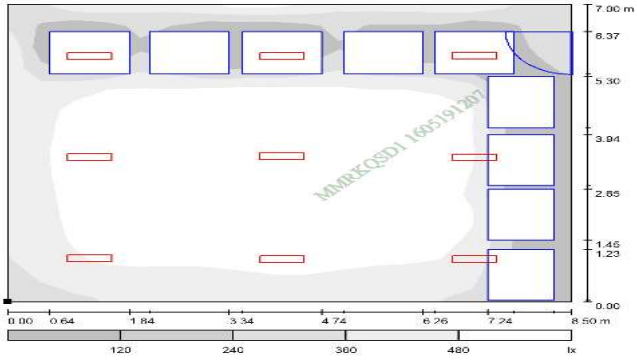


Figure-7.156(b): Greyscale on Work-Plane

e) 3D Standard View of Electric Drive Room:

Figure-7.157(a): 3D Standard View of Electric Drive Room

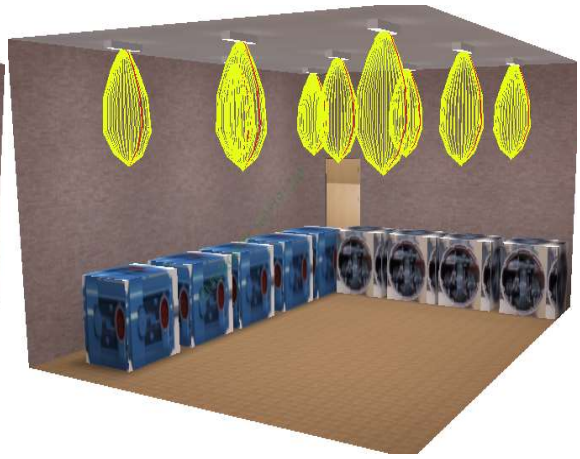


Figure-7.157(b): 3D Light Distribution Display

f) Simulated Output:

Summary of Results

Type	Quantity	Average [lx]	Min [lx]	Max [lx]	u0	E_{min} / E_{max}
perpendicular	1	525	416	593	0.79	0.70
cyl.	1	180	146	197	0.80	0.73

Figure-7.158: Maintained Average Illuminance ($\overline{E_m}$) and Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface

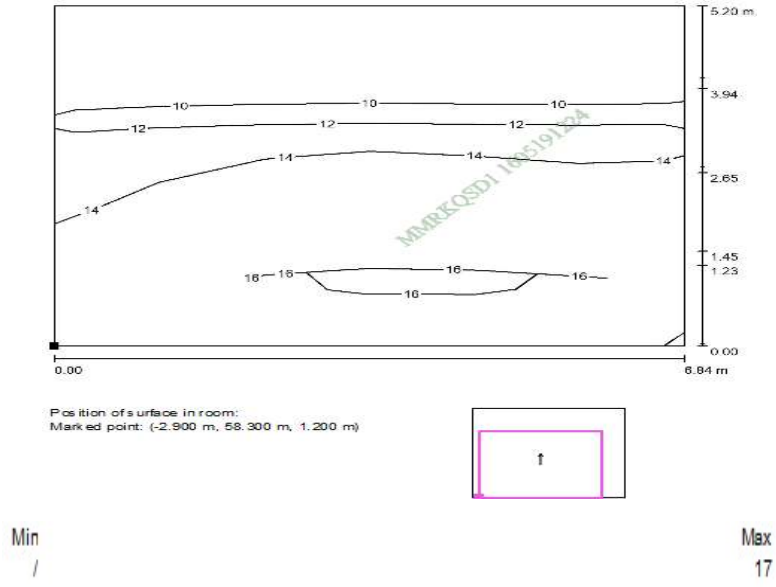


Figure-7.159: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	7.10 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	525	0.79	2.65W/m^2/100 lx or 12.10W/m^2	180	0.34	17

Table-7.31: Comparison Table for Calculation Surface

7.2.15 Lighting Design of Server Room

a) Design Consideration: Server room is a place that is used to store and operate computer servers and their associated components. This room is a part of data centre which has typically several physical servers lined up together in a rack mounted pattern.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Server Room,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 7.10 W/m^2.

b) Floor Plan:

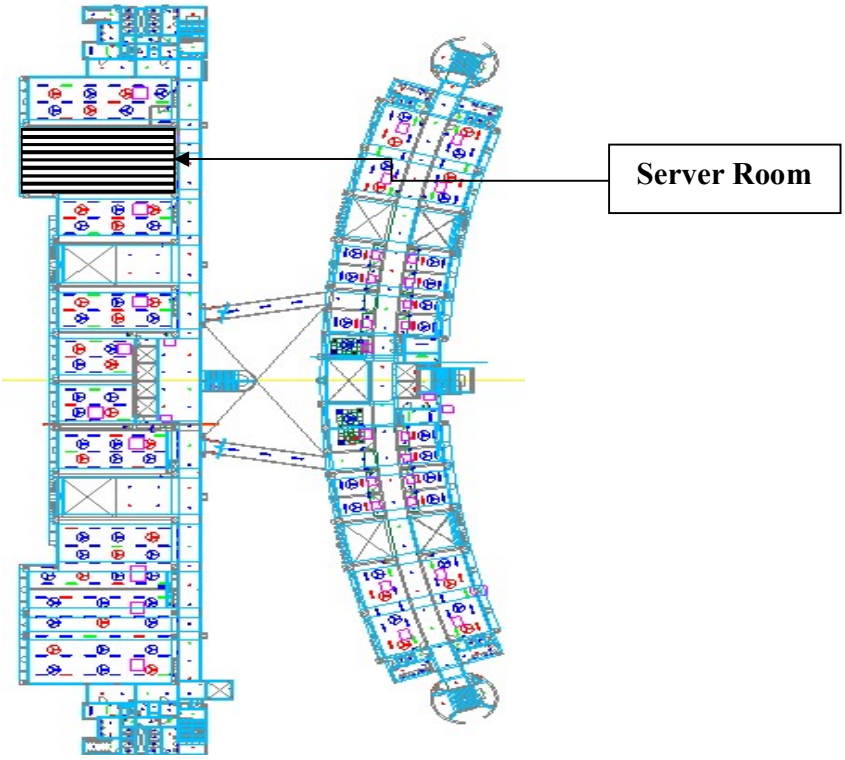
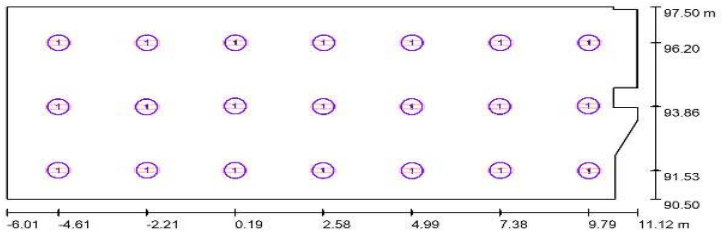


Figure-7.160: Floor Plan View of Server Room

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	21	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.161: Luminaire Layout of Server Room

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

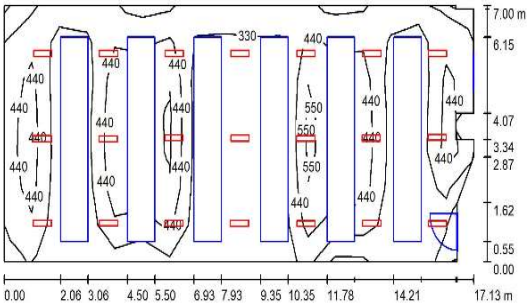


Figure-7.162(a): Isolines on Work-Plane

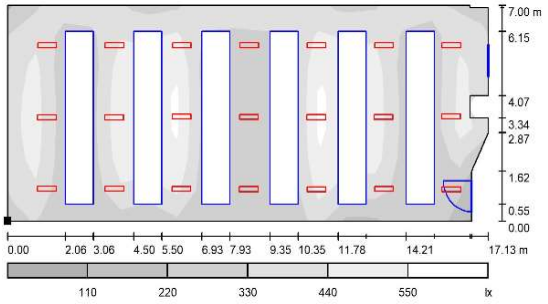


Figure-7.162(b): Greyscale on Work-Plane

e) 3D Standard View of Server Room:

Figure-7.163(a): 3D Standard View of VLSI CAD Workshop

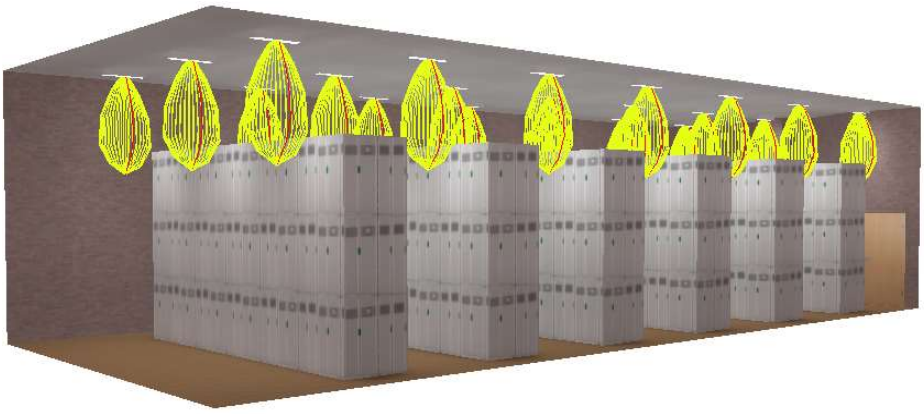
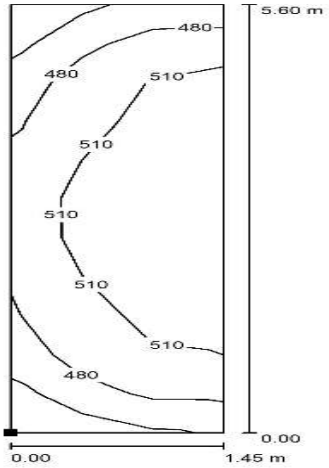


Figure-7.163(b):3D Light Distribution Display

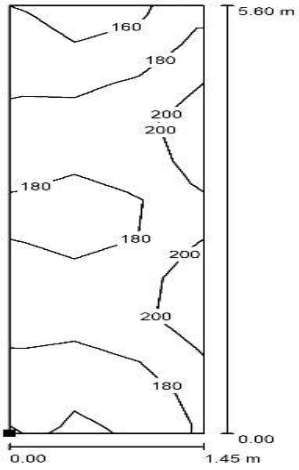
f) Simulated Output:



Position of surface in room:
Marked point: (-5.400 m, 91.050 m, 0.760 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
505	441	552	0.873	0.799

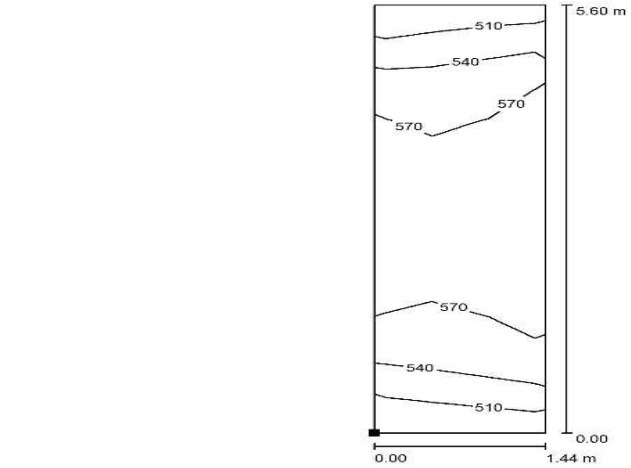
Figure-7.164: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 1

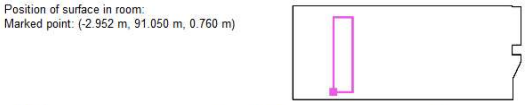


Position of surface in room:
Marked point: (-5.400 m, 91.050 m, 1.500 m)

E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
181	149	209	0.823	0.711

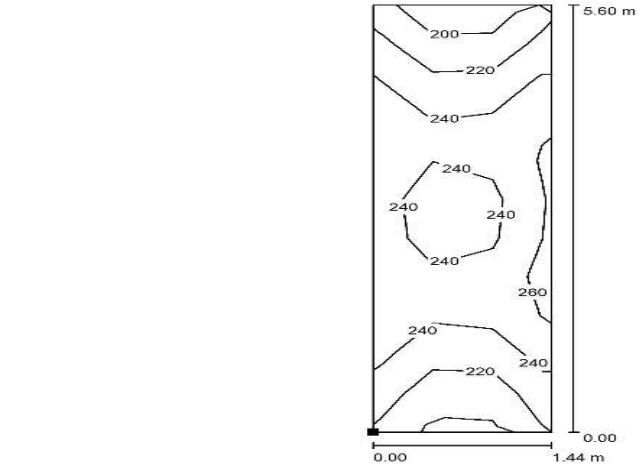
Figure-7.165: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 1

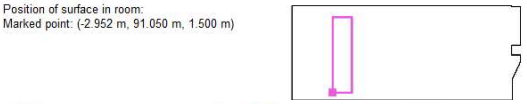




E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
566	500	613	0.884	0.816

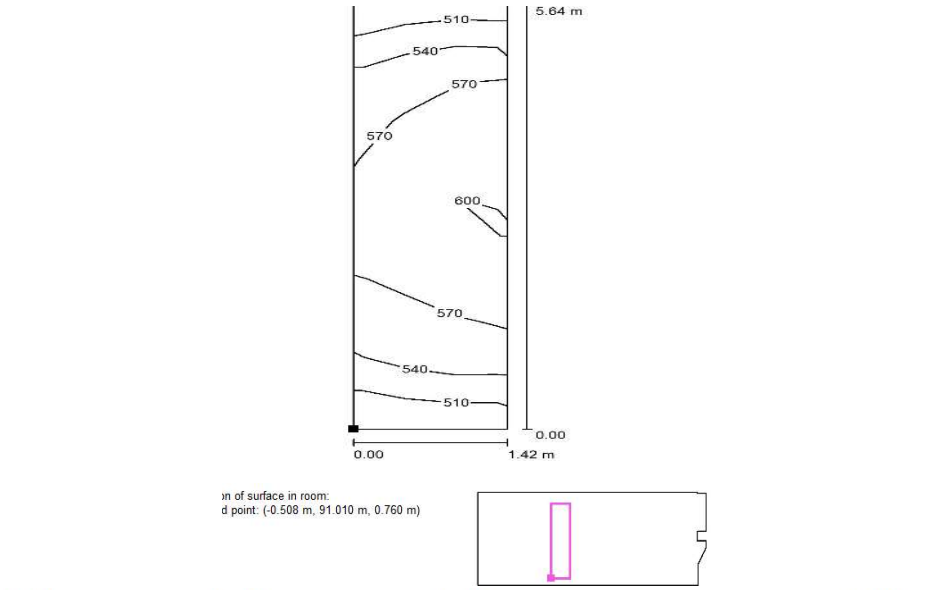
Figure-7.166: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 2





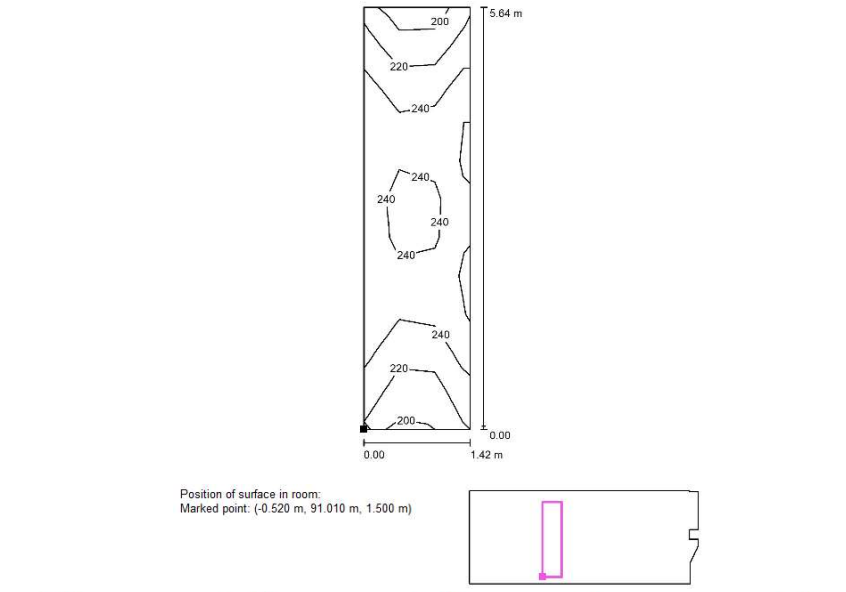
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
233	180	264	0.774	0.684

Figure-7.167: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 2



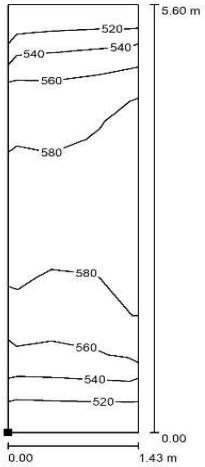
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
569	494	611	0.868	0.808

Figure-7.168: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 3

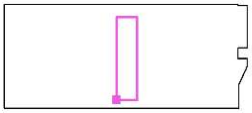


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
235	183	264	0.780	0.693

Figure-7.169: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 3

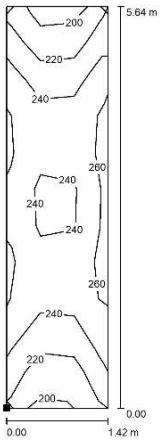


Position of surface in room:
Marked point: (1.919 m, 91.049 m, 0.760 m)

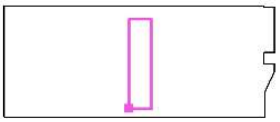


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
570	508	608	0.891	0.835

Figure-7.170: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 4

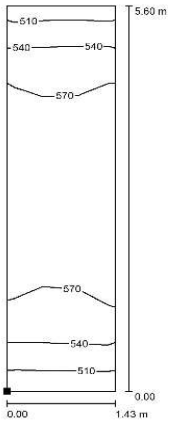


Position of surface in room:
Marked point: (1.922 m, 91.029 m, 1.500 m)

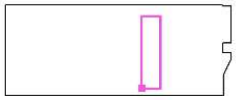


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
238	186	263	0.783	0.707

Figure-7.171: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 4

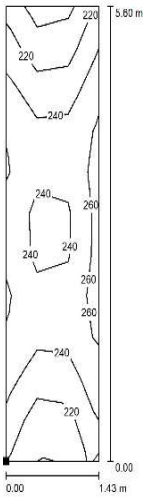


Position of surface in room:
Marked point: (4.346 m, 91.050 m, 0.760 m)

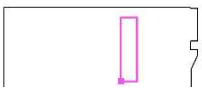


E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
572	508	611	0.889	0.833

Figure-7.172: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 5

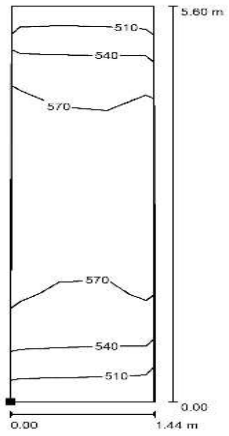


Position of surface in room:
Marked point: (4.346 m, 91.052 m, 1.500 m)



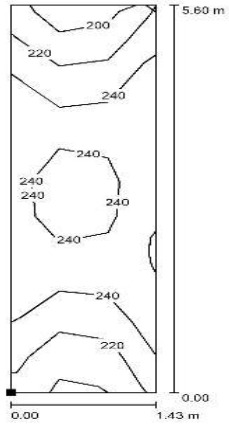
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
237	189	263	0.798	0.720

Figure-7.173: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 5



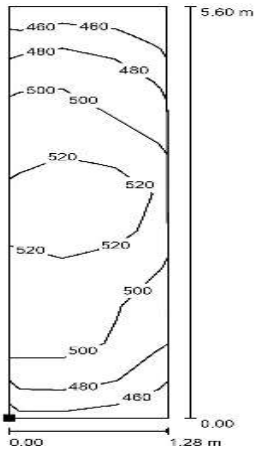
E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
567	502	610	0.886	0.824

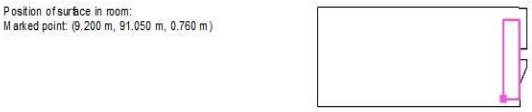
Figure-7.174: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 6



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
234	185	260	0.792	0.713

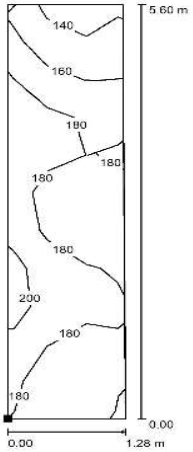
Figure-7.175: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 6

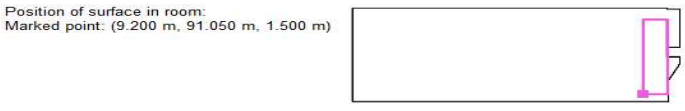




E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min}/E_{max}
506	454	546	0.898	0.831

Figure-7.176: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface 7





E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min}/E_{max}
173	129	206	0.747	0.626

Figure-7.177: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface 7

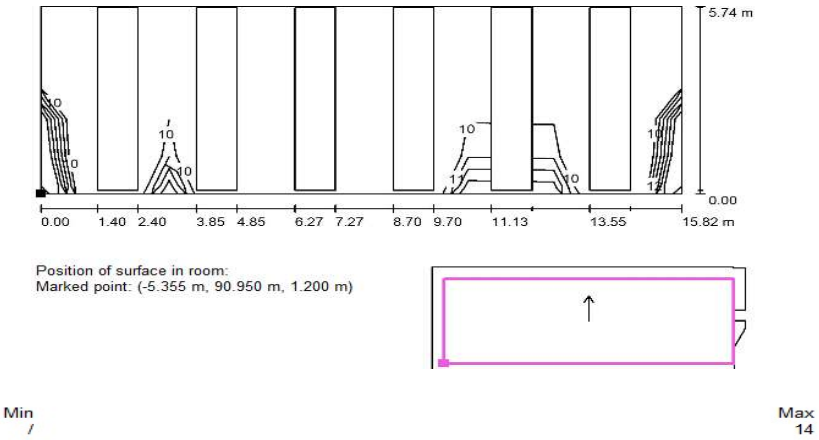


Figure-7.178: UGRL on UGR Calculation Area

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	505	0.873	2.53W/m^2/100 lx or 13.10 W/m^2	181	0.35	14

Table-7.32: Comparison Table for Calculation Surface 1

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	566	0.84	3.13 W/m2/100 lx or 14.24W/m2	233	0.41	14

Table-7.33: Comparison Table for Calculation Surface 2

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	569	868	3.13 W/m2/100 lx or 14.24W/m2	235	0.41	14

Table-7.34: Comparison Table for Calculation Surface 3

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	570	0.891	3.13 W/m2/100 lx or 14.24W/m2	238	0.41	14

Table-7.35: Comparison Table for Calculation Surface 4

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	572	0.889	3.13 W/m2/100 lx or 14.24W/m2	237	0.41	14

Table-7.36: Comparison Table for Calculation Surface 5

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	567	0.886	3.13 W/m2/100 lx or 14.24W/m2	234	0.41	14

Table-7.37: Comparison Table for Calculation Surface 6

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	15.1 W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	506	0.838	3.13 W/m2/100 lx or 14.24W/m2	173	0.34	14

Table-7.38: Comparison Table for Calculation Surface 7

7.2.16 Lighting Design of Library

a) Design Consideration: The library is an important area in an educational complex, which requires detailed consideration. General reading, both casual and sustained of a wide variety of printing types and styles, examination of drawings and maps, writing, etc. are among the more common visual tasks that will be encountered in a library.

According to the IS 3646 Part 1: 1992 and EN-12464-1:2011, in Library,

- Maintained Average Illuminance ($\overline{E_m}$)=500 lx.
- Overall Uniformity (U_o) =0.7.

As per EN-12464-1:2011 recommendation,

- Mean Cylindrical Illuminance (E_{cy}) =150 lx at 1.5 m height.

As per ECBC 2017 Space Function Method,

- Lighting Power Density (LPD) = 10.0 W/m^2.

b) Floor Plan:

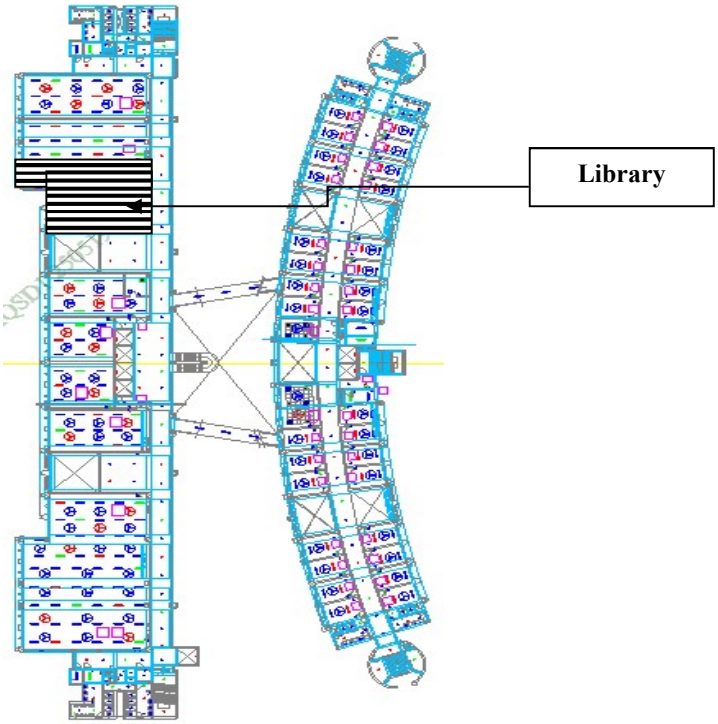
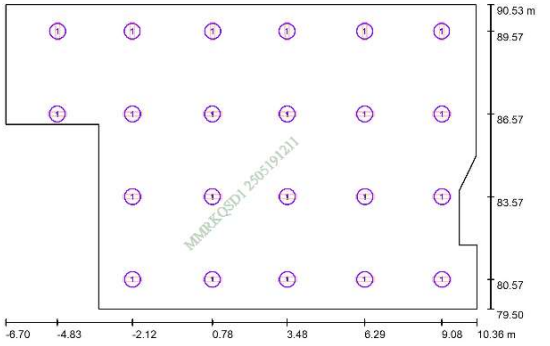


Figure-7.179: Floor Plan View of Library

c) Luminaire Layout:



Luminaire Parts List

No.	Pieces	Designation
1	22	IbLED IIBL01L-50WH LED Linear Highbay 50W

Figure-7.180: Luminaire Layout of Library

- Height of the room=4.2 m
- Light Loss Factor(LLF)=0.80
- Ceiling Reflectance Value=80%
- Wall Reflectance Value=50%
- Floor Reflectance Value=20%

d) Lighting Report:

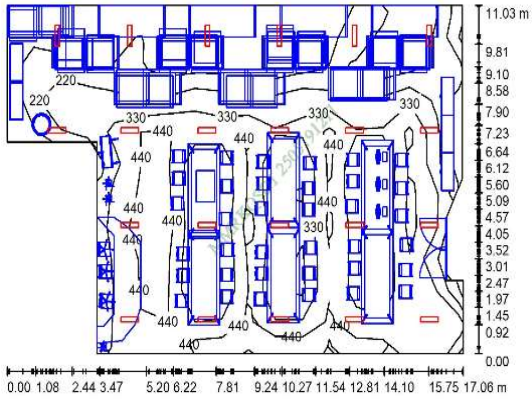


Figure-7.181(a): Isolines on Work-Plane

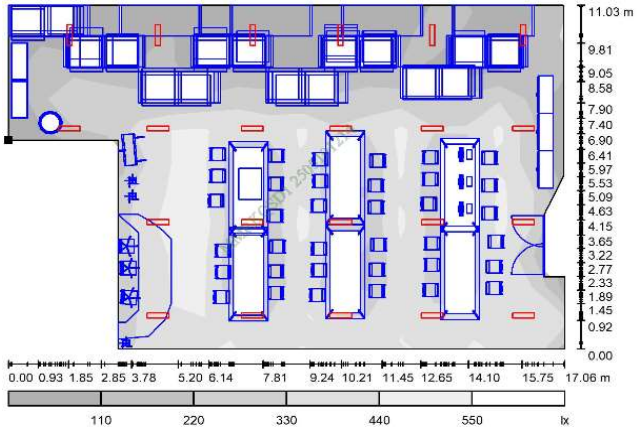


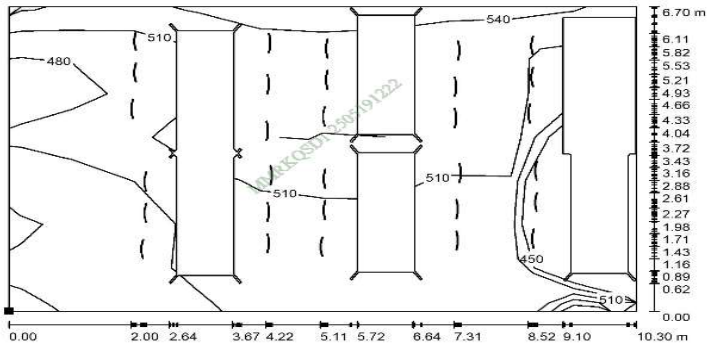
Figure-7.181(b): Greyscale on Work-Plane

e) 3D Standard View of Library:

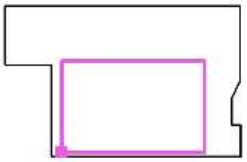
Figure-7.182(a): 3D Standard View of Library

Figure-7.182(b):3D Light Distribution Display

f) Simulated Output:

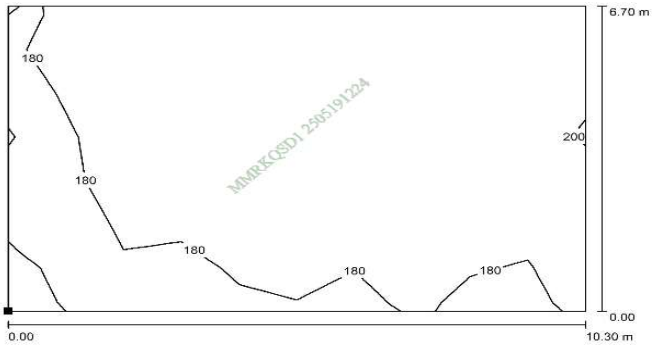


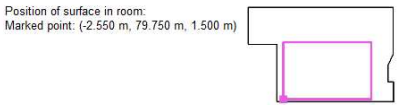
Position of surface in room:
Marked point: (-2.560 m, 79.800 m, 0.760 m)



E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
501	441	548	0.881	0.805

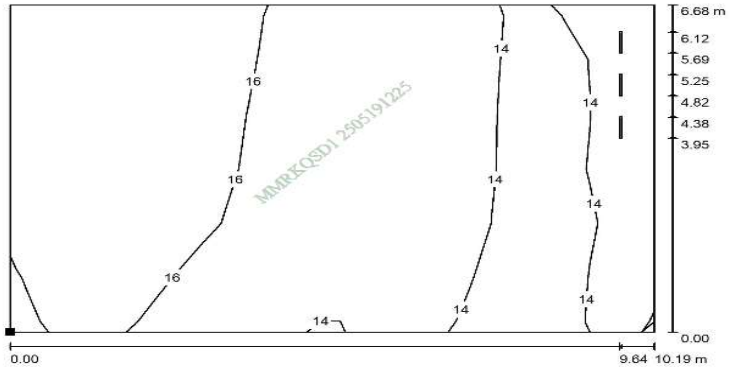
Figure-7.183: Maintained Average Illuminance ($\overline{E_m}$) on Calculation Surface

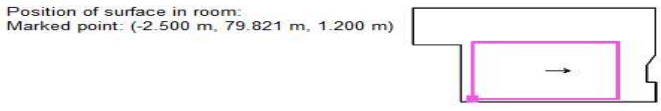




E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}
187	151	202	0.810	0.746

Figure-184: Mean Cylindrical Illuminance (E_{cy}) on Calculation Surface





Min	Max
12	18

Figure-185: UGRL on UGR Calculation Area 1

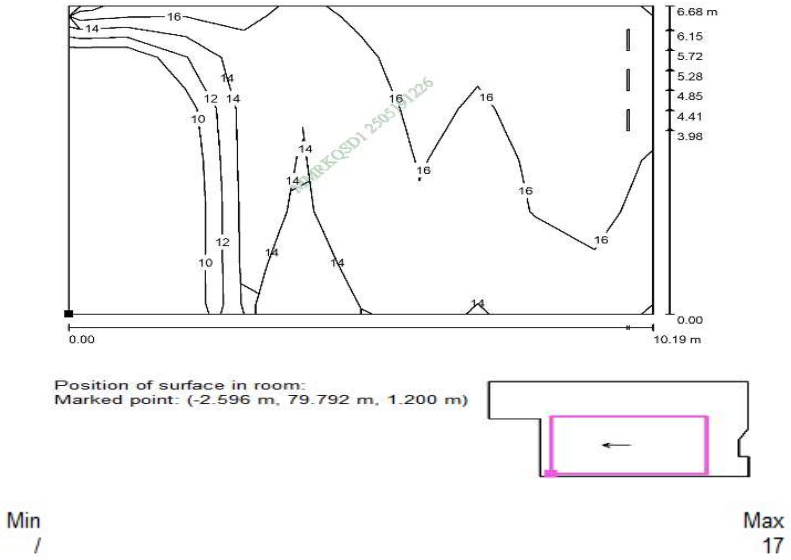


Figure-186: UGRL on UGR Calculation Area 2

g) Discussions:

Design Parameters	Maintained Average Illuminance($\overline{E_m}$)	Overall Uniformity (U_o)	Lighting Power Density(LPD)	Mean Cylindrical Illuminance(E_{cy})	Modelling Index	UGRL (Max)
Recommended Value	500 As per IS 3646 Part-1: 1992	0.7 As per EN-12464-1:2011	10.0W/m^2 As per ECBC-2017	150 As per EN-12464-1:2011	0.30 As per EN-12464-1:2011	19 As per EN-12464-1:2011
Achieved Value	501	0.881	2.53W/m^2/100 lx or 13.10 W/m^2	187	0.37	18

Table-7.34: Comparison Table for Calculation Surface

Chapter 8:
Conclusion and Future Scope

8.1 Conclusion

This Thesis Work 'Studies on Educational Facility Lighting System' associated with lighting design governs

- Good visual environment for education
- Improved concentration of students during lecture and educational objectives for each day
- Betterment of students' performance and creation of better learning environment
- Creation of an vibrant and relaxed environment for teaching and non- teaching staffs either during lecture session or in recess time respectively

To meet this above mentioned objectives, the case study here within this Thesis Work is done to achieve lighting design parameters and energy parameter so that they can comply with the recommended values as per National and International Standards. The level of illumination, uniformity and quality requirements are to be achieved by general principles of lighting as per IS 3646 Part-1: 1992, EN -12464-1:2002(E) and EN-12464-1:2011, mentioned in detail in Chapter 7. Lighting Power Density, also is achieved as per ECBC 2017 to describe the lighting design energy efficient.

For Office Staff Room, the uniformity achieved is 0.62, which is little less than 0.70 as per recommendation of EN-12464. It may be improved by either using luminaires of more lumen output or by changing the arrangement of luminaires.

8.2 Future Scope

Future scope of this study lies to build the lighting design by WELL Building standard. The WELL Building standard is meant for better support to the health and well-being of faculty, students and staffs.

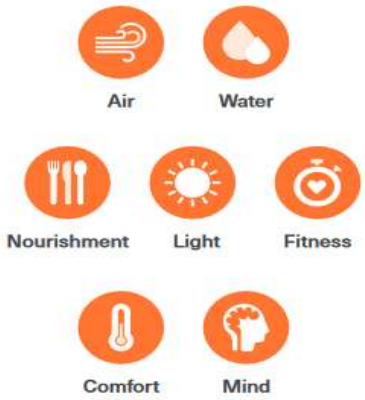


Figure-8.1: Seven Features of WELL Building Lighting Standard

As future scope this lighting design can be built as seven features of WELL Building Lighting Standard so that the circadian rhythm during the working environment be ameliorated.

References

References:

[1] https://en.wikipedia.org/wiki/Electromagnetic_radiation.

[2] National Lighting Code 2010.

[3] https://en.wikipedia.org/wiki/Light-emitting_diode.

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[5] https://en.wikipedia.org/wiki/Planckian_locus.

[6] IS **3646 (Part 1):1992 .**

[7] EN **12464-1:2009(E).**

[8] EN **12464-1:2011.**

[9] ECBC 2017.

[10] IbLED Price List.

[11] IbLED Technical Data Sheet.

[12] https://thesourcecad.com/autocad-tutorials/ .

[13] https://dialux4.support-en.dial.de/support/solutions/articles/9000116136-tutorials-trainings.

[14] R. G. Hopkinson, B.Sc. (Eng.), Ph.D. Fellow, 'Studies **of Lighting Vision in Schools'**, Volume: 14 issue: 8_IEStrans, page(s): 244-268, Issue published: September 1, 1949.

[15] PJC Sleegers PhD, Department of Educational Sciences, University of Twente, Enschede, The Netherlands, et al. '**Lighting affects students' concentration positively: Findings from three Dutch studies'** Lighting Res. Technol. 2013; 45: 159–175.

SORIL

INFRA RESOURCES

Date: 24th Jan 2018

Ms. Manjulika Bera
D/o Mr. Biraj Krishna Bera.
457 R N C Road Rajpur Sonarpur (M),South 24
Parganas Subhas Gram Rajpur Sonarpur (M)
West Bengal- 700147

Trainee Offer Letter

This is with reference to your application seeking winter Internship for a period of 11 Months. We are pleased to confirm the project, according to the details given below.

DESIGNATION	:	**INTERN - LAAS**
LOCATION OF TRAINING	:	**MUM-IFC**
DEPARTMENT	:	**LAAS**
TRAINING PERIOD	:	**15TH JULY 2018 TO 15TH JUNE 2019**
REPORTING PERSON	:	**KARTHIK RADHAKRISHNAN**
STIPEND	:	**20000/-**

You will be governed by the service rules and regulation including the conduct, discipline and appeal rules, administrative orders and any such other rules/orders of the company that may be in force during this duration.

Please carry a copy of this letter along with resume at the time of commencement of the Training.

Wishing you, a good learning experiences at **Indiabulls**

Yours truly,

For **SORIL Infra Resource Ltd**

Authorized Signatory
Human Resources

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