STUDIES ON EFFECTS OF SURFACE REFLECTANCES AND OTHER LIGHTING STRATEGIES AT DIFFERENT SKY CONDITIONS ON INDOOR LIGHTING

A thesis submitted towards partial fulfillment of the requirements of the degree of

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in
Illumination Technology and Design

Submitted by

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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled is **STUDIES ON EFFECTS OF SURFACE REFLECTANCES AND OTHER LIGHTING STRATEGIES AT DIFFERENT SKY CONDITIONS ON INDOOR LIGHTING** a bonafide work carried out by **MOHULI MAJUMDAR** under my supervision and guidance for partial fulfillment of the requirement of **Master of Technology in Illumination Technology and Design** in School of Illumination Science Engineering and Design, during the academic session 2016 -2019.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented by **MOHULI MAJUMDAR** (Exam Roll No- M6ILT19005) 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 there in but approve the thesis only for purpose for which it has been submitted.

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DECLARATION OF ORIGINALITY AND OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my **Master of Technology in Illumination Technology and Design** studies during academic session 2016-2019.

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

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

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CHAPTER-1

INTRODUCTION

- **OBJECTIVES:**

To study the effects of indoor lighting with the variation of:

I. Value of surface reflectances (ceiling, wall, floor)
II. Different type of sky conditions (clear,overcast,mixed)
III. Effects of dimming control as well as daylight integration
IV. Effects of glare (quantitative value) and veiling luminance at different positions of an observer.

- **LITERATURE SURVEY:**

This chapter shall briefly delineate and summarize the available academic literature regarding fundamentals of the effects of interior surface reflectance on indoor lighting design strategies on energy consumption and visual comfort with daylight integrations with the concept of window size, orientation, and wall reflectance with regard to various daylight metrics and lighting energy demand and the Impact of Building Geometry Factors along with the positions of the Glass Façade building.

There is an assessments takes place, through a statistical analysis by SPSS. The quantitative comparison between surface reflectance and these indices showed that wall visible reflection coefficient had the most important role for determining the variations of visual comfort parameters. The corresponding statistical analysis ascertains that there is a strong positive correlation between average illuminance and uniformity, which was statistically significant.So increasing reflectance value of interior surfaces could considerably help improving lighting in the space without increasing the number or the luminous flux of light sources,it is possible to conclude that the wall reflection coefficient considerably affect average illuminance and UGR although the effect of floor reflectance value on all of the selected indies was negligible. In fact, increasing refection coefficient of indoor surfaces and using light color materials could be considered as suitable passive energy efficiency solution for indoor environments, although discomfort glare limits for different visual task should be met.[1]

The number of luminaires is not an influential parameter in electric energy consumption. On the contrary, increasing the numbers of luminaire causes a relevant decrease in UGR values. The lower mounting height helped reduce energy consumption. On the contrary, the scenarios with 2.5m luminaire mounting height are characterized by the highest Uo and the lowest UGR values on average. This phenomenon is due to the fact that the higher distance of the lighting feature from the working place resulted in the better diffusion of the luminous flux on it.[2]

It is an issue when it comes to the application of glass facades in hot and humid climate country Window-to-wall ratio (WWR) and window orientation (WO) play a significant role in heat losses and gains by buildings due to its direct exposure to solar radiation. The WWR is optimised by considering the effect of carbon dioxide (CO2) emission. This advancement of methodology helps the designer to appropriately design buildings at its early stage. The indoor thermal performance is influenced by solar transmission through windows, and solar radiation that is absorbed by building facades.[3]

To find the optimum solutions, results were grouped by pairing two different performance indicators with conflicting trend that requires a trade-off. Three optimum solutions are found, all of which belong to four Pareto frontiers. The most optimum solution with the least mean distance to the utopia points is the combination of WWR 30%, wall reflectance of 0.8, and south orientation. It is however noted that more complex situations, for instance in the presence of additional building elements and shadings, may result in different optimum solutions. Different window configurations, though having the same WWR, can lead to a different energy and daylight performance as well. [4]

From obtaining the observation,relationship between surface colour reflectance and lighting power density for a given context. Analysis was based on digital modelling using validated lighting simulation tool, which is dialux. Mainly with the changed values of reflectances the total effects reflects on the visual comfort also, it evaluates the impact of vertical and horizontal planar interior elements reflectance and its impact on LPD. This is done through different scenarios derived from the base case. All derived scenarios were then confirmed to the established visual comfort standard. The study sought to examine a rational method for assessing visual comfort and lighting efficiency of an interior space. Therefore, colour choices for interiors; should also include a broader range of understanding in terms of visual balance implications and lighting efficiency.[5]

CHAPTER – 2

VISUAL FUNCTION & ENERGY EFFICIENCY

INTRODUCTION

Lighting design can have a number of objectives. Merely facilitating to carry out the work is rather a limited view of what a lighting installation can serve. Ideally these objectives are decided by the collaboration between the clients and the designers. For traffic routes, priority would be given to ensure the rapid movement of the vehicles and safety. In urban areas, safety is the sheer important factor although the appearance of the people and building are also important. Business sector use lighting for attracting more customers and promotion of their respective brands. Therefore when designing, it is always a good practice to know the expectations that the lighting has to fulfill.

To prevent loss of money and resources for failing to reap the benefits, remedial solution would be a holistic lighting strategy for lighting design. This approach starts with in-depth conversation with the client and the other members of the design team to chalk out a design brief. There should be clear cut idea regarding the demands of the client and function of the space. Mainly six distinct aspects should be kept in mind during these discussions as per shown in the following figure.

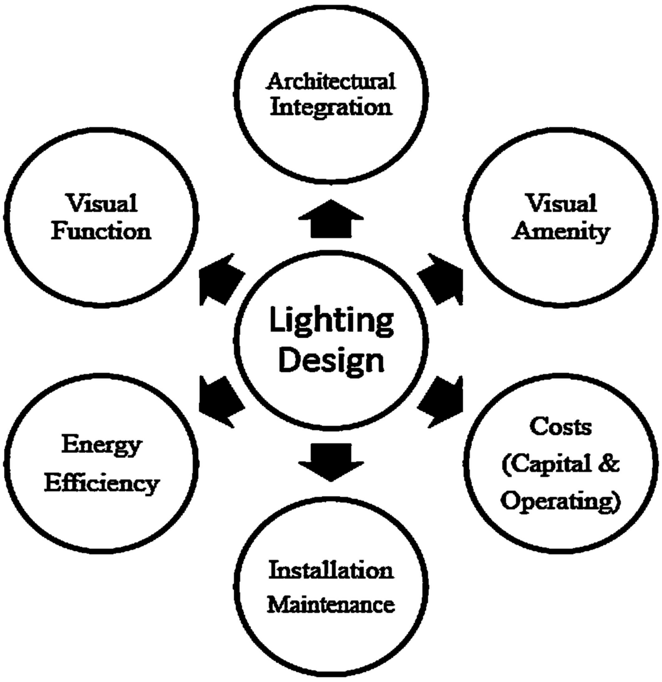


Fig:2.1 Strategies for lighting design[6]

All these aspects will contribute to the success of a design, but they may not all carry equal weight depending on the particular application and situation. Also there is no particular order in which they should be considered. The important thing is that all the elements are considered.

2.1.Visual function & amenity :

2.1.1. Visual function:

This aspect actually addresses the need for doing task without discomfort. The traditional way of lighting an interior work place has been a regular array of luminaires. For this approach, minimum task illuminance uniformity (minimum/average task illuminance $\geq$ 0.7) is Recommended. This ensures that the tasks can be carried out on the horizontal plane anywhere in the work place.

In some cases the task will have a colour recognition element. In such cases it will be necessary to use lamps with a high general colour rendering index (cri). For such tasks it will be appropriate to use lamps with a cri $\geq$ 80 but for tasks with a requirement for very good colour discrimination, lamps with a cri $\geq$ 90 will be indispensable.

At any single adaptation state the human visual system can adapt to a wide range of luminance but it can only cope with a limited luminance range. When this range is exceeded, glare will be experienced. If a field of view contains bright elements that cause glare, it is likely that they will cause inconvenience. To avoid glare, luminaires that have limited luminance within the normal fields of view relative to the adaptation level are to be used.

2.1.2.Visual amenity:

there is no doubt that lighting can add visual amenity to a space which can give pleasure to the

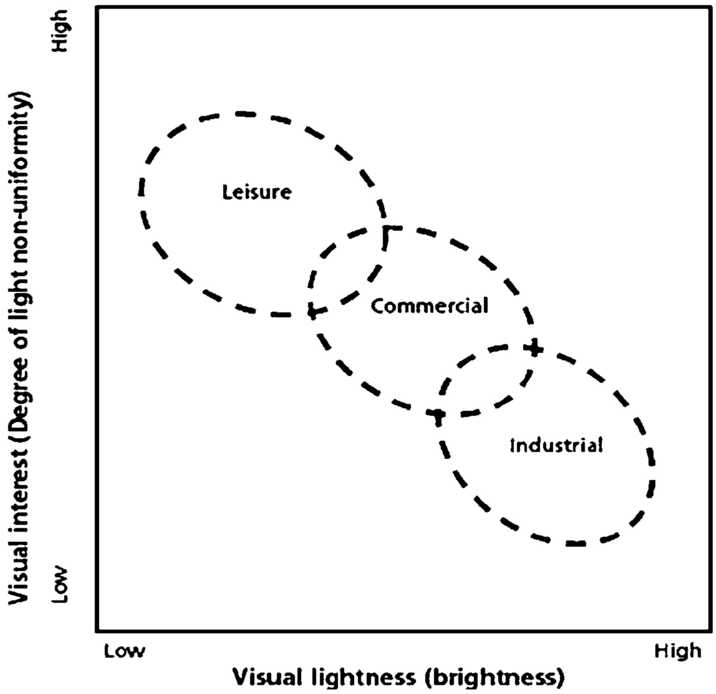


Fig:2.2 Brightness vs.visual interest relations[6] occupants but whether this provides a more tangible performance benefit is uncertain. Studies have shown that people respond to the lit appearance of a room on two independent dimensions: visual lightness and Visual interest. Visual lightness describes the overall lightness of the space, which is related to the average luminance of vertical surfaces. Visual interest refers to the non-uniformity of the illumination pattern or the degree of "light and shade". People prefer some modulation in the light pattern rather than an even pattern of illumination, the magnitude of the modulation depending on the application. There is some evidence that visual lightness and visual interest are inversely correlated which is shown in along fig.Although variation in the light pattern is desirable, it has to be seen as meaningful in terms of the application and the architecture.

2.1.2. Architectural integration:

Understanding the space plays an important role in arriving at a decision on what lighting is to be employed. All the staffs ranging from the dimensions, finishes, texture and colour of the materials forming the space and the appearance of the luminaires, lit and unlit, should be considered if the desired atmosphere is to be attained. A good option is to start with the Daylighting.[11] This means considering the amount and pattern of daylight required for the particular application, and hence the size and positions of windows and roof lights. But windows cannot be designed on the basis of the daylighting alone because at the same time other visual, thermal, acoustic and privacy issues are needed to be met. After making decision on daylighting, the artificial lighting can be planned. Integration of the artificial lighting with the architecture is not limited to considering only its operation with respect to the daylighting, but the appearance of the luminaires and controls and the way they are incorporated into the fabric of the building, as well as the lighting effect produced[11].

2.1.4. Lighting Quality:

Patterns of light and dark affect both our perceptions of the world and our emotional and physiological responses, and thus they are essential in gathering information about the physical world. Good-quality lighting can support visual performance and interpersonal communication and improve our feelings of well-being Poor-quality lighting can be uncomfortable and confusing and can inhibit visual performance. This chapter defines and discusses lighting quality.

The overall purpose of lighting is to serve the needs of people. The role of the lighting designer is to match and rank the needs of the people using the space with the economic and environmental considerations and the architectural objectives, and then to translate the results into a workable design and functional installation.

2.1.5. Lighting for Human Needs :

The needs of people are complex. Emotions, actions, perceptions, and health are influenced by lighting. Central to human needs is visibility, because it is the detection and organization of light patterns that allow a person to analyze and evaluate the environment. Once objects and patterns are visible, one can use a pencil to write a note, learn to pronounce new words by following the facial expressions of a teacher, walk down a corridor without bumping into a vacuum cleaner on the floor, appreciate a painting, or feel relaxed in a dimly lighted restaurant. Figure 10-2 illustrates that visibility is central to a larger number of human needs: task performance; mood and atmosphere; visual comfort; aesthetic judgment; health, safety, and well-being; and social communication.

2.1.6. Visibility:

Visibility is the ability to extract information from the field of view, whether that information is the location of a curb or of a flower arrangement. It is a necessary condition for good-quality lighting. Lighting installations exist to enable sight. For many years this fact led to a heavy emphasis on visibility over all other goals for lighting design. As a result, research was focused in this direction, and we have a good understanding of visibility and its importance. Contrast, luminance, time, and size are the most powerful variables influencing the visibility of objects. Age modifies this relationship; for the older viewer, the task must be larger and brighter and its contrast higher in order to achieve visibility levels equivalent to those of younger viewers. In general, high illuminances can offset visibility losses for tasks of low contrast and small size.

2.1.7. Task Performance:

Task performance is an essential human need. The task is the user's activity, whether measuring the size of a room, washing mud off hands, reading room numbers posted in a corridor to find a doctor's office, or seeing the details in the etchings displayed in a museum. Lighting must enable users to perform the "work" they came to do. Task performance and visual performance are not synonymous; in fact, several nonvisual factors contribute significantly to task performance. Training, motor skills, motivation, and many other human factors interact with visibility to affect the level of task performance. Visual performance, on the other hand, eliminates these factors from consideration in assessing the impact of visual stimuli, including lighting variables, on a behavioral response. Illuminance selection, discussed in its own section below, is largely based on visual performance, not task performance.

2.1.8. Mood and Atmosphere:

Needs for mood and atmosphere encompass the emotional response to the luminous environment. Preference, satisfaction, relaxation, and stimulation are influenced by lighting. These mood states can indirectly influence other behaviors, such as task performance.

2.1.9. Visual Comfort:

Visual comfort is an essential human need that can affect task performance, health and safety, and mood and atmosphere. Office workers may find themselves more fatigued in a glaring lighting installation, but flashing lights in a discotheque can temporarily excite and please that same person [12].

2.1.10. Aesthetic Judgment:

Aesthetic judgment needs differ from emotional responses. Humans appear to need to make sense of what they see, so the information must be either immediately available in a scene or implied. Lighting can communicate meaning, reinforce rhythmic patterns in the architecture, and enhance color, thereby creating a hierarchy of social significance in the visual field. Lighting can also hinder understanding by introducing patterns that conflict with the underlying scene. One research model that attempts to quantify aesthetic judgments uses four dimensions of appraisal: coherence, legibility, mystery, and complexity. Another uses visual interest and visual lightness (room surface brightness).These studies conclude that preference for a scene increases when the lighting is nonuniform; however, high levels of one quality can reduce levels of another. For example, a scene that is complex may rank low in coherence.

2.1.11. Health, Safety, and Well- Being:

Although they are needs of primary importance, health, safety, and wellbeing are often overlooked. As an example, flicker from some electric lighting can produce a stroboscopic effect with moving machinery, making the machine appear to move at a different rate. Electronic ballasts for fluorescent lamps reduce the perception of flicker, and it also appears that they reduce the incidence of headaches and eyestrain. Safety is an important need, but emergency lighting is only one aspect of it. Lighting also affects the visibility of curbs, stair edges, train platforms, roadway intersections, and labels of critical chemicals and pharmaceuticals.

Light also has a direct impact on wakefulness and the state of the circadian system (i.e., sleep-wake cycle) by suppression of melatonin in the brain. Recent evidence suggests that disruption of the circadian system may have long-term consequences for different types of cancer. This is a new field of research and should be carefully monitored by the lighting designer [7].

The relative importance of these needs differs for each setting. In a factory, aesthetic judgments are likely to be less important than health and safety or task performance. In a restaurant, social and communication needs, aesthetic judgments, mood, and comfort are all important; however, visual tasks such as reading the menu also need to be considered. One of the challenges in lighting design is to determine which human needs are to be served. In some cases, needs conflict and require careful thought to establish priorities.

2.1.12. Social Communication:

Social communication needs include the creation of luminous conditions conducive to such communications in a setting, especially by facial appearance. Much human communication occurs by nonverbal means, but these cues are missed if the lighting distracts from or masks the information. Facial recognition, for example, which is a critical element of security lighting, is influenced not only by the amount of light needed to detect a face, but also by the modeling of facial features created by the pattern of the light and shadow on the subject's face.

ENERGY EFFICIENCY & SUSTAINABILITY

It is always encouraged to use energy as efficiently as possible without compromising with the visual function that the lighting has to serve. Efficient lamps, luminaires and control circuits are helpful in achieving energy efficiency. Design option such as task/ambient lighting may further aid in attain energy efficiency. Automatic control of lighting is another strategy for an energy lighting efficient solution. It is also necessary for the lighting industry and its customers to use equipment that is sustainable. This means that the materials used are wherever possible from renewable sources and that at the end of life the redundant equipment can be disposed of safely with most of the base materials being recycled.

2.2. MAINTENANCE & LIGHTING COSTS

2.2.1. Maintenance:

It is known that both daylight and artificial light depreciate with time. A maintenance program is needed to be designed and implemented so as to arrest that effect. As the maintenance programme plays a significant role in lighting design, the designer will need to state the maintenance programme on which the design has been based, otherwise there could be problems when a client is comparing different design proposals. It will also be important for the client to be provided with a maintenance schedule so that they know what will need to be done.

2.2.2. Lighting costs:

Cost of a project is a very important factor. Cost of every project has basically two parts- capital costs and running costs. Capital costs are the first thing that needed to be agreed by the client otherwise lot of time will be wasted[11]. The operational costs include the cost of the electricity consumed, which comprises items such as standing charges, maximum demand charges and electricity unit costs. They will also include the cost of maintenance, which includes cleaning and re-lamping throughout the life of the installation. In some cases charges may have to be budgeted for the disposal of redundant equipment although this may be borne by the supplier. The two cost elements are to be considered together in terms of life cycle costing to avoid any kind of inconsistency.

CHAPTER – 3

DEFINATIONS AND PARAMETERS REQUIRED IN THE DESIGN

INTRODUCTION OF MAINTAINING CODES AND STANDERDS

It is a good practice to follow standards or guidelines during any lighting design. A good lighting is judged by both quantity and quality of light. This chapter intends to discuss briefly about the standards that are adhered to while presenting any indoor design. As will be mentioned in the coming chapters, all design parameters are evaluated on the basis of whether it is fulfilling the required standard values or not. This includes the specified illuminance levels required for a particular task, the lighting power density (LPD) value for the area, cri and cct of a lamp for a particular application. Other than design guidelines the tests that a led luminaire needs to qualify before being used is required to know and it is described in annexure.

3.1. Some definitions related with the designs:

The primary objective of this code is to indicate the factors which should be taken into account to achieve good lighting. It confines itself primarily to the lighting of working interiors, such as factories, workshops, offices, commercial premises, public buildings, pharmaceutical manufacturing plant, hospitals and schools, keeping two objects in mind, namely, to make the task easy to see and to create a good visual environment.

Lighting is good only when it is suitable in both quality and quantity for two purposes; for creating good environmental brightness which is at the same time agreeable and beneficial to the user, and for permitting a high degree of efficiency in seeing whatever is of special interest or importance. Many of the recommendations hold good whether lighting is artificial, natural or combination of the two and, as far as possible, the lighting of a building is regarded as a service which should be maintained at a high standard whenever the building is occupied [7].

Provision of a good lighting system calls for co-ordination from the initial stages among the various parties concerned, namely, the architect, the consultants and the illumination engineer.

Therefore, it is essential that information regarding lighting should be exchanged between the parties from the stage of planning to installation [7].

3.1.1.Illuminance:

The lighting level produced by a lighting installation is usually quantified by the illuminance produced on a specified, plane. In most cases, this plane is the major plane of the tasks in the interior and is commonly called the working plane. The illuminance provided by an installation affects both the performance of the tasks and the appearance of the space [7].

3.1.2. Scale of illuminance:

In order to be able just to discern features of the human face, a luminance of approximately 1cd/m2 is necessary. This can be achieved under normal lighting conditions with a horizontal illuminance of approximately 20 lux. So 20 lux is regarded as the minimum illuminance for all non-working interiors. A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminances. Therefore, the following scale of illuminances is recommended.20-30-50-75-100-150-200-300-500-750-1000-1500-2000, etc, lux [7].

3.1.3. Illuminance ranges:

Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity intended, of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

- The higher value of the range should be used when:
  1. Unusually low reflectance or contrasts are present in the task;
  2. Errors are costly to rectify;
  3. Visual work is critical;
  4. Accuracy or higher productivity is of great importance ;and
  5. The visual capacity of the worker makes it necessary.

- The lower value of the range may be used when:
  1. reflectance or contrasts are unusually high;
  2. Speed and accuracy is not important; and
  3. The task is executed only occasionally.

3.2. Some mandatory recommendations

Recommendations for lighting levels have been referred in the 9thedition of the iesna lighting handbook. The illuminating engineering society of north America is the recognized technical authority on illumination.

Lighting level : in IESNA there are different lighting levels specified depends upon the visual task, building area and task .

Table:3.1-ISENA 2000 DIFFERENT LUX LEVEL [6]

Type of visual task	Foot-candle	Lux	Comments
Tasks occasionally Performed	3	30	Orientation & simple Visual tasks
Simple Orientation/short visit	5	50	Orientation & simple Visual tasks
Working space/simple Task	10	100	Orientation & simple Visual tasks

High contrast/large Size	30	300	Common visual tasks
High contrast/smaller Size or inverse	50	500	Common visual tasks
Low contrast/smaller Size	100	1000	Common visual tasks
Tasks near threshold	300-1000	300-1000	Special visual tasks

3.2.1. Uniformity:

The uniformity of illluminance is a quality issue that addresses how evenly light spreads over a task area. Although a room's average illuminance may be appropriate, few factors may compromise uniformity [6]:

- Improper fixture placement based on the luminaire's spacing criteria (ratio of max recommended fixture spacing distance to mounting height above task height).
- Fixtures that are retrofit with reflectors or louvers that narrow the light distribution.

Non-uniform illuminance causes several problems:

- Inadequate light levels in some areas
- Visual discomfort when tasks require frequent shifting of view from under lit to over litareas.
- Bright spots and patches of light on floors and walls that cause distraction and generate a low-quality appearance.

Colour properties of light source

The colour properties of a light source depend on its spectral power distribution. The colour properties of a light source are described by three following quantities:

- Chromaticity
- Colour rendering index
- Efficiency

Chromaticity of colour temperature:

- All objects will emit light if they are heated to a sufficiently high temp.
- The chromaticity or colour temp of a light source describes the colour appearance of the source.
- The cct of a light source is the absolute temperature in kelvin(k) of a black body radiator, having the closest possible colour match to the light source.
- Sources with low colour temps-below 3000k have a reddish or yellowish colour,

described as warm colour.

- Sources with high colour temps-above 4000k have a bluish colour, described as cool colour.

Recommendations under energy conservation and building code ecbc 2016.

3.2.2. BUILDING AREA METHOD

Determination of interior lighting power specification (watts) by the building area method shall be in accordance with the following:

- Determine the allowed lighting power density from for each appropriate building areatype.
- Calculate the gross lighted floor area for each building area type ofecbc.
- The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area types.

Table:3.2-LPD (BUILDING AREAMETHOD)[6]

Building area type	LPD(w/m^2)	Building area type	LPD(w/m^2)
Automotive facility	9.5.2	Multifamily residential	5.2.5
Convention center	12.9	Museum	11.8
Dining: bar lounge/leisure	14.0	Office	10.8
Dining: cafeteria/fast food	15.1	Parking garage	3.2
Dining: family	15.2.2	Performing arts theater	15.2.2
Dormitory /hostel	10.8	Police/fire station	10.8
Gymnasium	11.8	Post office/town hall/	11.8
Healthcare-clinic	10.8	Religious building	14.0
Hospital/health care	12.9	Retail/mall	16.1
Hotel	10.8	School/university	12.9
Library	14.0	Sports arena	11.8
Manufacturing facility	14.0	Transportation	10.8

Motel	10.8	Warehouse	8.6
Motion picture theater	12.9	Workshop	15.1

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply for details work and overall checking through building area method.

3.2.3. SPACE FUNCTION METHOD

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

For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.
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 the allowed lighting power density for that space

Table:3.3-INTERIOR LIGHTING POWER – SPACE FUNCTION METHOD[6]

Space function	LPD (w/m^2)	Space function	LPD (w/m^2)
Office-enclosed	11.8	Library	
Office-open plan	11.8	Card file & cataloging	11.8
Conference/meeting/ Multipurpose	14.0	Stacks	18.3
Classroom/lecture/ Training	15.1	Reading area	12.9
Lobby	14.0	Hospitals	
For hotel	11.8	Emergency	29.1
For performing arts theater	35.5	Recovery	8.6

For motion picture theater	11.8	Nurse station	10.8
Audience/seating area	9.7	Ex am treatment	16.1
For gymnasium	4.3	Pharmacy	12.9
Patient room	7.5		
For convention center	7.5	Operating room	23.7
For religious buildings	18.3	Nursery	6.5
For sports arena	4.3	Medic al supply	15.1
For performing arts theater	28.0	Physical therapy	9.7
For motion picture	12.9	Radiology	4.3

Based on these LPD values, the designer can have an idea of the energy efficiency of his/her lighting design.

3.3. Parameters related to energy conservation

The energy conservation building code (ECBC), was launched by ministry of power, government of India in may 2011, as a first step towards promoting energy efficiency in the building sector [8].

The ecbc was developed by an expert committee, set up by india's bureau of energy efficiency, with support and guidance from united states agency for international development and significant inputs from various other stakeholders such as practicing architects, consultants, educational institutions and other government organizations.

The successful implementation of the code requires development of compliance procedures(compliance forms and development of field-test compliance forms and procedures), in addition to building capacity of architects/designers/builders/contractors and government official in states and urban and local bodies. It is also dependent on availability of materials and equipment that meet or exceed performance specifications specified in ecbc.

3.3.1. The ecbc provides design norms for:

1. Building envelope, including thermal performance requirements for walls, roofs, and windows
2. Lighting system, including day lighting, and lamps and luminaire performancerequirements

3. Hvac system, including energy performance of chillers and air distribution systems
4. Electricalsystem
5. Water heating and pumping systems, including requirements for solar hot-watersystems

3.3.2. Interior lighting power allowance:

The installedinteriorlightingpowerforabuildingshallnotexceedtheinteriorlightingpower allowance determined in accordance with the below mentioned methods. Ecbc 2011 recommended the value for the lighting power density thus calculated by the two methods. Suchas:

3.3.3. Building area method

This method provides the procedure of calculating the total watts per square meter for the entire building based on its type the sum of all the lighting power for various areas of the building cannot exceed the total watts to be in compliance

- The first step is to identify the allowed power lighting density for appropriate building area types.
- The second step is to calculate the gross lighted floor area types.
- Finally the last step is to multiply the allowed watts per square meter listed for each building type by the corresponding lighted floor areas to determine the allowed light power allowance.

Table:3.4- TABLE PROVIDES THE SPECIFIED LPD VALUES FOR DIFFERENT AREAS USING BUILDING AREA METHOD [8]

Building Area Type	LPD (W/m^2)	Building Area Type	LPD (W/m^2)
Automotive Facility	9.7	Multifamily Residential	7.5
Convention Center	12.9	Museum	11.8
Dining: Bar Lounge/Leisure	14.0	Office	10.8
Dining: Cafeteria/Fast Food	15.1	Parking Garage	3.2
Dining: Family	17.2	Performing Arts Theater	17.2
Dormitory/Hostel	10.8	Police/Fire Station	10.8
Gymnasium	11.8	Post Office/Town Hall	11.8
Health care-Clinic	10.8	Religious Building	14.0
Hospital/Health Care	12.9	Retail/Mall	16.1
Hotel	10.8	School/University	12.9
Library	14.0	Sports Arena	11.8
Manufacturing Facility	14.0	Transportation	10.8
Motel	10.8	Warehouse	8.6
Motion Picture Theater	12.9	Workshop	15.1

space function method: similar to the building area method, the first step of the space function method is to identify the appropriate building type and their allowed lighting power densities, which varies according to the function of the space. Then calculating total watt/sq. Meter for the entire buildingbasedonitstype.Thesumofallinteriorlightingpowersforvariousareasofbuilding should not exceed the total watts to be compliance as per furnished here in after.

Table:3.5-PROVIDES THE SPECIFIED LPD VALUES FOR DIFFERENT AREAS USING SPACE FUNCTION METHOD [8]

Space Function	LPD (W/m^2)	Space Function	LPD (W/m^2)
Office-enclosed	11.8	• For Reading Area	12.9
Office-open plan	11.8	Hospital	
Conference/Meeting/Multipurpose	14.0	• For Emergency	29.1
Classroom/Lecture/Training	15.1	• For Recovery	8.6
Lobby*	14.0	• For Nurse Station	10.8
• For Hotel	11.8	• For Exam Treatment	16.1
• For Performing Arts Theater	35.5	• For Pharmacy	12.9
• For Motion Picture Theater	11.8	• For Patient Room	7.5
Audience/Seating Area*	9.7	• For Operating Room	23.7
• For Gymnasium	4.3	• For Nursery	6.5
• For Convention Center	7.5	• For Medical Supply	15.1
• For Religious Buildings	18.3	• For Physical Therapy	9.7
• For Sports Arena	4.3	• For Radiology	4.3
• For Performing Arts Theater	28.0	• For Laundry – Washing	6.5
• For Motion Picture Theater	12.9	Automotive – Service Repair	7.5
• For Transportation	5.4	Manufacturing Facility	
Atrium-first three floors	6.5	• For Low Bay (<8m ceiling)	12.9
Atrium-each additional floor	2.2	• For High Bay (>8m ceiling)	18.3
Lounge/Recreation*	12.9	• For Detailed Manufacturing	22.6
• For Hospital	8.6	• For Equipment Room	12.9
Dining Area*	9.7	• For Control Room	5.4
• For Hotel	14.0	Hotel/Motel Guest Rooms	11.8
• For Motel	12.9	Dormitory – Living Quarters	11.8
• For Bar Lounge/Leisure Dining	15.1	Museum	
• For Family Dining	22.6	• For General Exhibition	10.8
• Food Preparation	12.9	• For Restoration	18.3
Laboratory	15.1	Bank Office – Banking Activity Area	16.1
Restrooms	9.7	Retail	
Dressing/Locker/Fitting Room	6.5	• For Sales Area	18.3
Corridor/Transition*	5.4	• For Mall Concourse	18.3
• For Hospital	10.8	Sports Arena	
• For Manufacturing Facility	5.4	• For Ring Sports Area	29.1
Stairs-active	6.5	• For Court Sports Area	24.8
Active Storage*	8.6	• For Indoor Field Area	15.1
• For Hospital	9.7	Warehouse	
Inactive Storage*	3.2	• For Fine Material Storage	15.1
• For Museum	8.6	• For Medium/Bulky Material Storage	9.7
Electrical/Mechanical Facility	16.1	Parking Garage – Garage Area	2.2
Workshop	20.5	Transportation	
Convention Center – Exhibit Space	14.0	• For Airport – Concourse	6.5
Library		• For Air/Train/Bus – Baggage Area	10.8
• For Card File & Cataloging	11.8	• For Ticket Counter Terminal	16.1
• For Stacks	18.3		

After studying all these codes and standards following points are extracted:

1.Every service illuminances for indoor area must be in compliance with the is- 3646 (part1).

2.Here, nothing can be concluded about the uniformity and ugr values which are important as well to ensure the lighting quality. National lighting code 2010, gives an understanding of strategies usually adopted for lighting design of different areas of a pharmaceutical manufacturing area.

3.Code of lighting 2002 in note 2, gives an understanding of cri, colour temperature of lamps usually adopted for lighting design of different areas of a pharmaceutical manufacturing area.

4.Ecbc 2011 actually guides in designing an energy efficient lighting system depending upon the building type. Space function method provides the LPD values for different types of space within a particular type of building. Therefore, if LPD of all spaces within a building lies within the prescribed value as per space function method, energy efficient lighting will be a guaranteed. On the other hand building function method provide the LPD values for particular type of buildings. This building function method is applied to indicate the degree of energy efficiency of an entire building in view of lighting.

The different lighting standard have already been discussed in details in this chapter. European norms are accepted for today's hospital lighting design. The lighting level consider in india mostly follows indian standards. The colour aspects i.e., colour rendering index, colour temperature values of source for indoor lighting design specified by the Indian and European norms is same.

3.3.4. Factors affecting the office lighting

Lighting plays an important role in any indoor area. The main functions of lighting in office area is to meet the lighting requirements (both quantitative and qualitative) to perform important visual tasks in working areas. There are many types of visual tasks in office, which should be done very carefully and accurately. These visual tasks cannot be done perfectly without proper lighting levels.

3.3.5. Line of sight:

In office lighting some common lines of sight are unusual with respect to general indoor lighting. For conference room, common lines of sight are towards the ceiling and the upper parts of the opposite walls. For such common lines of sight special care is necessary to avoid glare.

3.3.6. Standby lighting:

It is a part of an emergency lighting system provided to enable normal activities to continue substantially unchanged. Standby lighting will be required in certain parts of the pharmacy to enable essential activities to be carried out in the event of a supply interruption. This industry normally follows two standards of illuminance for standby lighting. In critical areas, such as solution preparation, treatment & testing area, the illuminance provided by the standby lighting should equal, or nearly equal to 90 percent of the normal mains illuminance. Other non-critical but important areas will require standby lighting to a reduced illuminance, generally to 50 percent of the normal light level [8].

CHAPTER – 4

INTRODUCTION TO OFFICE LIGHTING DESIGN PARAMETERS

OFFICE LIGHTING DESIGN PARAMETERS:

The following hospital lighting parameters are under consideration of any design.

4.1.1. Illuminance level:

The lighting level produced by a lighting installation is usually qualified by the illuminance produced on a specific plane. In most cases this plane is the major plane of the tasks in the interior and is commonly called the working plane. The illuminance provided by an installation affects both the performance of the tasks and the appearance of the space. The above-mentioned lighting standards recommend different illuminance levels [19].

4.1.2. Luminance distribution:

A well-balanced adaptation luminance is needed to increase visual acuity (sharpness of vision), contrast sensitivity(discrimination of small relative luminance differences),efficiency of the ocular function and also effects visual comfort.

4.1.3. Uniformity:

The term uniformity for indoor hospital lighting design generally signifies the ratio of minimum illuminance value calculated or measured under the different grid points to average value of all illuminances. According to the three 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.

4.1.4. Direction of incidence of light and shadow effect:

Lighting from a specific direction may reveal details within a visual task, increasing their visibility and making the task easier to perform. Veiling reflections and reflected glare should be avoided. Directional lighting may be used to highlight objects, reveal texture and improve the appearance of people within the space. Directional lighting of a visual task may also affect its visibility [20].

4.1.5. Colour appearance and colour rendering:

The colour appearance of a lamp refers to the apparent colour (CCT). The choice of colour appearance is a matter of psychology, aesthetics and of what is considered to be natural. The choice will depend on illuminance level, colours of the room and furniture, surrounding climate and the application.

4.1.6. Colour appearance and colour rendering groups of lamps:

The colour of light emitted by a source can be indicated by its correlated colour temperature (CCT). The apparent colour of light source in a room is largely determined by the function of the room[21].

Each lamp has a specific correlated colour temperature, but for practical use the correlated colour temperatures have been grouped into three classes like:

Table:4.1-CCT TYPE AND VALUES

CCT	CCT type
CCT≤3300k	Warm
3300k<CCT≤5300k	Intermediate
5300k<CCT	Cold

The ability of the light source to render colours of surfaces accurately may be conveniently quantified by the general colour-rendering index. The colour rendering groups of the various lamps to be used for lighting of interior at hospital are also specified.

Table:4.2-COLOUR RENDERING GROUPS

Colour rendering groups	Cie general colour rendering index(r_a)	Typical application
1a	Ra≥40	Wherever accurate colour matching is required
1b	$80 \leq r_a < 90$	Wherever accurate colour judgements are necessary and good colour rendering is required for reasons of Appearance
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

CHAPTER – 5

THEORY BEHIND THE LIGHTING DESIGN

THEORY BEHIND THE LIGHTING DESIGN:

Indoor lighting design is done using DiaLux4.13. The lumen method of illuminance calculation is used to estimate the average service illuminance produced by the installation which is given by the following formula:

$$E = \frac{n * N * F * UF * LLF}{A}$$

Where,

E= average service illuminance on working plane (lux);
F = initial luminous flux of the light source;
n = number of lamps per luminaire;
N = number of luminaire;
A = area to be lit (in m^2)
UF = utilization factor for type of luminaire in specific room conditions; and
LLF=light loss factor [10]

5.1.1. LIMITATIONS OF LUMEN METHOD:

- The method is based on average illuminance formula. So we can't get information about uniformity, illuminance distribution of the luminaire on the working plane.
- The above said formula is dependent on utilization factor . So utilization factor for type of luminaire in specific room conditions is to be calculated [10]
- This method holds for general lighting system not applicable for task lighting.

Design methodology -To discuss on lighting design, in general, let us have a look in to some important the lighting design tools and after that the design process will be described.

5.1.2. TOOLS REQUIRED FOR LIGHTING DESIGN:

The following tools are the basic requirement to start a lighting design.

a) DiaLux: DiaLux is lighting simulation software which is used to calculate the luminaire quantity required to achieve the illumination level on the area as per the standard as well as spatial distribution of many important photometric quantities. It also gives information on the total power consumption by the lighting load for the given area and also calculates the LPD value of the proposed lighting scheme which helps in identifying the most efficient lighting scheme.

b) Lux meter: it is a instrument used to measure the illumination level at different points in working area. The proper calibrated lux meter was used for carrying out the lighting audit.

c) AutoCad: AutoCad is an architectural tool which provides complete information on the dimensions of the room like length, width and height of the room.

d) IS 3646 part i and ii: lighting design are done as per the is:3646(part I, part II)

e) ECBC 2011: lighting power density, as calculated for any design, is checked as per ECBC guidelines[8].

The software lighting design simulation which will be discussed here are done using the design tools DiaLux 4.12 & auto cad 2018.

5.1.3. Design process:

I. Problem finding & discussion: as a first step the problem finding & discussion is to be carried out with the guide and the other member of the design team to get the essence of what is the function of the space and hence what is to be done.

II. Obtaining the layout of the site and studying it: after discussing with the guide , AutoCad layout is collected and detail analysis of the AutoCad layout is done to understand the complete plan of the site like height of the room, luminaire mounting height, ceiling layout, etc. Which would help in proper selection and arrangement of the luminaire.

III. Partition of site layout using lighting simulation software: DiaLux software is used as the lighting simulation tool for designing the lighting system as per the standards. Grouping the entire area into different types of area in terms of their common functionality/purpose. For example, among many office rooms, one is arbitrarily chosen and design has to be done keeping in mind that the chosen one is representative of all the other rooms of same purpose. The design is carried out for office room areas and the other areas like team rooms, administration & workspace, meeting and conference areas etc.

IV. Study of guidelines: to study the relevant codes, guide lines in detail. For indoor lighting design is.3646.1992 (part i &part ii), national lighting code is.sp.72.2010 & outdoor lighting designis.1944arereferred.

V. Lamp &luminaire study: A different area of this industry requires installation of suitable lamp &luminaire depending upon the application of area. These phases involve the understanding of luminaires, their light distribution, IP ratings and their application areas & explore the possible lamps and luminaires which could be used in the project. The comparisons with different luminaires are made in order to provide the best energy efficient lighting solution to the client.

VI. Workout with the site layout: import of the AutoCad files in the lighting design software e.g. DiaLux4.13. During import of .dwg file, proper dimension of the auto cad file should be taken. For example if the dimension is in millimeter in the AutoCad layout then import that file into DiaLux by selecting the dimension in milli meters.

VII. Design simulation: simulation is checked for every possible case using DiaLux. If the simulation does not comply with the standards & client requirements, the redesigning is carried out until the requirements are met.

CHAPTER – 6

GENERAL INPUT DATA FOR DESIGN

GENERAL INPUT DATA FOR DESIGN:

The following details are given as input while performing a design:

i. **The drawing of the workspace giving floor plan andelevation:**

This provides information on length, width and height of the area and about the type of ceiling and any constraints in locating the furniture.

ii. **Reflectance properties of thesurrounding:**

This data helps in deciding the reflectance factors of wall, floor and ceiling. Normally client does not specify this data. In such cases, the environmental factors prevailing in the area, and experience of the designer helps in deciding the reflection properties.

If no data is given, normally following factors are considered:

General office area: reflectance of ceiling:

- ρc :50% reflectance of wall
- ρw : 30% reflectance of floor
- ρf:20%

iii. **The maintenance factor as per the surroundingarea:**

A chief factor affecting the performance of a lighting system is the deterioration of its components with age. Since reflectance of the walls tends to decrease over time due to dirt deposition. Hence maintenance factor is an important parameter of consideration [22].

iv. **Nature of work to be performed:**

This will help in deciding the illumination level for a particular type of application from BIS codes on lighting.

v. **Layout and heights of machine andtools:**

This will help in locating the luminaires and also determining the workplane height. If the height of the working table is not given then the following heights should be taken:

Work plane height: 0.75m

6.1 DESIGN CONSIDERATIONS:

6.1.1. Reflectance factor

Specifications made in standard design: ceiling, wall and floor reflectance (ρc, ρw,ρf)

This gives the fraction of light that is contributed on the workplane after reflection from ceilings, walls and floors. Quite impliedly, darker walls absorb more light, while lighter walls reflect.

For official area the ceiling, walls and floor reflectance are considered as 50%, 30% and 20% respectively.

Forcabin roomareastheceiling,wallsandfloorreflectanceareconsideredtobe50%,30%and 20% respectively. Sometimes for special cases the ceiling, walls and floor reflectance are considered to be 70%, 50% and 20%respectively.

For other areas like meeting room, conference hall, workstation the ceiling, walls and floor reflectance are considered to be 50%, 30% and 20% respectively. Sometimes for special cases the ceiling, walls and floor reflectance are considered to be 30%, 20% and 10% respectively.

6.1.2. Maintenance factor

A chief factor affecting the performance of a lighting system is the deterioration of its components with age. As the light source ages, its light generating ability declines, an effect known as lamp lumen depreciation(LLD). As paint and fabrics age and dirt accumulates on ceilings, walls and floors, the resultant decrease in light levels is attributed to room surface depreciation (RSD). Similarly like the walls and ceilings even the luminaires start accumulating dust over time, which also renders lower light output as compared to initial installation. This factor is attributed as luminaire dirt depreciation (LDD) [22].

a) Lamp lumen depreciation (LLD): the light output of all the lamps commonly used decreases as they get older. Numerically it is the light emitted at 70% of rated life expressed as a percentage of initial light output. Thus if a new lamp gives 1740 lumens and that lamp emits 1575 lumens after it has burned for 70% of its rated life, then its lld is 1575/1740 = 90.5%. The effect of lumen depreciation can be reduced by planned replacement, such as group relamping where all the lamps are replaced at some interval less than 100% of rated life [22] .

b) Luminaire dirt depreciation (LDD): airborne dirt deposited on luminaire surfaces affect the amount of light leaving the luminaire and the intensity distribution of the luminaire. The amount light leaving the luminaire decreases for the simple reason that dirty surfaces absorb more light than clean ones. The distribution is affected because specular surfaces become more diffuse when dirty, something which is analogous with watching one’s self on a dusty mirror.

c) Room surface depreciation (RSD): it would seem that, if the luminaires are cleaned and relamped occasionally, the major light loss factors are taken care of. However, since high room surface reflectance have shown to be a requirement for good system efficiency, any decrease in room surface reflectance will also increase light loss.

Other factors contributing to decreased light levels includes the number of lamps burned out in a system, and the condition of luminaire surfaces such as lenses.

From a designer’s point of view, the design of a lighting system should be such that the required light level is provided when the system has reached its worst state of deterioration, so that it ensures that the occupants will receive at least the minimum illuminance requirement throughout the life of the lighting system [22].

Since maintenance factor (M.F) is a conglomeration of all the above mentioned factors, it mathematically described as:

M.F = LLD*LDD*RSD

Sometimes described as light loss factor (LLF)

a) Using conventional luminaires:

For administrative blocks& cleanroom areas, the maintenance factor is considered to be 0.8 whereas for industrial areas it is considered to be 0.7 owing to faster rate of dirt deposition and ill maintenance of room surfaces.

b) Using LED luminaires:

For administrative blocks& cleanroom areas, the maintenance factor is considered to be0.85whereasforindustrialareasitisconsideredas0.75.Maintenancefactorincase ofled isconsideredhigherbecauseofitshigherlamp lifeand lesserchancesofbeing burntout.

6.2. DESIGN PARAMETERS:

For any designer, the first task is to identify the parameters based on which the design is to be carried out. Generally, any design is evaluated on four main parameters.

- They are: Average illuminance (Eavg): this mainly implies the amount of light falling on the work plane per unit area of the light receiving surface. The work plane height is normally chosen at a height of 0.8 metres from the floor.

Mathematically it is described as:

$$e_{avg} = \frac{amount\ of\ light\ falling\ on\ the\ task\ area\ (in\ lumence)}{Task\ area\ (\ in\ sq\ m)}$$

The lighting of any work plane should be both sufficient and suitable in terms of:

a) Adequate quantity of the work plane and surrounding area.
b) The light should be such that it should not have any harmful effects on people's health and performance. In other words, an attempt should made to make the design robust and glare free.

The code of practice for interior recommends illumination levels according to the tasks involved. They are mentioned in terms of the mean illumination levels, throughout the maintenance cycle of lighting system and averaged over the relevant area which may be whole interior or just that occupied by tasks and immediate surroundings.

- Overall uniformity of illuminance (U_0): code of practice recommends that the uniformity of illuminance should be measured as the ratio of minimum illuminance to the average illuminance over the task area, which may be the whole interior or specific task areas. For example, when we are designing for a conference room, which normally is equipped with furniture, it is recommended that ratio of the minimum illuminance to mean illuminance i.e. U_0 on the table to be > 0.7. Similarly while designing for a paint shop which requires very high lux levels, the overall uniformity for the entire surroundings is maintained at u_0> 0.9.

It is mathematically described as ,

$$U = (\mathbf{Emin})/(\mathbf{Emax})$$

Where,

E_{min} = minimum value of illuminance over the task area (in lux or fc)

E_{avg} = average value of illuminance over task area (in lux or fc)

Unified glare rating (UGR) : glare in the installation is defined in two different terms:

a) Disability glare
b) Discomfort glare

Disability glare is the glare, which reduces the ability to perceive visual information needed for task performance. This is because too much light gets scattered in the eye.

Degree of discomfort glare, is the glare that causes discomfort without necessarily impairing the vision of objects and task area.

Generally UGR ranges from 5-30, higher the value, greater the glare. The following scale of UGR should be used: 5-10-13-16-19-22-25-28. UGR of 10 creates absolutely no glare. If it is below 19, it is called 'satisfactory' where as a UGR value of 16 is considered 'perceptible'. UGR>19 shows presence of glare.

6.2.1. Limitations of UGR:

i. There is insufficient research to show whether the UGR method can be applied for indirect lighting, task lighting, and wall mounted lighting and luminous ceilings.

ii. In principle, the UGR scale can be related to the visual comfort probability scale used by the IESNA by fixing two sets of equivalent value on the two scales. This has not been done as there is no firm basis for the choice of the sets of values.

iii. B.m.paul and h.d.einhorn suggested that glare from 'small' sources was grossly over rated by the UGR method and also suggested suitable modification for evaluation of glare for small light sources.

iv. Einhom also suggested that the UGR method was far too tolerant in case of 'large' sources, including luminous ceilings.

CHAPTER – 7

DISCUSSIONS OF DESIGN ISSUES

7.1. DISCUSSIONS OF DESIGN ISSUES

The following are brief discussions of the design issues that appear in the IESNA Lighting Design Guide.

7.1.1. Appearance of Space and Luminaries:

Appearance includes both the arrangement of elements such as furnishings and luminaires in a space and their relationship to one another. These elements can provide visual cues that assist occupant orientation. It is important that the style of the luminaires coordinate with and enhance the design and architecture of the space. Lighting systems can also help create an image for the space (e.g., "corporate," "casual," "luxurious," "industrial").

Another important issue is "visual clutter," that is, confusing or distracting details in the visual field. For instance, lighting equipment can interfere with the view of a natural landscape or a carefully designed visual

7.1.2. Composition:

The eye is drawn to areas of greater brightness. Bright areas should be important to the composition, and preferably they impart some visual information (e.g., identify key paths for wayfinding, define boundaries, and delineate circulation patterns). Color patterns should also lead the eye to the areas of greatest importance.

7.1.3. Color Appearance (and Color Contrast):

Color appearance can affect visibility and aesthetics. For example, fluorescent paint can enhance visibility of an object but clash with the aesthetic composition in the space. Factors that contribute to color appearance include the spectral power distribution of the light source, the color perception abilities of the observer, and the transmission and reflection properties of objects and surfaces in the room or area. Color contrast, the difference in perceived color between a task and its background, is often an important issue for industrial tasks and for safety signage or markings.

Generally, lamps with a color rendering index (CRI) greater than 80 should be used to ensure a pleasant appearance of skin tones, food, and merchandise. For most office, educational, health care, and institutional workplaces, a CRI of 70 or above is acceptable. A CRI of 50 provides adequate color rendering for most industrial tasks. If color matching, paint mixing, or color selection is involved, a lamp with a CRI of 90 or above should be used.

7.1.4. Daylighting Integration and Control:

A view of the outdoors is believed to be important for psychological and physiological reasons by providing cues about the time of day and weather, and by providing distant objects on which to focus, thereby allowing people to relax the muscles of their eyes. Diffusing window glass should be avoided because it obscures views of the outdoors.

Daylight and sunlight can be used to help light a space, but care should be taken to control the quantity and distribution of the light and to control heat gain. Overhangs, light shelves, window blinds, and shades are all useful. It should be noted that more illumination is sometimes needed on interior surfaces near windows to reduce the brightness contrasts between those surfaces and the windows. For example, occupants' faces and other important surfaces can appear in dark silhouette against a window unless illuminated by electric lighting. Daylighting is most effective when used as ambient illumination, but it is too variable as a reliable source for task illuminance.

7.1.5. Direct Glare:

Glare can cause discomfort and interfere with visibility. Direct glare occurs when the light travels directly from the source to the eye. This may include "disability glare," "discomfort glare," and "overhead glare".

Luminaires, windows, and skylights can be uncomfortable to view, but there appears to be more tolerance of window brightness than of comparable luminaire brightness. Presumably this is due to viewers' preference for the visual information attained from windows.

Glare criteria for luminaire luminances between 50° and 90° from luminaire nadir (i.e., 0° to 40° above horizontal) have been established. Light from other angles can also produce glare if luminances exceed 10,000 cd/m2. As a rule, luminaire luminances should not be more than 100 times those of surrounding surfaces to minimize glare. This can be achieved with luminaires that illuminate the ceiling as well as the task and by increasing ceiling reflectance.

7.1.6. Flicker (and Strobe):

Flicker is the rapid variation in light source intensity, usually most noticeable in peripheral vision. Individuals vary widely in flicker sensitivity. Lamp flicker may interact with the movement of industrial machinery or with moving balls in various sports to produce a stroboscopic effect, where the machinery or ball appears to move at a rate different from its actual movement. The flashing seen in lamp startup is not considered flicker.

In industrial applications, flicker can be mitigated by using a three-phase electric distribution system with circuiting adjacent luminaires on alternate phases. High-frequency (20 to 60 kHz) electronic ballasts effectively eliminate flicker.

7.1.7. Illuminance (Horizontal):

Horizontal illuminance is the density of luminous flux falling onto a horizontal surface, measured in lux (lumens per square meter) or footcandles (lumens per square foot). Unless otherwise indicated, the plane on which the illuminance is specified and measured is assumed to be a horizontal plane 0.76 m (30 in.) above the floor for interior and industrial locations and tasks, 0.91 m (36 in.) above the ground for sports and recreational locations and tasks, and at grade for the outdoors.

7.1.8. Illuminance (Vertical):

Vertical illuminance is the density of luminous flux falling onto a vertical surface, measured in lux (lumens per square meter) or footcandles (lumens per square foot).

7.1.9. Intrinsic Material Characteristics:

Visual cues about surfaces and materials, such as texture or transparency, are revealed by lighting. The ability to see these cues, like nap and grain, may be critical to evaluating the type or quality of material, or the degree of consistency.

7.1.10. Light Distribution on Surfaces:

Patterns of light resulting from the spacing and light distribution of the luminaires, as well as from objects that can cast shadows, can affect task visibility, comfort, and perceptions. Harsh striated patterns of excessive brightness or noticeable shadow should be avoided. Illuminance patterns should correspond with architectural features (e.g., a regular pattern of glowing sconces) or objects (e.g., lighting art on the walls). Random patterns can be confusing or distracting.

Surfaces should not have extremely different brightnesses. For example, ceiling and walls should have luminances within a 3:1 ratio. Spaces with totally uniform brightness, however, lack visual interest. "Luminance ratios" refer to the relative luminances of any two areas in the visual field (e.g., ceiling-to-wall luminance ratios or immediate-surround-to-task luminance ratios).

7.1.11. Light Distribution on Task Plane (Uniformity):

Patterns of light on the task plane can be distracting, confusing, or beneficial. The task plane varies according to the application. In an office, the task plane is most often the desk top; in a corridor, it may be the floor; in an industrial plant, the cutting table; in a parking lot, the pavement surface. These patterns of light and shadow can affect task visibility, comfort, and perception. Use photometric data and luminaire manufacturer's guidelines to achieve the uniformity recommended for the application.

7.1.12. Light Pollution/Trespass:

Light that is directed upward to the sky or reflected from surfaces that interferes with astronomical observations or appreciation of the night sky is termed "light pollution." "Light trespass" is unwanted light that falls beyond the property line or area intended to be illuminated [23].

7.1.13. Luminaire Noise:

Sound generated by the internal parts of a luminaire can be annoying and distracting. Electromagnetic ballasts are the usual sources of sound, but incandescent lamps operated on certain types of dimmers and air moving through air-handling luminaires can also produce noise.

7.1.14. Luminances of Room Surfaces:

Room surface luminances influence the perception of brightness in a space. Illuminance and reflectance affect luminance. Matte surfaces of high reflectance (e.g., white-painted walls and light-colored furniture finishes) are effective materials for increasing room surface luminances. Luminaires expressly designed for lighting walls or ceilings are effective tools for increasing room surface luminances.

Average wall luminances of at least 30 to 100 cd/m2 are preferred in typical office work spaces (where 300 to 1000 lx [30 to 100 fc] is provided on the workplane). Minimize dark areas at tops of walls. If there are no luminaires dedicated to illuminating the walls, locate general lighting luminaires close to walls and utilize lenses, reflectors, or louvers to soften the pattern of light and distribute more light to the top of walls.

Spaces that deliver both direct and diffuse light to the occupant and task increase user comfort and satisfaction. This approach reduces distracting shadows from hands, desk objects, partitions, and overhead cabinets; reduces overhead glare; and improves facial modeling.

7.1.15. Modeling of Faces or Objects:

Lighting can reveal the depth, shape, and texture of an object. Through the creation or elimination of shadows, faces and objects can have more or less contrast.

The distribution of light in a retail display is critical to attracting attention and making the merchandise look appealing. Appropriate direction and distribution depends on the type of merchandise, but generally a combination of diffuse light and directional light will enhance appearance.

7.1.16. Peripheral Detection:

The human visual system is designed to detect movement in the periphery of the visual field and to guide the fovea to that movement for inspection and interpretation.

7.1.17. Point(s) of Interest:

A point of interest is the object or place to which attention is drawn, using movement, luminance contrast, and color contrast.

7.1.18. Reflected Glare:

Bright reflections from polished or glossy surfaces are uncomfortable and reduce task visibility; this is known as "reflected glare." "Veiling reflections" are contrast-reducing reflections from semispecular surfaces that reduce task visibility. The possible negative impact of reflected glare and veiling reflections can be estimated. The ratio of illuminance on the task from the mirror angle relative to the total illuminance on the task should be less than 0.3 for satisfactory results, whereas unsatisfactory results can occur if the ratio exceeds 0.7. For VDT applications the most practical solution to both veiling reflections and reflected glare is to select a VDT monitor with a diffuse reflecting screen and one that provides a bright background and dark text.

7.1.19. Shadows:

Shadows can interfere with task visibility by placing detail in darkness (e.g., a body shadow on a paper task), and they can also enhance definition of three-dimensional details (e.g., imperfections in a piece of cloth). Point sources (e.g., incandescent or high-intensity discharge [HID] lamps) can cause sharp shadows from obstructions, whereas linear or area sources (e.g., luminaires with a large uplight component, fluorescent lamp luminaires with large prismatic lenses and white reflectors) produce more diffuse shadows. Local task lighting can increase illuminances to minimize shadows on machinery or under cabinets.

7.1.20. Sparkle/Desirable Reflected Highlights:

Small points of high luminance can enhance visual interest (e.g., a candle flame or decorative tree lights).

7.1.21. Special Considerations:

Often there are special issues associated with a specific location or task (e.g., photo degradation or hazardous location requirements).

7.1.22. Surface Characteristics:

Object characteristics such as texture, color, and specularity and reflectance values of surfaces can affect the perceived brightness of walls, ceilings, exterior building facades, and pavement. Interior

workspaces should have high reflectances (walls, 50 to 70%; ceiling, 75 to 90%) to increase interreflections and thus help reduce the undesirable contrast of luminaires against their background. High reflectances also allow the designer to produce an effective lighted environment with fewer watts and fewer luminaires.

Surfaces should be matte or satin finished to avoid reflected glare. Dark surfaces (20 to 50%), saturated colors, and glossy finishes can maintain visual interest and stimulation, but they should be used to a limited degree. The Finish Schedule of construction documents should include material reflectances available from manufacturers of paint, wall covering, fabrics, and ceiling tiles.

7.1.23. System Control and Flexibility:

Many spaces require different light levels for a variety of tasks. Conference rooms and auditoriums in particular need to have equipment that provides for different settings for slide shows, personnel interviews, financial meetings, presentations, and cleaning. Two or more lighting circuits can be used separately or together to achieve a wide range of appearances and light levels. One system can light walls, another can provide downlight on the workplane, and a third can provide general ambient illumination from a decorative luminaire mounted over a table. Preset scene controls can be employed with combinations of circuits. Dimming provides additional flexibility.

There are widely differing personal preferences for illuminance in work areas. User satisfaction can be enhanced through control of illuminance with switching or dimming of task or overhead lighting. Task lights can also be used so that the occupants can control the location, direction, and intensity of light. This is particularly important in spaces where both VDT and paper tasks are used.

Veiling Reflections, Reflected Glare, and Shadows. The contrast of a visual task depends on the glossiness of the task surface and on the geometric relationships between the light sources, the task, and the eyes. If the visual task produces a mirror angle between the eye and the luminaire or another bright object, contrast is reduced. This effect is called veiling reflections (Figure 11-3). The area from which a luminaire or bright object can reflect light off the task and into the viewer's eyes is termed the offending zone. This may be a specific area of the ceiling or, often in open-plan workstations, the area directly in front and above the occupant, which is a common area for placement of task-light luminaires .

7.1.24. Task Lighting:

Like ceiling luminaires, task lighting, either as desk luminaires or as part of open-plan furniture systems, ordinarily should not be placed in the offending zone. However, the light distribution characteristics of some luminaires minimize veiling reflections through optical design elements. Such luminaires may be placed in the offending zone if they use an optical system that redirects light so that these veiling reflections are eliminated or at least reduced. This can be accomplished with lenses and/or reflectors. Many task lights use a batwing lens. This type of lens is made up of a series of linear prisms that minimize the light output at nadir (straight ahead) and redirect light out to the sides. As a result most of the light striking the task originates from the sides or ends of the task light .

Free-standing or mobile-arm task lights allow the user to position the light for best task visibility .This may be a useful approach when linear task lights cannot be used. Many of these portable task lights offer little optical control; a shade can block light from the user's eyes, and generally most of the light is concentrated directly below the unit.

7.2 LIGHTING METHODS

7.2.1 General Lighting Versus Localized Lighting:

There are basically two methods for lighting office tasks. One is to design the general lighting so that required illuminances are provided at all task locations. This is most appropriate for private offices or special situations where task lighting is inappropriate. The other is to supply localized lighting from task-lighting luminaires in conjunction with a low level of general illumination. In open-plan arrangements where vertical partitions or storage cabinets over work surfaces cause shadows, localized lighting becomes essential for adequate task illumination and shadow reduction. When localized lighting is used, the general illumination should be designed with a low illuminance appropriate for circulation, for casual viewing of tasks, and to provide the recommended luminance ratios between the task and other areas within the field of view. The design of the general illumination can also be better coordinated with the interior design and the architecture.

7.2.2. Direct, indirect, and direct-indirect lighting:

alternatives for general lighting are direct (downward), indirect (upward), or a combination of the two.

7.2.3. Indirect lighting:

Indirect lighting illuminates the ceiling, which in turn reflects light downwards. Thus, the ceiling becomes the brightest surface in the visual field . To avoid excessive luminance, the illumination on the ceiling should be evenly distributed. Two criteria that should be established in evaluating an indirect lighting approach are maximum ceiling brightness, typically directly above the luminaire, and uniformity ratios. The maximum allowable ceiling luminance should be determined by the task illuminance requirements.

If the primary task in a large office space is reading a vdt screen, the maximum allowable ceiling luminance should not exceed 850 cd/m2. The uniformity ratio is the ratio of the brightest area of the ceiling, typically above the luminaire, to the darkest area of the ceiling, between luminaires, in other words, the ratio of the maximum to the minimum.

7.2.4. Ceiling uniformity:

It is also should be assessed in terms of aesthetic considerations and of acceptable luminance ratios between the task and more remote surfaces. If extreme ceiling luminances are present, lower visual comfort can result.

Many indirect luminaires emit light below the horizontal plane. This can provide both an increased sense of perceived brightness and a recognizable source of light, if a luminaire does emit light below the horizontal plane, the average intensity in the lengthwise, crosswise, and 45° horizontal planes, at angles between 55° and 90° from vertical, should be limited to avoid direct glare. Indirect lighting can provide a calm, diffuse light that is void of highlights and shadows, similar to the light of an overcast day. Indirect lighting can provide good visual task illumination, since it tends not to cause bright images in vdt screens nor appreciable veiling reflections on paper-based tasks. It may be especially good for drafting tasks because it does not create shadows from the tools used to perform the task. It may, however, reduce the sense of visual clarity, depth perception, or orientation. The lack of highlight and shadow minimizes visual cues. This problem can be addressed by using more color, adding accent lighting, or wall washing, all of which establish visual cues and make it easier to interpret the visual environment, as well as to contribute to the pleasantness of the space.

A major consideration in designing an indirect lighting scheme is the selection of lamps. The most common choices are metal halide and fluorescent. These sources differ greatly as to luminaire size and color. Luminaire size varies because of the inherent difference in the lamp sizes and, as a result, the luminaire shape and scale can determine luminaire location and the appropriateness of the design. Color consistency is an important consideration when lighting a flat, white plane, such as the ceiling. The color shift in metal halide lamps through life is more noticeable when illuminating a ceiling plane than downlighting the floor.

7.2.5. Direct lighting:

Direct lighting emphasizes horizontal planes, such as work surfaces and the floor. Floor colors are reflected and may actually tint the ceiling. With wide-distribution luminaires and perimeter placement, direct luminaires emphasize vertical surfaces.

There is a wide range of direct-type luminaires with a variety of distribution characteristics. These characteristics are dependent on lamp type, size, and reflector and shielding materials. Light distributions range from broad, using translucent diffusing shielding, to concentrated, using specular reflectors and louvers.

Luminaire light distributions may be compared by reference to their intensity distribution curves and related values on a photometric report. Luminaire luminances can also be compared by referring to the luminance summary section of a photometric report. This information is typically given in two or three horizontal planes (lengthwise, crosswise, 45°) at angles of 0° (vertical), 45°, 55°, 65°, 75°, and 85°.

7.2.6. Diffusers:

A diffuser scatters the light emitted by the lamps before it leaves the luminaire. Since the area of the diffuser is much larger than the area of the lamps, the total flux is more evenly distributed, and thus the average luminance is less than that of bare lamps. Nevertheless, the average luminance of a diffuser is still rather high and nearly constant for all viewing angles. In a large office, diffusers may have low vcp as well as producing unacceptable reflections in vdt screens. Diffusers are not recommended for open office environments, except when a special effect is desired, such as with a luminaire that mimics a skylight. In small private offices, they may be appropriate if they are not visible at viewing angles required for visual tasks. Their broad distribution does not create excessive brightness on the walls.

7.2.7. Lenses:

A lens incorporates a series of small prisms that reduce the apparent brightness of the luminaire at the near-horizontal viewing angles of 45° to 90° from vertical. Depending on the specific optical characteristics of a lens, acceptable glare ratings may be obtained. However, most lenses do not reduce glare sufficiently to prevent luminaire reflections in vdt screens. The luminaire efficiency depends on the specific lens.

7.2.8. Polarizers:

Polarized light can reduce veiling reflections and reflected glare under special conditions. Some commercially available luminaire lenses are designed to polarize the emitted illumination by transmitting light through multiple refractive layers (see chapter 1, light and optics). The degree of polarization in the illumination depends on the number of layers through which the light is transmitted, as well as the angle of transmission. There is no polarization produced at the angle perpendicular to the transmission plane, that is, directly below the luminaire. As the angle of transmission increases, for a given number of layers, the degree of polarization increases up to brewster's angle, approximately 60° for these lenses. At this angle, and depending on the number of transmission layers, the light can be polarized by between 30 and 50%.

The benefits of polarized light in reducing veiling reflections and reflected glare depend on the degree of polarization in the illumination, the luminaire-task-eye geometry, and the specular characteristics of the task surface. Because the effectiveness of polarized light depends on all of these factors, it is difficult to provide a general statement on polarized light that is correct for every application.

7.2.9. Parabolic louvers:

Luminaires with a grid of parabolic louvers having a specular finish can control brightness precisely. The louver is an array of open cells, the walls of which form parabolic reflectors. The smaller cell types are usually injection-molded plastic, which is then vacuum metalized with aluminum. The larger cell types are usually fabricated from aluminum sheets, usually anodized prior to forming. When either type is made with a specular finish, the light output can be precisely controlled so that practically no light is emitted at angles above the cutoff angle. When this is the case, the louver can look darker than the ceiling. This precise light cutoff angle also darkens walls near the ceiling and places greater importance on illuminating vertical surfaces.

Parabolic louvers actually have two cutoff angles. The first is the physical cutoff angle, which is the angle from vertical that just occludes a view of the lamp. The second is the optical cutoff, which is the angle from vertical at which light reflected from the parabolic surfaces is just occluded. This angle depends on the precise shape of the reflector surfaces and is not always the same as the physical cutoff angle. For a precise cutoff, the two cutoff angles should be the same.

7.2.10. Direct-indirect lighting:

A combination of direct and indirect approaches can produce excellent results. luminaires that provide both upward and downward light are most commonly used for this application. The indirect portion should have characteristics so as to not create hot spots or excessive luminance on the ceiling. The direct portion should provide diffuse lighting and adequate shielding to provide good visual comfort and avoid glare. The results of direct-indirect lighting can be quite satisfactory. Typically this design solution obscures the inadequacies of each individual approach and maximizes the advantages of each, creating both a pleasant and a functional environment.

7.2.11. Photometric data:

An intensity distribution curve, which is a part of the luminaire photometric report,

Will show how light exits the luminaire. This curve helps to determine luminaire placement, layout, uniformity, and whether or not the luminaire can achieve the desired results for both illuminance and luminance criteria.

Along with the intensity distribution, a photometric report can also provide information on luminaire luminance. The luminance summary data provide information on the average luminance of the luminaire at a variety of angles in several planes. Along with the luminance summary, vcp data give further information on luminaire brightness for direct luminaires within the context of a given set of spatial dimensions.

It should be noted that most vcp data are reported for task illuminance of 1000 lx (100 fc). For lower-illuminance applications, additional vcp data should be requested. Within open-plan offices, where large ceiling areas are within typical fields of view, and especially in vdt-task environments, where the tasks are typically performed in a heads-up position, the vcp should be at or above 80. In smaller private offices, vcp data are less significant because of partitions, unless full-height walls are brightly illuminated and the ceiling luminaires are visible.

7.2.12. Final selection process:

Although much of a luminaire's performance can be evaluated through data analysis, the final selection process should include more than just reviewing printed information or photographs. Actual luminaire samples should be obtained and examined. Physical inspection of the luminaire can reveal aspects of both performance and quality not represented in printed information. A mock-up is a further step to assure the quality of both the design and the luminaire selection. Mock-ups should duplicate the characteristics of the final space as closely as possible. Variations in finishes or ceiling heights, for example, may greatly influence perceptions. Also, mock-ups should contain a suitable number of luminaires so that appropriate judgments can be made concerning illuminance values under realistic conditions. If a mock-up is not feasible, visits to installations with the same luminaires give both designer and client the opportunity to see the luminaires function, even if the spatial conditions are different.

CHAPTER – 8

SOFTWARE USED IN THE LIGHTING DESIGN

SOFTWARE USED IN THE LIGHTING DESIGN

8.1.1. Usage of software for lighting design:

Lighting design software is one of the important thing in lighting application. We have two main difference applications in lighting which are indoor and outdoor. Outdoor applications cover road lighting, tunnel lighting, area lighting i.e. Landscape lighting in parks and gardens, sports lighting and facade lighting. Indoor applications cover industrial lighting, office lighting, retail lighting, hospitality lighting, museum lighting, indoor stage lighting [24].

There are some advantages of using lighting design software during lighting design in indoor areas as compared to mathematical calculation regarding determination of lux level and no fixtures needed. Those are:-

- Faster time to calculate required lux level and uniformity
- Better accuracy
- View 3d and 2d of a room
- Import luminaires' photometric data sheet with their catalogue no. Of the world's leading lighting manufacturers in the softwares
- Use tools, objects and surface colours
- View luminaire' layout plan in a room
- View 3d false colour rendering and isolines of illuminance value
- Evaluate glare distribution and energy evaluation
- Utilization of daylight and daylight sensor and also create control group among the luminaires' for dimming purpose wherever needed

8.1.2. SELECTION CRITERIA FOR LAMPS AND LUMINAIRES BEFORE IMPORT TO LIGHTING DESIGN SOFTWARE

The most appropriate light source can then be chosen followed by the luminaire. The following attributes should be studied when choosing the proper light source and luminaire :

- Light output (lumens) of lamp and luminaire
- Output wattage of luminaire
- Efficacy (lumens per watt)
- Lifetime of lamp
- Physical size of luminaire
- CCT and cri characteristics of lamp
- Electrical characteristics
- Light distribution of lumianire i.e beam angle of luminaire
- Requirement for control gear and its efficiency
- Luminaire efficiency (% light output transmitted out of the fixture)

- Thermal management and power management
- Ip rating
- Surge protection in KV
- Compatibility with existing electrical system
- Ambient temperature for operation
- Diffuser/optical compartment material

8.1.3. METHODOLOGY TO IMPORT LUMINAIRE OF PARTICULAR WATTAGE IN LIGHTING DESIGN SOFTWARE

After collecting photometric and electrical data (light intensity distribution along vertical angles and horizontal angles, luminaires' lumen output, luminaire efficacy, luminaire wattage, output operating current, percentage of threshold harmonic distortion and power factor), CCT and cri of lamp and lamp life used as indoor and outdoor luminaires testing in lab, photometric data sheet should be created in notepad format by using aforementioned data with test date, catalogue no. And manufacturer's name which is considered as ies file and it is approved by iesna (illuminating engineering society of north america). The ies file of a particular fixture wattage is imported to lighting design software.

Table 8.1. TABLE OF CCT AND CRI OF DIFFERENT LAMPS

Type of lamp	CCT (k)	Cri
GLS	2500 – 2700	100
Tungsten halogen	2700 – 3200	100
FTL	3000 – 6500	60 - 90
CFL	2700 – 6500	> 80
High pressure mercury	3200 – 3900	40 - 50
Quartz tube metal halide	3000 – 5000	60 -90
Ceramic tube metal halide	3000 – 4400	78 - 93
Sox (low pressure sodium vapour lamp)	2100	19
Son (high pressure sodium vapour	1900 – 2500	40

lamp)		
Induction lamp	2500 – 4000	80
Led	2700 – 6500	> 70

8.1.4. Different types of lighting simulation softwares

There are different types of lighting simulation softwares as described below :

Table:8.2-LIGHTING DESIGN SOFTWARES

Sl. No.	Title	Description
1	Dialux	Dialux is a free light planning software for both indoor and outdoor lighting with daylight and artificial light scenarios.
2	Optiwin 3d pro	A free lighting design program for a building or renovation project by importing large 3d models for (lighting energy numeric indicator) calculations, lux level calculation and also simple calculation of emergency lighting.
3	Vectorworks spotlight	It is the industry-leading design software for the landscape lighting, urban lighting and entertainment business i.e. For stage lighting with 2d and 3d capabilities.

4	Tracepro	A software tool for modelling the propagation of light in imaging and non- imaging opto-mechanical systems. The models are created by importing from a design or cad program, or through directly creating the solid geometry in trace pro[25]. The source rays propagate through the model with portions of the flux of each ray allocated for absorption, specular reflection and transmission, fluorescence, and scattering. Designers can analyses from the model: ➢ Light distributions in illumination and imaging systems ➢ Lumens exiting, absorbing, and incident at the component and system levels ➢ Candela distributions ➢ Optical efficiency, luminance, and radiance metrics ➢ Photo realistic rendering ➢ Fluorescence effects of phosphors
6	Ma lighting software	Lighting design software for indoor and outdoor stage lighting
7	Visual 3d	This type of lighting design is used for many outdoor lighting scenarios e.g. Parking lots and exterior facade lighting. Visual design tools can be used to quickly calculate scenarios with simple geometrics where inter-reflected light will not significantly effect the resulting illuminance.
8	Agi32	A lighting design software for providing numeric and rendered solutions for almost any lighting application, interior or exterior, including roadway and day-lighting.
9	Relux	Free lighting design software for indoor, outdoor and tunnel lighting.

11	Optisworks	This type of software is for scientific simulation of light effect- light levels, light distribution, photometric performance and light colour with respect to human visualization within a virtual reality environment. Users use this software to simulate and optimize lighting performance, product appearance, as well as the visibility of information, taking into visual angle, various ambient light conditions, glare on human product interfaces. Applications are in automotive lighting, aerospace lighting, traffic light, illuminated road signs, led backlight and indoor lighting (for museum and hotel). In automotive lighting system intelligent automated adaptive lighting effect can be created by using this software to enhance driver safety, good mood and visual comfort.
12	Radiance	Radiance is a free open-source suite of programs for the analysis and visualization of lighting in design. Its input files specify the scene geometry, materials, luminaires, time, date, and sky conditions (for daylight calculations). Calculated values include illuminance values, luminance values include and glare indices. Simulation results may be displayed as colour images, numerical values, and contour plots
13	Rayfront	This type of software is used for lighting design in educational institutions and industries with daylight to compute daylight factors, work-plane illuminance and evaluate glare distribution.
14	Lx series software	Lighting design software for indoor stage lighting that helps to display beam of spotlight in particular area, lux values on stage by using dmx controlling software and glare distribution with respect to visual effect of spectators.

15	Microlux	Lighting design software for indoor stage lighting
16	Lighting reality	Lighting software for street and outdoor area lighting
17	Capture	Capture is used for stage lighting design. Capture allows users to work with lighting, video/laser media state, motion control system and water jets. It supports a wide range of ethernet dmx protocols such as art-net and sacn
18	Lumicept	Lumicept is hybrid light simulation software that simulates the behavior of light, allowing the user to know how light propagates and is distributed in space.
19	Ld assistant	Lighting design software for indoor and outdoor stage lighting as well as used entertainment industries. Users can insert lighting fixtures along camera, speaker, sound cabinets, video projectors. It supports a wide range of ethernet dmx protocols such as art-net and sacn
20	Lightcalc	Lighting design software for indoor areas with features that include the following: It can be used to determine the overall reflectance in a room. It can find the proper footcandle level or lux level for general, task, and art lighting. It helps the user determines the proper spacing needed. It uses both inverse square law and lumen methods. A grid layout is suggested for general lighting.
21	Elumtools	Lighting design software for interior lighting design with or without daylight and exterior lighting design for light level calculation

22	Calculux	This type of software has been developed at philips lighting design and application centre and it is applied for illuminance value calculation in indoor and outdoor area[26].
23	Light-in-night road	Lighting software for street lighting
24	Ulysse	Lighting design software by schreder company, calculate the necessary lighting levels for road applications

Out of the above mentioned lighting design softwares dialux software has been adopted for present study considering following aspects :-

- Simple, effective and professional light planning
- Latest luminaire data of the world's leading manufacturers
- Latest state of the art software always available free of charge
- Energy evaluation facility and lighting control system facility
- Lux level calculation in presence of integrated daylight and electrical light sources
- Coloured light scenes with led or other colour changing luminaires

8.1.6. PROCEDURE FOR INDOOR LIGHTING DESIGN USING LIGHT SIMULATING SOFTWARE:

While designing indoor lighting system using light simulating software to achieve desired lux level and maintaining good uniformity recommended by is : 3646 some basic steps will have to be followed. The key steps in the design process are :

- Import architectural drawing of interior building to the software.
- Room dimension (i.e. Length, width and height).
- Identify type of task in each room.
- Consider proper value of reflectance of floor, ceiling and wall.
- Consider proper value of light loss factor depending on degree of pollution factor in different types of interior area.
- Identify type of ceiling (i.e. Rcc type, armstrong grid based false ceiling or gyp board false ceiling).
- Proper selection of surface mounted and recessed mounted luminaires having excellent

thermal and optical management with proper CCT and cri of lamps having energy efficient and long lifespan and inserts its ies file to the software.

- Requirement of proper fixture quantity and arrange the fixtures in matrix form that create fixtures' position symmetric.
- Maintaining actual fixture-to-fixture spacing with respect to their wattage along row and column wise.
- Utilization of daylight with energy efficient electrical light source by using building management system i.e. Dimming system wherever it should be required in a particular zone of a space.
- Start calculation to determine lighting parameters i.e. Lux level, lpd and uniformity required to perform a particular task as per the standard.
- Calculation of monthly energy consumption by determining total luminaires' quantity with total power consumption needed in an interior building.

CHAPTER – 9

LIGHTING CONTROLS

- **LIGHTING CONTROLS**

Lighting controls are to be taken care during lighting design which leads an energy efficient design. All non-emergency exterior & common area lighting such as facade, pathways, landscaping, surface and covered parking, street lighting, staircases should have at least one of the following:

i. Daylight sensor
ii. Occupancy / motion sensor
iii. Timer

Occupancy control coupled with daylight control should be used where ever possible and utilize daylight as primary source where ever possible daylight integration & occupancy sensor are briefly described below:

- **LUMINAIRE GROUPS:**

The luminaire groups define which luminaires in a light scene are connected together (dimmed). Any luminaire of a light scene could only be in one lighting group. Luminaire groups can be managed in the light scenes tool [27].

- **CONTROL GROUPS:**

Control groups can not be created manually and you can't give the control groups own names. The control groups represent the necessary wiring to realize all created light scenes. Luminaires in a control group would connected together (regardless of the light scene). If it is needed the control groups will be recalculated from evo (for example, if another light scene is applied).
A luminaire group in a light scene can internally consist of several control groups. You have to adjust the dimming values for the entire luminaire group only once [27].

- **PURPOSE OF CONTROL GROUPS**

Control groups are added to lighting scenes and include the different luminaires positioned in the project. The control group provides the lighting scene with information about which luminaires may be used. In addition to this, when a control group is added to a lighting scene, you have the option of dimming. You will find further details in our DIALux manual [28].

GENERATE A PROJECT WITH LIGHT SCENES AND CONTROL GROUPS

Insert a new room and adapt all settings in the accompanying Property Pages (see chapter Edit Room Data). Subsequent you can insert the luminaires which you would like to use in your project. Select those which you want to assign to a control group. If you have inserted a luminaire field, you should activate the function "Allow single luminaires selection", because the possibility exists to select single luminaires. DIALux offers the option to add your luminaire arrangement(s) to one or several control groups. In the menu → Paste → Control group, as well as in the context menu in the CAD window or in the Project manager you can add your selected luminaire(s) to a new or existing control group.

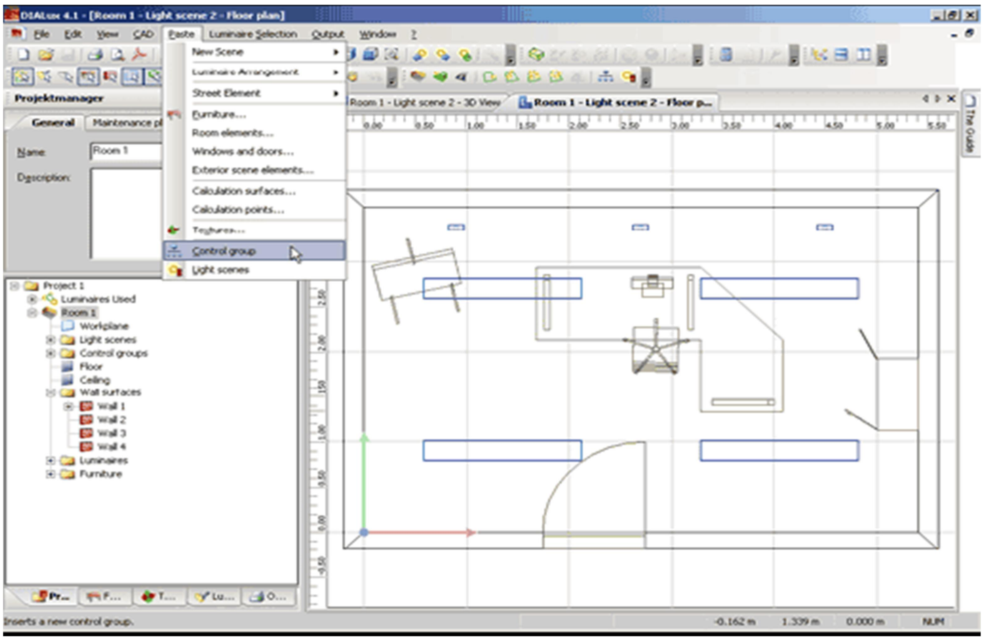


Fig.Paste a control group via menu

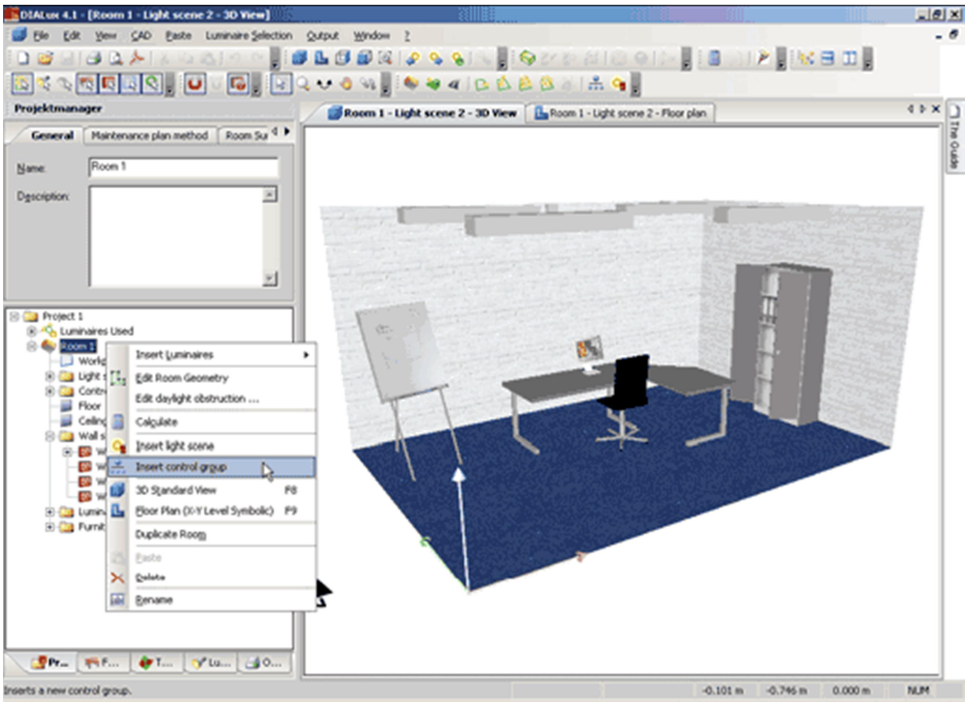
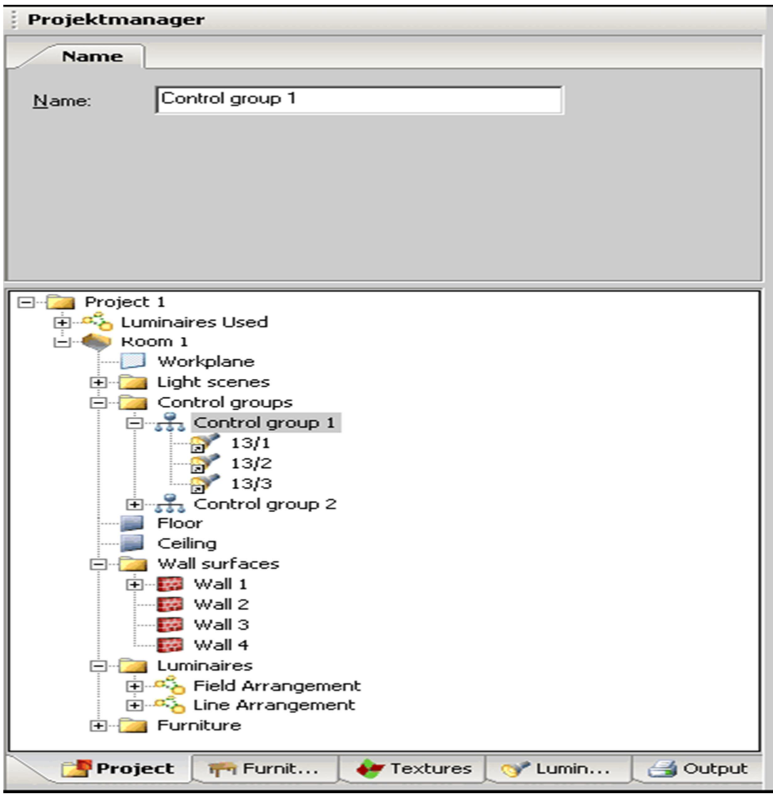


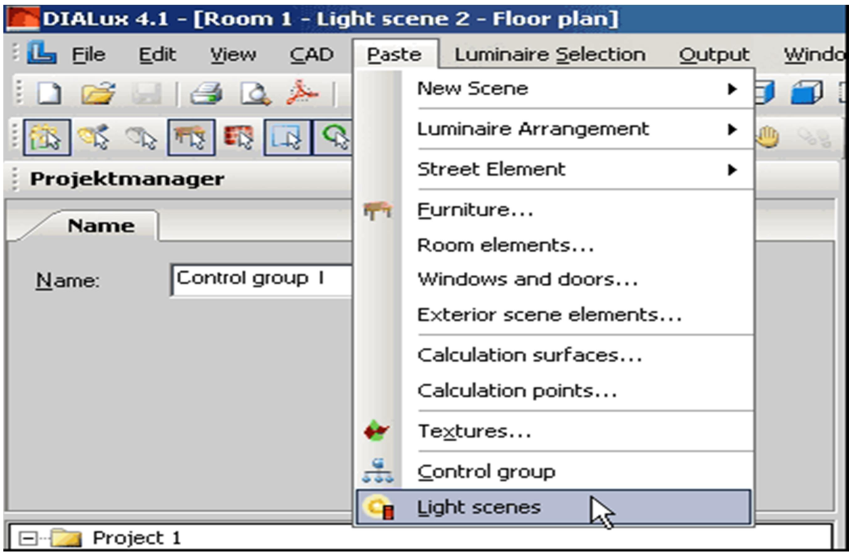
Fig. Paste a control group – Context menu of the room

Then in the Project manager the control group appears with a link to the luminaires. The control group has the Property Page Name.

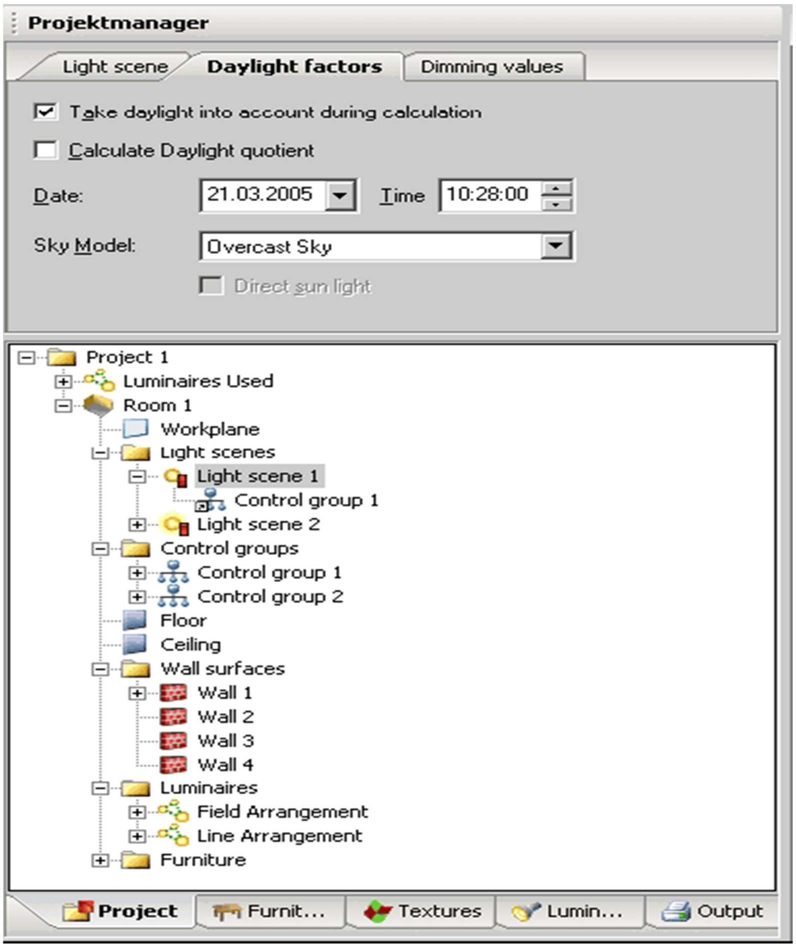


If luminaires are deleted, these are also removed at the same time from the appropriate control group, provided that these belong to a control group[28].

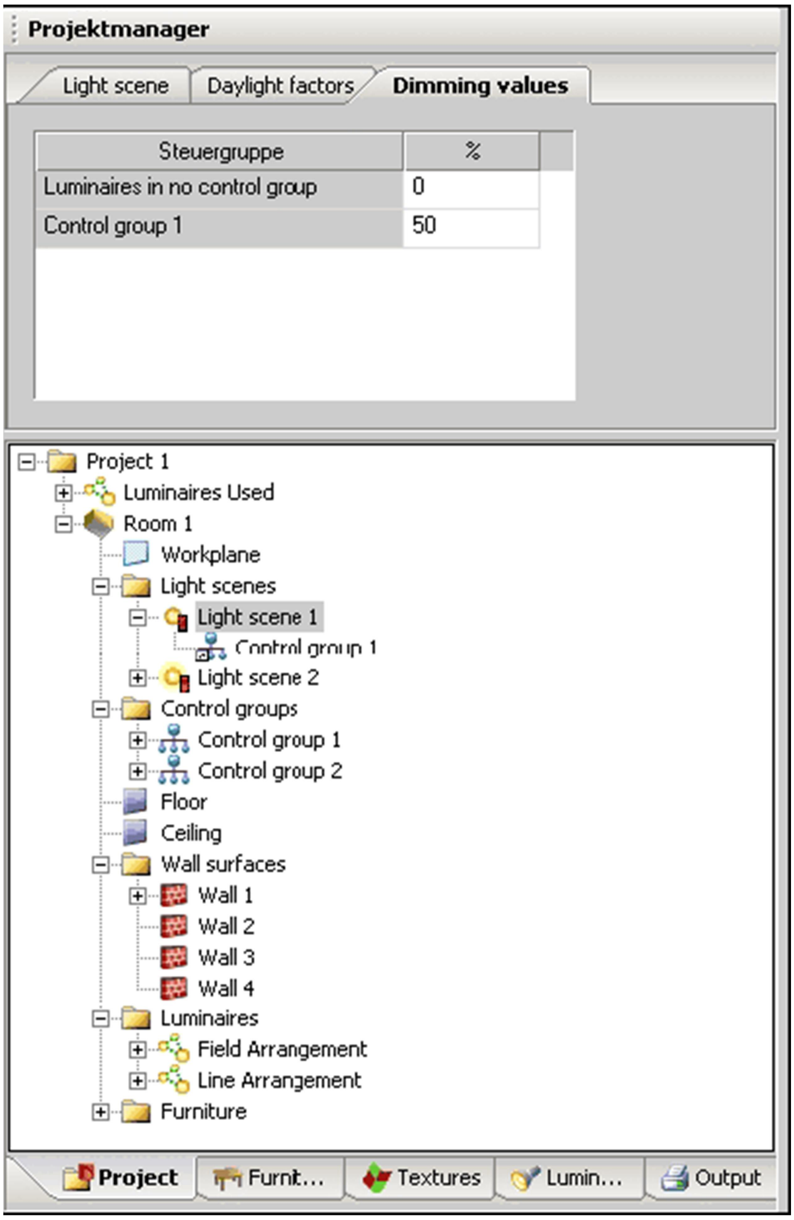
In the menu Paste you can insert a light scene in your project.



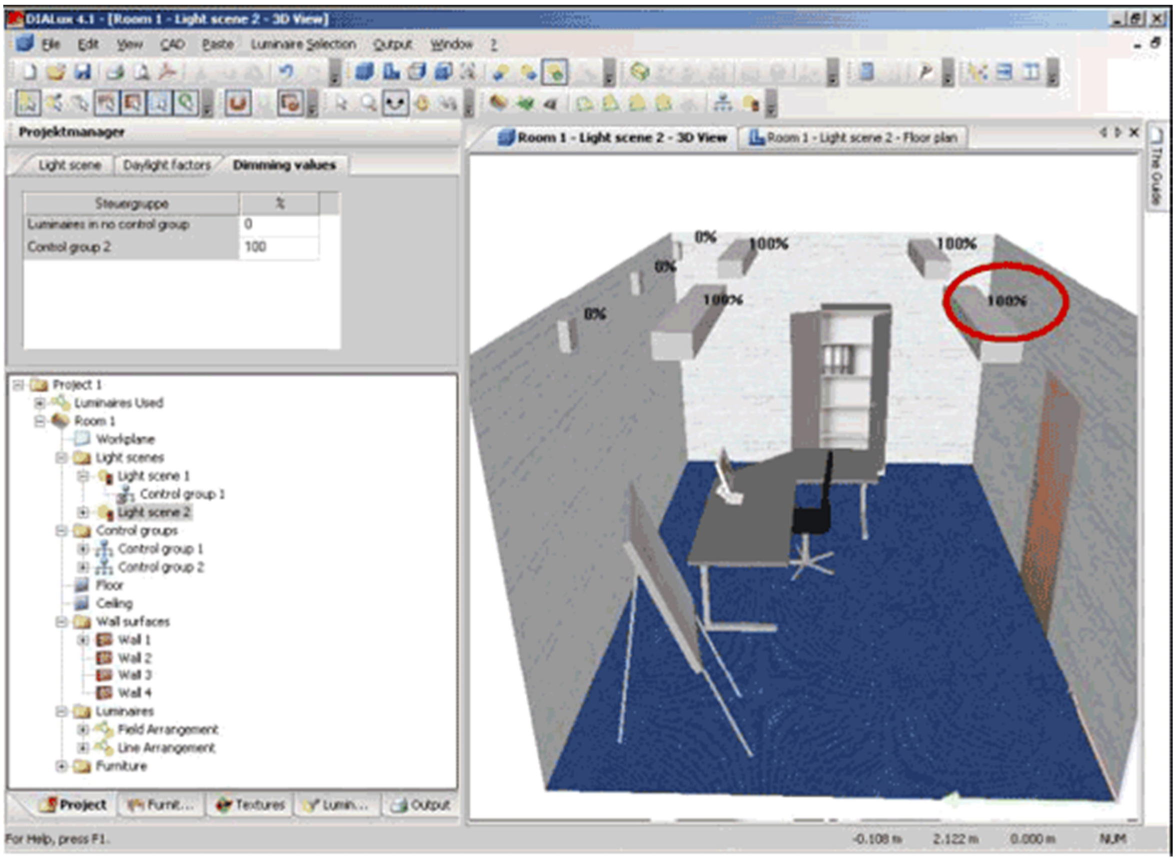
The Daylight factors tab enables the determination of the position of the sun for the daylight calculation. You have the option to make various settings in the Inspector with respect to daylight. Activate the checkbox Take daylight into account during calculation, that way you include the daylight in your project. If the checkbox is deactivated, the room is calculated without daylight. Individual or all light scenes of a room can be calculated at the same time [28].



In the Property Page Dimming values the control groups with dimming levels are set in an editable list.



The user has the option to make set dimming levels of the used luminaires visible in the CAD view and to edit in the appropriate Property Pages [28]. By means of the icons in the menu bar the dimming levels can be switched on and off. Also there is the option to change between individual light scenes with the arrows, provided that several light scenes exist.



If luminaires with more than one light output are used, the dimming values for each light emitting object (LEO) can be adjusted separately. In the Property Page of the control group in the lighting scene, you can define the dimming values for each LEO. This dimming value will be multiplied with the dimming value of the control group [27].

Example:

The control group will be dimmed to 100%. In this control group there is a luminaire with independent direct and indirect light output. The direct light should be switched off; the indirect light should be completely on [28].

Settings:

Dimming value of the control group: 100%

Light output direct: 0%

Total: 100% x 0% = 0%

Light output indirect: 100%

Total: 100% x 100%= 100%

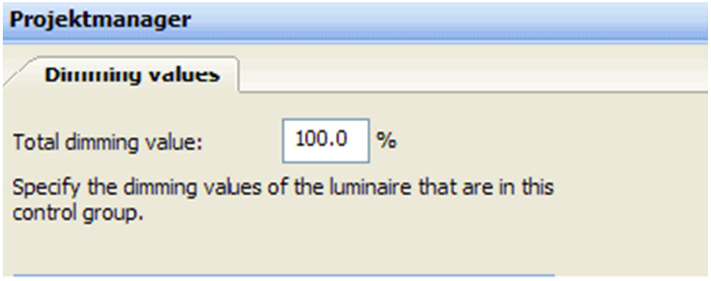
If the indirect light should be dimmed to 50%, you can either dim the control group or the LEO.

Either:

Total: 50% x 100% = 50%

Or

Total: 100% x 50% = 50%



CHAPTER – 10

DAY LIGHT INTEGRATION

10.1. DAY LIGHT INTEGRATION:

Daylight availability depends on both the light received directly from the sky and light reflected from interior surfaces. Generally in pharmaceutical manufacturing unit the scope of daylight is less as all room sareair packed. But in administrative block like in office, lighting is optimized by daylight integration. A daylight official room uses light from the sky for day time illumination, effectively reducing the need for electric light. The amount of daylight that comes into a room depends upon the area and location of the window and the amount of the sky the window "sees." The distribution of that light is a function of the window's shape and location in the window wall and the proportions of the room, room reflectivity, and obstructions within the space.

Task-ambient electric lighting design strategies work well with day lighting because room ambient light levels, lower than task lighting requirements, are easy to meet with daylight. Ambient daylight should be supplemented with task electric lighting to increase lighting levels where specific tasks are performed.To take advantage of available daylighting, electric lighting should be designed and controlled either by dimming, or by switching off completely. A light sensor and continuous or step dimmer can maintain ambient illumination levels at a constant value, based on the amount of daylight in thespace.

As sky conditions change, automatic, dimmable, indirect lighting luminaires make an unnoticeable transition from electric lighting to daylighting and back. Thus it can be predicted thatasufficientamountofenergycanbesavedifthecontrolofartificiallightisintegratedwith daylight, with daylight linked sensor.

For daylight integration design steps are given below:

1. Exploration of daylight availability from database
2. Selection of suitable daylighting system
3. Selection of type and mounting of sensors
4. Luminaire grouping or scheduling
5. Prediction of the energy saving

As daylight has very dynamic characteristics thus for daylight integration some sensor must be used which is capable to produce a constant light by sensing the presence of daylight and by diming artificial light.

10.2. USAGE OF OCCUPANCY SENSOR:

Occupancy sensor ensure light in the working zone only when the zone is occupied by somebody to work . In a pharmaceutical administrative building these are helpful in for example in the following spaces:

- Intermittently used office areas like-conference hall, meeting rooms, cabins, workstation
- Toilets and washroom facilities
- Store rooms
- Reception and other common areas

- Areas where lighting is zoned

Occupancy sensors can be used to lower the light level for the corridors at night time which can be an effective cost savings measure. However it is imperative to maintain minimum light level so as not to compromise with health and safety standard.

10. 1

CHAPTER – 11

LIGHTING CRITERIA FOR INTERIOR SPACES

LIGHTING CRITERIA FOR INTERIOR SPACES

11.1. Quality of light:

Lighting may be diffuse or directional. Diffuse light minimizes shadows and provides a more relaxing and less visually compelling atmosphere. When diffuse light is used alone, no object in the visual scene is given prominence. Artful use of directional light can provide highlights and shadows that emphasize texture and form. Brilliance or sparkle can be achieved with small unshielded sources, such as a bare lamp or a candle flame. The glitter of crystal and polished brass, the luster of table settings, and the sheen of surface materials can be heightened by directional lighting to create a sense of warmth and festivity. Low-voltage cable systems can be used for ambient and directional illumination.

In many residential spaces, it is desirable to create more than one mood or to be able to vary the atmosphere. Lighting control systems can provide this flexibility and should be an integral part of the design.

11.2. Brightness:

Brightness is an impression of the appearance of a light source or an illuminated surface, described in terms of its perceived relative luminosity. This subjective impression can be correlated with light measuring instruments that determine the luminance of the surface or of the source. Luminance is expressed in candelas per square meter (cd/m2). Luminance ratios play an important role in the comfort, eye fatigue, and difficulty of visual tasks.

11.3. Seeing zones:

A person's visual field consists of three zones :

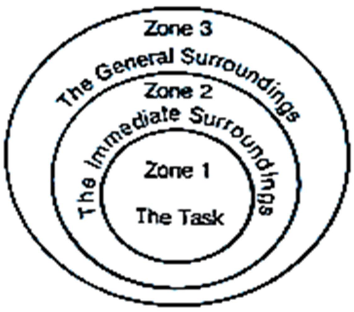


Figure12.1 seeing zones and luminance ratios for visual tasks

Zone 1: the task area itself

zone 2: the area immediately surrounding the task

Zone 3: the general surroundings

For visual comfort the luminance of the immediate surround (zone 2) should range between one-fifth of the task luminance and 5 times the task luminance. The luminances of areas in the general surround (zone 3) should range between one-tenth of the task luminance and 10 times the task luminance. These relationships should not be exceeded for visual comfort in visually demanding tasks such as studying, sewing, or reading.

11.4. Reflectance:

Reflectance is the ratio of the amount of light leaving a surface to the amount of light incident on it. Reflectance can be expressed as a percentage or more roughly as a munsellvalue . Pale, high-reflectance colors for room surfaces and furnishings are important and often essential in achieving desirable luminance ratios. To assist the designer in obtaining the recommended luminance ratios, recommended surface reflectances with approximate munsell values as per the standarad.

Surface	Reflectance (%)	Approximate Munsell Value
Ceiling	60–90	8 and above
Curtain and drapery treatment on large wall areas	35–60	6.5–8
Walls	35–60*	6.5–8
Floors	15–35*	4.0–6.5

* In areas where lighting for specific visual tasks takes precedence over lighting for the environment, the minimum reflectance should be 40% for walls, 25% for floors.

Figure12.2 recommendedreflectances for interior surfaces of residences

11.5. Veiling reflections:

Light reflected from the task surface, which partially or totally obscures the details by reducing the contrast, is called a veiling reflection. When tasks involve specular glossy surfaces, such as high-gloss photographs and slick magazines, veiling reflections can be a problem (see chapter 3, vision and perception).

11.6. Reflected glare:

When light sources are imaged on glossy glass-top tables or mirror-like surfaces in or near the visual task, the condition is known as reflected glare. If these reflections are excessively bright, they cause visual discomfort.

11.7. Light and color:

Color recognition depends on the spectral characteristics of the light source and the spectral reflection characteristics of the object being lighted. These two factors provide object color to the observer.

Surface or object colors may match under one light source but not under another. For example, two colors may match under incandescent lighting but not under daylighting .this fact should be noted when selecting materials, pigments, or dye lots for interior surfaces. One should examine and compare materials under the light sources that will ultimately illuminate them.

11.8. Surface finish:

Colors of objects sometimes appear to change with surface finish. Specular or mirror reflections from glossy surfaces may, in extreme cases, increase the chroma and saturation at one angle and obscure color at other angles. A matte finish reflects light diffusely and appears more or less the same from any viewing angle. Deeply textured finishes, such as velvet or deep-pile carpeting, cause shadows within the fibers that make the materials appear darker than smooth-surfaced materials such as satin, silk, or plastic laminates of the same color [29].

11.9. Fading:

Light fades fabrics and finishes. Ultraviolet (uv) energy is one cause of fading. Since uv radiation cannot be completely eliminated, the amount, frequency, and length of exposure should be considered when materials or objects are of great value or irreplaceable .the use of appropriate uv and ir filters in luminaires to protect fabrics, furnishings, and art from light sources is recommended.

11.10. Quantity of light:

Visual activities in living spaces range from simple to extremely difficult tasks. For example, sewing is an activity with small visual details and low contrast that requires higher illuminance than determining orientation in an entry foyer.

CHAPTER – 12

LIGHTING METHODS

LIGHTING METHODS

12.1. General lighting:

Areas with visual activities: residential lighting is planned on the basis of activities, occupants' ages, and physical capabilities and limitations, not on the basis of room type. The designer should provide enough general lighting for a range of activities. General illumination prevents a spotty effect, maintains recommended luminance ratios in the field of view, and provides light throughout the interior for safety and housekeeping activities. General illumination also prevents excessive differences in illuminance between adjacent rooms [30].

In some spaces, particularly utility areas, general illumination can be designed to supply all of the lighting needed for visual activities. For most living areas, high-illuminance, uniform general lighting would be unacceptable [30].. The equipment most commonly used to light room surfaces and create a satisfactory background for visual work includes general-diffuse ceiling luminaires, wall luminaires, indirect luminaires, built-in lighting systems, or portable floor or table luminaires .in small rooms, general illumination can even be supplied by the luminaires used for specific task lighting, as in the case of a vanity mirror light or an open-shade portable luminaire used primarily for reading or studying. In addition to a system that provides general illumination, portable task lighting may be needed for demanding visual tasks.

Areas for relaxation: a low level of illumination in combination with small areas of bright light creates a relaxing atmosphere .uniformity of illumination need not be the objective. The primary considerations for these spaces are comfort and aesthetic satisfaction.

Connection areas: illuminance levels for hallways and stairs should allow for visual adaptation. If they adjoin an interior area with a higher illuminance, the level in the hall or stair should be no less than onefifth that of the adjacent area [30]. Wall luminances are crucial in creating a sensation of brightness and reducing shadows on the stairs. Wall and floor finishes should have high reflectance values. Lighting in an entry hall should be flexible so that adjustments can be made for visual adaptation during the day and at night .on stairs, it is critical that treads be emphasized, and that the top and bottom steps be well lighted for safety [30]. Under no circumstances should a built-in wall-mounted luminaire or portable luminaire be located where a person descending the stairway can see the light source directly.

lighting contributes to a room's aesthetics and atmosphere. This inviting living room, with its extraordinary view of the city, features downlighting in the seating area, accent lighting on the painting and sculpture over the fireplace, and shelf lighting to illuminate the stereo and highlight decorative items. High-color-rendering light sources should be selected, since color matching is a critical task in closets. Select lamps with a high color temperature and a color rendering index (CRI) of 80 or higher [30].

12.2. Lighting for common visual tasks:

In providing the recommended illuminance on the task, which corresponds to zone 1 in figure, the essentials of good lighting quality, as previously discussed in this part but quality of the visual environment, must not be overlooked. Rarely can the desired illuminance be provided by general lighting alone. At the same time, task lighting by itself is seldom totally satisfactory or comfortable; therefore, a combination of task and general lighting is needed .daylighting also improves the quality of the lighting in a residence.

12.3. Mainly in office area following things can be happened:

1. The task: the task is reading the computer terminal screen, the keys and templates on the keyboard, and information written or printed on paper. In addition, printer and fax machine status settings must be read. Speed and accuracy may not be important for casual operation, but they may be important when doing work at home. Reflectances of equipment surfaces (other than the screen) are between 30 and 70%.

2. Description of the task plane: the terminal screen usually is in a vertical to near-vertical plane, while the keyboard is on a near-horizontal plane. The paper-based tasks can be on any plane from horizontal to vertical. Printer and fax status settings are usually in a near-horizontal plane.

3. Special design considerations: luminance ratios between the terminal screen, the paper-based tasks, and the equipment and surface in the surround should be limited (see chapter 11, office lighting). Luminaire, ceiling, and window brightness should be controlled to avoid reflections on the screen and specular surfaces of equipment.

4. Typical equipment locations:

(a) desk-mounted or floor-mounted task lights for paper and keyboard tasks

(b) wall-mounted direct/indirect luminaires at the front or side of the desk for ambient and task lighting

(c) ceiling-mounted low-brightness luminaires

1. The task: the majority of people who read in bed are only casual readers, perhaps reading for a few minutes before going to sleep. They are often interested in closely confining the light distribution so as not to disturb another occupant of the room. Such lighting arrangements are not satisfactory for comfortable reading over a long period. The following recommendations are for the person who reads for a more extended period, or for the person who performs critical seeing tasks while confined to bed. The normal materials vary from books and magazines to pocket editions and to newspaper print, with reflectances of 30 to 70%. Speed and accuracy vary from not important (for leisure reading) to important to critical (for critical tasks).

2. Description of the task plane: the task plane is 310 by 360 mm (12 by 14 in.), tilted at an angle of 45° from the vertical. The center of the task plane is 610 mm (24 in.) Out from the headboard or wall and 310 mm (12 in.)Above the mattress top. There are no customary reading positions or habits. These recommendations assume that the reader is in an upright or semireclined position.

3. Special design considerations: equipment should be located so that no shadows are cast on the reading plane by the head or body, and so that the luminaire does not interfere with a comfortable position.

4. Typical equipment locations:

(a) wall-mounted directly in back of or to one side of the user (both linear and nonlinear designs)

(b) luminaire on bedside table or storage headboard

(c) ceiling-mounted:

(1) suspended, adjustable, or stationary;

(2) surface-mounted, directional, or nondirectional;

(3) recessed, directional, or nondirectional

(d) luminaire incorporated into furniture design

(e) track-mounted luminaires: several types of lighting should be provided in the bedroom to accommodate different functions and moods--relaxing, romantic, and adequate for reading.

12.4. If any one wants to read in a chair then they have to follow the below methods:

1. The task: typical reading tasks encompass a wide range of seeing difficulty, from short-time casual reading of material with good visibility (large print on white paper) to prolonged reading of poor material (small type on low-contrast paper). The majority of tasks have reflectances between 30 and 70% or higher. Speed and accuracy may not be important for casual reading and may or may not be important for prolonged reading.

2. Description of the task plane: the task plane measures 360 mm (14 in.) Wide by 310 mm (12 in.)High with the center of the plane approximately 660 mm (26 in.)Above the floor. The plane is tilted at 45° from the vertical. The reader's eyes are approximately 1 m (40 in.) Above the floor.

3. Special design considerations: the normal seated eye level is 0.97 to 1.07 m (38 to 42 in.) Above the floor and is a critical consideration when the light source is to be positioned beside the user. The lower edge of the shielding device should not be materially above or below eye height.

This prevents discomfort from bright sources in the periphery of the visual field, yet permits adequate distribution of light over the task area. Variations in chair and table heights necessitate selection and placement of equipment to achieve this relationship for each individual case.

4. Typical equipment locations:

(a) table-mounted, floor-mounted, and wall-mounted beside or behind the user

(b) ceiling-mounted, suspended beside or behind the user

(c) directional small-area luminaires may be used (wall-, ceiling-, pole-mounted)

(d) recesseddownlight, placed over center of seat cushion (with a sofa, use an adequate number of luminaires to evenly distribute light over the cushions)

(e) track-mounted luminaires for flexibility

12.5. In office area there occurred various type of multipurpose table and for that we have to maintain the following steps:

1. The task: the task includes both the creation of the desired mood or atmosphere for dining and provision for other general visual tasks such as sewing, reading, hobbies, and table games. Task reflectances are generally 30 to 70%, and speed and accuracy can be important, particularly when sewing.

2. Description of the task plane: the entire table top must be considered as the task plane.

3.special design considerations:

(a) a broad distribution pattern of light is required to illuminate the entire table top uniformly. To minimize veiling reflections, the light sources should have a high degree of diffusion or have substantial direct components.

(b) it is difficult for a single static light source to provide drama and atmosphere for dining while also providing widespread, diffused lighting (at a higher level) for other table activities; therefore, a multipurpose table usually requires more than one lighting system or a means of switching from one effect to another.

4. Typical equipment locations:

(a) task area--center-of-table luminaires:

(1) recessed (a group of recessed units is generally required)

(2) surface-mounted

(3) suspended--generally mounted so that the bottom of the luminaire is 690 to 910 mm (27 to 36 in.) Above the table top

(4) track-mounted luminaires

(b) area surrounding the task:

(1) large luminous area

(2) luminous wall

(3) cornice

(4) valance

(5) cover

(6) brackets, for example, fluorescent or decorative incandescent

(7) recessed luminaires, for example, incandescent downlights or wall washers

(8) ceiling luminaires, for example, shallow large-area types

(9) track-mounted luminaires

(10) pendant luminaires, for example, small pendants

(11) table lamp and floor lamp or torchiere

(12) chandelier with or without downlight

12.6. Other interior lighting design considerations:

Sparkle, highlight, and spatial effects :

In addition to lighting tasks and providing general illumination, lighting can be important in reinforcing spatial perception, activity, and mood. These effects depend on a person's previous experience, perception, attitude, and expectations. Specific impressions include perceptual clarity, spaciousness, relaxation, privacy, and pleasantness. Lighting can set a mood, render people flatteringly, and enhance colors and textures in a space . To create these effects, many factors have to be considered. One is the luminance between a highlighted space and its adjacent spaces. The contrast of a brightly lighted area adjacent to a dim area can create a dramatic effect. A minimum ratio of 10:1 is required for dramatic effects and to focus attention.

Wall washing provides smooth, even illumination that emphasizes the vertical plane and minimizes texture. When wall washing, the wall should be illuminated as close to ceiling planes as possible. Wall washers should be spaced 600 mm (24 in.) From the wall and 600 mm (24 in.)On center for a recessed adjustable accent or wall-wash downlight. Wall grazing provides drama and accentuates the textures of wall surfaces. Grazing luminaires should be spaced 300 mm (12 in.) From the wall and 300 mm (12 in.)On center. This technique is very effective for brick, marble, and stone.

Sparkle is a small brilliance of light used to add visual interest to objects in a space and to attract attention. Glare results if the area of sparkle is too big, if the source is too bright, or if adjacent reflective surfaces are mirrorlike. The angle, intensity, and shielding of the source must be evaluated to assure visual comfort.

Playing light against darkness can create a striking visual effect within a space. The brightness ratios between luminaires and their background are very important. For example, the brightness of a translucent portable luminaire against a dark wall may result in a dramatic effect, but it can cause discomfort if the shade is excessively bright.

Lighting can reinforce spatial perceptions. It can make a space appear larger or smaller.9 uniform lighting can make a space seem larger, but at the same time it can make the space seem flat or dull if there are no shadows. In contrast, nonuniform lighting can make a space seem smaller, particularly if walls, ceilings, and corners are dark, and can also create a sense of intimacy. Pretesting spatial effects is always recommended.

Art created by light :

Light as an art medium is a way to enhance interior spaces. Art can be created by projections onto surfaces or transmission through surfaces of glass, acrylic, or neon and should be designed as part of the overall luminous environment . The effect that a luminous piece of art has on the space must be evaluated by the same criteria as other lighting effects, including luminous contrast, glare, and day and night time impact.

Design effects :

The visual effects that can be created with lighting are almost limitless. Some of these possibilities are organized for easy reference in chapter 10, quality of the visual environment.

12.7. Light sources for interior spaces:

The most common electric light sources used in residential interiors are incandescent, tungsten-halogen, linear fluorescent, and compact fluorescent lamps. Tungstenhalogen sources provide whiter light, longer life, and higher efficacy than standard incandescent lamps. Incandescent and tungsten-halogen lamps are available for line voltage as well as low voltage, and are used extensively in portable luminaires, recessed downlights, track lights, wall sconces, and chandeliers.

Fluorescent sources are appropriate for most rooms in a residential space. Even the slender t-5 and t-2 lamps are being used in residential lighting.

T-8 lamps are more energy efficient than t-12 lamps and provide very good color rendering properties. They are available in a variety of lengths and color temperatures. T-12 lamps are still available but are gradually being replaced by the more readily available and efficient t-8 products.

Compact fluorescent lamps offer good color rendering and an energy-efficient alternative to standard incandescent lamps. For best results, luminaires designed specifically for compact fluorescent lamps should be used. When choosing luminaires for a room, the designer should select more than one light source (layering the light) to create interest and to define a particular object, wall, or painting. A variety of light sources allows the designer to create a mood, enhance a focal point, and create a warmer, friendlier place for living and entertaining.

12.8. Retrofitting :

Compact, self-ballasted screwbase fluorescent lamps are commonly used to replace standard incandescent a-type lamps. These lamps can reduce energy consumption. They may not fit in existing luminaires, and the light may not be distributed properly when using a luminaire intended for an incandescent source. Typical applications are downlighting, wall sconces, and portable luminaires. Compact fluorescent lamps often require a special harp or extender for portable table or floor lamps. In downlighting luminaires and wall sconces, the dimension of the luminaire must also be checked to assure proper fit. The operating temperature may cause the lumen output to be lower than expected. The color appearance of compact fluorescent lamps differs slightly from incandescent sources. Fluorescent retrofit kits for downlights, available from luminaire manufacturers, include ballast, cone, lamp, and trim. Some "energy saver" incandescent lamps reduce the wattage while producing nearly the same light output as their equivalent incandescent lamps.

12.9. Luminaires for interior spaces:

Luminaires for interior living spaces range from portable luminaires to custom-made architectural lighting. Luminaires are categorized by their different light distributions by cie designation as to the type of luminaire used (direct, indirect, or general diffuse). The choice depends on structural conditions, aesthetics, and economics. To select lighting equipment wisely, the designer should interpret manufacturers' literature, photometric data, and charts for estimating illuminance. .

In typical residential applications, the average luminance of the luminaire that provides general illuminance to the space should not exceed 1700 cd/m2, except in utility areas. For equipment used in utility spaces, luminances as high as 2700 cd/m2 are acceptable. Within the diffusing element, the luminance of the brightest 645 mm2 (1 in.2) area should not exceed twice the average luminance of the overall element. Luminance ratios between the luminaire and the ceiling should not exceed 20:1. Even with the best diffusing glass or plastic, spottiness occurs if the lamps are widely spaced or too close to the diffuser.

When selecting interior luminaires, the designer needs to consider appearance, efficiency, and the luminaire's ability to properly distribute light. Color rendering ability, color temperature, energy use, detailing, durability, finish, cost, and ease of maintenance are important considerations when choosing light sources.

CHAPTER – 13

THE IMPORTANCE OF VISUAL TASKS IN OFFICES

THE IMPORTANCE OF VISUAL TASKS IN OFFICES

Office work entails a variety of visual tasks. In addition to creating a pleasant and stimulating environment, office lighting should support the various visual tasks performed. The visibility of task details is determined by their size and contrast with the background, the absolute luminance of the background, and the viewing duration. Although visual performance follows a law of diminishing returns, one can say that in general the greater the contrast and size of the task details, the higher the background luminance, the longer the viewing duration, and the higher the level of visual performance. Within limits, a given level of visual performance can be maintained by trading off reductions in the magnitude of one factor with improvements in another. So, for example, leaning forward to make task details appear larger can offset reduced background luminance caused by low illuminances.

Visibility also depends on the age of the worker. As a person ages, the pupil becomes progressively smaller (for a fixed level of ambient illumination) and the crystalline lens becomes thicker and less transparent. For example, a typical 50-year-old needs twice the illuminance falling on a task that a typical 20-year-old needs for that task to provide the same amount of light falling on the retina.

13.1. Illuminance selection :

Illuminance levels should be determined based on visual performance research as well as on design experience. The procedure is task specific, and knowledge of the task is important. If a specific task is unknown, then the designer must design for typical office tasks. If possible, a survey of future occupants should be conducted to gather information about the activities that will occur in the space and the ages of the people who will perform them.

For a given office task, illuminance design levels are provided with quality of the visual environment. The designer can tailor the illuminance to the specific situation. The designer is provided with this flexibility in order to specify a level that is suited to the visual task, keeping in mind the lighting design issues listed at the beginning of this chapter.in determining an appropriate illuminance level, the designer must also consider how the illuminance is to be delivered, and to what locations. It is essential to differentiate between general lighting for the space and the illuminance specifically on the task or at the task location. In open plan offices, providing tasklevel illumination only at specific task locations and at a lower illuminance level throughout the space is typically appropriate. In private offices with free standing desks, it is more likely that the general illumination of the room provides the task level illumination.

The general illumination level of an office facility should be determined by several factors. The reflectance values of surfaces surrounding the task area should be considered to create a visually comfortable environment. Luminance levels surrounding the task should not be greater than three times the luminance value of the task, or less than one-third the luminance value of the task. If the offices contain vdts, the general illumination should meet the guidelines established for that specific type of task (see the section "offices with video display terminals" in this chapter). Additionally, the general illumination should meet the psychological need for light of the occupants of the space. It should be remembered that room reflectance values and the distribution characteristics of the luminaire may be as important as illuminance level.

In a vdt screen, veiling reflections from bright objects, which reduce contrast, are prominent on a white-on-black display, these reflections are less noticeable on a black-on-white display.

If there is more than one task in the space, with each requiring a different illuminance, the designer must choose among them. There are several alternative methods for combining different target values.

The illumination requirements of different tasks may be satisfied by providing different task lights. A flexible lighting system, individual dimming controls, and multilevel switching are other available alternatives, depending on furniture layout and architecture. For locations with multiple tasks, designers can design for the task requiring the highest level of illumination and provide dimming capabilities that allow the user to adjust the lighting level in various areas to suit different tasks. Multilevel lighting systems also may be appropriate. If flexibility is not possible, the designer may be forced to choose one criterion over another for the entire system. However, it should be noted that most task lights provide more than enough illuminance.

Often, office buildings are built on speculation, so that the visual tasks and the occupants are unknown. A building in which the lighting has been thoughtfully designed for today's typical office tasks is more attractive for prospective tenants. A logical recourse is to design for the modern electronic office in which a combination of paper and vdt tasks will be performed. Ambient illuminances throughout the office space should not exceed 500 lx (50 fc), where vdts are used, and extreme care should be given to providing a general lighting system that does not create disability glare, or reflected glare off of vdt .higher illuminances at task locations can be provided by task-light luminaires.

13.2. Quality of lighting

It should be remembered that task visibility can be affected by the quality of light. Poor lighting quality can provide veiling reflections, reflected glare, and shadows, resulting in reduced visibility. The angle at which light strikes the task, the location of the luminaires relative to the task, the distribution of the light emitted from the luminaires, the location of luminaires in the office, and the specific properties of the task and work surface all affect lighting quality.

13.3. Veiling reflections, reflected glare, and shadows:

The contrast of a visual task depends on the glossiness of the task surface and on the geometric relationships between the light sources, the task, and the eyes. If the visual task produces a mirror angle between the eye and the luminaire or another bright object, contrast is reduced. This effect is called veiling reflections . The area from which a luminaire or bright object can reflect light off the task and into the viewer's eyes is termed the offending zone. This may be a specific area of the ceiling or, often in open-plan workstations, the area directly in front and above the occupant, which is a common area for placement of task-light luminaires.

13.4 Reflected glare:

Reflected glare is usually caused by a mirror image of the light source in the offending zone reflected to the worker's eyes from vdts or highly polished wood or glass-covered desk tops. It can be reduced by the use of matte surfaces and by carrying out the procedures for reducing veiling reflections on the task. Additionally, large-area low-luminance luminaires or indirect luminaires can be used when specular surfaces cannot be avoided.

13.5. Shadows:

In most office work, shadows reduce visibility. Shadows reduce the illuminance on the task and, if sharply defined, can be distracting and cause excessively high luminance ratios on desk tops. Shadows are minimized if the light arrives at the task from many directions, helped by high-reflectance matte finishes on room surfaces. Large area luminaires can also reduce shadows.

13.6. Task lighting:

Like ceiling luminaires, task lighting, either as desk luminaires or as part of open-plan furniture systems, ordinarily should not be placed in the offending zone. However, the light distribution characteristics of some luminaires minimize veiling reflections through optical design elements. Such luminaires may be placed in the offending zone if they use an optical system that redirects light so that these veiling reflections are eliminated or at least reduced. This can be accomplished with lenses and/or reflectors. Many task lights use a batwing lens. This type of lens is made up of a series of linear prisms that minimize the light output at nadir (straight ahead) and redirect light out to the sides. As a result most of the light striking the task originates from the sides or ends of the task light .

Free-standing or mobile-arm task lights allow the user to position the light for best task visibility, this may be a useful approach when linear task lights cannot be used. Many of these portable task lights offer little optical control; a shade can block light from the user's eyes, and generally most of the light is concentrated directly below the unit.

the designer should always consider multiple working areas within the space. In open office areas, for example, one luminaire placed outside the offending zone for one worker may be in the offending zone for another. Luminaire light output should be limited at angles greater than 55° from vertical in order to prevent veiling reflections and to reduce discomfort glare.

13.7 Overall room brightness:

Workplaces that have dark walls and ceilings may not be as well accepted by employees as spaces with bright room surfaces. White and light-colored paint finishes, combined with the washing of walls and ceilings with light, can brighten both the space and worker attitudes. This applies to furniture, too. Dark brown partitions and walnut grain work surfaces may not look as cheerful as lighter finishes, and they certainly do not use lighting energy as efficiently.

13.8. Patterns of wall and ceiling brightnesses:

Gradients of light on a wall, ceiling, or desk top affect brightness perceptions. Until there is a better understanding of this, it is a good idea to avoid harsh or striated patterns of luminance. Even more important, patterns of light must make sense; otherwise they are distracting. A scallop of light on a wall looks odd, for example, unless there is a piece of art centered in it or it is one of several rhythmical scallops that correspond to the spacing of wall panels.

13.9. Modeling of faces:

in spaces such as conference rooms, interview rooms, and video conference facilities, faces should be easily seen and pleasantly lighted. Strongly directional downlighting, for example, can cause harsh raccoon-like shadow patterns on the face. Diffuse lighting or light bounced off of surfaces can help soften shadows and make facial features more readable.

13.10. Color appearance:

People's preferences for warm or cool light sources are often cultural or climate related, so it is difficult to recommend color temperatures appropriate for office spaces. However, the color rendering ability of the lamp is important if food, faces, or fine architectural finishes are involved. In general, choose lamps of 70 cri or greater, or 85 cri or above if color critical tasks are being performed.

13.11. Flicker:

Perceived flicker can cause headaches. Electronic ballasts can eliminate flicker for fluorescent lamps, and magnetically ballasted hid lamps can be wired to alternate phases of a three-phase system to reduce flicker.

13.12. Daylight and view:

access to windows provides many benefits for workers. It provides a view, allowing an individual to relax his or her eyes by focusing on distant objects. It provides a contact with time of day, weather conditions, and activities outdoors. If designed to introduce daylight without glare, windows and skylights can provide ambient light, reducing the need for electric light during daylight hours .

CHAPTER – 14

INTERPRETATION AND LIMITS OF CALCULATED QUANTITIES

INTERPRETATION AND LIMITS OF CALCULATED QUANTITIES

Calculated quantities can be used to provide the designer of a lighting system with information that could not otherwise be obtained except with an actual mock up of a lighting installation. Information on illuminance, luminance, existence, contrast, visual comfort probability, visibility, and visual performance metrics can be used to compare alternative designs and to verify that design criteria are met. These calculated quantities can also be used to protect or challenge a specification. Calculations are often required to meet strict design requirements imposed by labor unions, owners, local codes, or the like. If used correctly, computer models can be a valuable asset in designing a lighting system to meet particular design criteria.

With recent advances in the field of computer graphics, it is now possible to view the effects of a lighting system on a room through a computer-generated rendering of a space. At the heart of these renderings is a complex lighting analysis. The transformation from luminance data to a realistic-looking synthetic image requires special attention, since a computer screen has a limited range of available luminances. These tools are now being used by lighting professionals to evaluate and market their designs. Further improvements in this process will certainly make computer-generated visual methods more popular in the future.

In reviewing any lighting calculations, the results should first be screened for possible errors. Improper orientation or placement of a luminaire may produce incorrect results. Improper photometry, lamp lumen output, or light loss factors may also cause errors. If the results appear unreasonable, an error may be producing an inaccurate result. Assuming that the results are for the proper arrangement of lighting equipment and room surfaces, some advice is provided below to help evaluate computer output.

14.1 Illuminance :

Often a designer has selected a target illuminance, and a detailed analysis is performed to determine if the target value is provided. For maintained illuminance, a design is generally acceptable if the illuminance is within 10% of the target value. For energy conservation purposes, values below the target value are preferred over values above.

It is difficult, however, to achieve a uniform value everywhere within a space, or even across a desk or workplane. A 14% variation in illuminance is generally considered to be tolerable. In all cases it is the responsibility of the designer to determine if a particular variation is acceptable.

In evaluating illuminance, it is important to focus on the actual task locations. Most general lighting systems provide a higher illuminance in the middle of the room than near the walls. If the principal task locations are against the walls, a more detailed analysis may be needed to properly evaluate the illuminance at those areas.

Obstructions in a space, such as partitions, should be considered in a lighting calculation model if possible. If an empty room is modeled, the illuminance near a vertical partition is likely to be much lower than predicted.

14.2. Luminance :

Luminances can be used to evaluate the appearance of a space. Scallops, sharp luminaire cutoffs, and the general pattern of brightnesses can be studied through numerical and graphical models. Computer renderings or simple luminance contours for room surfaces can provide the needed information for a designer to evaluate the performance of lighting equipment.

Luminances can also be evaluated with respect to a luminance ratio criterion. In the lighting of spaces containing VDTs, the uniformity of the luminance on the ceiling and the maximum ceiling luminance are critical aspects to study.

14.3. Contrast :

The calculation of task contrast, particularly for specular tasks, provides an indication of where veiling reflections occur within a space. Contrast can also be used to compare the performance of two different lighting systems. Visibility and visual performance metrics that use task contrast can provide some insight into the significance of the contrast and the task luminance provided by a lighting system.

14.4. Visual Comfort Probability :

Visual comfort probability (VCP) is a metric with limited application. It was developed for lensed fluorescent lighting equipment. It is not valid for use with incandescent or HID equipment. It also cannot be used with luminaires that have an upward component. The procedure has never been proven to accurately model the discomfort caused by parabolic fluorescent luminaires, although many lighting professionals continue to apply it in such situations. Parabolic luminaires are much less uniform in luminance than lensed luminaires, and the difference can have a noticeable effect on the comfort of occupants. Small differences in VCP are not significant. VCP differences of less than 5 points do not indicate a meaningful difference in discomfort glare potential.

14.5. Comparison of Calculated and Measured Quantities :

Although it seems reasonable to expect calculated values of quantities to be reproduced in the field, in practice it is very difficult to reconcile measured quantities with those provided by calculation. Assumptions inherent in any calculation model often represent conditions very different from those in an actual lighting installation. Some of these conditions are listed below:

- Lambertian surfaces are assumed in most computer programs. Real-world surfaces may contain some degree of specularity.
- The room surface reflectance input to analysis software may not accurately represent what is present in the field.

- Reduced electrical voltage in the power system may produce reduced light output.
- The assumed ballast factor may be much different from that present in the field.
- Thermal effects in an installed luminaire may alter light output.
- Minor differences incurred in the manufacturing process or in the positioning of the lamp within a luminaire may alter the luminaire's photometric distribution.

Furniture and other absorbing and reflecting surfaces may not have been considered in the computer model. No analysis model is an exact representation of any real room. Simplifying assumptions in the calculation method may limit the accuracy of the results. Far-field photometric methods applied in a near-field situation may not accurately model the luminaire performance.

Another reason for disagreement can be errors in the measurement process. It is important to follow strict guidelines when measuring the photometric performance of lighting systems. For example, it is important that the lighting system be measured at a temperature that is representative of its thermal equilibrium condition. New lamps should operate for at least 100 h before measurements are taken. The operator of a photometer must ensure that his or her own presence does not influence the reading. Orientation and positioning of the photometer are also critical; a tripod with a leveling device is particularly useful when conducting horizontal illuminance measurements. Finally, all daylight should be eliminated from the measurements on interior lighting systems, perhaps by conducting measurements at night. Any attempt to subtract out daylight levels is difficult and is likely to introduce errors because of the temporal variations in daylight illuminance.

The magnitude of the differences between detailed analysis methods and field measurements varies. In general, differences of less than 20% can be expected, but in extreme cases, where a calculation method simply cannot handle the complexity of the lighting system, they may be greater. For a more complete discussion of the uncertainties.

CHAPTER – 15

DESIGN ISSUES FOR SPECIFIC AREAS

DESIGN ISSUES FOR SPECIFIC AREAS

15.1 Open-Plan Office Lighting

15.1.1 General Considerations:

Open-plan or open offices are areas that accommodate workers in a common space with few, if any, floor-to-ceiling partitions or walls. There can be many different kinds of visual tasks and activities, and the furniture configurations may be specific to the activity. Individual work areas can consist of:

- Bullpen-like desk arrangements
- Desk-and-credenza combinations
- Floor-standing panels partially enclosing a space, often supporting work surfaces and storage components
- Freestanding screens or panels between desks

The office configurations have an effect on the light distribution and illuminance. Panels and storage shelves above work surfaces can create undesirable shadows on the visual task and on adjacent surfaces. Panel heights and workstation density and size change the distribution of the general illumination and affect luminance and illuminance uniformity at the work surface. As the number of vertical partitions increases, their reflectances become more significant; dark finishes absorb more light and lower the general impression of brightness as well as the actual illuminance on the task. An open plan office with several types of lighting: decorative pendants and column luminaires provide indirect lighting; recessed downlights provide general illumination; and task lighting is provided by portable task lamps as well as by luminaires built into the workstations. Daylight also contributes to the pleasantness of the room, and is utilized through skylights as well as perimeter windows.

15.1.2. Calculating Illuminance:

Accurately calculating illuminances in open-plan office areas can become complex. Often perceptions of brightness may depend more on vertical illuminances rather than horizontal illuminances. Additionally, when calculating illuminance for general illumination that is supplemented with task lighting, the general illumination calculation may not be critical because absolute ambient illuminances are less important than task illuminances to the success of the office environment. When calculating illuminance, the empty-room assumption is not a valid approximation of the environmental condition. Vertical obstructions such as partitions and filing cabinets play an important role in determining the lighting within and surrounding a workstation. For example, an average density of partitions 1.5 m (60 in.) high may decrease task surface illuminances by 10 to 50% (depending on reflectances and illuminance distribution characteristics). Since classical room zonal cavity computations cannot include these obstructions, their value is limited.

Since a partitioned work space takes on many of the visual aspects of a small room, the importance of surface reflectances, color, and height should be stressed. Point-by-point computer calculations may be required if an accurate prediction of illuminances is desired. An alternative might be a controlled mock-up in which illuminance readings can be taken.

It may be desirable to plan general illumination separately from task illumination, given the limits of calculation procedures and the expense of a mock-up. In this way, localized illuminance calculations can be performed from the photometric characteristics of the task luminaire and the reflectance characteristics of the workstation.

15.1.3. Luminance Considerations:

The background luminance at the visual task can be considered from two perspectives. Luminances within the immediate task area should maintain a maximum bright-to-dark ratio of 3:1. Away from the immediate task area, but within the field of view, greater contrast may be desirable to enhance visual clarity, depth perception, and a sense of spatial orientation. In these areas a maximum ratio of 10:1 is recommended.

Consideration of task versus background luminance is different for VDT screens than for paper tasks, and different for partitioned workstations than for visually open spaces. In the open office the immediate surround is the work surface for horizontal paper tasks. For tasks with an elevated line of sight, such as VDT screens or vertical copy stands, the immediate surround is part of more remote room and furniture surfaces or the panel surface of a partitioned workstation.

15.1.4 Flexibility:

In the design of the lighting for an open-plan office, the permanence of workstation location must be considered. A planned design or layout may be quite different from the actual furniture layout six months after initial occupancy. A lighting design tailored to a specific furniture orientation, such as rectilinear or diagonal, may create glare or low illuminances if furniture is moved.

15.1.5. Psychological and Design Issues:

One of the most overlooked design aspects of open-plan office lighting is the consideration of the psychological effect of all the elements in the space. The spatial arrangement and the lighting distribution become integrated by the user, whether the interior and lighting designs were integrated or not, causing a psychological effect.

Large open spaces create an entirely different feeling from that of partitioned workstations. The lighting, the furniture layout, and the room and furniture finishes must work together to communicate to the occupant the sense of the design concept.

In open-plan offices, another major objective is the identification of circulation patterns and activity areas. Users need to have a sense of orientation with respect to their environment. This may involve the ability to quickly locate exits, reception areas, specific departments, individual offices, and locations of adjacent areas like the copy machine room and the conference room. The lighting system, in conjunction with the interior design, can provide the appropriate visual cues to communicate orientation and circulation. As open-plan offices become larger, the need for users to understand the limits of space and their relationship to the space becomes increasingly important.

15.1.6. Acoustical Aspects:

The acoustical criteria for open-plan offices are often quite stringent. Of special concern is the acoustical privacy between workstations. In closed office spaces this is provided by permanent walls, but in their absence, the ceiling takes on increased importance along with the space dividers. Luminaires, either recessed or surface mounted, can have an adverse effect on acoustical absorption. Lensed luminaires can reflect sound to adjacent workstations, whereas louvered units break up the reflected sound. To ensure a completely satisfactory open-plan installation, the designer should work with an acoustical consultant.

15.2. PRIVATE OFFICES

A private office is generally a fairly small space (8 to 12 m2) with floor-to-ceiling partitions and one occupant. Ceiling-mounted direct luminaires are typical. Usually luminaires outside the private office cannot be seen by the occupant, so the luminaire brightness may be less important than it is for larger spaces. However, if the partition walls are glazed or contain clerestory windows, overhead lighting within the private office may affect those outside and vice versa. In this case, the overhead lighting should be treated as in open-plan areas.

As in open-plan offices, task lighting, combined with low-level general illumination, can be used for private offices. Because the wall area of a private office is large relative to the room size, there is opportunity for wall lighting to provide all or part of the general lighting; the result is often more pleasing in appearance than lighting from ceiling sources alone. Wall washing with individual luminaires or continuous linear sources produces a more open, brighter appearance. Highlighting features such as artwork or creating patterns of brightness on the walls also lend variety and interest.

For the best lighting layout, the furniture arrangement should be determined before the lighting is planned. This allows for specific placement of luminaires so as not to cause veiling reflections. This is rarely possible in a private office, so alternatives should be considered. These include indirect lighting from wallmounted or ceiling-suspended luminaires, a combination of indirect luminaires and direct lighting, wall coves to provide both wall luminance and task illumination, and direct-indirect illumination from suspended or wall-mounted luminaires.

Downlighting should not be used to provide task illumination. The point source nature of these types of luminaires is likely to cause harsh hand shadows on the task. Additionally, if these luminaires are placed in the offending zone, reflected glare or veiling reflections can occur. Downlighting may be appropriate for wall washing or accent lighting, however.

15.3. Conference Rooms

Visual tasks in conference rooms range from casual to difficult. Direct glare and modeling of faces or objects as well as design composition, style, and image are the key issues for the lighting design for meetings. See Chapter 10, Quality of the Visual Environment. Two or more lighting systems should be planned to provide flexibility for this range:

1. A general lighting system in which the control of illuminance is provided by switches or dimmers.

2. A supplementary lighting system consisting of downlighting with dimmer control for slide projection and other low-level illumination requirements. Due to improved technology and the reduced cost of electronic dimming systems for fluorescent lamps, it is sometimes effective to incorporate dimming into the general fluorescent system, thus eliminating the need for a second system.

3. A perimeter or wall-wash lighting system controlled with dimmers for better visual appeal and for wall-mounted presentations.

15.3.1 Video Conference Lighting

Video conference lighting serves two purposes: to illuminate people working and interacting with each other, as in any conference room, and to illuminate people interacting with other people at remote locations, via video displays. These two requirements do not always complement each other. Lighting that is designed for maximum visual comfort and minimal glare does not always lend itself well to the lighting requirements for high-quality camera images.

Lighting for video conferencing has its roots in photographic and television lighting, where most of the fundamental principles and techniques for camera lighting apply. Camera lighting consists of key light, back light, and fill light. Key light creates dimensionality and a modeling effect for the subjects of the scene. Back light helps to outline the subjects, creating depth of field and heightening the sense of drama. Fill light provides general illumination, reduces harshness, and softens shadows. Both key and back light are task-specific, focused light aimed at the main subjects of the scene, whereas fill light can be regarded as ambient and diffused light.

Since video conference room lighting should create a normal conferencing setting without having the feeling of being on stage or under the spotlight, it is desirable not to have dramatic lighting for video conferencing. Practical implementation can also be achieved with two different layers of lighting: one with totally indirect luminaires for fill light, and the other with totally direct luminaires to provide key and back light. One benefit of using two separate lighting systems is that dimming can be separately applied to each lighting layer, creating a flexible lighting design that is more accommodating to individual preferences and to the varying functions of the conference room.

Typically, illuminances of 500 lx (50 fc) are adequate for occupants and for most modern video cameras.

15.4. Drafting and Graphic Production Rooms

Visual requirements for drafting demand high-quality illumination, since discrimination of fine detail is frequently required for extended periods of time. Significant graduation of shadows from drawing equipment and hands reduces visibility and productivity. Lighting systems that avoid reflected glare, veiling reflections, and task shadows are very important in providing maximum visibility. Indirect, semidirect, or other forms of overall ceiling lighting minimize shadows. When ceiling heights or energy constraints do not permit the use of these systems, direct lighting systems can be applied where the work surface is illuminated from both sides. In such a system, the absence of any luminaire in the offending zone also minimizes veiling reflections and reflected glare. Supplementary lighting equipment with user adjustable support stems may be attached to the working surfaces, allowing the worker to position the light for critical task requirements or to overcome shadows and reflections. Some lighting systems are attached to drafting machines so that the light moves with the task. The requirements for computer-aided drafting (CAD) are very different

15.5. Reception Areas:

Reception areas are designed for people who are waiting for their appointments and, while waiting, reading or conversing with others. The lighting should be restful and yet provide enough illumination for reading [31].

One way to provide a restful atmosphere without direct glare is by illuminating one or more of the walls. Another way is to light the ceiling and part of the walls. Accent lighting for pictures or for a piece of sculpture enlivens the appearance of the room. If there is a receptionist located in the area, the ambient illumination may need to be augmented, depending on the visual tasks involved [31]. Care should also be taken to illuminate the receptionist's face, so as to make this person look approachable, and also to eliminate harsh shadows caused by the downlights directly overhead. Task lighting can be provided for people waiting in the reception area[31].

15.6. Files:

Files are primarily vertical work surfaces. In active filing areas, the work is likely to be long and visually difficult. Illumination should be directed onto the opened file drawers to minimize shadowing within the drawer. Where files are located in a general office environment and vertical illumination may also cause glare, consideration should be given to local illumination at the files, with individual manual or automatic switching located nearby.

15.7. Restrooms:

Uniform illumination is not required in restrooms. Luminaires should provide light in the vicinity of the mirrors to illuminate the face. Other luminaires should illuminate bathroom fixtures and stalls and should be located so that partitions do not cast shadows on the plumbing or floors of the stalls. High illuminances in these areas also have a tendency to encourage cleanliness.

15.8. Public Areas:

Public areas in a building include entrance and elevator or escalator lobbies, corridors, and stairways. Since many people move through these areas, the appearance of the space is very important, but so are safety requirements and the brightness balance with respect to adjacent areas. Public areas must remain illuminated for long periods, if not continuously. Therefore, serious consideration should be given to lowpower lighting systems. Since many public areas are egress areas, an auxiliary lighting system is required to cope with power outages and system failures. These auxiliary systems can also serve as security lighting.

15.9. Entrance Lobbies:

First impressions of office buildings are often perceived in entrance lobbies. The lighting should complement the architecture and provide for safe transition from the exterior to the interior. Consideration must be given to adaptation by the visual system from bright daylight conditions to darker interiors, or vice versa.

Perhaps the most important element in a lobby is the walls. Some may be of glass and some of opaque materials [31]. Walls, if they are of high reflectance, can be illuminated, and the reflected light can provide all of the illumination for the lobby to provide orientation for people moving through it. If specular materials are used, unwanted reflections from luminaires must be considered. Grazing light from luminaires close to specular surfaces will minimize visible reflections.

The main lobby of a building should provide a good impression. Materials in lobbies are often of high reflectance. The lighting should enhance the beauty of the building materials and at the same time minimize visible reflections.

If the lobby is enclosed with glass, the interior walls need to be at a higher brightness during the day in order to be seen from outside against the high daylight brightness. At night, a much lower brightness is required. The variable brightness also makes it easier for eyes to adapt to the ambient conditions when entering or leaving a building. For these reasons, the lobby lighting should incorporate dimming or switching controls [31]. Since surfaces have a profound effect on the interaction of light and the space, the designer should work with the architect to choose building materials and lighting systems that work together to achieve the desired appearance from different perspectives and at different times.

15.10. Corridors:

Corridor illumination on the floor should be at least one-fifth the illuminance of the floor in adjacent areas. This illuminance is both safe and energy efficient and does not require major visual adaptation upon entering and leaving the corridor. Wall finish reflectances should equal or exceed those in adjacent areas. Linear luminaires oriented crosswise to the corridor generally make the narrow space appear wider. Continuous linear luminaires located adjacent to the side walls provide high wall brightness and can give a feeling of spaciousness. Corridors, which are paths of egress, must be provided with emergency lighting.

15.11. Elevator Lobbies:

These are classified as casual seeing areas, so high-luminance differences are acceptable. Relatively high illuminance should be provided at the elevator threshold to call attention to possible differences in elevation between the elevator cab and the floor.

15.12. Elevators:

Brightnesses approximately equal to those provided in the building corridors should be provided in elevators. Elevators are small confined spaces often shared by strangers, so the lighting should help people feel comfortable. Bright ceilings and walls can give a feeling of increased size and will also indirectly light people's faces. The lighting in an elevator should always be connected to the building's emergency power supply to help alleviate distress in the event of an elevator power failure or malfunction.

15.13. Stairways:

The stair treads should be well illuminated, and the luminaires should be located to avoid glare and shadows cast by occupants onto the stairs. Luminaires should be easy to maintain because ladders are difficult to use in stairways. Emergency lighting should be provided in all public stairways. Although the lighting requirements are the same for all stairways, the lighting design solutions may be different.

15.14. Direct Lighting:

Specific luminance-value limitations are important for designs using direct luminaires. The geometry shown in Figure 11-18 illustrates the offending zone for VDT lighting. Since some screens provide a wideangle reflection of the space, many luminaires can be in the offending zone in an open-plan environment. When a luminaire is viewed lengthwise, crosswise, or from 45°, the average luminances should be constrained. The current method for describing the luminance of a luminaire at specific angles is a calculated value. It is called average luminance and is typically provided in five- or ten-degree increments. It is determined by photometric laboratories by factoring the intensity at a given angle and the projected surface area of the luminaire at that angle. As a result, luminance values for luminaires of different sizes vary, even if the actual intensity at a specific angle is the same. The maximum levels provide a higher potential for veiling reflections or reflected glare on the VDT screen, but may be suitable for offices where the VDT task is performed only on an occasional basis and is not the primary visual task. Depending on the eye-screen geometry, the offending zone may be located on the ceiling plane, a wall, or a partition. Screen curvature may enlarge or change the location of the offending zone.

Using low-brightness luminaires may solve the technical problems associated with VDT glare, but eliminating glare does not in itself result in a pleasant environment. Additional design efforts are needed to create an appropriate perceived brightness and a sense of well-being.

15.15 Indirect Lighting:

With indirect lighting, luminaire distribution characteristics, luminaire spacing, and the distance between the luminaires and ceiling become critical .This is especially true if, while viewing a VDT screen, the offending zone is the ceiling plane, and indirect luminaires light this plane. The maximum ceiling luminance should not exceed 850 cd/m2. Also to be considered is the relationship between the ceiling luminance and the task luminance. Since the VDT task is typically a heads-up task, the ceiling may be visible in the peripheral view while looking at the screen. To meet current recommendations, the ceiling luminance should not exceed 10 times the average screen luminance. Thus, if the screen luminance is only 70 cd/m2, the maximum ceiling luminance should not exceed 700 $cd/m^{2.}$

Indirect luminaires should have a widespread light distribution as shown in the upper sketch. A narrow light distribution as shown in the lower sketch may cause patches of brightness.

Additionally, since it is an area of the ceiling and not a single point that is reflected in the screen, that area should have uniform brightness in order to prevent a distracting reflection in the VDT screen. An 8:1 uniformity ratio between the brightest area, typically directly above the luminaire, and the least bright area, typically between luminaires, should be the maximum allowed.

In addition to ceiling luminance, the luminaire itself must also be considered. The luminaire creates contrast when seen against an illuminated ceiling. When reflected in the VDT screen, the image of the luminaire can be distracting and can alter the task contrast when compared to other areas of the screen. To avoid this problem, the luminaire itself should have a high reflectivity, and the reflectivity of the surfaces below the luminaire should be considered as well. Some luminaire luminance may be useful in enhancing the perceived brightness of the space, however. This luminance should be evaluated to assure that it is not excessive and is not reflected as glare on the VDT screen. Because this brightness is viewed against the background of a luminous ceiling, it does not have to meet the full guidelines for direct luminaires.

15.16. Direct-Indirect Lighting:

A direct-indirect lighting system can combine the positive attributes of both direct and indirect lighting and often eliminate the shortcomings of both. With this approach, either one luminaire produces both direct and indirect illumination or different luminaires are used to create different distributions.

CHAPTER – 16

DAYLIGHT SOURCES AND AVAILABILITY

DAYLIGHT SOURCES AND AVAILABILITY

Daylight is distinguished as a light source by its unique, changing spectra and distributions. It can increase occupant satisfaction and conserve energy if considerations such as view design, glare control, human factors, and integration of building systems are properly addressed. It is essential that daylight effects be considered in any space where daylight is admitted, even if it is not exploited as a light source, in order to avoid problems with glare and damage to materials.

To use daylight effectively, the following factors should be taken into account:

i. Human factors, including physiology, perception, preferences, and behavior
ii. Effects of daylight on all materials, including furniture, artwork, and plants
iii. Controlled admission of direct sunlight
iv. Controlled admission of diffuse daylight
v. Effects of local terrain, landscaping, and nearby buildings on the available light

Integration of building systems, including the electric lighting, fenestration, interior geometry and finishes, manual and automatic control systems, and active climate control systems.

The daily and seasonal movements of the sun with respect to a particular geographic location on the earth produce a predictable pattern of amount and direction of available daylight. Superimposed on this predictable pattern is variation caused by changes in the weather, temperature, and air pollution.

Of the solar energy received at the earth's surface, 40% is visible radiation. The rest is ultraviolet (UV) and infrared (IR) wavelengths. When absorbed, virtually all the radiant energy from the sun is converted to heat. The amount of usable visible energy in the solar spectrum varies with the depth and condition of the atmosphere through which the light traverses. Because the spectral distribution of daylight changes continuously with sun position and sky conditions, the Commission Internationale de l'Éclairage (CIE) has adopted three standard spectral radiant power distributions for daylight.

16.1.1 Sun as a Light Source :

The rotation of the earth about its axis, as well as its revolution about the sun, produces an apparent motion of the sun with respect to any point on the earth's surface. The position of the sun with respect to such a point is expressed in terms of two angles: the solar altitude, which is the vertical angle of the sun above the horizon, and the solar azimuth, which is the horizontal angle of the sun from due south in the northern hemisphere .

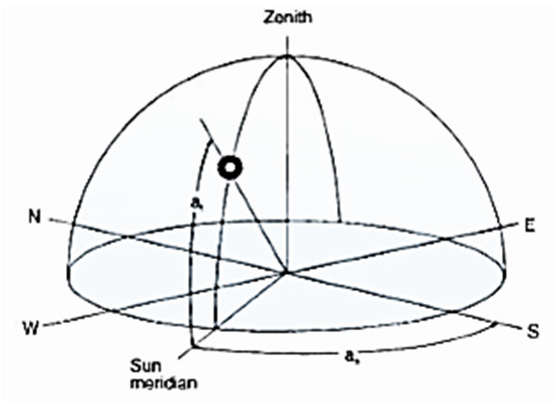


Figure -16.1: The sun's position in terms of solar altitude (at) and azimuth (as) with respect to the cardinal points of the compass.

16.1.2 The Sky as a Light Source :

As sunlight passes through the atmosphere, a portion is scattered by dust, water vapor, and other suspended particles. This scattering, acting in concert with clouds, produces sky luminance. Skies are divided into three categories:

(1) clear, (2) partly cloudy, and (3) overcast.

When the sky is not completely overcast, the sky luminance distribution may change rapidly and by a large amount as the sun is alternately obscured, partly obscured, or fully revealed.

16.1.3. The Ground as a Light Source :

Light reflected from the ground may be important in daylighting design. Such light is, in turn, reflected from the ceiling or walls onto other interior surfaces. On daylighted elevations, the light reflected from the ground typically represents 10 to 15% of the total daylight reaching a window. It frequently exceeds this with light-colored ground surfaces such as sand and snow. On shaded exposures, it may account for even more of the total light reaching a window, depending on the sky condition and building design.

16.1.4. Daylight Availability :

Lighting calculations for daylighting can be considerably more complex than for electric lighting. Determination of the illuminance incident on windows and skylights must take into account the time-varying characteristics of the sky and sun, including the changing spatial relationship between the sun and daylighting apertures.

The phrase "daylight availability" refers to the amount of light from the sun and the sky for a specific location, time, date, and sky condition. Over the past 60 years measurements of daylight illuminance by researchers in locations all over the world have resulted in very similar mean values.

In other words, the equations provide best fits to data averaged over time and measurement sessions. For this reason, measured instantaneous luminances and illuminances may differ widely from those determined by calculation methods based on daylight availability. It is not unusual for the instantaneous values to be more than twice or less than half the mean design values.

Calculation of daylight availability at a site begins with a determination of the solar position, which is a function of latitude and longitude of the site, day of the year (Julian date), and local time.The local time is converted to solar time. Angles are computed that give the position of the sun in the sky. Finally, for a particular sky condition, the daylight availability equations are used to compute the daylight illuminance. All angles are expressed in radians.

16.1.5. Site Location :

The site location is specified by a latitude and a longitude . Latitudes and longitudes may be found in any standard atlas or almanac. Conventions used in expressing latitudes are:

Positive = northern hemisphere

Negative = southern hemisphere

Conventions used in expressing longitudes are:

Positive = west of prime meridian (Greenwich, United Kingdom) Negative = east of prime meridian

16.1.6. Time :

A 24h clock is used to express time. Solar time can be determined from standard time (or daylight time) by correcting both for site longitude within a time zone and for the equation of time. The equation of time gives the difference between solar time and clock time due to elliptical orbit of the earth and solar declination of the axis. The value for the equation of time may be determined from:

$$ET = [7.637 \sin\left(\frac{2\pi(J-2.5)}{365.25}\right) - 9.863 \sin\left(\frac{2\pi(J-8\ .6)}{365.25}\right)]\frac{1}{60}$$

Where,

ET = time expressed in decimal hours (for example, 1:30 p.m.=13.5),

J = Julian date, a number between 1 and 365.

This equation is accurate to within 5 degrees and suitable for most terrestrial daylighting calculations. If an application requires more accuracy, the equation by Meeus may be used.

The relationship between standard time and daylight time is given by , $t_s=t_d-1$;

where t_s is standard time in decimal hours and t_d is daylight time in decimal hours.

Solar time is calculated from standard time by the equation,

$$T= t_s + ET + \frac{12(SM- \ )}{\pi}$$

where ,

t = solar time in decimal hours,

t_s = standard time in decimal hours,

ET = time from equation in decimal hours,

SM = standard meridian for the time zone in radians,

L = site longitude in radians.

16.1.7. Solar Position:

The position of the sun is specified by the solar altitude and solar azimuth and is a function of site latitude, solar time, and solar declination. The solar declination can be closely approximated by

$$б = 0.4093 \sin(\frac{2\pi(J-81)}{368})$$

where

δ= solar declination in radians,

J = Julian date.

The solar altitude is given by

$$a_{1} = arcs \quad \left(\sin l \, sin \, б - cos \, l \, cos \, б \, cos \frac{\pi t}{12}\right)$$

where

a_t = solar altitude in radians,

l = site latitude in radians,

δ=solar declination in radians,

t = solar time in decimal hours.

In many day lighting calculations, it is necessary to calculate the daylight on a vertical surface such as a wall or a window. The elevation azimuth angle is needed for this calculation. It is the angle, measured in the horizontal plane, between the normal to the vertical surface and south (in the northern hemisphere) . It is measured clockwise from south.

The solar elevation azimuth gives the azimuthal angle between the sun and the normal to a vertical surface of interest . It is given by ,

$$a_z = a_s - a_e$$

where

az = solar elevation azimuth in radians,

as = solar azimuth in radians,

ae = elevation azimuth in radians.

Figure-16.2: Azimuth angles (plan view).

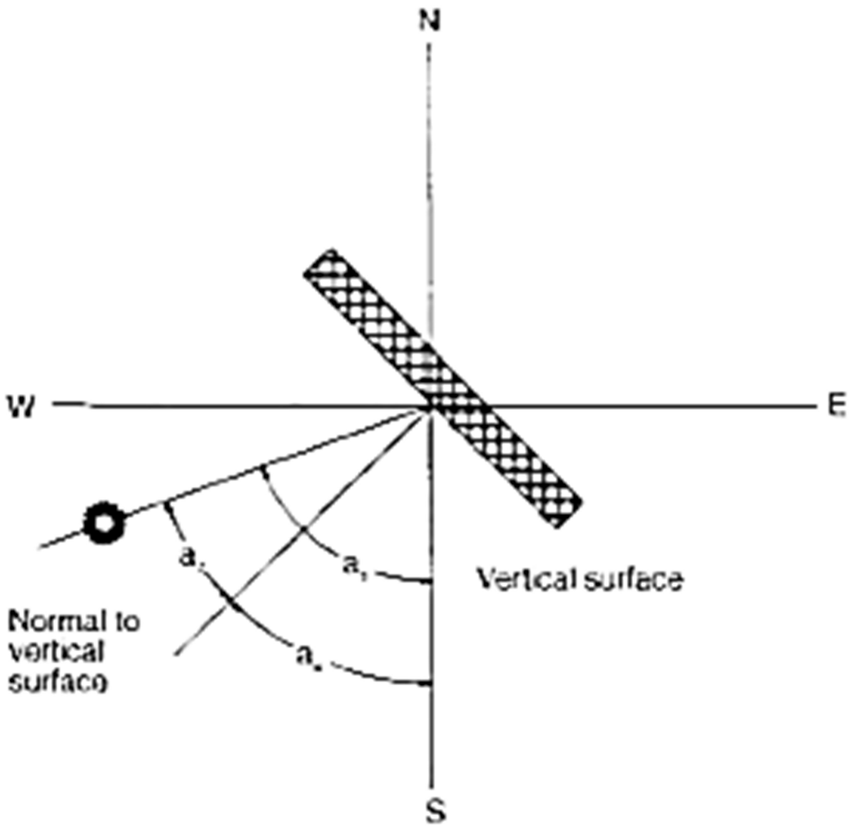
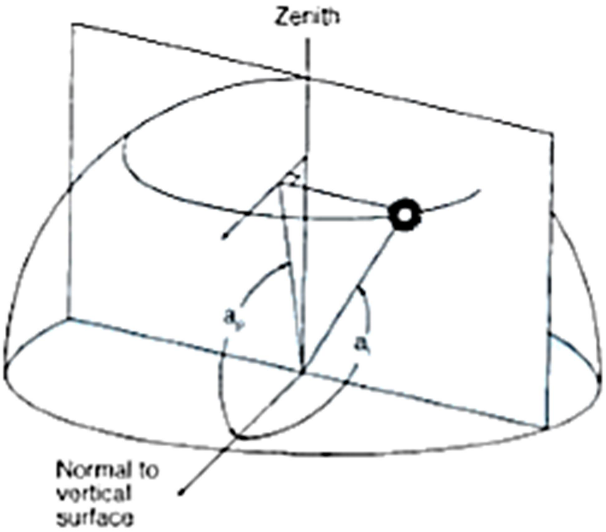


Figure-16.3: Incident and profile angles.



The incident angle is the angle between the normal to a vertical surface of interest and the direction to the sun and can be computed from,

$$a_i = \arccos(\cos a_t \cos a_z)$$

where

a_i = incident angle in radians,

a_t = solar altitude in radians,

a_z = solar elevation azimuth in radians.

16.1.8. Sunlight :

For the purpose of most basic daylighting calculations, the sun is considered to be a point source that provides a constant illuminance at a point on a plane that is normal to the direction of the sun and near the earth's orbit. The solar illumination constant is the total solar illuminance at normal incidence on a surface in free space at the earth's mean distance from the sun.

It is obtained from

$$E_{x=K_{x}\int_{380}^{770} G_{\lambda} V_{\lambda} d\lambda}$$

where ,

Esc = solar illumination constant in klx,

Km = spectral luminous efficacy of radiant solar flux in lm/W,

G(λ) = solar spectral irradiance at wavelength λ, in W,

V(λ) = photopic vision spectral luminous efficiency at wavelength λ,

λ = wavelength in nm (for photopic vision at 380 to 770 nm).

The following are important solar parameters based on current standards:

Solar illumination constant: 128 klx

Solar irradiation constant: 1350 W/m2 (126 W/ft2)

Solar luminous efficacy: 94.2 lm/W

To calculate the sunlight reaching the ground, two conditions must be considered: the varying distance of the earth to the sun caused by the earth's elliptical orbit and the effect of the earth's atmosphere.

16.1.9. Skylight :

Either the sky-ratio method or the sky-cover method is used to classify a sky. The sky ratio is determined by dividing the horizontal sky irradiance by the global horizontal irradiance. Since the sky ratio approaches 1.0 when the solar altitude approaches zero (regardless of the sky condition), this method is not accurate for low solar altitudes. The sky conditions are defined as follows:

Clear : sky ratio≤ 0.3

Partly cloud : 0.3< sky ratio < 0.8

Overcast : 0.8 ≤ sky ratio

The sky cover method uses estimates of the amount of cloud cover. Cloud cover is estimated in tenths and is expressed on a scale from 0.0 for no clouds to 1.0 for complete sky cover. The sky conditions are as follows:

Clear : 0.0 to 0.3

Partly cloud : 0.4 to 0.7

Overcast : 0.8 to 1.0

A different equation is used to represent the mean luminance distribution of each of the three sky conditions. The luminance of the sky is a function of luminance distribution with respect to zenith luminance and absolute value of the zenith luminance.

The position of a point p in the sky (at which the sky luminance is calculated) is given by angles z, the zenithal point angle in radians, and ξ, the azimuth angle from the sun in radians.

The limits of integration depend on the position and extent of the sky patch. In the limit of the entire sky, the integration is over a hemisphere.

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16.2.DAYLIGHTING AND HUMAN FACTORS

16.2.1 View Design and Human Reaction to Windows :

It is important that the provision of view and the delivery of daylight be clearly differentiated. Although the terms "view" and "daylighting" are sometimes used interchangeably, the view function of windows is very different from the daylight delivery function. The provision of daylight alone (for example, through skylights) will not satisfy user desires for views including sky, horizon, and ground. It has been suggested that, to satisfy most workers, windows must cover at least 20% of the window wall area. Heavily tinted glass, used to reduce glare and solar heat gain from such windows, gives outdoor areas an overcast and gloomy appearance, even on sunny days.

16.2.2 Glare from Daylight :

Daylighting systems can produce discomfort glare.Very high luminance ratios are produced unless care is taken to balance and reduce luminances. Increased interior electric lighting may be required to balance luminances and reduce glare produced by daylight, thus increasing energy use when daylighting is used. Glare is critically dependent on the luminance of the window. Methods for predicting the presence of glare from large area sources have been developed.

Because of its intensity, direct sunlight also must be considered in glare control. While it may be used as an amenity, it should be excluded from critical task areas. The duration of sunlight, rather than its intensity or the size of the illuminated patch, correlates best with the appreciation of interior sunlight.

16.2.3. Human Behavior with Respect to Blinds and Shades :

Venetian blinds and curtains are commonly used devices for adjusting the amount of daylight entering spaces and reducing window luminance to control glare. These devices can drastically reduce the amount of daylight admitted to a space, so occupant use of blinds is an important consideration in estimating energy savings from daylighting. Occupants adjust venetian blinds infrequently, having preferred blind positions that are dependent on the orientation of the facade and the season of the year.

16.3.DAYLIGHT EFFECTS ON BUILDING CONTENTS

16.3.1 Daylight Effects on Materials and Artwork:

Daylight is of particular concern with respect to light damage to materials and artwork because of its high intensity relative to light from electric sources. Light at all wavelengths, not just in the UV range, contributes to fading, bleaching, and other damage.30 However, UV is known to be especially active in the fading and bleaching process. Unfiltered daylight has about ten times as much UV radiation per lumen as light from incandescent lamps. The length of time that materials are exposed to daylight is a factor in fading; the longer the exposure time, the greater the damage.

16.4.CALCULATION OF INTERIOR ILLUMINANCES

Calculation methods are useful in comparing alternative daylight delivery systems or considering the limits of daylight utilization for various buildings and systems under a wide variety of lighting conditions. Calculation methods are useful alternatives when weather or sky conditions do not permit appropriate or comparable scale model measurements and evaluation.

16.4.1 Manual Methods :

Manual methods for calculating illuminance at a point involve determination of the sky, sun, and inter reflected components of daylight. The sky and sun components are computed from flux that reaches a window aperture or point directly. The inter reflected component results from sunlight and skylight that have initially reached other surfaces and have then been reflected to the point of interest.

Because of the speed with which design alternatives can be explored and the complexity that can be evaluated, computer-based daylight calculations are important design tools. Capabilities for visualization of interior scenes with combined electric sources and daylighting are included with many software packages.

Calculations of point illuminance are usually made with computer software because of the capacity to model electric lighting and to calculate lighting energy savings, which may be problematic with scale models and other manual methods. There are two basic approaches to the computer computation of daylight: radiative transfer and ray tracing.

The summation is performed using only those (small) sections of the sky that illuminate the points directly. The inter reflected component of illuminance is determined using the finite element radiative transfer method. In its application to daylight calculations, the initial exitances of room surfaces are determined from the flux input from windows and skylights. Most radiative transfer methods assume that room surface reflectances are diffuse. Hybrid flux transfer programs that provide for the display of specular highlights often use a second pass of the scene to add gloss to the surfaces.

Because the flux-transfer approach bases its calculation on a finite-element analysis of the surfaces of the scene, calculation of the direct and interreflected components can become very complicated for elaborate fenestration and skylight systems if space contents are to be modeled (for example, partitions and furniture) or if the space geometry is complicated. There is a logarithmic relationship between geometric complexity (number of surfaces) and computer resources necessary to complete the calculations. Ray tracing is inherently slower for geometrically simple spaces but is capable of handling almost unlimited geometric complexity with a sublinear relationship to computer resource. The utility of the computational technique is usually dictated by the nature of the information required. If illuminances at points are the only requirement, a radiative transfer procedure is usually sufficient. If accurate and realistic visualization of a space is required, ray tracing can be the better technique. The advantage of radiative transfer is that one computation allows for all views of the room to be readily redisplayed without additional computations, facilitating a simulation of a walk-though of the space. Several commercially available programs use this technique. The advantage of ray tracing is that non-diffuse surfaces and greater geometric complexity are inherently more accurately and easily calculated. Programs using this technique are also available. The software packages most successful at solving real-world problems usually employ a hybrid of these methods.

16.4.2. Lumen Method :

The lumen method for calculation of interior illuminances is similar to the zonal cavity method for electric lighting and is simple enough to permit manual computation. It provides a simple way to predict interior daylight illumination through skylights and windows. It assumes an empty rectangular room with simple fenestration and shading devices.

The lumen method consists of four basic steps:

1. The exterior illuminances at the window or skylight are determined. These can be calculated as shown in the above section "Daylight Availability."

2. The net transmittance of the fenestration reduces the amount of light that reaches the interior of the room. It includes the transmittance of the glazing, the light loss factor, and other factors that may be required, depending on the sophistication of the fenestration controls used.

3. Coefficients of utilization are ratios of interior to exterior horizontal illuminances. For the lumen method for toplighting the coefficients provide the average daylight illuminance on the workplane. For the lumen method for sidelighting, coefficients give the illuminance at five predetermined points.

4. The interior illuminance is calculated by taking the product of the factors determined in the first three steps.

The procedures for determining the net transmittance and the coefficient of utilization differ for toplighting and sidelighting. If both types of systems are being employed, the illuminance can be computed for each and the illuminances added to give the combined effect.

The exterior horizontal illuminance is the sum of the illuminances from the sun and sky. These are determined using the procedures given in the above section "Daylight Availability."

The net transmittance is also affected by the shape of a skylight, multiple layering, the presence of a skylight well, the presence of louvers or other shades, and light loss factors.

The procedure described here provides for shades, drapes, solar film, or other simple daylight controls on or at the fenestration. It does not provide for horizontal or vertical window blinds, nor for exterior elements such as sidewalks, streets, other buildings, and overhangs. A more elaborate procedure is available to take account of such elements. Superposition is used to obtain the final interior illuminance at a reference point due to multiple sets of daylighting apertures. For instance, the illuminance from the sky and ground are calculated separately and added together to determine the combined effect. The lumen method does account for direct sunlight entering into the room cavity.

The exterior vertical illuminance Exv is the illuminance on the vertical aperture, excluding direct sunlight. For simple exterior situations, that is, with no obstructions, this illuminance is from the sky and ground. That portion due to the sky can be determined using the procedures in the above section "Daylight Availability." The illuminance on the vertical aperture due to the ground can be determined using the method of configuration factors (see Chapter 9, Lighting Calculations), in which exitances and configuration factors are used to calculate the illuminance produced at a point by a large diffuse source.

16.4.3. The Daylight Factor Method :

The daylight factor method is a low-precision procedure for determining the illuminance at any point in an interior space produced by a sky with a known luminance distribution. Direct sunlight is excluded. The method is generally used with uniform or CIE overcast skies. It is used in northern Europe, where overcast skies predominate, and has some application in North America as well. Daylight factor (DF) is the ratio of the illuminance at a point on a plane, generally the horizontal work plane, produced by the luminous flux received directly or indirectly at that point from a sky whose luminance distribution is known, to the illuminance on a horizontal plane produced by an unobstructed hemisphere of this same sky.

There are three ways in which daylight may reach a point on a horizontal plane within an interior space . The sky component (SC) is due to daylight received directly at the point from the sky. The externally reflected component (ERC) is due to daylight received directly at the point from external reflecting surfaces. The internally reflected component (IRC) is due to daylight reaching the point after one or more inter-reflections from interior surfaces. The daylight factor is the sum of the three components. In simple interior environments, daylight factor can be determined by hand calculation methods using tables of pre-calculated components for typical geometries. These environments are usually rectangular rooms with a wall of windows. Daylight factors from individual windows can be added to produce the daylight factor due to all the windows.

16.4.4. Sky Component of Daylight Factor :

The sky component is due to flux reaching the point directly from the sky through the window. It is the illuminance at the point due to the window, divided by the horizontal illuminance produced by the entire sky. Values have been calculated and tabulated for various sky luminance distributions. Figure 8253 is such a tabulation for the CIE overcast sky, a window transmittance of 0.85, and point located a distance q perpendicularly away from a lower corner of the window.

16.4.5. Externally Reflected Component of Daylight Factor:

The externally reflected component is generally small and is usually roughly approximated. To obtain its value for the CIE overcast sky, the obstructed sky component (obtained in steps 6 to 10 above) is multiplied by 0.2 if it is less than 20, or by 0.1 if it is greater than 20.

16.4.6. Internally Reflected Component of Daylight Factor:

The procedure for obtaining the internally reflected component is based on the theory of the integrating sphere and the concept of split flux, namely that the internally reflected flux reaching the point in question is composed of two parts, a component reflected first from the room cavity above the workplane and a second component reflected first from the floor cavity.

Values of minimum internally reflected component of daylight factor can be tabulated for various room sizes, surface reflectances, and amount of window area. Values for a room of 36 m2 (390 ft2) floor area, 3 m (10 ft) ceiling height, and 70% ceiling reflectance are shown in Figure 8-26. With a precision appropriate for the daylight factor method, these values of minimum internally reflected component can be modified for different floor areas and wall reflectances, different ceiling reflectances, and average internally reflected component.

16.4.7. Approximate Average Daylight Factor:

Very often the average daylight factor on a horizontal reference plane, usually the work plane, is desired. This can be obtained from the following empirical expression:

$$ADF=f(\tau , Ag, As, \rho, \theta)$$

where

ADF = average daylight factor, in percent,

τ = the decimal transmittance of the glazing,

Ag = the net glazing area,

As = the total interior surface area, including windows, in the same units as Ag,

ρ = is the area-weighted average reflectance of all interior room surfaces, including windows,

θ = the angle in degrees in the vertical plane subtended by the portion of the sky that is visible from the center of the window.

Experience has shown that when ADF is 5% or greater, an interior space will appear to be well lighted. When the ADF is less than 2%, the interior space will seem dimly lighted.

16.4.8. Comparison and Accuracy of Methods :

The utility of computational methods for daylighting depends on the information required, the complexity of the daylighting system, and the stage in the design process at which computations are being performed. Methods that give average illuminance for typical sky conditions can be useful early in the design process when alternative strategies are being evaluated. The relative simplicity of these methods can not only help make clear what the lighting will be like in the space but also reveal changes to the design that yield improvement.

Later in the design process, detailed calculations are often necessary to verify illuminances at points and luminance ratios. In this case, insight into how the design functions is not revealed by the computational method itself but by the results it gives, that is, illuminances and luminances. The most complex methods are required to produce computer visualizations of daylighted spaces.

The accuracy of these computational methods depends on the nature and extent of the assumptions they make, and on the accuracy of the data used. Predicting absolute levels of illuminance in daylighted interiors is difficult and often unnecessary, since the amount of light getting into a building will depend on the availability of daylight; often the ratios are what is important. Reasonable accuracy in the ratio between interior levels and exterior availability can be expected from most physical models and computational models. Ten percent is achievable in a carefully made physical model or an accurate computer model based on physical principles and an accurate description of the geometry of the space.

16.5.DESIGN METHODS AND EVALUATION TECHNIQUES

Daylighting designs may be evaluated throughout the design stages by manual methods, scale model photometry, and computer simulation.

16.5.1.Shading Mask and Sun Path Diagram :

A shading mask, when combined with a sun path diagram, can be used to determine several important metrics of daylighting efficacy, including hourly and annual solar exposure of fenestration; degree of shading provided by trees; effects of overhangs, fins, or other architectural features; and solar penetration. Successful construction of a shading mask depends on an accurate determination of the relevant profile angle.

The performance of most models is evaluated under both clear and overcast sky conditions. Artificial sunlight is created with a nearly parallel beam electric light source. The variation in solar angles can be reproduced either by moving the "sun" in an arc around the model or by inclining the model on a tilting heliodon table. For quantitative sun studies, the CIE standard clear-sky component also must be simulated. If the clear-sky component is not represented, the sun study is limited to qualitative evaluations of shading angles, sunlight penetration, and glare, which are usually documented visually, photographically, or on video.

The overcast sky condition is simulated by reproducing the luminance distribution of the CIE standard overcast sky inside a model testing room. The daylighting model is placed inside the room and illuminance measurements are taken with a series of photocells at selected locations inside the model. The photocells are usually connected to a lighting logger or computer. The measurements are used to generate interior daylight illuminance contours and to estimate potential electric lighting energy savings from daylighting control systems.

However, photometry requires the use of special-purpose equipment, and illuminances can be determined only for the sky conditions under which measurements are made. They may not be representative of average conditions, because instantaneous sky conditions can vary considerably from longterm averages.

16.5.2.Considerations in Using Photometric Instruments :

Because of the short-term variability of daylight, it is usually necessary to use sensors connected to a data logger with recording capability. An alternative is the use of artificial skies and suns, although only a few such facilities exist, mostly at universities or research institutions. Artificial skies and suns also have limitations.

Some factors contributing to error in scale model photometry are substantially under the control of the user, including relative calibration of sensors, surface reflectances, and the fidelity with which the model replicates the space and fenestration of interest (although this can become quite difficult with complex fenestration systems). Other factors to consider are listed below.

16.5.3.1Photocell Leveling: At the rear of deep sidelighted spaces, where much of the light striking a photocell does so at an oblique angle, small errors in leveling a photocell may produce large errors in illuminance measurements; for an incidence angle of 85°, a sensor misalignment of 2° will result in an error of 40% for the sky component.

16.5.3.2 Photocell Size : A given sensor has a different view of the sky in a model than in a fullscale space. Where illuminances are changing rapidly and by large amounts (for example, close to a window without shading controls), significant error may result.

16.5.3.3. Sensor Placement : While it is not difficult to place photocell faces with sufficient accuracy for most conditions, small placement errors in models result in large errors where flux gradients are steep.

16.5.3.4. Effects of Space Contents : Space contents, such as sensor holders in scale models, may increase internal reflections and lead to significant overestimates. Such holders should be painted matte black unless their luminous characteristics correspond to features that would exist in the proposed design.

16.5.3.5 Measurement of Sky Conditions :

It is generally necessary to make measurements of the total illuminance on an unobstructed horizontal surface (the global illuminance) simultaneously with interior measurements as a record of daylight availability. Other important measures are the diffuse illuminance on an unobstructed horizontal surface and the zenith luminance. The most basic means of determining the diffuse illuminance is screening a sensor with a shadow band and using a correction factor to compensate for the diffuse daylight obstructed by the shadow band. It may also be useful to record daylight on vertical planes of interest, usually facing one or more of the cardinal directions, which necessitates the use of screening devices to cut off ground-reflected light.

16.5.3.6. Computer Simulation :

Computer-based simulation methods for daylighting evaluation offer flexibility that scale-model photometry and manual methods sometimes cannot. They are especially valuable when the complexity of the building would make a scale model too costly to construct or when there is the need to evaluate a variety of glazing options. Computer-based simulations provide a convenient means of parametrically evaluating designs in comparison to other design alternatives. Computer programs are readily available for common computer hardware. They can calculate workplane illuminance, daylight factors, surface luminance, a variety of glare and illumination quality, and performance metrics, and often can produce realistic color renderings. The procedures used in these programs are described in the section "Computer Calculations."

Analysis of sunlight penetration and fixed shading can be carried out with many CAD programs that provide shadowcasting as part of their rendering features. For calculation of illuminances, dedicated lighting software with daylighting capability is available.

16.6.DAYLIGHTING DESIGN CONSIDERATIONS

16.6.1 Developing Goals :

The earlier in the design process that daylighting is considered as a fundamental, form-giving component of building design,63 the greater the building benefits from the use of daylighting features.

The most successfully implemented daylighting design involves broad agreement among all design disciplines as the goals and features of the building are developed. The provisions for daylighting are affected by decisions pertaining to many other building parameters. For example, the installation of dimmable lighting control systems may provide only minimal savings if heavily tinted glazing, specified to control heat gain and glare, excessively reduces the admission of all daylight, even if there is no direct sun.

Daylight apertures serve two distinct purposes: allowing views to the exterior and providing functional ambient light for the interior. Frequently the design considerations for these functions conflict. For example, view windows occur low in the wall at eye height, while functional daylight apertures distribute light most evenly when they are placed high in the wall. It is important to identify the role and function each aperture is intended to perform, which may require providing separate apertures for view and daylighting.

16.6.2. Daylight Penetration and Glare Control :

Glare control is a major consideration in daylighting because of the intensity of the source (especially in the case of direct sunlight) and because, in many situations, achieving spatially balanced illumination is difficult with a source that is unevenly distributed through the space (for example, sidelighting of deep-plan buildings). A rule of thumb is that the distance of useful daylight penetration with sidelighting is usually not more than twice the window head height. Room furnishings in particular may drastically reduce daylight penetration in sidelighted spaces.

Advanced daylighting designs manipulate the daylight entering the space to carefully control the distribution of light and the balance of surface luminances under a variety of sun angles and sky conditions. The effects of daylight on the luminance and illuminance ratios in a space can be studied with daylight models, computer simulations, and full-scale mockups.

16.6.3. Control of Glare from Direct Sunlight :

Designs should be developed such that direct sunlight is, or can be, excluded from critical task areas. Sources of direct specular reflection should also be identified and eliminated, or their reflectances reduced as much as possible. An exception is if the reflecting surface is used as part of a daylight harvesting feature such as a lightshelf. In this case, care should be taken to ensure that the reflected sunlight is sufficiently diffused and strikes surfaces that are not in the direct line of sight of building occupants.

16.6.4. Control of Glare from Diffuse Skylight :

Glare increases substantially with larger views of the upper portions of the sky. This can be avoided by limiting the height of the view window head in critical task areas, by screening upper window areas from view, or by placing daylighting apertures high enough to be out of the normal field of vision. The task also may be arranged so that the user does not face the window, although this may conflict with user view preferences. Glare can also be reduced by using light colors on interior surfaces, especially near windows, to reduce luminance ratios.

16.7 EVALUATION OF DESIGNS:

A logical sequence in evaluating a proposed design is the following:

1. Evaluate the balance of luminances and illuminance levels through the space. Surface luminance balances (or imbalances) and illuminance levels are major factors in lighting quality and mood, task performance, and associated comfort.

2. Determine whether sunlight will fall on any areas where it should be excluded, and address any resulting problems by changing the daylighting apertures or providing fixed or movable controls.

3. Determine whether sky glare will be a problem, and either make adjustments to the design to control glare or provide fixed or movable controls.

4. Evaluate the performance of the daylighting system acting in concert with the electric lighting, using illuminance, luminance, and energy use as metrics. Assess the pattern of sunlight in spaces where it is being provided as an amenity.

For a minimum investigation at the conceptual stage, daylighting should be evaluated with solar altitudes corresponding to the solstices, around December 21 and June 21, and one equinox, around March 21 or September 22. A range of sky conditions should be tested, including, at least, the extremes for a particular orientation, such as solar noon and the earliest and darkest hours when daylighting occurs for a south-facing facade.

It is important that designs be checked for critical conditions when sunlight may enter spaces. For instance, at northern latitudes, direct sunlight may strike the north-facing facades of buildings on summer evenings. In the winter, the sun will be low in the sky, resulting in deep penetration of shading systems and sidelighted spaces. Nearer the equator, the high midday summer sun can more readily enter spaces through skylights.

16.7.1. Assessment of Daylighting Effects on Energy Use :

Daylighting apertures can have either a positive or negative impact on the overall building energy performance. Direct solar gains into the building interior can require additional cooling, whereas electric lighting load reductions can have a direct electricity cost savings as well as an indirect reduction in cooling loads. A well-designed daylighted building can provide significant improvement in overall building energy performance when these impacts are balanced for the building type, use, and location.

Use of daylight in buildings can reduce the need for electric lighting during the day while maintaining sufficient illuminance levels. Because the IR heat component of daylight can be excluded from the building with spectrally selective, low-emissivity glazing and low U-value glazing assemblies, the result is a building that places a lower demand upon the cooling system. In heating-dominated climates daylighting permits the maximum benefit from passive solar heating and can shift heating costs from electrical sources to more economical gas sources. The Illuminating Engineering Society of North America (IESNA) and the American Society of Heating, Refrigerating, and AirConditioning Engineers (ASHRAE) have produced an energy-efficient design guide,which provides procedures for estimating the contribution of daylighting to energy conservation.

16.7.2. Integration of Daylight and Electric Lighting :

The integration of daylight and electric light begins with an understanding of the overall intention of the lighting design. The designer must decide what roles daylight and electric lighting will play in meeting the lighting objectives. Daylight's contribution across the space at different times of the day and year must be determined. This may include evaluating daylight surface luminance ratios, illuminance levels and contours, daylight zones, temporal variations in daylight availability (direction and intensity), and how daylight distribution changes with adjustable shading and fenestration elements.

The electric lighting may be designed to contrast with the daylight, as in an atrium that dramatically changes moods as it goes from a predominantly daylighted, daytime ambiance to a predominantly electrically lighted night time scene. In many daylighted buildings, however, the two components are designed to work together in a task/ambient approach, where daylight provides the ambient lighting (supplemented by electric light as necessary) and electric light provides the task and accent lighting. In this case, the ambient electric lighting system is designed to reduce daylight gradients and to balance luminances in the space. The ambient electric lighting must be circuited and zoned to follow the daylight zones. This is accomplished by aligning the electric lighting circuits parallel to the daylight contours. Ideally, the ambient electric light is delivered to the same surfaces as the daylight so that the transition between daylight and electric light is smooth.

16.7.3. Electric Lighting Control :

If ambient electric lighting has been designed to correspond with daylight zones, an automatic control system can be implemented to turn off or dim the electric lights in response to daylight availability. Automatic control is accomplished by a photocell that evaluates the light level and sends a signal to a control unit to dim or switch the electric lights to maintain a preset target level. Automatic control provides more predictable performance than manual control, but control zones must be sufficiently small and matched well with daylight availability to achieve light level consistency.

For sidelighting, the photocell usually is placed on the ceiling looking down at a representative task area; for skylighting, it is frequently placed in a skylight looking up at the available daylight. Switching of electric lighting in response to daylight produces abrupt changes in the light level when the switching occurs. This can be reduced by using multiple switching steps. Dimming is more expensive, but it is also more gradual and acceptable to building occupants.

16.7.4. Commissioning :

In order for a well-designed daylighting system to provide the benefits expected by owners and occupants over time, the system should be commissioned after installation. Commissioning can be defined as a systematic process that ensures that all elements of the daylighting system perform interactively and continuously according to documented design intent and the needs of the building owner. Most daylighting systems consist of a fenestration element, typically with some operational elements to modulate daylight and glare, and an electric lighting control system, which may consist of a sensor, a controller, and a dimming ballast. At a minimum, commissioning implies verification that the proper equipment was installed in a manner that meets documented installation requirements. In this context, commissioning could be completed by the general contractor. However, commissioning more typically includes calibration of any electrical or mechanical sensors such that they produce the desired control signal to the system under the specific conditions of the room design and over a wide range of incident daylighting conditions. This often requires special skills and equipment, such as a photometer to set proper light levels.

Experience to date suggests that commissioning of daylighting systems is commonly ignored and, when it is done, is often fraught with technical and procedural difficulties. Commissioning criteria should be specified by the designer and/or provided by the manufacturer. In most cases, commissioning activities should be carried out in spaces that are furnished and ready for occupancy. Commissioning must be completed for each unique physical zone or control system zone and for each building orientation.

Operationally it is useful to think about the daylighting system in two elements: fenestration controls and lighting controls. Commissioning of fenestration controls can be divided into three cases, each with its own specific requirements and procedures:

1) systems with fixed elements that may need adjustment after installation, such as some lightshelves;

2) systems with manually operated controls, such as interior venetian blinds, and

3) systems with automated controls, such as exterior motorized louvers. Once the performance of the fenestration systems is verified, the lighting control system can be commissioned. The placement and orientation of the photosensor must be verified for optimum operation. The light sensor and controller must be adjusted to provide the desired light level at the task location. The specifics of this procedure vary with control system type (open versus closed loop control) and hardware selection.

16.8. DAYLIGHTING SYSTEMS

16.8.1. Unilateral Sidelighting :

This design lends itself to continuous fenestration and curtain wall construction. To avoid large ranges in daylight illuminances (greater than 25:1), the distance from the window wall to the inner wall should normally be limited to twice the window head height with clear glazing. For this reason, window heads are often placed close to the ceiling, although the resulting increase in the view of the sky also increases glare. Deeper spaces may be created if additional lighting opposite the window wall is used to balance illuminances.

16.8.2. Window with Overhang :

Overhangs may be used to reduce sunlight penetration in latitudes where the sun is high in the sky during the times that spaces are occupied. This reduces the view of the upper portion of the sky and provides a less drastic range of illuminances across a space. However, overhangs also reduce daylight penetration, although this may be offset to some degree by the redirection of ground-reflected light into the space.

16.8.3. Window with Blinds :

Venetian blinds can be effective in controlling the entry of sunlight, reducing sky glare, and redirecting light to the ceiling. They can provide a shading effect equivalent to a very substantial overhang. Building occupants claim to enjoy the control offered by blinds, but they tend to adjust blinds infrequently.

16.8.4. Split Window with Upper and Lower Blinds:

This allows for different adjustments for the upper and lower portions of the glazing. For instance, daylight can still be admitted deep into the space when the lower blinds are closed to exclude sunlight from a task area.

16.8.5. Split Window with Low-Transmittance Upper Panel :

This reduces glare from the upper portion of the sky while not distorting the view of the ground plane.

16.8.6. Window with Vertical Shading Elements:

Devices such as fins are effective sun controls on east and well walls. Combinations of vertical and horizontal elements (for example, egg crate shades) as sun controls are common in southern latitudes.

16.8.7. Window with Light Shelf:

Light shelves are fixed exterior and interior shading systems used in combination with glazing placed above the lower glazing used for viewing in sidelighting systems. By screening the upper portion of the sky, they allow the use of higher window heads, providing deeper and more uniform daylighting while eliminating the glare that would normally accompany the use of tall windows.

16.8.8 Bilateral:

Bilateral daylighting balances the admission of light. This system permits doubling of the room width receiving light that is possible with unilateral daylighting. The second set of windows often occupies only the upper part of the wall. At least one set of windows is exposed to the sun, necessitating glare control. Sloped ceilings, sometimes employed with this design, have little effect on the quantity or quality of illumination except where they can allow a higher window head.

16.8.9. Roof Monitor:

This daylighting system is most frequently used in industrial buildings where a central high bay is set between two lower flanking areas.High-reflectance roof surfaces below the monitors increase interior illuminances.

16.8.10. Clerestory:

Additional windows on the roof, facing the same direction as the main side-lighting window, aid in overcoming the daylighting penetration limitations of the unilateral section .

16.8.11. Staggered Building Sections:

Staggered building sections can allow for deep penetration of daylight along with greater flexibility in the layout of spaces. They are a variation on combinations of clerestory lighting and other sidelighting systems.

16.8.12. Sawtooth:

This fenestration is used principally in large industrial buildings. Slanting the windows to face the sky increases the potential daylighting contribution, but this may be offset by increased dirt collection on the glazing. Heat gain may also increase.

16.8.13. Skylights:

Skylights assume many forms, including domes, panels with integral sun and luminance control, panels of fiber-glass-reinforced plastic, and louvers for heat and glare control. Skylight detailing requires special attention to prevent moisture penetration and dripping due to condensation. Operable skylights may also provide ventilation and cooling .The use of skylight wells, splayed at about 60° and matte-white finished, is essential if a uniform, glare-free daylight distribution is to be achieved.

16.8.14. Atria:

These are large-area daylighting sources that have several forms, such as ridge-type sheds, pyramids, and domes. Because of the large area, lower-range (10 to 25%) light transmissions are used. Translucent sandwich panels with highly diffusing glass fiber-reinforced polymer faces are especially suitable for diffuse shadow free daylighting, even under direct sun conditions. These panels provide excellent control of light and heat.

16.9. Solar Lighting Systems:

Solar lighting systems include systems of reflectors or other optical elements intended for steering or redirecting direct solar flux with relatively minor contributions from diffuse sky light. Tubular skylights are representative of such systems, as are a variety of additional schemes including mirrored louvers in clerestory windows, mirrored louvers in otherwise conventional skylights, and more complex systems using sun-tracking, concentrating, and piping subsystems.

16.9.1. Material and Control Elements :

A variety of materials are used in daylighting systems. Transmittance data for several of these materials are provided in. It should be noted that the transmittance of materials is a function of the incident angle of the light.

16.9.2. Transparent (High-Transmittance) Materials:

These transmit light without appreciably changing its direction or color; they are image preserving. Common types are sheet, polished plate, and float and molded glass, as well as some rigid plastic materials and formed panels.

16.9.3. Transparent (Low-Transmittance) Materials:

Low-transmittance (gray) glasses and plastics offer luminance reduction that increases as their transmittance decreases. During daylight hours, the ability to view into a room is reduced. At night, the view into a room is apparent while the view from a room to the outdoors is reduced. Lower transmittances, below 0.5, can give a gloomy appearance to daytime outdoor views.

16.9.4. Angular Dependence of Transmittance:

The transmittance of glazing materials is a function of the incident angle. Designers can reduce or increase solar gains by orienting the glass of toplighting systems. For instance, glazing tilted at a steep angle to the south admits more direct solar radiation in winter than horizontal glass because of the lower incident angle of sunlight.

16.9.5. Electrically Controlled Glazings :

These have transmittance properties that are a function of applied voltage. Currently available products require the application of a low voltage to render them colored. They become clear when the voltage is switched off.80 Recent advancements in the development of electrochromic technologies have resulted in glazing assemblies that can switch between 7 and 68% transmittance in two to three minutes.

16.9.6. Translucent Diffusing Materials :

The amount of diffusion in materials varies over a wide range, depending on the material and its surface treatment. Generally, transmittance and luminance decrease as diffusion increases. The luminance of highly diffusing materials is nearly constant from all viewing angles (Lambertian). Diffusing materials include translucent and surface-coated or patterned glasses, plastics, translucent sandwich panels,81 and diffusing glass blocks.

16.9.7. High-Reflectance, Low-Transmittance Materials :

Reflective glasses and plastics provide luminance control by having high exterior reflectances. These materials act as one-way mirrors, depending on the ratio of indoor to outdoor illuminance. Their low transmittance often gives outdoor areas an overcast or dark appearance, even on sunny days. Some selectively admit visible light while reflecting IR wavelengths that would otherwise add to the cooling load.

16.9.8. Directional Transmitting Materials :

These include glasses and plastics with prismatic surfaces that are used to obtain directional control of light and luminance. Most of these use the exterior or interior structure of the material to totally internally reflect direct radiation from the sun. In skylights and hollow light pipes, they can reduce throughput in summer and enhance it in winter. In windows under clear sky conditions, they can redirect radiation onto the ceiling and hence deeper into the room while reducing glare close to windows. Recent examples include laser-cut panels and polymer sheets with internal cavities and smooth external surfaces.

Many of these systems interfere with the view through a window and thus are often used above the line of sight. Lasercut panels used in a flat configuration (e.g., as louver panels) allow preservation of view. Thin films for windows can attenuate direct radiation from high angles while preserving view and admitting most sky radiation from lower angles. These are good for glare control. All of these systems are often referred to as angular-selective, since their effect on radiation strongly depends on the direction of incidence.

16.9.9. Superglazings :

High-performance glazings use multiple cavities, often separated by films and usually filled with special gases. They have low-emissivity coatings on one or more glass surfaces to reduce heat transfer.

16.9.10. Specularly Selective Transmitting Materials :

These include the various heat-absorbing and reflecting materials that are designed to pass most visible radiation but absorb or reflect a portion of the IR radiation, which would otherwise contribute to cooling loads. Absorbed heat is reradiated indoors and outdoors in approximately equal proportions. Low emissivity glass comes under this general classification because it selectively admits the visible portion of the spectrum while rejecting the far IR. However, the term "specularly selective glazing" is usually reserved for glass that transmits the visible while rejecting near (and far) IR radiation. The appropriateness of these types of glazing strongly depends on building use and site climate.

16.9.11. Louvers :

Louvers may be fixed or adjustable, horizontal or vertical. They are capable of excluding direct sunlight and reducing radiant heat while reflecting sun, sky, and ground light into the interior. In the case of fixed louvers, the spacing and height of the slats should be designed to exclude direct sunlight at common sun angles. Overhangs for sun control are often made with louver elements so that light from the rest of the sky can reach the windows. Louvers are also employed in top-lighting arrangements, sometimes with two sets of slats set at right angles to form an egg crate. Matte textures and high reflectances should be used where possible.

16.9.12. Shade and Draperies. :

These include opaque and diffusing shades and draperies for excluding or moderating daylight and sunlight, to darken a room, as for projection.

16.9.13 Landscaping. :

Trees can be effective shading devices for buildings of low elevation if placed in an appropriate position with respect to windows. Deciduous trees provide protection against glare due to direct sun during the warm months but transmit sunlight during the winter.

16.9.14.Exterior Reflecting Elements :

Reflective pavements and similar surfaces increase the amount of ground light entering the building. Reflecting materials or finished roofs below windows have the same effect.

16.10.**DAY LIGHT INTEGRATION**

16.10.1 Day light integration :

Daylight availability depends on both the light received directly from the sky and light reflected from interior surfaces. Generally in pharmaceutical manufacturing unit the scope of daylight is less as all rooms are air packed. But in administrative block like in office, lighting is optimized by daylight integration. A daylit official room uses light from the sky for daytime illumination, effectively reducing the need for electric light. The amount of daylight that comes into a room depends upon the area and location of the window and the amount of the sky the window "sees." The distribution of that light is a function of the window's shape and location in the window wall and the proportions of the room, room reflectivity, and obstructions within the space.

Task-ambient electric lighting design strategies work well with day lighting because room ambient light levels, lower than task lighting requirements, are easy to meet with daylight. Ambient daylight should be supplemented with task electric lighting to increase lighting levels where specific tasks are performed. To take advantage of available daylighting, electric lighting should be designed and controlled either by dimming, or by switching off completely. A light sensor and continuous or step dimmer can maintain ambient illumination levels at a constant value, based on the amount of daylight in the space.

As sky conditions change, automatic, dimmable, indirect lighting luminaires make an unnoticeable transition from electric lighting to daylighting and back. Thus it can be predicted that a sufficient amount of energy can be saved if the control of artificial light is integrated with daylight, with daylight linked sensor.

For daylight integration design steps are given below:
1. Exploration of daylight availability from database
2. Selection of suitable daylighting system
3. Selection of type and mounting of sensors
4. Luminaire grouping or scheduling
5. Prediction of the energy saving

As daylight has very dynamic characteristics thus for daylight integration some sensor must be used which is capable to produce a constant light by sensing the presence of daylight and by diming artificial light.

16.10.2. Usage of occupancy sensor:

Occupancy sensor ensure light in the working zone only when the zone is occupied by somebody to work .

In a pharmaceutical administrative building these are helpful in for example in the following spaces:Intermittently used office areas like-conference hall, meeting rooms, cabins, workstation

- Toilets and washroom facilities

- Store rooms
- Reception and other common areas
- Areas where lighting is zoned

Occupancy sensors can be used to lower the light level for the corridors at night time which can be an effective cost savings measure. However it is imperative to maintain minimum light level so as not to compromise with health and safety standard.

CHAPTER –17

SOLAR PANEL ORIENTATION AND POSITIONING

17.1 SOLAR PANEL ORIENTATION AND POSITIONING

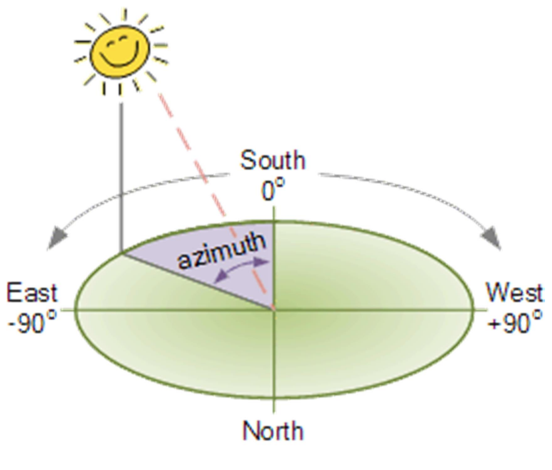
Solar power offers many advantages in the generation of electricity. It has zero raw fuel costs, unlimited supply and no environmental issues such as transport, storage, or pollution. Solar power is available everywhere, even on the moon. But to get the most out of a solar panel or solar array, it has to be pointed or "orientated" directly at the suns radiant energy because as we know, the more surface area that is exposed to direct sunlight, the more output the photovoltaic panel will produce, but here lies the problem [32].

While the photovoltaic solar panel may be perfectly aligned to receive the suns energy, it is a stationary object being fixed to either a roof or mounted directly onto a frame. With regards to a solar panel, the sun however is not in a stationary position and is constantly changing its position in the sky relative to the earth from morning through to night making the correct solar panel orientation difficult. So the challenge in getting the maximum benefit of free solar power is to ensure that a photovoltaic solar panel or a complete PV array, is correctly orientated and positioned with regards to the direct sunlight coming from the sun at all times of the day. As well as the "solar panel orientation", the number of hours of sunlight a day the solar panel receives as well as the intensity or brightness of the sunlight is also important.

For example, when the sun is lower in the sky during the winter months the solar panels orientation needs to be more vertical as the solar radiation passes through more atmosphere to reach the solar panel and therefore its intensity is reduced by the scattering and absorption effect of atmosphere and clouds. In the summer months when the sun is higher in the sky the solar radiation is more direct and therefore stronger as it has less distance to travel through the Earth's atmosphere so the solar panel orientation is more horizontal.

17.1.1. Solar Panel Azimuth and Zenith Orientation

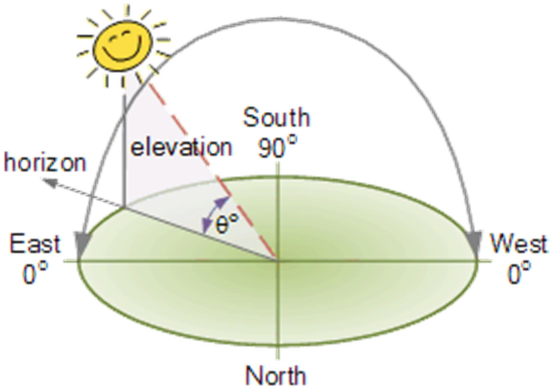
Solar PV modules and panels work best when their absorbing surface is perpendicular to the suns incoming rays. The position of the sun in the sky can be plotted using two angles, azimuth and zenith and the angle of the solar panel orientation relies upon these two values.



Azimuth – This is the compass angle of the sun as it moves through the sky from East to West over the course of the day. Generally, azimuth is calculated as an angle from true south. At solar noon which is defined as an azimuth angle of zero degrees, therefore Azimuth = 0^o, the sun will be directly south in the northern hemisphere and directly north in the southern hemisphere [32].

Solar azimuth angles to the east of due south are negative in nature, with due east having an azimuth angle of -90^o. Solar azimuth angles to the west of due south are positive in nature, with due west having an azimuth angle of +90°. In general however, the azimuth angle required for the correct solar panel orientation varies with the latitude and time of year.

17.1.3. Solar Panel Orientation – Zenith Orientation



Zenith – This is the angle of the sun looking up from ground level or the horizon. The zenith angle of the sun varies throughout the day in the form of an arc with the sun reaching its maximum elevation (also called solar altitude) around midday. The suns elevation is defined as 0° at sunrise and sunset, and 90° at midday when the sun is directly overhead.

However, the elevation of the sun at midday is different between the summer solstice and the winter solstice representing the longest and shortest days of the year as the suns path forms an arc across the sky representing either spring or autumn.

The solar elevation and azimuth over the period of a full year can be plotted onto a solar chart. A sun chart enables you to locate the position of the sun at any time of the day, during any month and for any location making solar panel orientation much easier. Pre-made sun charts or sun path diagrams, can be purchased, downloaded from the internet or constructed using graph paper for any location on the earth surface using the same principal as the sun dial in the garden.

On a sun chart the zenith scale is generally represented as a series of concentric circles spreading out vertically from left to right, while the azimuth scale is set around the perimeter of the chart. The azimuth angle is read by setting a straight edge from the centre of the chart to the intersection of the required hour and date path lines and noting where it cuts the charts perimeter. Different charts are required for different locations.

In Northern Europe, at a latitude of about 50° North, (London) the sun's path is 262° wide at the summer solstice and the maximum solar zenith (elevation) is 62°. At the winter solstice, the sun's path is only 104° wide with the maximum solar zenith reducing to about 15°. Likewise in Southern Europe, at a latitude of 40° North (Spain), the sun's path is 245° wide at the summer solstice and the maximum solar zenith is 72°. At the winter solstice, the suns path is 120° wide and the maximum solar zenith is 25°.

These are all those datas of European countries but for india or more preciselely Kolkata that data will be changed but all those procedure will be same.

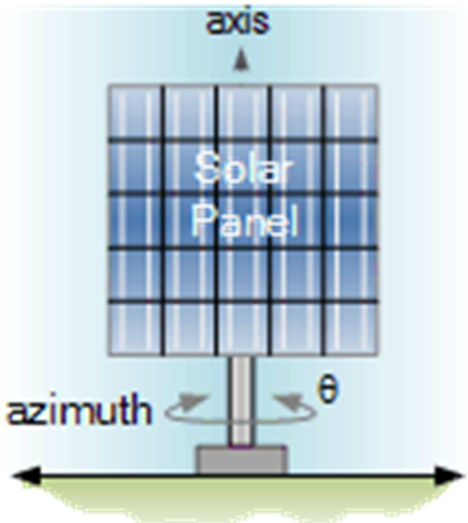
17.1.4. Solar Panel Orientation and Tilt

So we can see that as well as moving across the sky (solar azimuth), the sun also moves up and down (solar zenith) throughout the year making it difficult to provide a fixed solar panel orientation. Then for maximum conversion of sunlight into solar electricity, solar panels need to be mounted at an angle for them to point directly at the sun. Depending upon how the panel is mounted, it may be kept at a permanent angle, or adjusted throughout the year to take full advantage of the suns solar energy. Adjustment of a static mounted photovoltaic solar system can result in 10% to 40% more power output yearly making a considerable difference to the charging time for batteries.

17.1.5. Solar Panel Orientation

Solar Panel Orientation refers to our azimuth setting. Most of the energy coming from the sun arrives in straight line. A solar panel or solar array will capture more energy if it is facing directly at the sun, perpendicular to the straight line between the position of the panels installation and the sun.

Figure.17.1: Solar Panel Orientation



Then we need to have the solar panel turned towards the terrestrial equator (either facing south in the northern hemisphere, or north in the southern hemisphere) so that during the day its orientation allows the panel to catch the greatest possible amount of solar radiation possible.

There are different ways of achieving the required solar panel orientation. We could just point the PV panel or array due south or north using a compass, find the central angle between the summer and winter azimuth settings or more accurately position the panels relative to the central solar noon.

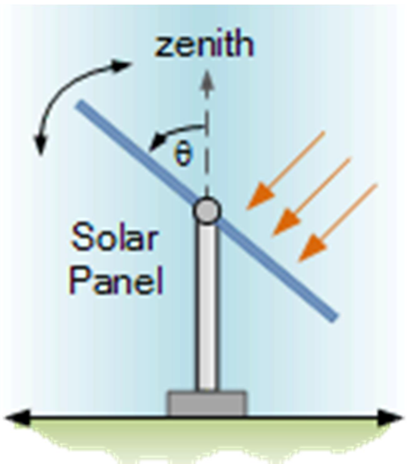
The solar noon refers to the highest position of the sun as it arcs across the sky and is different to 12:00 o'clock noon or midday as a measurement of time. Generally the solar noon occurs between 12:00 o'clock and 14:00 o'clock depending upon the location.

It is very important when positioning and aligning a solar panel or array that no part of a solar panel or solar array are ever shaded from the sun as we need 100% solar radiation across the panel. Check that the elements that surround the panel or array (trees, buildings, walls, other panels, etc.) to be sure that they will not cast a shadow on the panels at any time of the day or year.

17.2. Solar Panel Tilt

Solar Panel Tilt refers to our zenith or elevation setting. Once the best azimuth position is found, the next parameter that is key to producing the most solar electricity is the elevation of the PV panel. We saw from our data example above for London, that the maximum height that the sun reaches every day varies, with the maximum angle of the sun on the day of the summer solstice being about 62^{o} and the minimum angle for the winter solstice about 15^{o}.

Figure.17.2: Solar Panel Tilt



For a fixed solar installation, it is preferred that the PV panels are installed with a centralized tilt angle representing the vernal equinox, or the autumnal equinox, and in our example data above this would be about 38 degrees (38^{o}).

However, this tilt orientation is not as critical with regards to the solar panels orientation as even at a tilt angle of nearly 45 degrees (45^{o}) with respect to the suns solar rays will still receives more than 75 percent as much energy per unit surface area as it does when it is optimally aligned.

Then a misalignment of up to 15^{o} either positive or negative makes very little difference to a photovoltaic panels output. Ideally, solar panels should be located where they will receive as much sunlight as possible, averaged out during the course of the day and the course of the year.

The solar panel orientation and tilt of a fixed solar PV panel or array can also be optimized for a particular month or season during the year. For example, a solar power system might be designed to produce maximum power output only in the winter months in order to reduce peak electricity costs thus, the system should be installed so that the optimum solar panel orientation and tilt occurs for the maximum winter power output.

One of the most popular fixed solar power systems involves mounting a PV panel, or a set of PV panels, directly onto a steeply pitched roof that faces toward due south (or north) allowing for very little adjustment of both the solar panel orientation and tilt although most mounting brackets and support frames do allow for some small adjustments. Maximizing the power output from a home solar power system is desirable to both increase the solar panels efficiency and reduce the payback time.

But in order to maximize the power output from the solar panels, we need to keep the panels perfectly aligned with the sun. As such, a means of tracking the sun across the sky is required and a PV panel or PV array with tracking ability will yearly produce about 25 to 30% more power than one mounted on a roof in a fixed position. Also solar tracking can reduce the number of PV panels required by increasing the conversion efficiency.

17.3. Solar Tracker

Solar Tracker

Tracking the position of the sun in order to expose a solar panel to maximum radiation at any given time is the main purpose of a solar tracking PV system giving the best solar panel orientation at all times of the day. A solar tracking system can track the movement of the sun across the sky from sunrise to sunset creating optimal power output for a longer period and can also accommodate for seasonal changes of the sun direction.

The ideal solar tracking arrangement for a solar panel would be a motor-driven equatorial mount, similar to those used with sophisticated telescopes or satellite dishes. This would allow the PV panel to follow the suns rotational path all day, every day of the year giving it the best solar panel orientation and generating the maximum possible output power.

However, such large motorized tracking systems are impractical for most people, and the cost would be prohibitive for large panels or multi panel arrays. Also, solar trackers cannot be used on a roof installation as they need to be mounted on the ground and have sufficient space around the panel in order for it to rotate. The next best thing is a mount with a single bearing that allows for the panel to be manually orientated and tilted throughout the day if required.

Commercially available solar trackers include single-axis tracking which tracks the sun across the sky during each day at a fixed constant tilt angle. This increases the solar radiation received by up to 25-30% compared to no tracking. Twin or dual-axis tracking, tracks the sun across the sky during each day but also adjusts the tilt angle of the array more in winter and less in summer to accurately locate the position of the sun in the sky. Dual-axis tracking increase the solar radiation received by up to 33-38% compared to no tracking. Sunnier locations benefit more from dual-axis tracking.

Photovoltaic Solar Panels can the be used as single panels on a buildings roof or walls pointing directly due south or due north depending upon their location. While this type of solar panel orientation works fine for most domestic applications, in order to increase efficiency and reduce the payback period the photovoltaic panel needs to produce the maximum amount of solar energy for the maximum amount of time during sunlight hours. While not cheap or viable for small PV panel installations, solar trackers can be used for this purpose often with the benefit of a reduction in the number of PV solar panels required.

In the next tutorial about “Solar Power”, we will look at connecting solar panels together to produce larger Solar Arrays with higher voltages and currents which can then be used to build a typical solar power system

OPTIMUM TILT OF SOLAR PANELS

Figure.17.3: OPTIMUM TILT OF SOLAR PANELS

To get the most from solar panels, you need to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. This page is designed to help you find the best placement for your solar panels in your situation.

This advice applies to any type of panel that gets energy from the sun; photovoltaic, solar hot water, etc. We assume that the panel is fixed, or has a tilt that can be adjusted seasonally. (Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels.

Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere. True north is not the same as magnetic north.

As because we are calculated this total things from Kolkata so the hemisphere will be southern, and all the mathematical derivations will be only for that particular region. If you are using a compass to orient your panels, you need to correct for the difference, which varies from place to place. Search the web for “magnetic declination” to find the correction for your location.

The angle from horizontal should the panels be tilted is the tilt should be equal to the latitude, plus 15 degrees in winter, or minus 15 degrees in summer.

17.3.1. FIXED OR ADJUSTABLE TILT ANGLE

It is simplest to mount your solar panels at a fixed tilt and just leave them there. But because the sun is higher in the summer and lower in the winter, you can capture more energy during the whole year by adjusting the tilt of the panels according to the season.

In short, adjusting the tilt twice a year gives you a meaningful boost in energy. Adjusting four times a year produces only a little more, but could be important if you need to optimize production in spring and fall [32]. You can jump to the section on the best fixed tilt angle, or skip to the sections on two-season or four-season adjusting.

17.3.2. FIXED TILT

If the solar panels will have a fixed tilt angle, and we want to get the most energy over the whole year, then this section is the best part. A fixed angle is convenient, but note that there are some disadvantages.

Use one of these formulas to find the best angle from the horizontal at which the panel should be tilted:

- If the latitude is below 25°, use the latitude times 0.87.
- If the latitude is between 25° and 50°, use the latitude, times 0.76, plus 3.1 degrees.
- If the latitude is above 50°, see Other Situations below.

This table gives some examples for different latitudes. It also shows the average insolation on the panel over the year (in kWh/m^2 per day), and the energy received compared to the best possible tracker.

17.3.3. Adjusting the Tilt Twice A Year

If you are going to adjust the tilt of your solar panels twice a year, and you want to get the most energy over the whole year, then this section is for you.

17.3.4. Adjusting the Tilt Four Times A Year

If you are going to adjust the tilt of your solar panels four times a year, and you want to get the most energy over the whole year, then this section is for you. This would be your situation if you are connected to the grid and can use or sell all the power you produce.

The following table gives the best dates on which to adjust:

Parameters	Northern hemisphere	Southern hemisphere
Adjust to summer angle on	April 18	October 18
Adjust to autumn angle on	August 22	February 21
Adjust to winter angle on	October 5	April 6
Adjust to spring angle on	March 5	September 4

Table.17.1: Adjusting the Tilt Four Times A Year

If your latitude is between 25° and 50°, then the best tilt angles are:

- For summer, take the latitude, multiply by 0.92, and subtract 24.3 degrees.
- For spring and autumn, take the latitude, multiply by 0.98, and subtract 2.3 degrees.
- For winter, take the latitude, multiply by 0.89, and add 24 degrees.

If you want to adjust the tilt of your panels four times a year, you can use these figures to keep capturing the most energy year-round. This table gives some examples:

Table.17.2:Adjustable tilts

Latitude	Summer angle	Spring/autumn angle	Winter angle
25°	-1.3	22.2	46.3
30°	3.3	27.1	50.7
35°	7.9	32.0	55.2
40°	12.5	36.9	59.6
45°	17.1	41.8	64.1
50°	21.7	46.7	68.5

In winter, a panel fixed at the winter angle will be relatively efficient, capturing 81 to 88 percent of the energy compared to optimum tracking. In the spring, summer, and autumn, the efficiency is lower (74-75% in spring/autumn, and 68-74% in summer), because in these seasons the sun travels a larger area of the sky, and a fixed panel can't capture as much of it. These are the seasons in which tracking systems give the most benefit [32].

Note that the winter angle is about 5° steeper than what has been commonly recommended. The reason is that in the winter, most of the solar energy comes at midday, so the panel should be pointed almost directly at the sun at noon. The angle is fine-tuned to gather the most total energy throughout the day [32].The summer angles are about 12 degrees flatter than is usually recommended. In fact, at 25° latitude in summer, the panel should actually be tilted slightly away from the equator.

17.3.6. Tilt Fixed At Winter Angle

If your need for energy is highest in the winter, or the same throughout the year, you may want to just leave the tilt at the winter setting. This could be the case if, for instance, you are using passive solar to heat a greenhouse. Although you could get more energy during other seasons by adjusting the tilt, you will get enough energy without making any adjustment. The following tables assume that the tilt is set at the winter optimum all year long [32]. They show the amount of insolation (in kWh/m^2) on the panel each day, averaged over the season.

Latitude 30° Tilt 50.7°		
Season	Insolation on panel	% of winter insolation
Winter	5.6	100%
Spring, Autumn	6.0	107%
Summer	5.1	91%

Latitude 40° Tilt 59.6°		
Season	Insolation on panel	% of winter insolation
Winter	4.7	100%
Spring, Autumn	5.8	123%
Summer	5.1	109%

CONFUSED ABOUT TILT ANGLES?

A zero tilt angle means that the face of the panel is aimed directly overhead. A positive tilt angle means that the panel faces more towards the equator. In the northern hemisphere that would mean tilting so it faces towards the South. Rarely, the tilt angle can be negative; this means the panel faces away from the equator.

17.4. ASSUMPTIONS

These calculations are based on an idealized situation. They assume that you have an unobstructed view of the sky, with no trees, hills, clouds, dust, or haze ever blocking the sun.

You may need to make adjustments for your situation. For example, if you have trees to the east but not the west, it may be better for you to aim your solar panels slightly to the west. Or if you often have clouds in the afternoon but not the morning, you might aim your panels slightly to the east. The calculations also assume that you are near sea level. At very high altitude, the optimum angle could be a little different.

If you are estimating energy output, remember that temperature affects the efficiency of photovoltaic panels. They produce less power at higher temperatures. Panels vary so you will need to contact your panel manufacturer for their specifications [32].

Don't obsess about the exact angles just because I've calculated them to the tenth of a degree. A difference of a few degrees will make very little difference in the energy you gather.

17.5.. IN THE SCENARIO FOR INDIA

India encompasses 29 states and 6 union territories spread between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude which causes varied climatic conditions across the country. Such varied climatic conditions coupled with varying latitude would affect the solar irradiance between places at same time.Hence in order to reach the country's target of 100 GW from solar energy by 2022, it is important to understand the effect of orientation and positioning of the module at various locations. For this study, the locations are selected based on all the four directions(Ahmedabad in west, Delhi in north, Kolkata in east and Tiruchirappalli in south) [33].

Adjust the facing of your panels by the magnetic declination value in your location. The direction you adjust the panels depends on where you live:

In the Northern Hemisphere:

- If your magnetic declination is east (positive), rotate your panels east.
- If your magnetic declination is west (negative), rotate your panels west.

In the Southern Hemisphere:

- If your magnetic declination is east (positive), rotate your panels west.
- If your magnetic declination is west (negative), rotate your panels east.

CHAPTER – 18

EXPERIMENTAL SETUP

For simulating this experiment at first the Dialux 4.13 have to be open and the page will appear like this which shows in following figure 18.1.1.

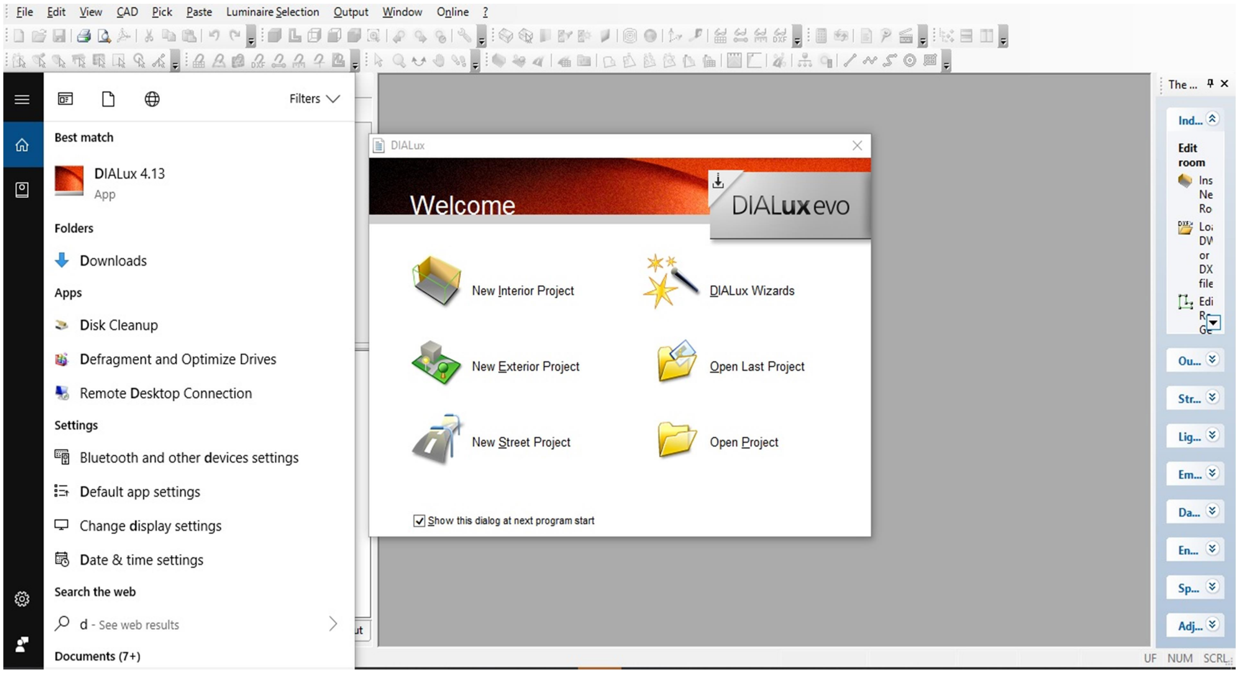


Figure:18.1.1.OPEN PAGE OF A PROJECT

As discussed previously, after opening an interior project then a room has to be inserted and after setting all the geometrical parameters (such as:length,width,height) then required luminares are inserted into the room, and here all luminaires are previously settled as per field arrangement.And 5GR observer have to be inserted into that room for glare calculation,as shown in figure 18.1.2.

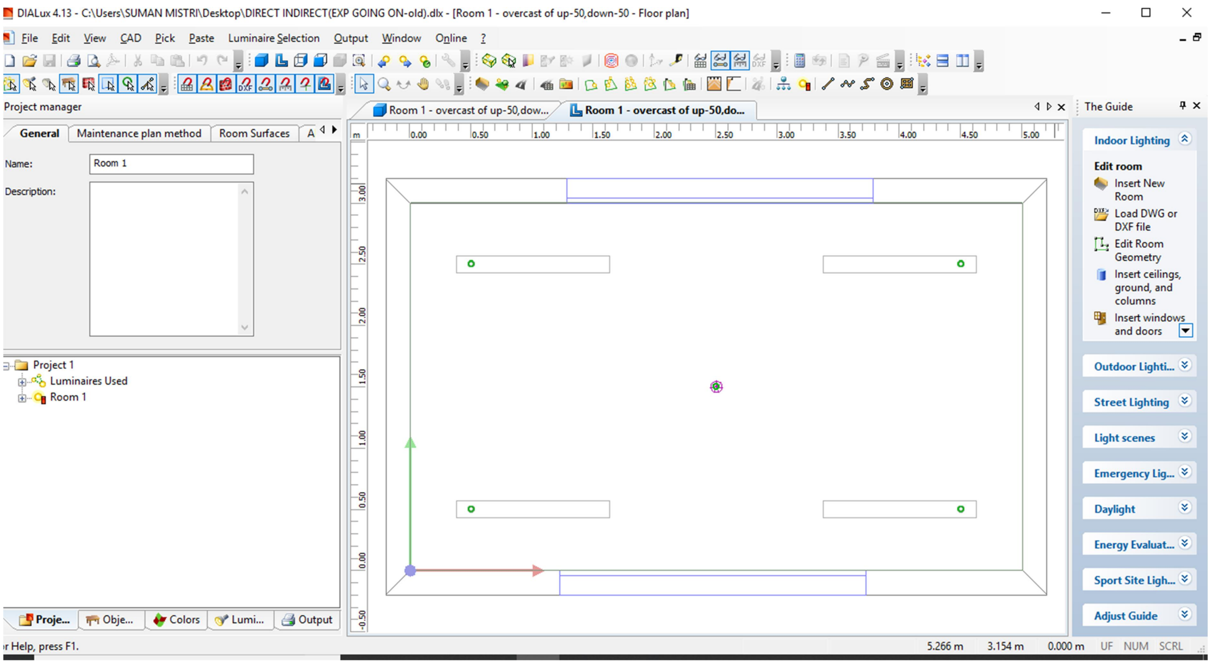


Figure:18.1.2.ROOM WITH LUMINAIRES ARRANGEMENT

In this project daylight integration takes a huge part for that location, address of the particular project, date and time are highly required and the setting page of all of these parameters are looked like the following figure 18.1.3.In this setting page for this project the location is set at Kolkata, along with its longitude and latitude, along with the standard time specification and season.

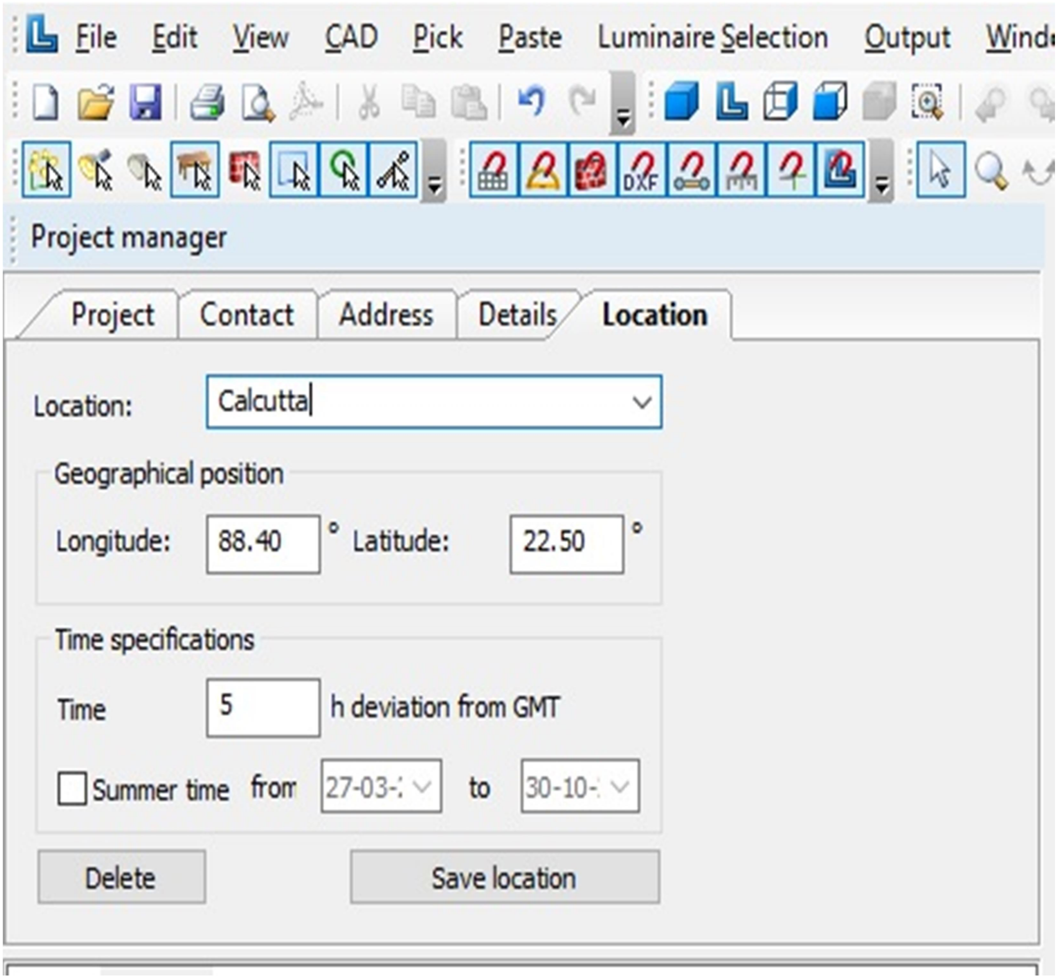


Figure: 18.1.3:SETTING PAGE FOR LOCATION,TIME,DATE,ADDRESS

Now,this is the most important part of this experimental setup which lead to the total change in illuminance values as well as overall uniformity, in this total procedure this reflectance factor can be changed from 10 to 90%,and for setting all of these values in the same project, the below setup figure 18.1.4 will be the main path finder for this part. In this part there are the scope of inserting material specification by the user. And in this project the transparency factor is also varied in the range of 0 to 90%,and it has an effect on the total design.

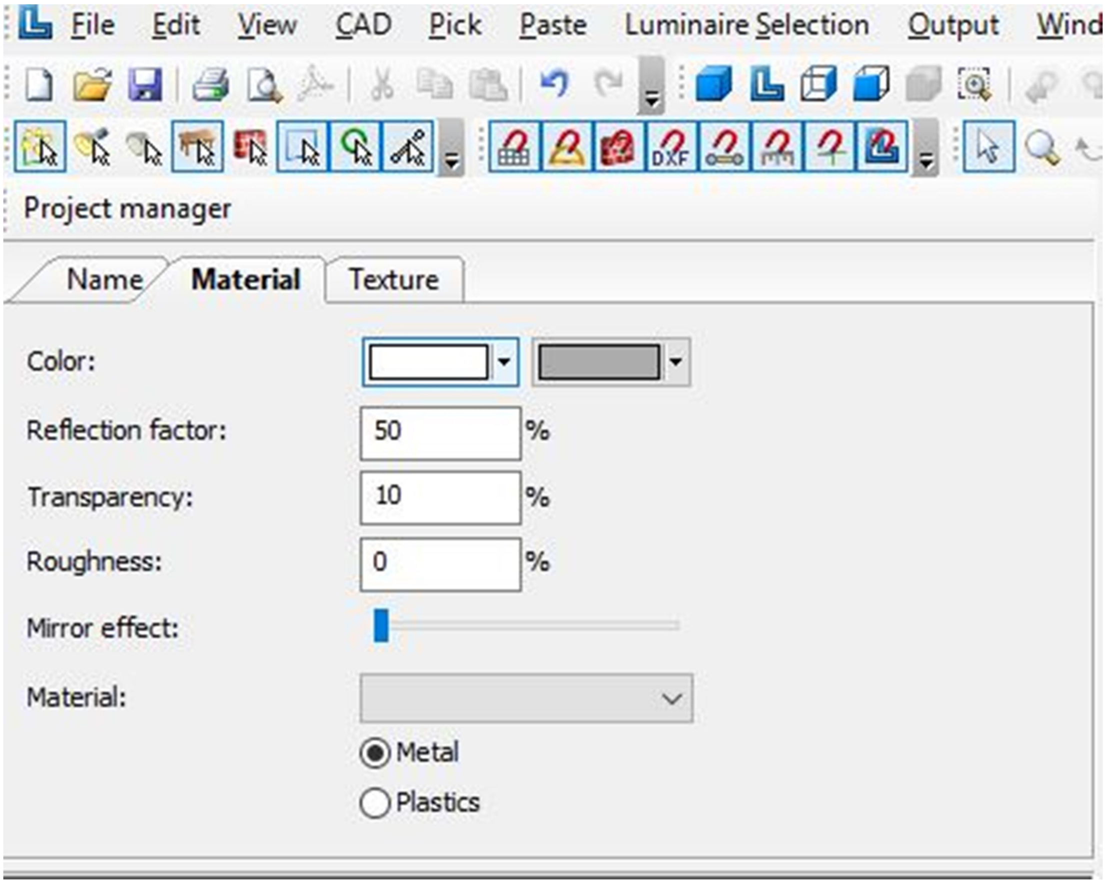


Figure: 18.1.4.SETTING SECTION FOR REFLECTION FACTORS

For daylight integration the window is inserted into the project with the help of the following figure 18.1.5.

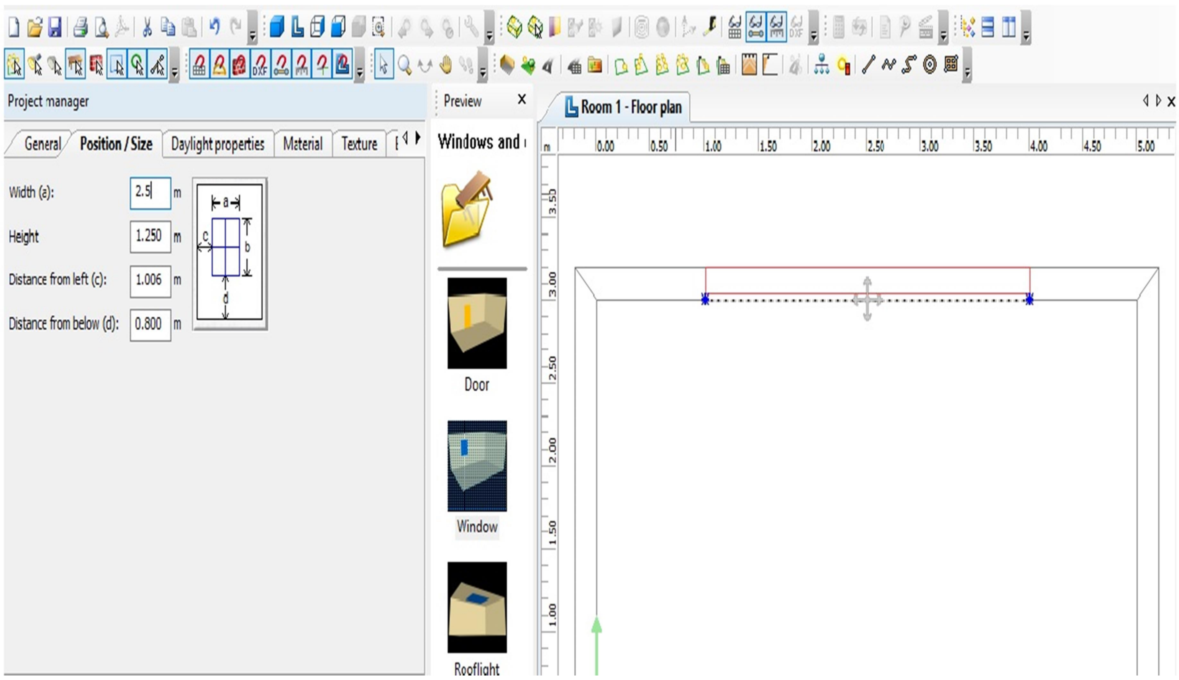


Figure: 18.1.5:SETTING THE POSITION OF WINDOWS

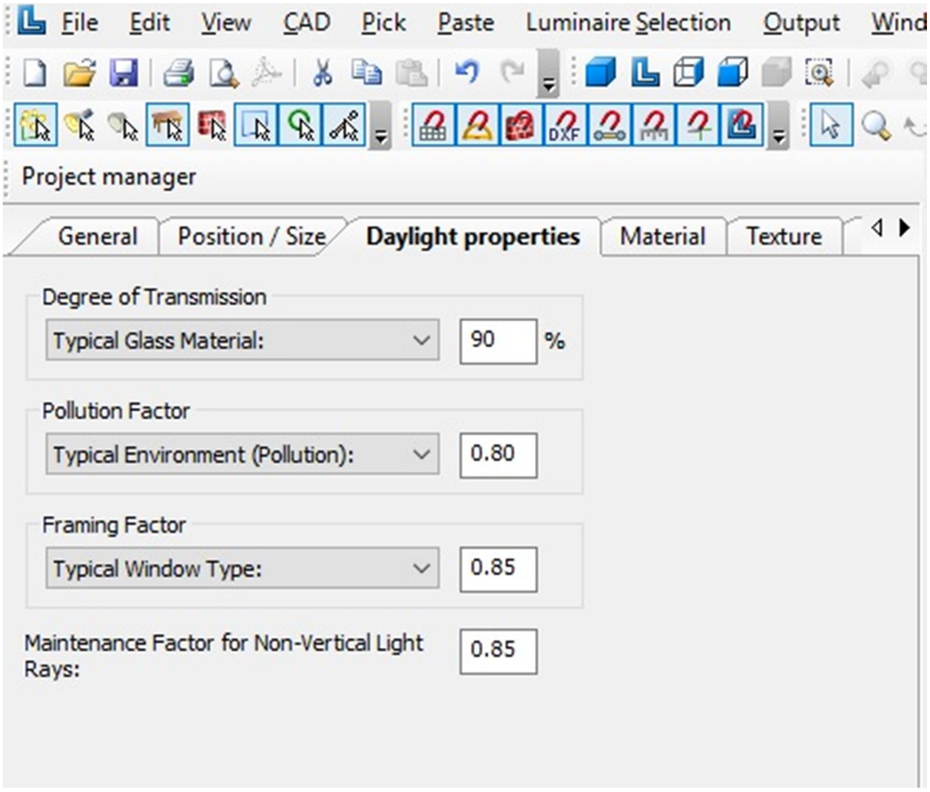


Figure: 18.1.6: SETTING PAGE FOR DAYLIGHT PROPERTIES & WINDOW POSITIONS

After inserting the window,the specification f that particular object can be inserted by the setting and that particular page is looked like the above figure 18.1.6

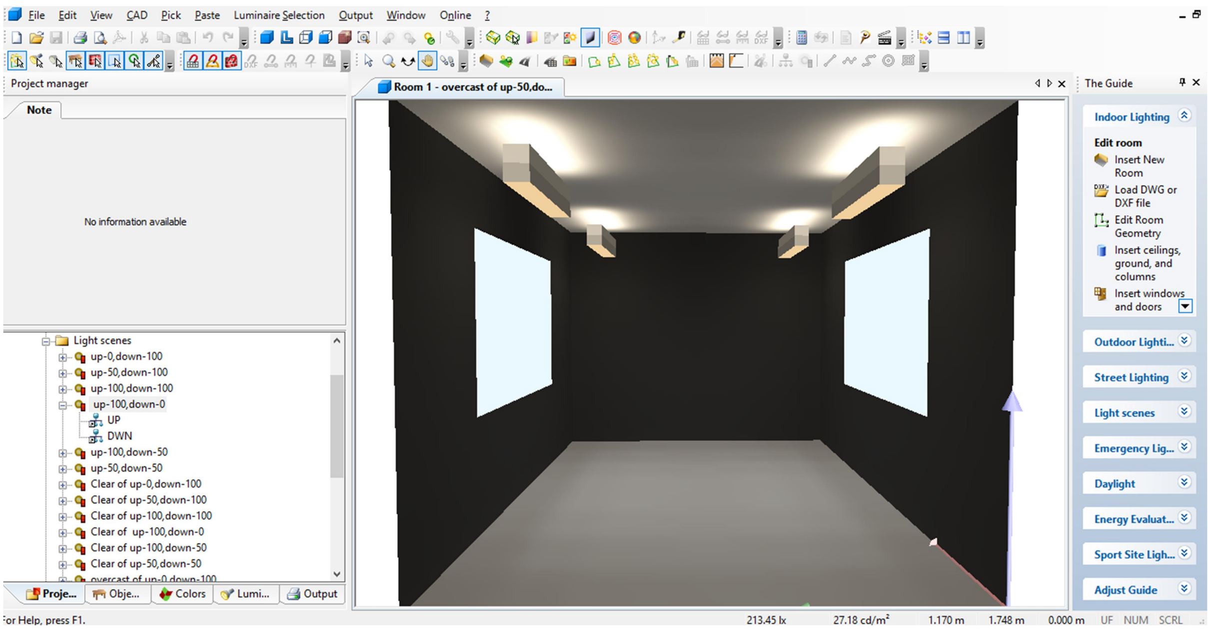


Figure: 18.1.7: CONTROL GROUP WITH DIMMABLE LUMINAIRES

With dimmable control group and all the luminaires the 3D view of the test room is looked like the figure 18.1.7.

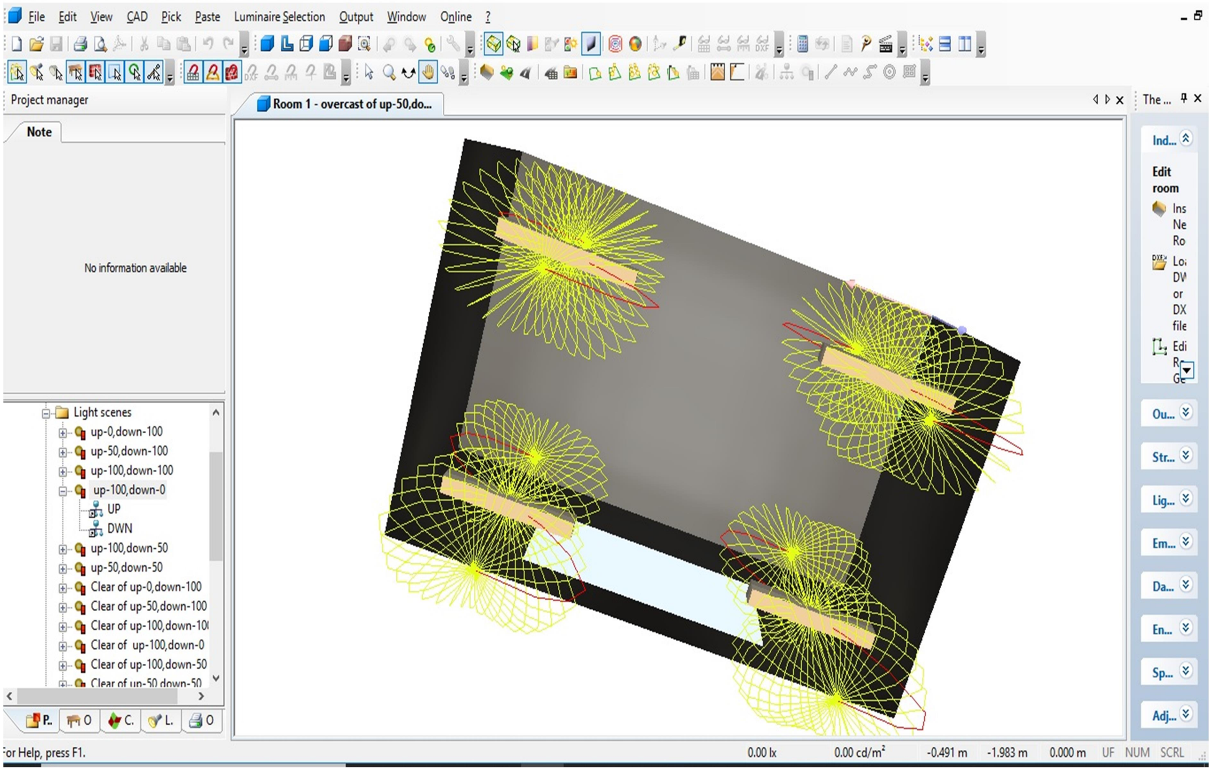


Figure: 18.1.8 :3D RENDERING IMAGES FROM THE TOP VIEW

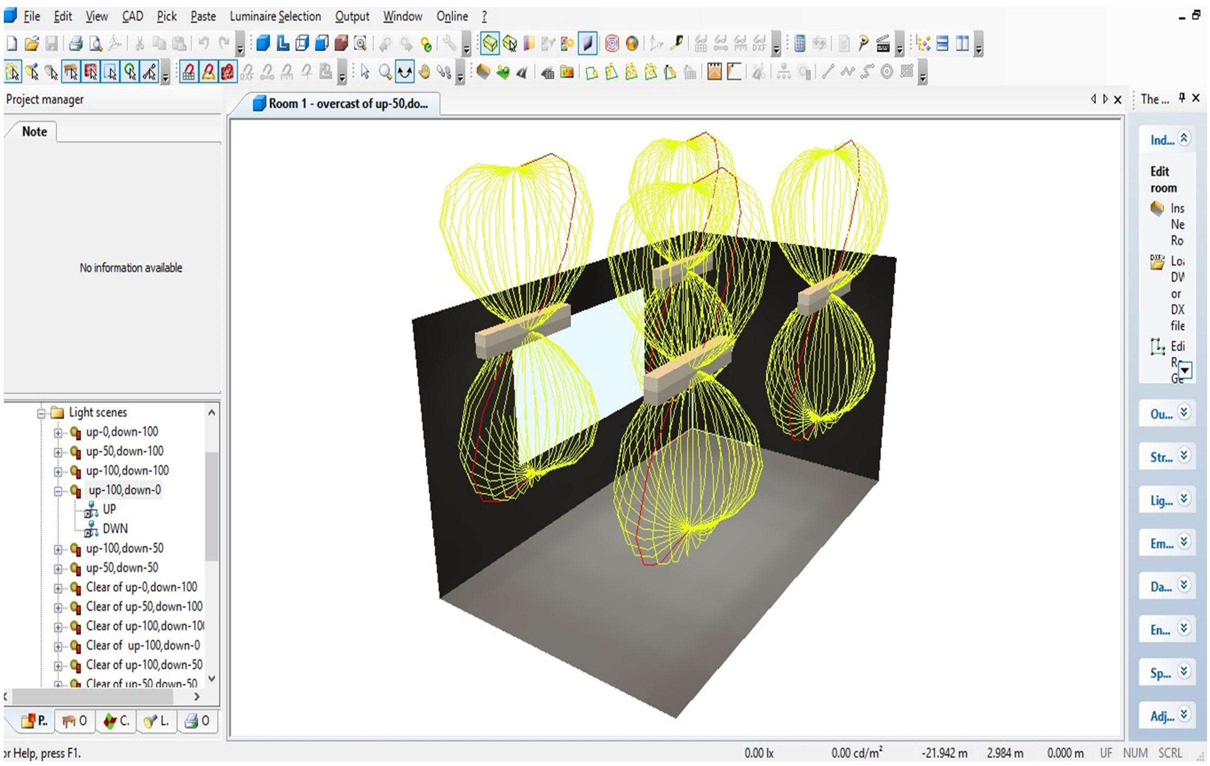


Figure: 18.1.9: 3D RENDERING IMAGES OF DIMMABLE GROUPINGS

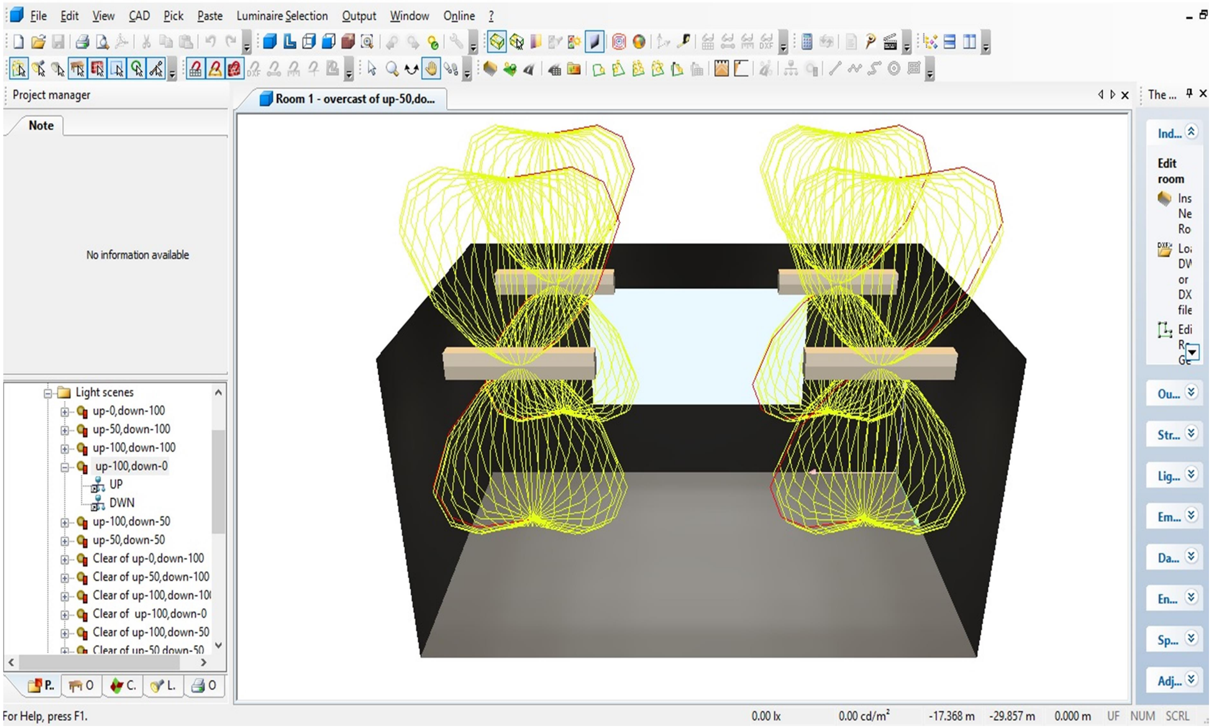


Figure: 18.1.10: 3D RENDERING IMAGES FROM FRONT VIEW FOR LOWER HEIGHTS

From the figure 18.1.8 to 18.1.10 are the 3D rendering images of luminaires which are acted as direct indirect luminaires and the control group can be adjustable ,with user defined different mounting heights of those luminaires.

RESULTS AND DISCUSSIONS:

We know that there are several reflection factors took place in indoor area for illuminating that area, according to the colours and texture of the wall, ceiling, and floor and we also know that this factor has an effect on some parameters, such as- glare, veil luminance, mood of that place and etc.

So, at first we took a room, having length- ,width- ,and height- and we placed two glass windows in south and north wall, which are same in physical measurements.

CASE 1:

WORKPLANE, FLOOR, CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN TRANSPARENCY OF WINDOW IS 0%

Here,change the transparency of the glass material of windows and after changing that this data will be fixed, but mainly change of the reflection factors of the wall, ceiling, and floor from 10% to 90%,and then simulate those design and then plot the graph between reflection factor(in X-axis) and lux level (in Y-axis) gave the following observations.

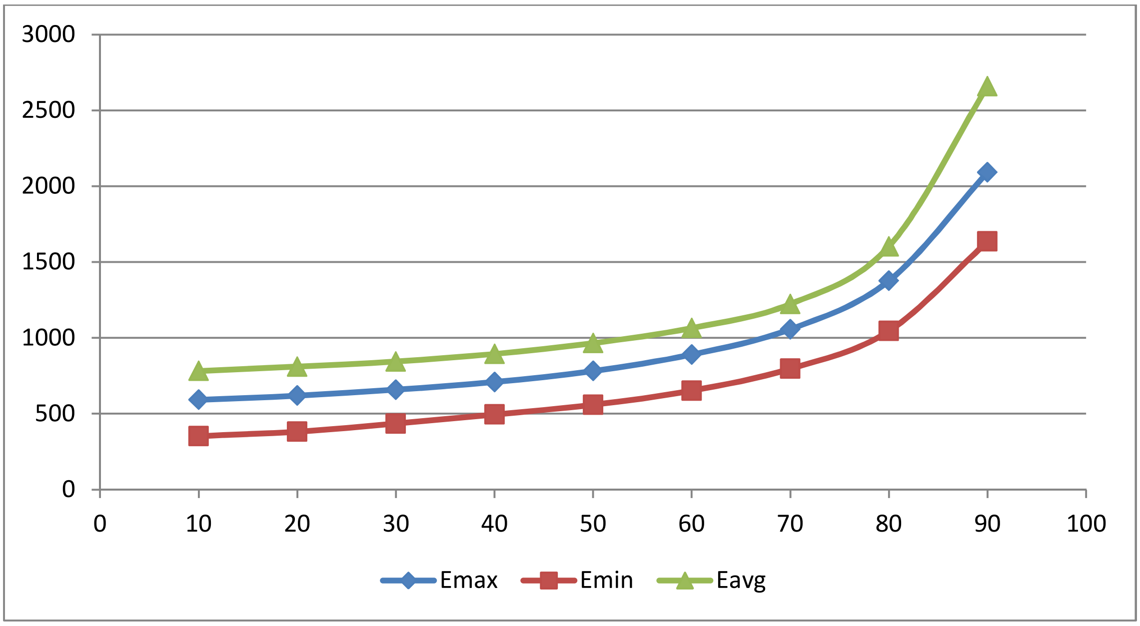
Here the data of transparency factor fixed at 0%.

Table:19.1.1. WORKPLANE VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	592	352	782
20	619	381	810
30	658	435	844
40	709	495	894
50	782	559	965
60	890	652	1065
70	1057	796	1223
80	1376	1045	1603
90	2092	1635	2659

To plot the following graphs with the help of above data table named as 19.1.1,and put these three parameters against ranges of reflection factors.

Figure:19.1.1. GRAPH FOR THE WORKPLANE WHEN TRANSPARENCY OF WINDOW IS 0%



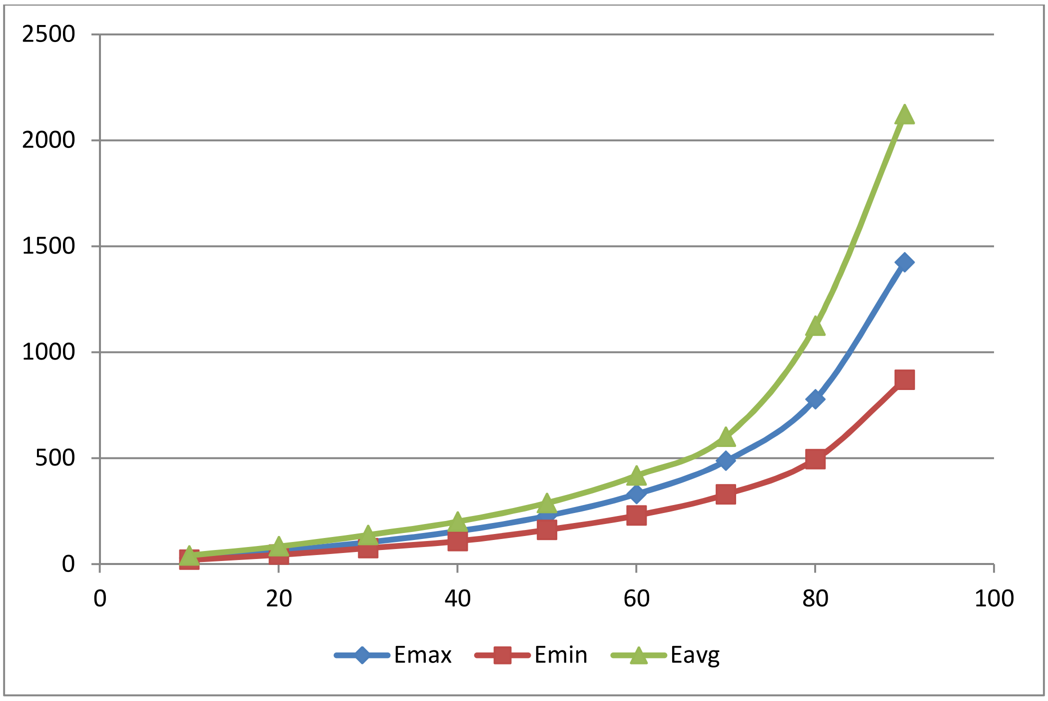
In this graph,as shown in figure 19.1.1 it can easily observe that, when there occurred any changes in reflectivity,like, increasing the value of reflectivity then it achieve more lux level without changing the luminaire, it can easily achieve more output luminance.

Table:19.1.2. CEILING VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	29	21	41
20	62	45	84
30	104	76	138
40	156	109	201
50	228	162	289
60	331	230	418
70	487	329	601
80	778	495	1124
90	1423	869	2122

To plot the following graphs with the help of above data table named as 19.1.2,,and put these three parameters against ranges of reflection factors

Figure.19.1.2. GRAPH FOR THE CEILING WHEN TRANSPARENCY OF WINDOW IS 0%



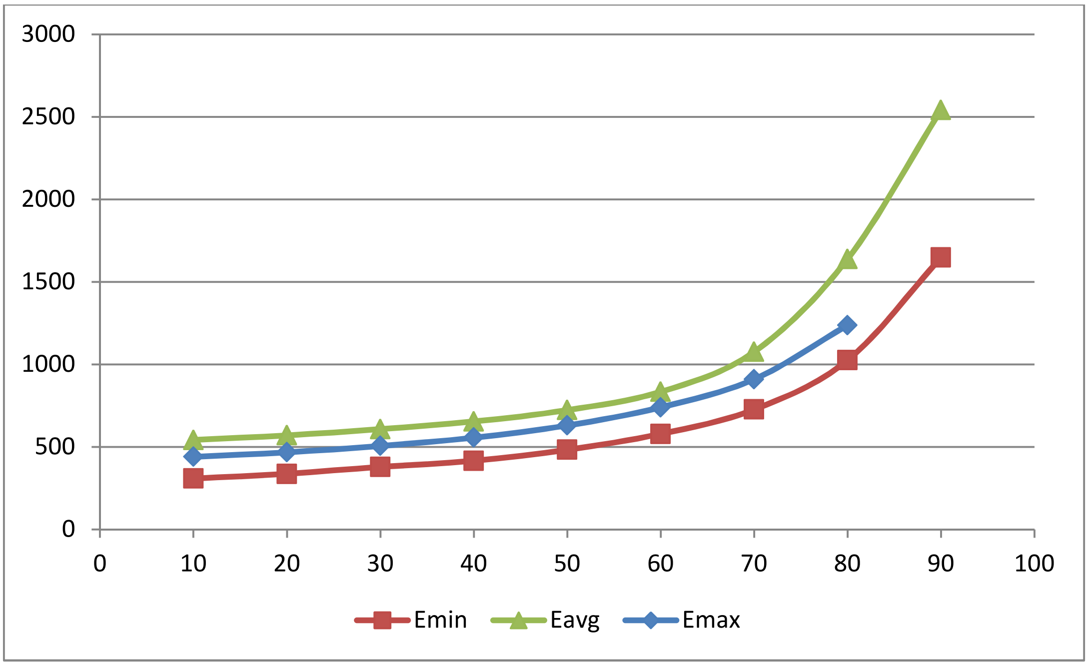
Herein the figure 19.1.2, upto 30% reflection factor the lux level is lower in all three parameters, and mainly in that range these graphs are linear in nature but above 60% lux level increases rapidly and took the shape of an exponential nature of graphs.

Table:.19.1.3. FLOOR VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	440	308	542
20	467	337	570
30	506	379	608
40	556	416	654
50	630	483	723
60	740	579	834
70	910	727	1076
80	1237	1025	1638
90	1932	1648	2541

To plot the following graphs with the help of above data table named as 19.1.3,,and put these three parameters against ranges of reflection factors.

Figure.19.1.3. GRAPH FOR THE FLOOR WHEN TRANSPARENCY OF WINDOW IS 0%



From these plots it can easily assume that there is a similarity in two aspects, when the topic is mainly the graphs of workplane then it is observed that,these type of nature and if the observation shifts into these graphs then also it is obtainable that same linearity and the increasing nature occured after 40% reflectivity,these all observations shown in figure 19.1.3.

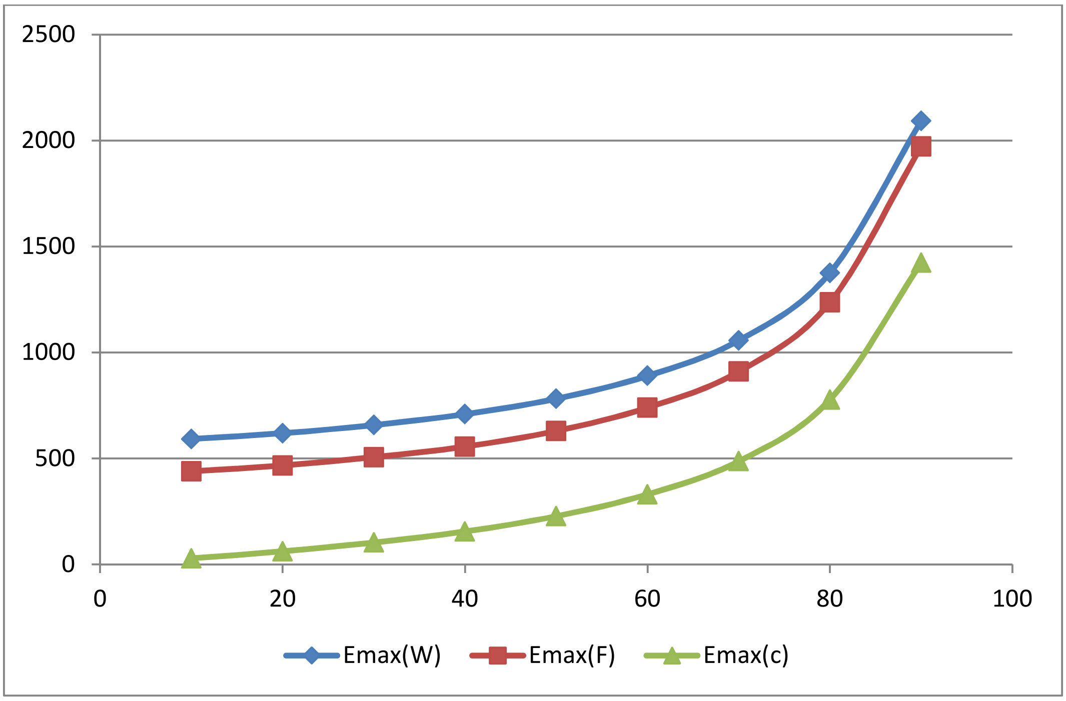
Now, for comparing all these datas,here one table is created with all maximum values and then plot the Emax value with respect to the reflection factors.

Table:.19.1.4. ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emax(W)	Emax(F)	Emax(c)
10	592	440	29
20	619	467	62
30	658	506	104
40	709	556	156
50	782	630	228
60	890	740	331
70	1057	910	487
80	1376	1237	778
90	2092	1972	1423

To plot the following graphs ,as shown below, in figure 19.1.4 with the help of above data table named as 19.1.4,and put these three parameters against ranges of reflection factors.

Figure.19.1.4. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



From these graphs it can be easily conclude that, increasing the value of reflection factor get the higher lux level without replacing new luminaires. This graph which named as figure 19.1.4,also show that the floor and workplane graphs are similar to each others but the maximum value of ceiling is same in nature but the values are much lower than the workplane and floor.

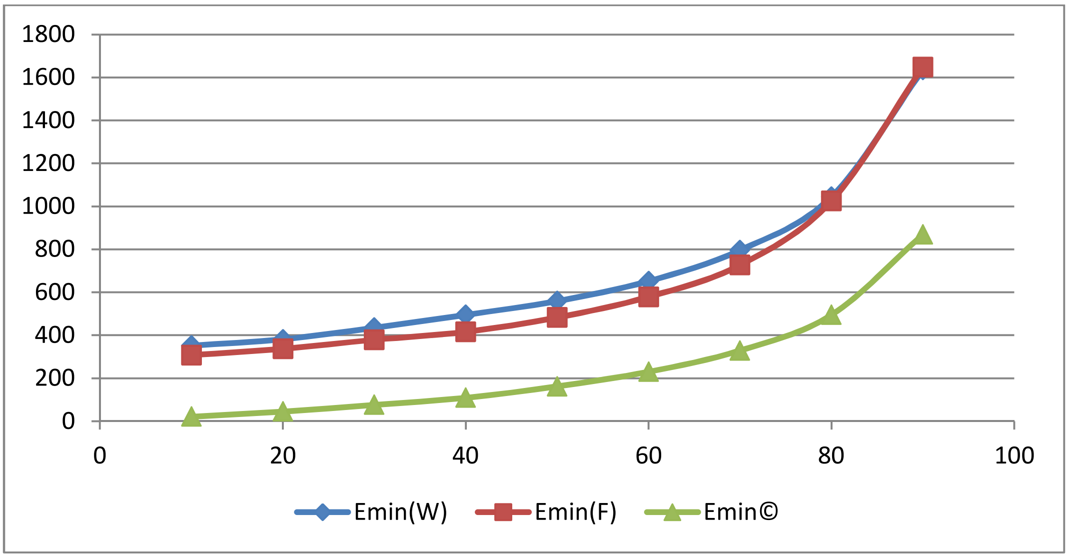
Again, for comparing all these datas,here one table is created with all maximum values and then plot the Emax value with respect to the reflection factors.

Table:.19.1.5. ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emin(W)	Emin(F)	Emin(C)
10	352	308	21
20	381	337	45
30	435	379	76
40	495	416	109
50	559	483	162
60	652	579	230
70	796	727	329
80	1045	1025	495
90	1635	1648	869

To plot the following graphs with the help of above data table named as 19.1.5,and put these three parameters against ranges of reflection factors

Figure.19.1.5. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



From the above graphs it can say that the values of workplane and floor are nearly equal to each other in the higher reflection factor but the minimum values of ceiling part is always maintain its own nature.

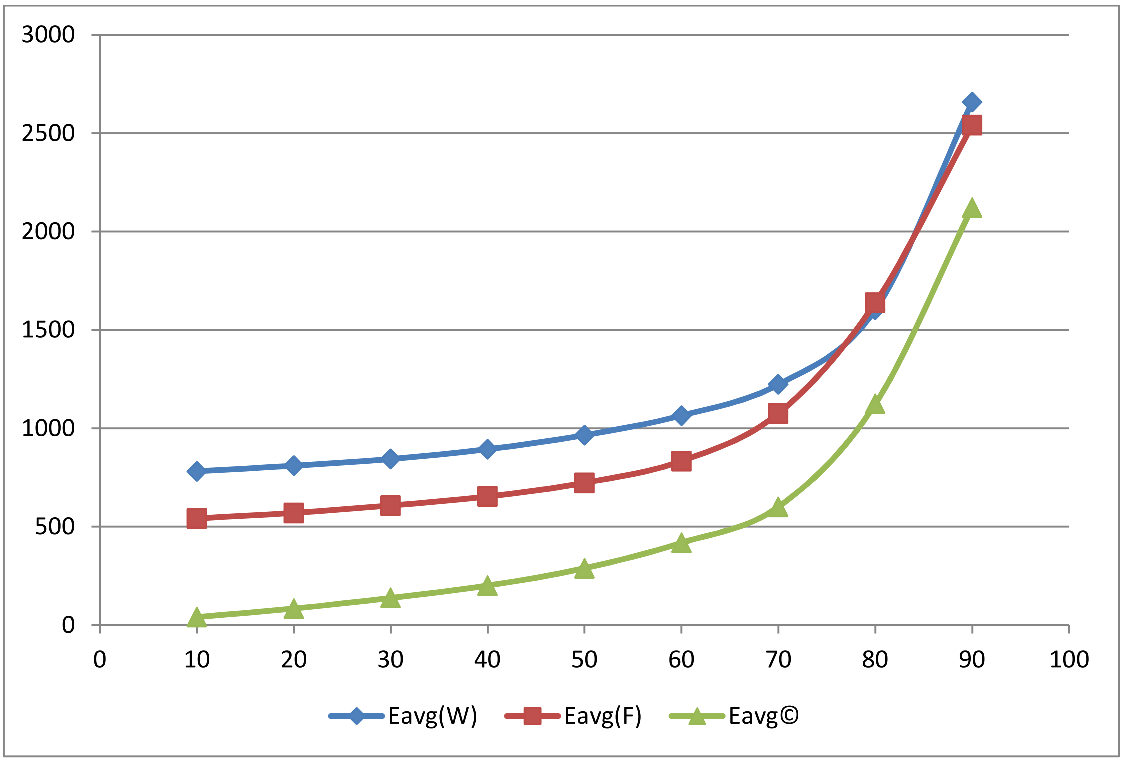
And lastly for comparing in the similar manner we put all the average lux level in a table and made a graph using those datas,as per figure 19.1.5.

Table:.19.1.6. ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Eavg(W)	Eavg(F)	Eavg(C)
10	782	542	41
20	810	570	84
30	844	608	138
40	894	654	201
50	965	723	289
60	1065	834	418
70	1223	1076	601
80	1603	1638	1124
90	2659	2541	2122

To plot the following graphs with the help of above data table named as 19.1.6,and put these three parameters against ranges of reflection factors.

Figure.19.1.6. THE GRAPH FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



In the above figure 19.1.6,there is a change which is not in those earlier graphs,thatis,the intersect part between the average illuminance value of workplane and floor.

CASE 2:

WORKPLANE, FLOOR, CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN TRANSPARENCY OF WINDOW IS 50%

In this case ,change is takes place for the transparency of the glass material of windows and after changing that this data will be fixed, but ,here the reflection factors of the wall, ceiling, and floor are changed from 10% to 90% ,and then simulate those design and then plot the graph between reflection factor(in X-axis) and lux level (in Y-axis).

Here the data of transparency factor fixed at 50%.

Table:.19.2.1. WORKPLANE VALUE CHART

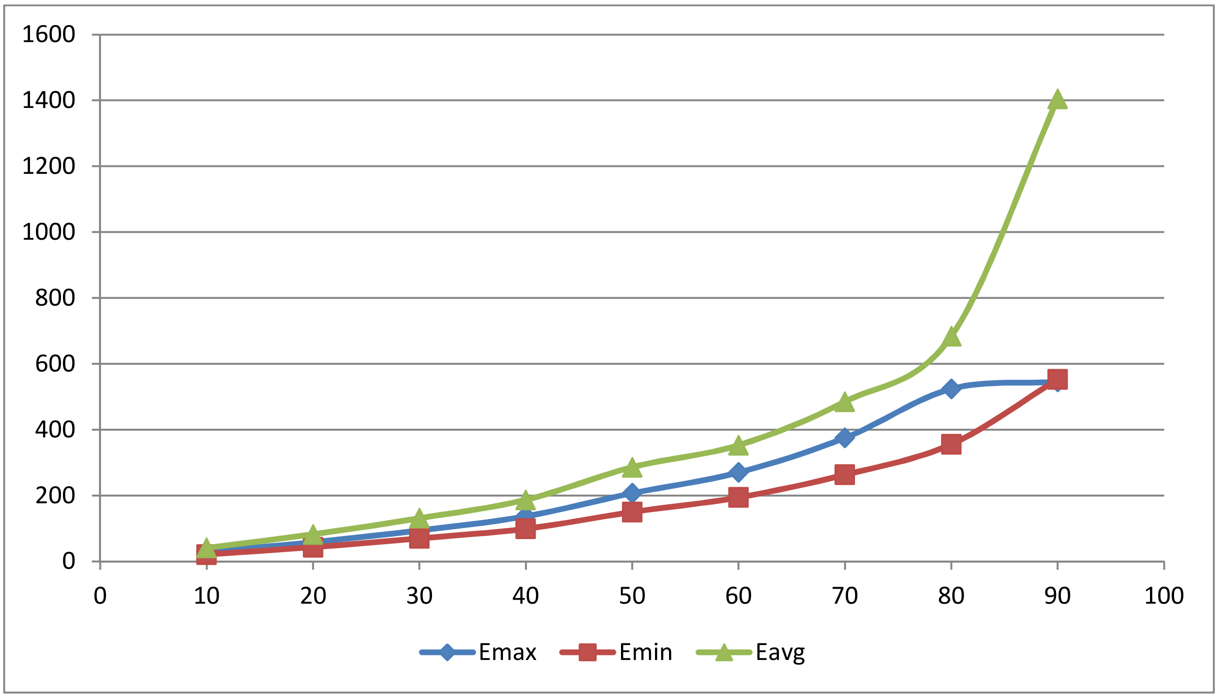
Reflection Factor	Emax	Emin	Eavg
10	29	21	41
20	58	43	82
30	94	70	131
40	137	99	187
50	207	150	286
60	270	194	353
70	375	263	485
80	524	356	684
90	545	553	1405

To plot the following graphs with the help of above data table named as 19.2.1,,and put these three parameters against ranges of reflection factors_.

In this figure 19.2.1,the initial values are nearly same for all but there is a intersection part where maximum and minimum illuminance values intersect with each others in the higher reflection factor.

This graph is generated from the help of table 19.2.1.

Figure.19.2.1. THE GRAPH FOR WORKPLANE VALUE



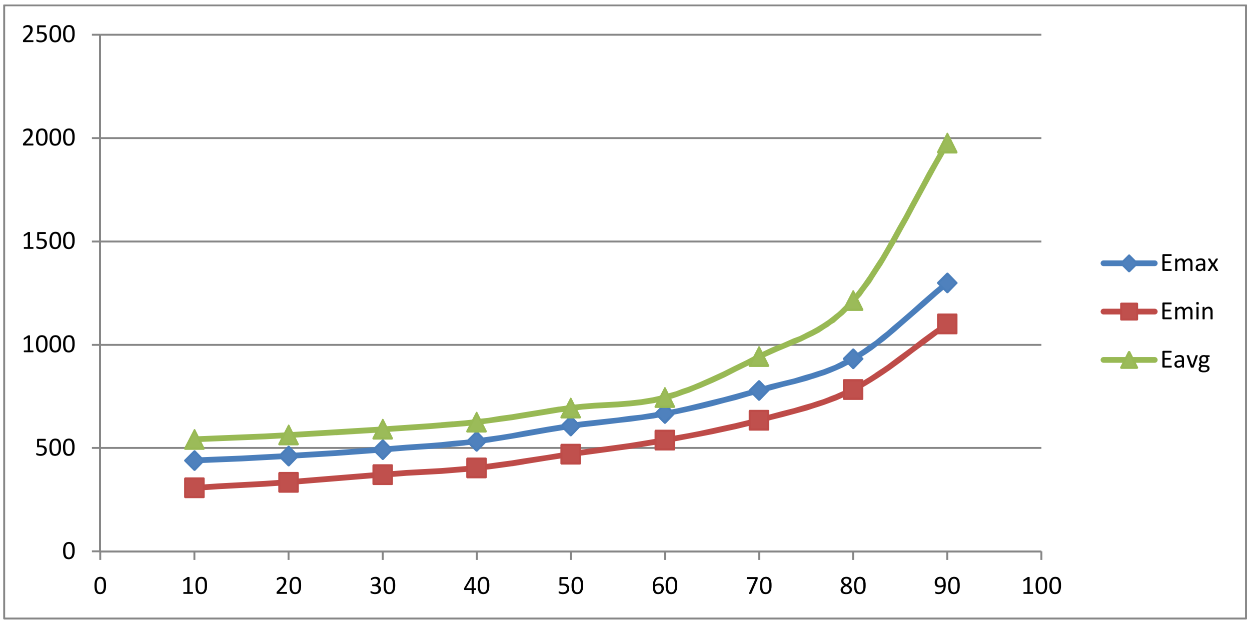
And here the tabulated datas,in the table 19.2.2 for floor area, when 50% windows transparency took place.

Table:.19.2.2. FLOOR VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	440	308	542
20	462	335	563
30	493	372	591
40	533	404	626
50	607	471	694
60	667	538	745
70	779	635	942
80	932	784	1213
90	1299	1100	1975

After putting all these data's , a graphical representation is formed,like the following one,as shown in figure 19.2.2, where Emax, Emin and Eavg are plotted against the reflection factor ranges from 10% to 90%.

Figure.19.2.2. THE GRAPH FOR FLOOR VALUE



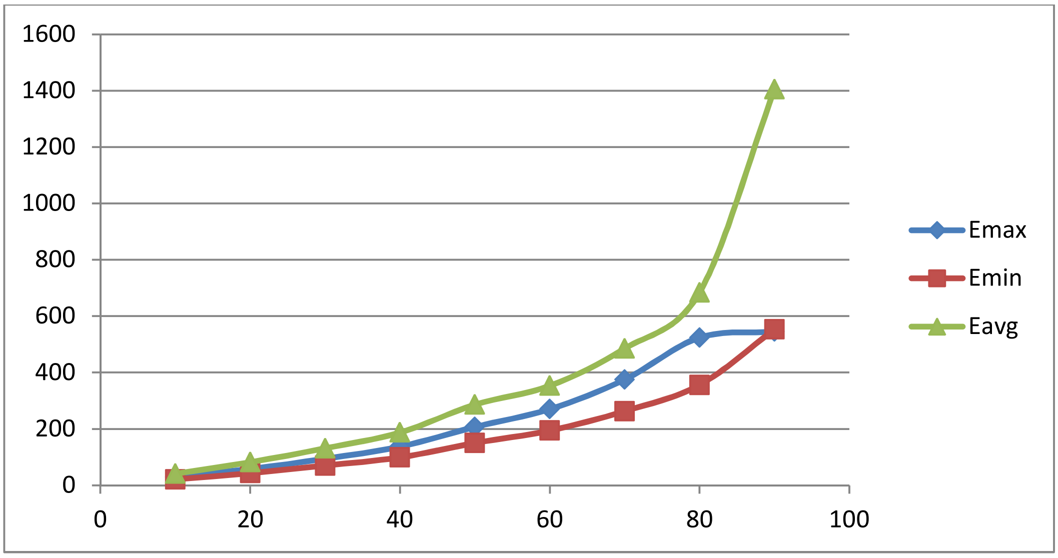
In similar way this graph is also in same nature as discussed in the previous case,so,there is no huge changes occurred after changing the transparency factor from 0% to 50%.

Table:.19.2.3. CEILING VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	29	21	41
20	58	43	82
30	94	70	131
40	137	99	187
50	207	150	286
60	270	194	353
70	375	263	485
80	524	356	684
90	545	553	1405

To plot the following graphs with the help of above data table named as 19.2.3 and put these three parameters against ranges of reflection factors.

Figure.19.2.3. THE GRAPH FOR CEILING VALUE



According to the figure 19.2.3,from the above graphs, some observations takes place,that,at the initial stage the graphs are very linear to the axis and there is no more significant changes took placed between maximum, minimum and average values. Till 50%reflectivity these nature will same as above but above 50% reflectivity there is a sharp change with increasing values in average lux level bt there is also an intersect part took place at the range of 85 to 90%reflectivity.

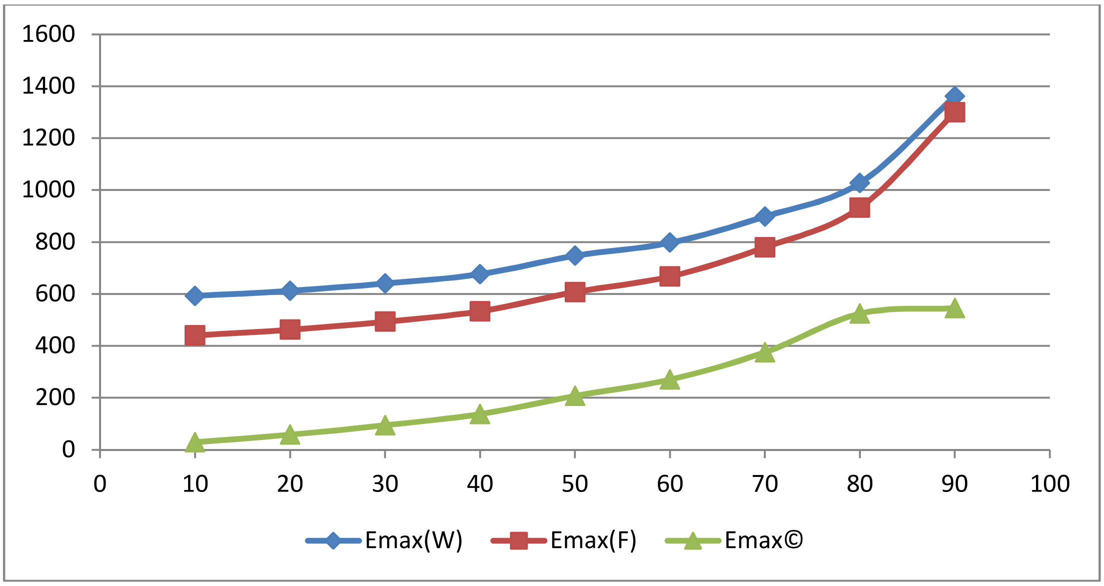
As per the above study,for comparing in the similar manner we put all the maximum lux level in a table and made a graph using those datas.

Table:.19.2.4. ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emax(W)	Emax(F)	Emax(C)
10	592	440	29
20	612	462	58
30	640	493	94
40	676	533	137
50	747	607	207
60	797	667	270
70	898	779	375
80	1027	932	524
90	1361	1299	545

To plot the following graphs with the help of above data table named as 19.2,4 and put these three parameters against ranges of reflection factors.

Figure.19.2.4. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



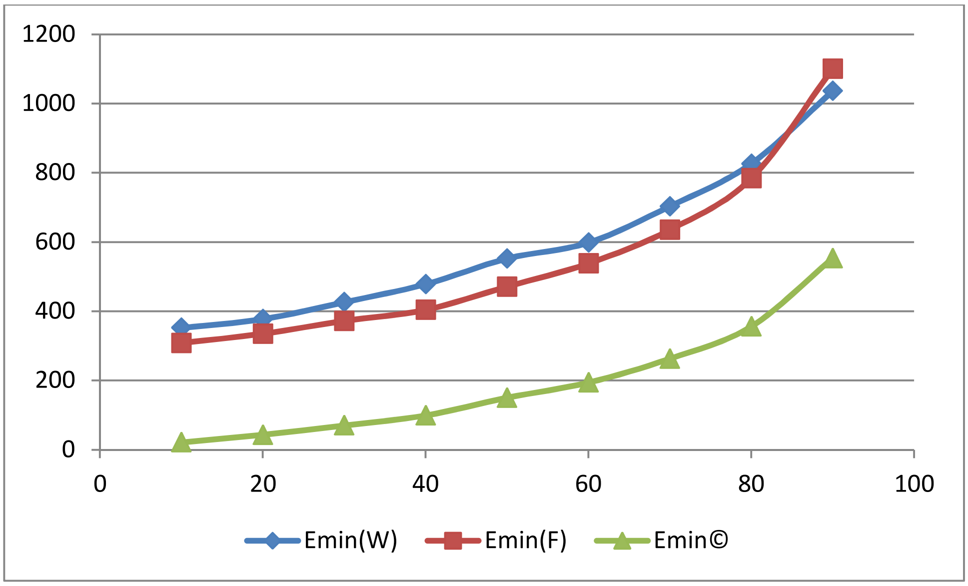
Now,for comparing all these datas,here one table is created with all minimum values and then plot the Emin value with respect to the reflection factors In this graph it can be observed that the earlier nature of graphs which are plotted against minimum luv level in 0% windows transparency is remain same as per the curve nature but values are changed mainly increased in this part.

Table:.19.2.5. ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emin	Emin	Emin
10	352	308	21
20	377	335	43
30	426	372	70
40	478	404	99
50	552	471	150
60	598	538	194
70	703	635	263
80	826	784	356
90	1036	1100	553

To plot the following graphs as shown in figure 19.2.5 with the help of above data table names as 19.2.5 and put these three parameters against ranges of reflection factors.

Figure.19.2.5. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



There is a significant change take place where we can see that a intersection occurs in between reflectivity factor 70% to 90%.

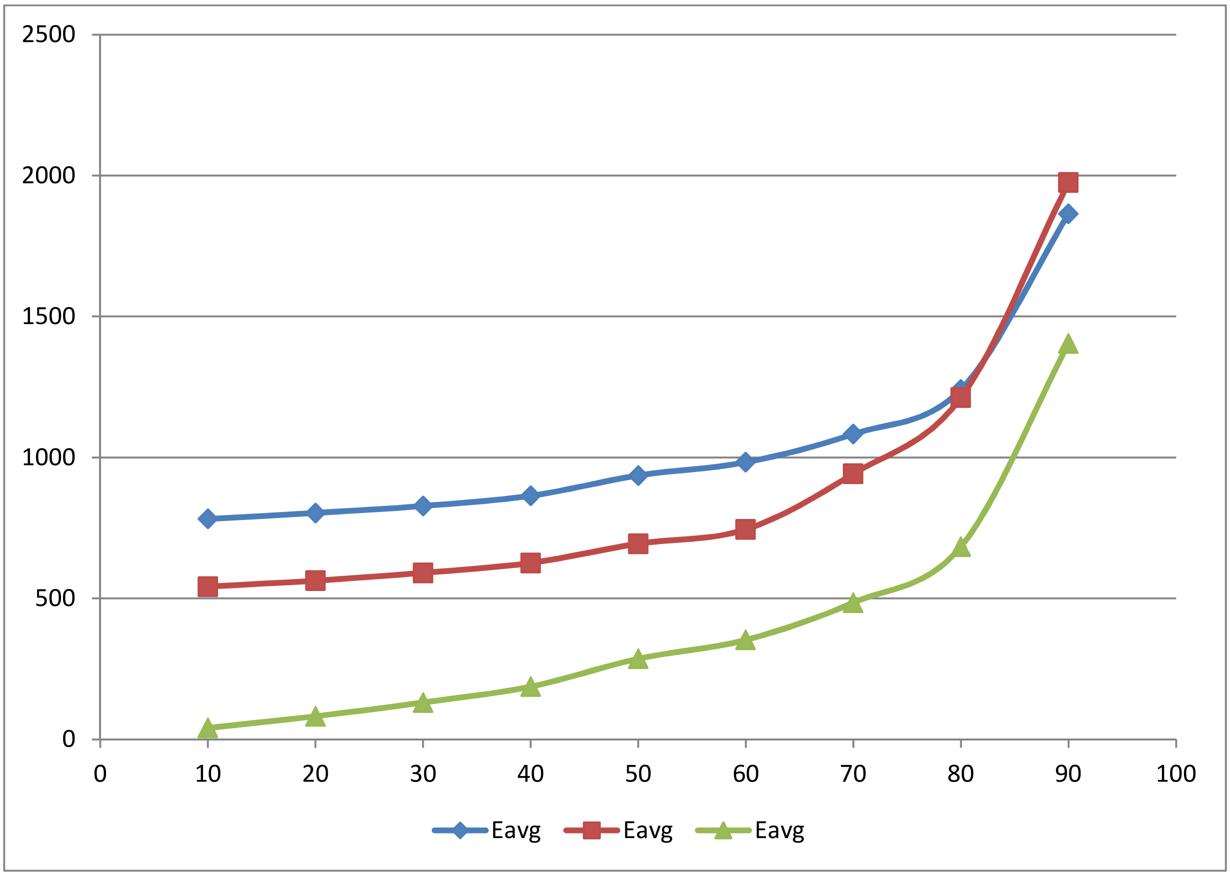
According to the above manner, now for compareing between all the average lux level ,and for that have to put all the datas in a table and made a graph using those datas.

Table.19.2.6. ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Eavg	Eavg	Eavg
10	782	542	41
20	803	563	82
30	828	591	131
40	864	626	187
50	936	694	286
60	983	745	353
70	1083	942	485
80	1241	1213	684
90	1864	1975	1405

To make the following graphs with the help of above data table19.2.6 putted all these three parameters against ranges of reflection factors.

Figure.19.2.6. THE GRAPH FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



In the figure 19.2.6,there is also a intersect part take place which lies in the range of 80%.

CASE: 3

WORKPLANE, FLOOR, CEILING VALUE CHART AND GRAPHS OF Emax ,Emin and Eavg WHEN TRANSPARENCY OF WINDOW IS 90%

In this case the main change occurred in the transparency of the glass material of windows and after changing that this data will be fixed, but in this case, the reflection factors of the wall, ceiling, and floor are changed from 10% to 90%,and then simulate those design and then plot the graph between reflection factor(in X-axis) and lux level (in Y-axis). Here the data of transparency factor fixed at 90%.

Table.19.3.1. WORKPLANE VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	592	352	782
20	612	377	803
30	640	426	828
40	676	478	864
50	727	534	915
60	797	598	983
70	874	680	1063
80	951	765	1152
90	1024	362	1217

Now putting all these datas in a graph and the output of the table will be like the following one.

Figure.19.3.1. THE GRAPH FOR WORKPLANE VALUE

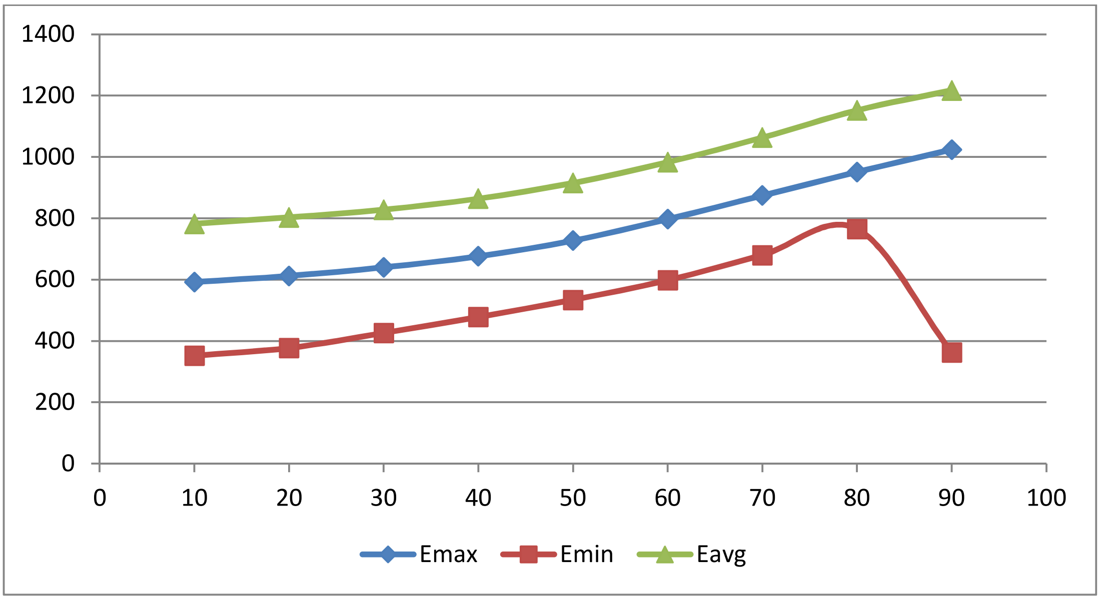


Table.19.3.2. FLOOR VALUE CHART

Reflection Factor	Emax	Emin	Eavg
10	440	308	542
20	462	335	563
30	493	372	591
40	533	404	626
50	588	458	675
60	667	538	745
70	753	599	924
80	844	650	978
90	921	763	1029

With the help of these above data the following graph is formed which is depicted as figure 19.3.2.

Figure.19.3.2. THE GRAPH FOR FLOOR VALUE

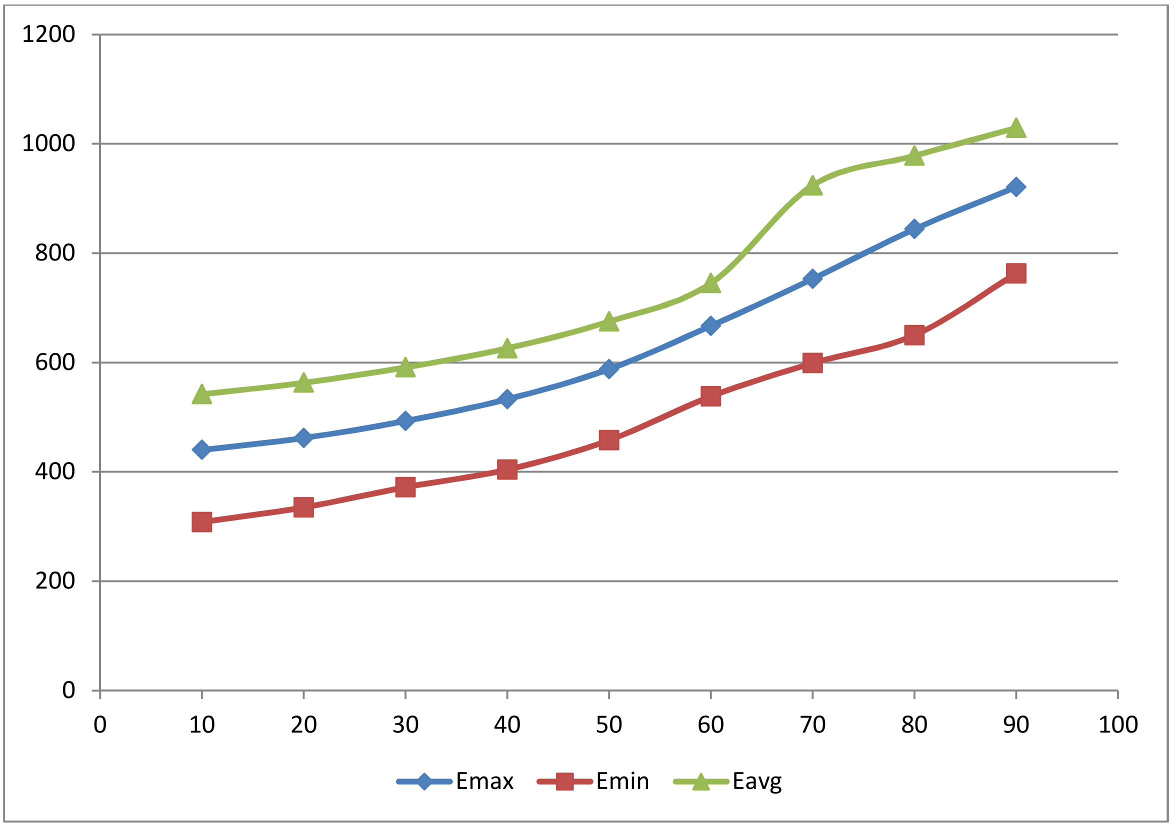
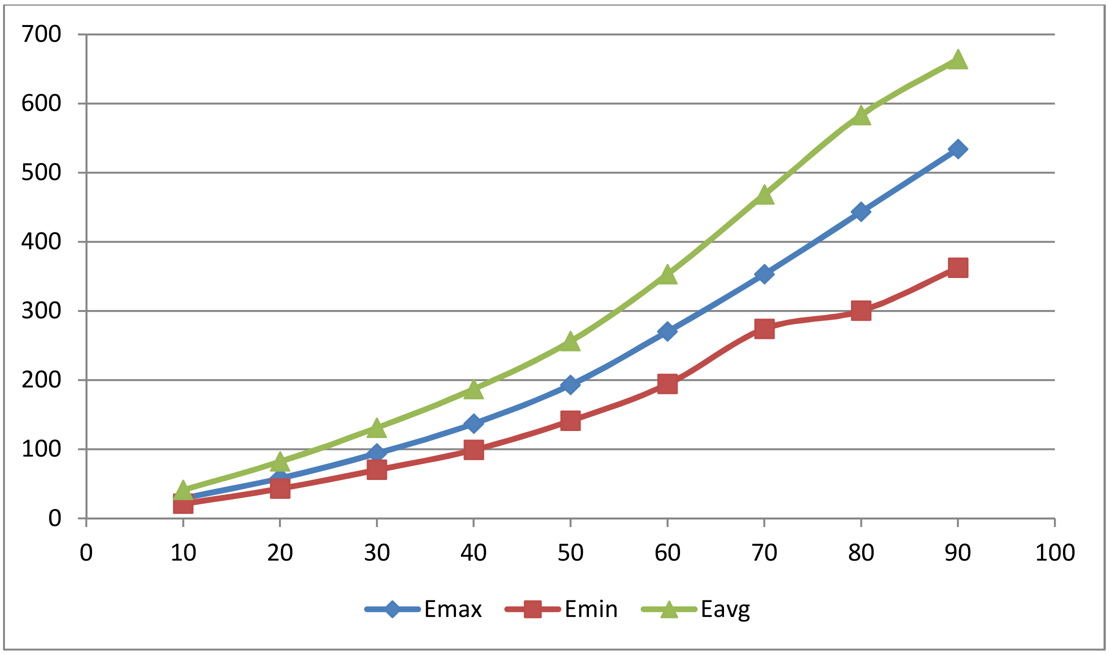


Table.19.3.3. CEILING VALUE CHART

Reflection Facctor	Emax	Emin	Eavg
10	29	21	41
20	58	43	82
30	94	70	131
40	137	99	187
50	193	141	256
60	270	194	353
70	353	274	468
80	443	300	583
90	534	362	664

To plot the following graphs with the help of above data table named as 19.3.3 and putting these three parameters against ranges of reflection factors, where transparency of window is 90% is generated the graphs shown below as figure 19.3.3.

Figure.19.3.3. THE GRAPH FOR CEILING VALUE



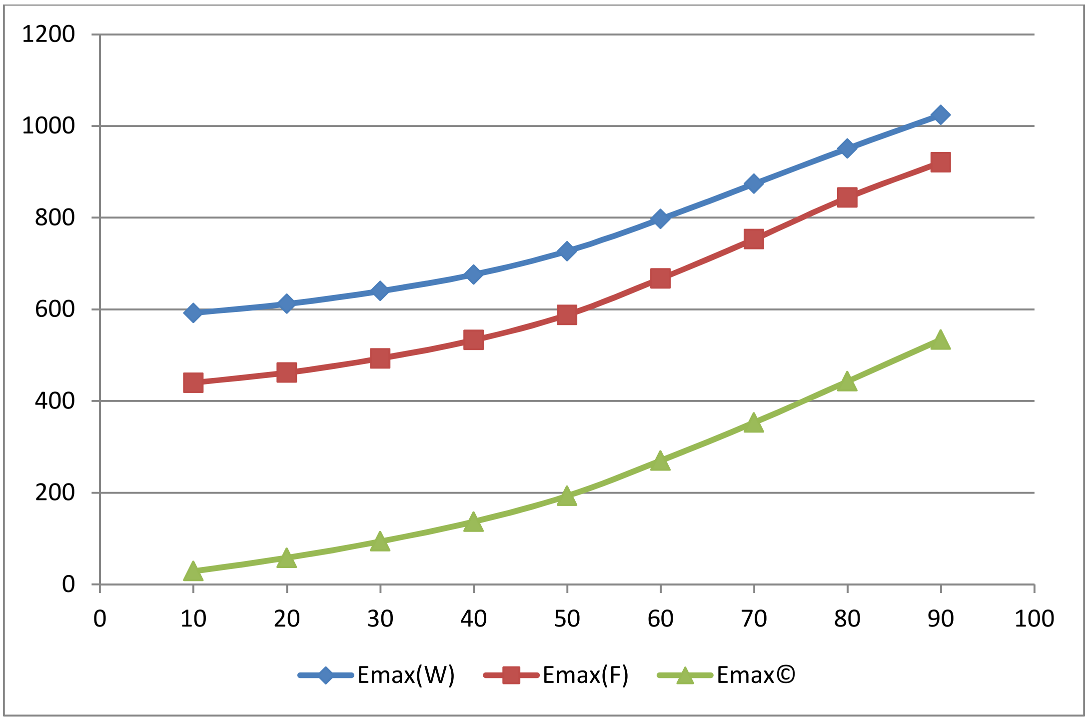
Here, all three graphs are started nearly at a same point, but then it maintain its nature, because with respect to the reflectivity it will enhanced its lux level. Now for comparing all maximum values ,here also the prior process applied and putted all of the max values in one table for workplane, ceiling and floor.

Table.19.3.4. ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emax(W)	Emax(F)	Emax(C)
10	592	440	29
20	612	462	58
30	640	493	94
40	676	533	137
50	727	588	193
60	797	667	270
70	874	753	353
80	951	844	443
90	1024	921	534

As per the formar cases,all the datas of table 19.3.4 can be putted into a single graph then it will look as following figure 19.3.4.

Figure.19.3.4. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



Here,it is clearly observable that the nature of graph is similar to the earlier cases.

Again for comparing all minimum values,all those values from the table of 19.3.4 is putted and all of the max values in the table for workplane, ceiling and floor is shown in the figure 19.3.5.

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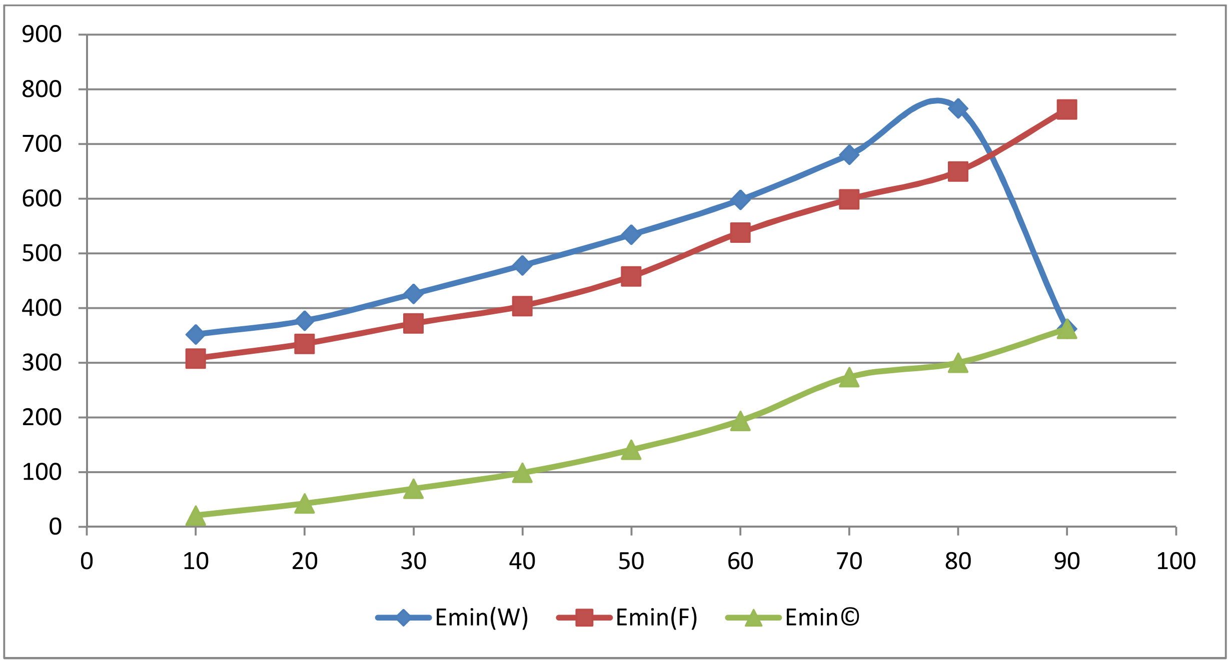
Table.19.3.5. ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Emin(W)	Emin(F)	Emin©
10	352	308	21
20	377	335	43
30	426	372	70
40	478	404	99
50	534	458	141
60	598	538	194
70	680	599	274
80	765	650	300
90	362	763	362

To plot the following graphs as shown in figure 19.3.6 with the help of above data table names as 19.3.5 and put these three parameters against ranges of reflection factors.

Figure.19.3.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



Here it is noticed that,a massive change in minimum value of workplane,and the graph for Emin(W) intersect with the graph of Emin(F) and the prior graph touched with the extreme value of Emin(C) at 90% reflective factor.

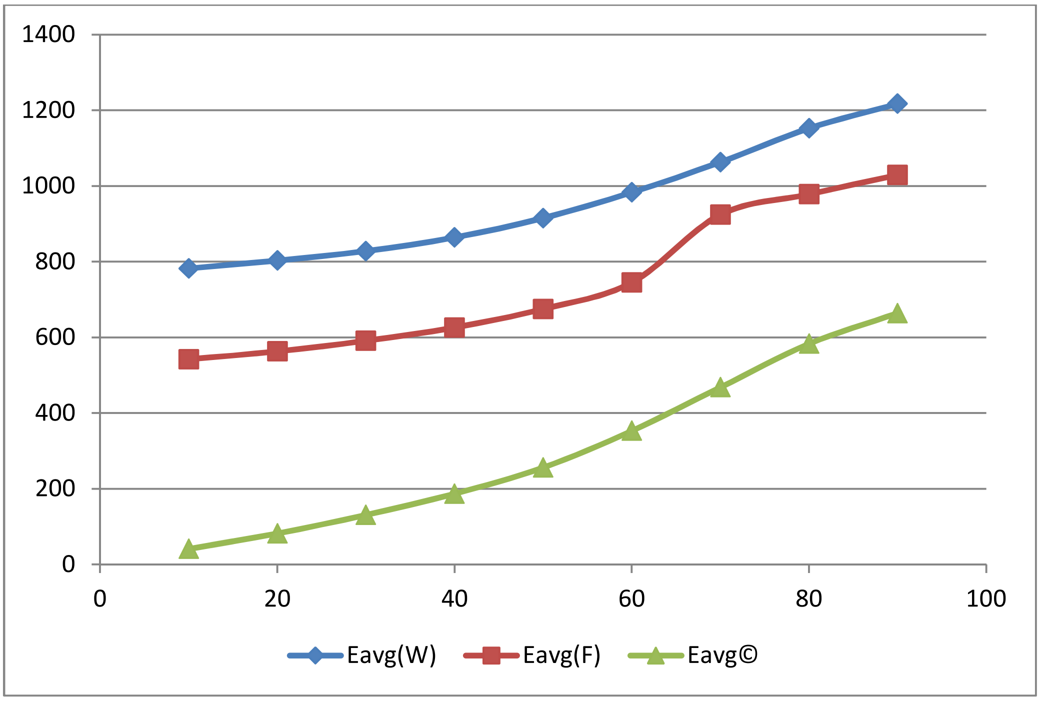
For comparing all average values are putted in a graph which is shown below as figure 19.3.7,and in that figure all of the average values in the table numbered as 19.3.7 are used for workplane, ceiling and floor.

Table.19.3.7. ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING CHART

Reflection Factor	Eavg(W)	Eavg(F)	Eavg©
10	782	542	41
20	803	563	82
30	828	591	131
40	864	626	187
50	915	675	256
60	983	745	353
70	1063	924	468
80	1152	978	583
90	1217	1029	664

Now, for comparing all these datas, here one table is created with all average values and then plot the Eavg value with respect to the reflection factors in the figure 19.3.7.

Figure.19.3.7. THE GRAPH FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



From all the datas and graphs,it can be concluded into some points, those are as follows:

Now we applied this into a test room, which having length of 5m,width of 3m and height of 2.8m,and we put luminaires having lumen output of 3200 lumen. In the room we put 8 luminaires and put them into two control groups, and named them as middle control group and side control group. In the room we put two windows having width of 2.5m, one is north facing and the other one is south facing. Here we have to calculate the daylight integration and no daylight data analysis along with a comparative study between reflectivity factor and the lux value, so we can make a conclusion where we can know what will be the lux level when we dimmed the control groups and what factors changed the lux levels for changing the reflectivity of the wall, ceiling and floor. Here we also take the sky conditions, mainly clear sky, overcast sky and mixed sky conditions are considered for calculation, on a particular date and particular location. For all of these calculation we have to look into following cases.

CASE: 4

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON.

In this case study we follow the following parameters,which are as follows:

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition.One control group is fully off and the other one is fully on.

In the left figure we can see the graphs of three parameters which are tabuled in the right table and this table is only for the workplane.

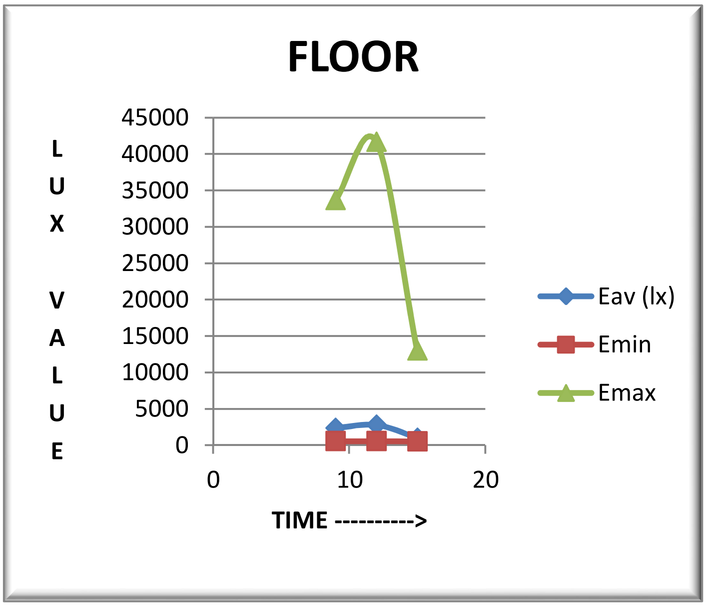
Figure.19.4.1.WORKPLANE GRAPH OF IT

Table.19.4.1. WORKPLANE VALUE CHART

TIME	WORKPLANE		
	Eav	Emin	Emax
	(lx)	(lx)	(lx)
9	2588	615	27640
12	3168	627	43597
15	1654	607	14194

In the left figure we can see the graphs of three parameters which are tabuled in the right table and this table is only for the floor.

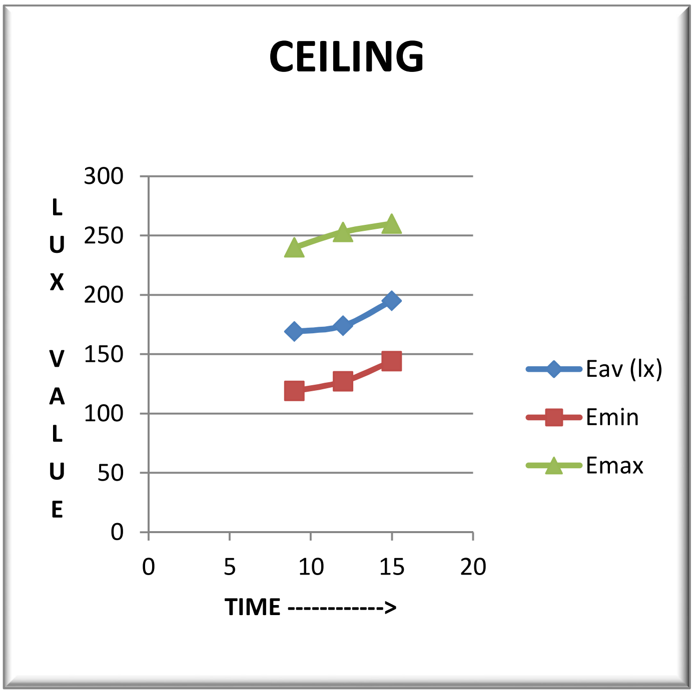
Figure. And Table 19.4.2.FLOOR VALUE CHART AND GRAPH OF IT



TIME	FLOOR		
	Eav	Emin	Emax
	(lx)	(lx)	(lx)
9	2375	556	33664
12	2802	555	41655
15	1021	520	12999

In the left figure we can see the graphs of three parameters which are tabuled in the right table and this table is only for the ceiling.

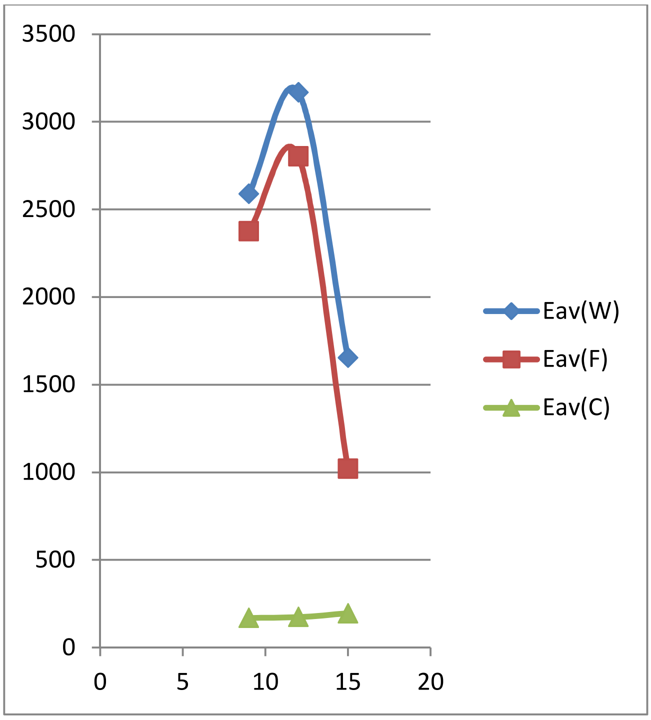
Figure. And Table 19.4.3.CEILING VALUE CHART AND GRAPH OF IT



TIME	CEILING		
	Eav	Emin	Emax
	(lx)	(lx)	(lx)
9	169	119	240
12	174	127	253
15	195	144	260

Now for comparison we have to put all the average lux level in a table, and make a graph of them and if we look into this graph then there is a symmetrical graphs takes place for workplane and floor but in the data table we also see that a wide range of lux values are tabulated against floor,but mainly in ceiling there is a moderate changes takes place with the changes of time.

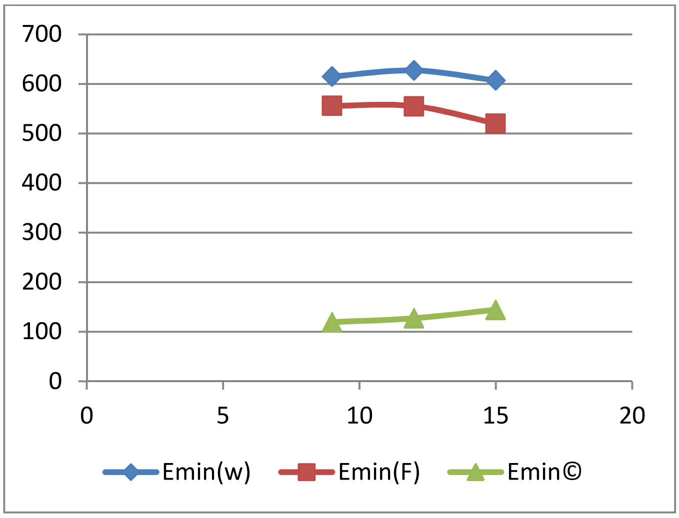
Figure. And Table 19.4.4.THE GRAPH AND CHART FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav(C)
9	2588	2375	169
12	3168	2802	174
15	1654	1021	195

Following the same procedure now we put all minimum lux values which are changed with time in a tabular format and with the help of the table we draw a graph, which is shown in the left side of the following figure.

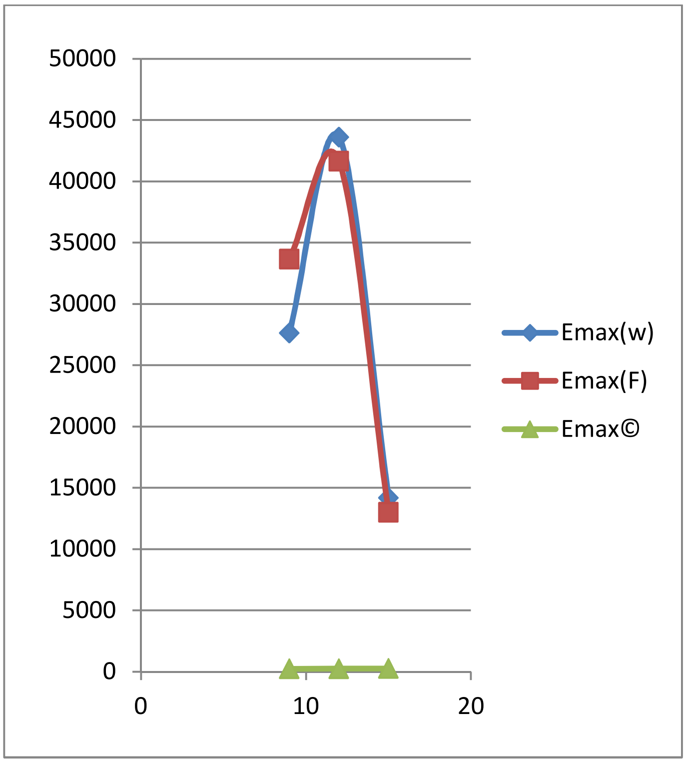
Figure. And Table 19.4.5.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(w)	Emin(F)	Emin(C)
9	615	556	119
12	627	555	127
15	607	520	144

This graph also maintain the same nature of the earlier cases, more or less the values are almost same in workplane and floor,and this changes are totally depending on the time of the day.But inn the case of ceiling here also same things occurred and the lux levels are all most same for through out the day.

Figure. And Table 19.4.6.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

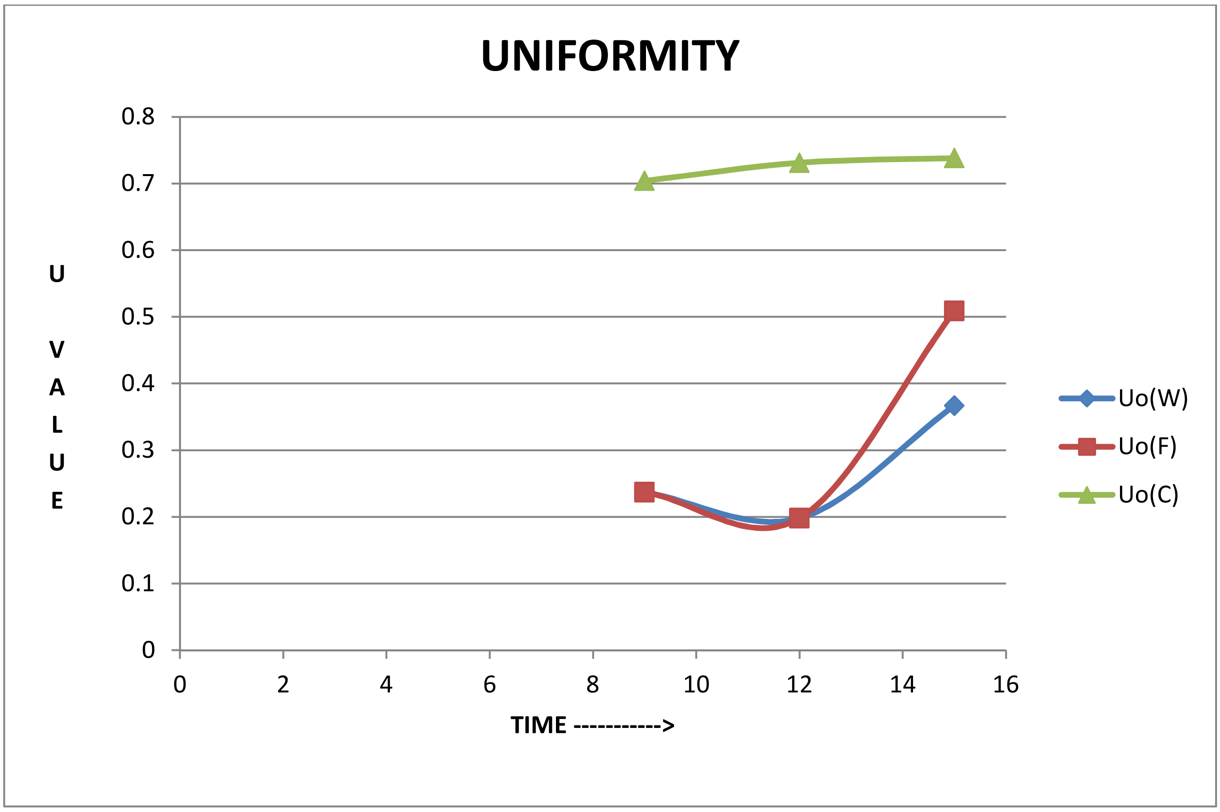


TIME	Emax(w)	Emax(F)	Emax(C)
9	27640	33664	240
12	43597	41655	253
15	14194	12999	260

Here we put a new parameter which is overall uniformity of workplane,floor and ceiling area, so we tabulated all the simulated datas in a table and make a graph with those datas.

Figure and Table 19.4.7.THE GRAPH AND CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Uo(W)	Uo(F)	Uo(C)
9	0.237	0.237	0.704
12	0.198	0.198	0.731
15	0.367	0.509	0.738



When we consider this new parameter then we can see a new phenomenon arrive which is the common point between workplane and floor on the same time of a particular day. The uniformity enhanced with the time cause as much as we increased the artificial lighting instead of day light we will get greater uniformity.

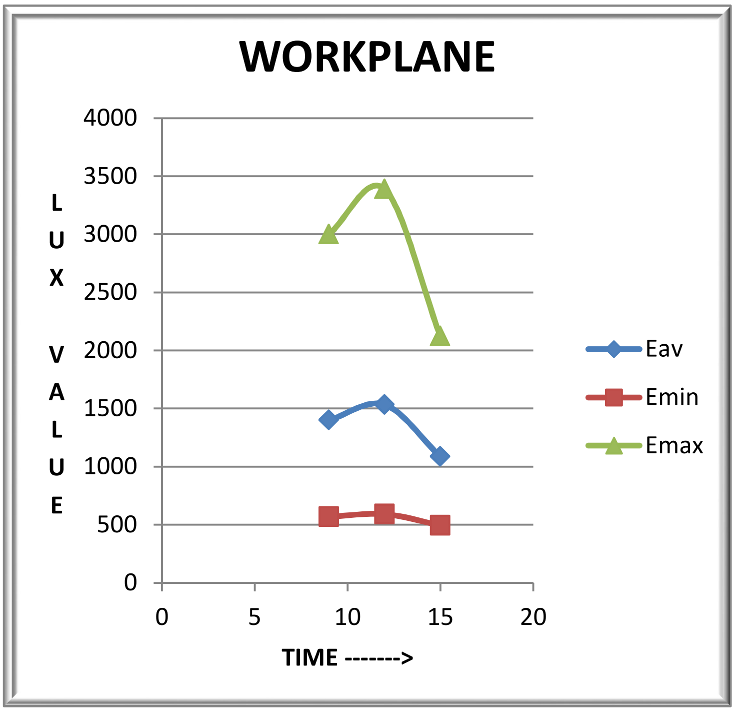
CASE : 5

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition. One control group is fully off and the other one is fully on.

Figure and Table 19.5.1.WORKPLANE VALUE CHART AND GRAPH OF IT

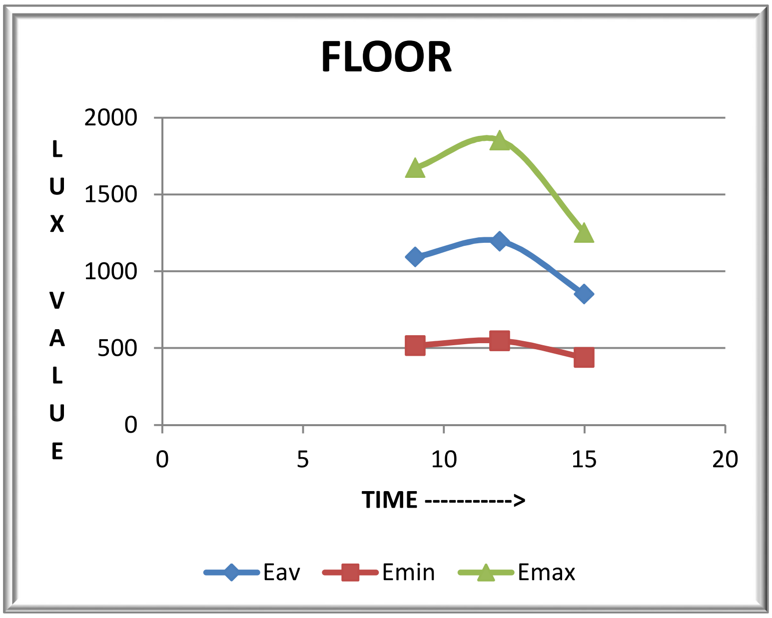


WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1401	569	3001
12	1533	591	3388
15	1086	495	2122

Above table is only for the overcast sky condition and these are only for workplane.The left figure shows all of these datas are putted into graph and the end result is shown above.

Now we put all those datas of floor illuminance values in the following table and make the graph from it.

Figure and Table 19.5.2.FLOOR VALUE CHART AND GRAPH OF IT

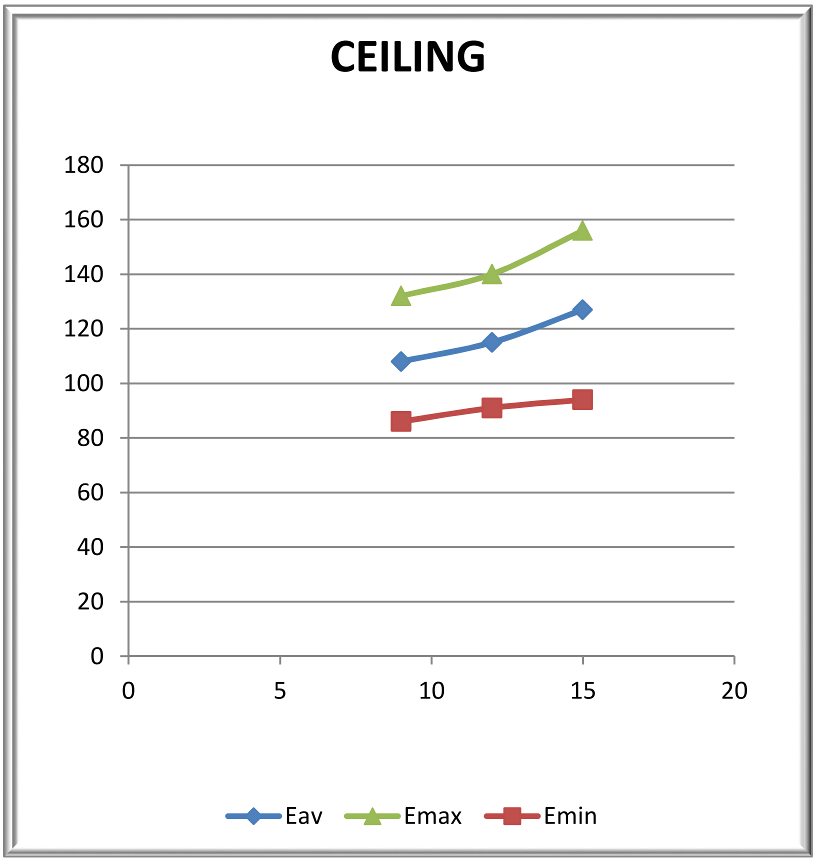


FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1093	516	1673
12	1196	548	1852
15	851	439	1252

As because we considered daylight integration so we get the graph of maximum values of illuminance above the range of thousands of lux ,and for this same reason the average lux values are also in the same range.

Now the following table shows the values of ceiling and the graph shows the same values in it.

Figure and Table 19.5.3.CEILING VALUE CHART AND GRAPH OF IT

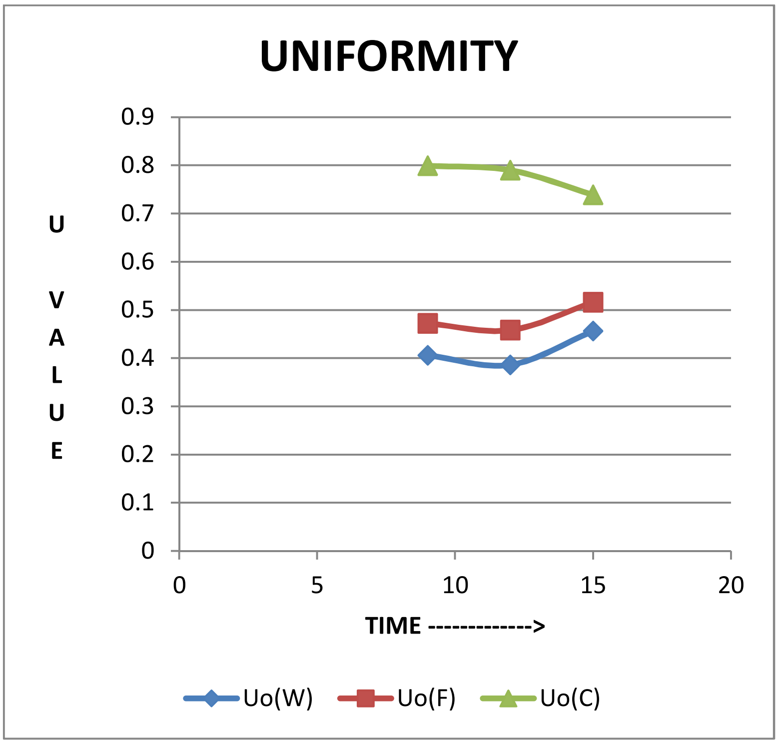


CEILING			
TIME	Eav	Emin	Emax
9	108	86	132
12	115	91	140
15	127	94	156

This graph is very smooth and all the nature of three graphs are similar because the control group and the daylight integration.

The following graph and table is only for uniformity in the same condition, and from these two we can easily observe that daylight could not provide good amount of uniformity, but when we look into the ceiling part then we quickly get the required uniformity within that particular time period.

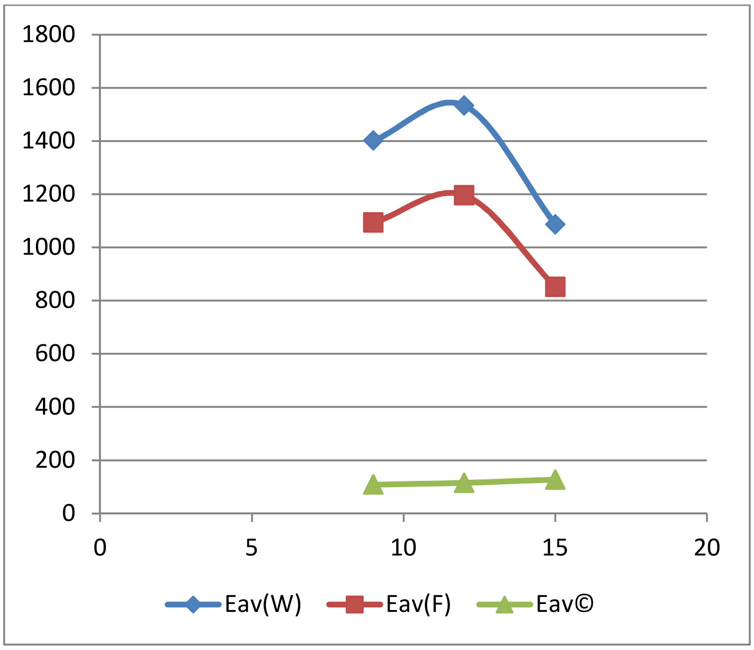
Figure and Table 19.5.4.UNIFORMITY VALUE CHART AND GRAPH OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.406	0.472	0.799
12	0.386	0.458	0.79
15	0.456	0.516	0.739

As we discussed in the prior section,here we observe the same thing happened.Now for comparative study here we also put all average lux values in the table and make a graph from it.

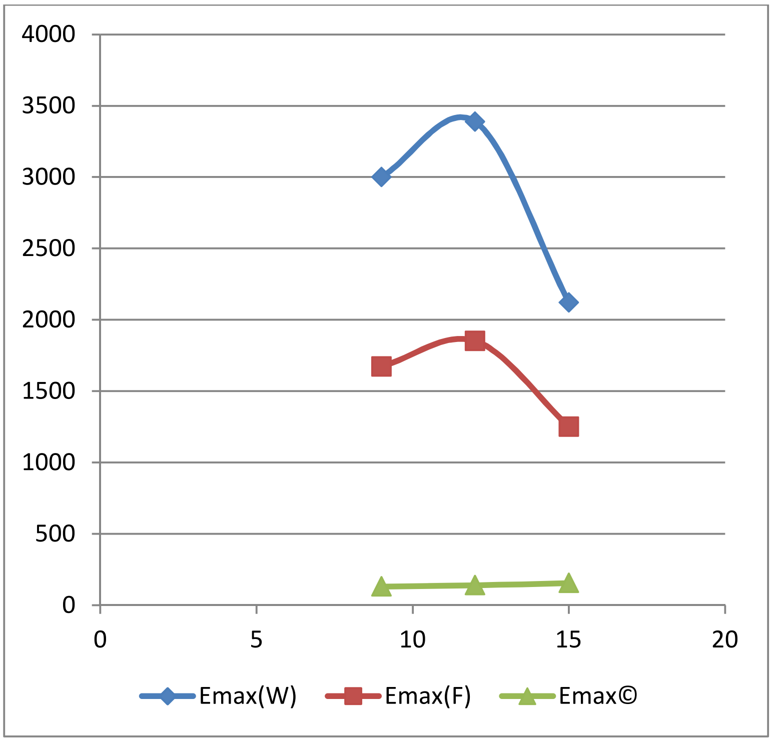
Figure and Table 19.5.5.THE GRAPH AND CHART FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav(C)
9	1401	1093	108
12	1533	1196	115
15	1086	851	127

Marinating the same flow of analysis now we put all of the maximum values in a table and make a corresponding graph from those datas and put them in below section.

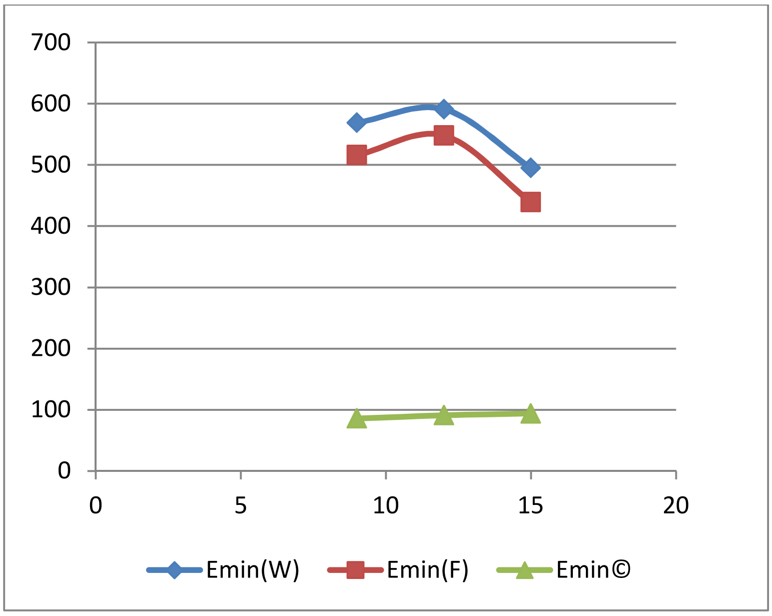
Figure and Table 19.5.6.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	3001	1673	132
12	3388	1852	140
15	2122	1252	156

Similar to the above comparison here we put all the minimum values and that comparative graph for better understanding.

Figure and Table 19.5.7.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin(C)
9	569	516	86
12	591	548	91
15	495	439	94

CASE :6

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

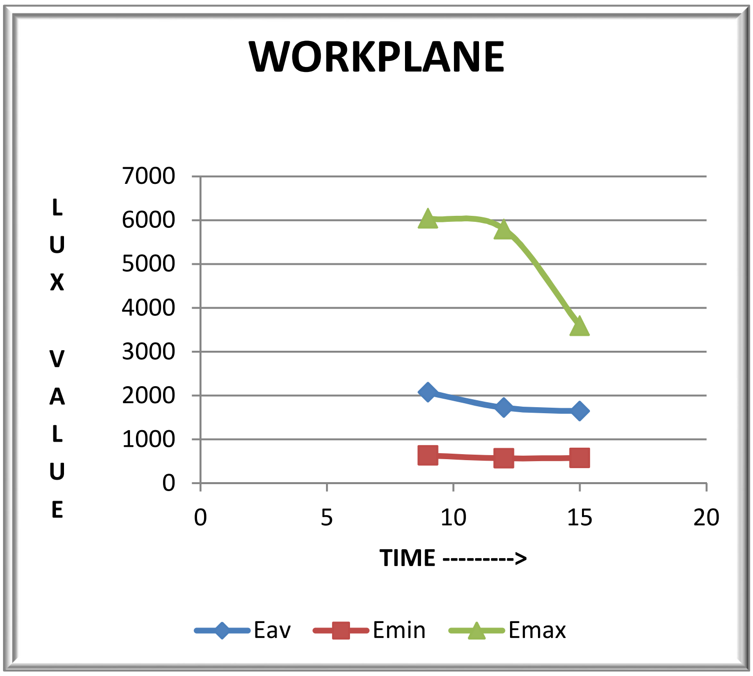
In this case study we follow the following parameters ,which are as follows:

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is fully off and the other one is fully on.

Following table is only for the mixed sky condition and these are only for workplane. The left figure shows all of these datas are putted into graph and the end result is shown below.

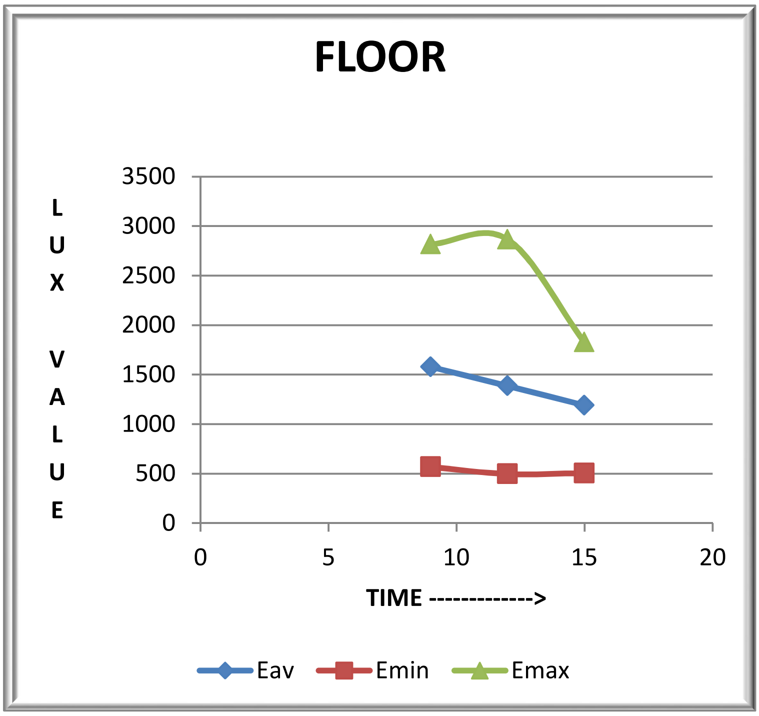
Now we put all those datas of floor illuminance values in the following table and make the graph from it.And the floor area shows the same nature of workplane,but in a smaller range,just the values are different from the prior part.

Figure and Table 19.6.1.WORKPLANE VALUE CHART AND GRAPH OF IT



WORKPLANE			
TIME	Eav	Emin	Emax
9	2068	628	6040
12	1721	568	5794
15	1638	575	3590

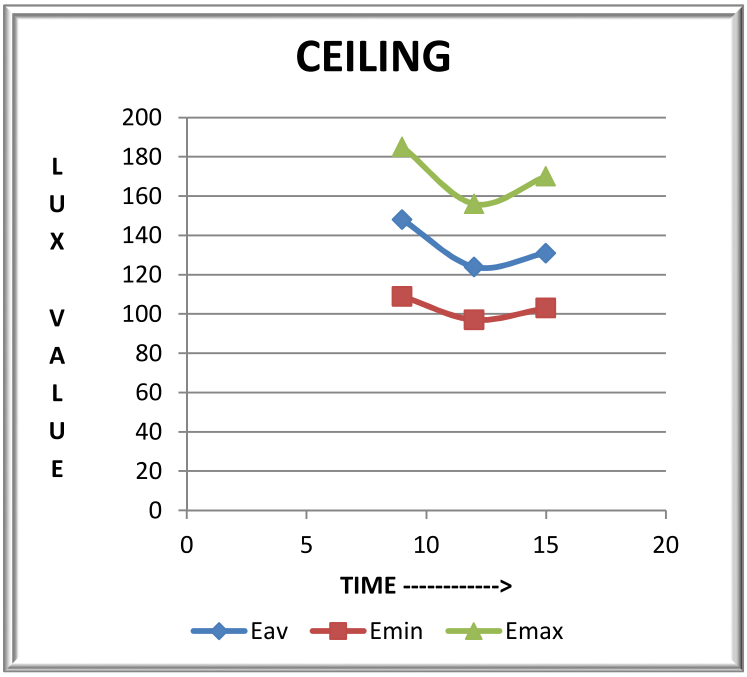
Figure and Table 19.6.2.FLOOR VALUE CHART AND GRAPH OF IT



FLOOR			
TIME	Eav	Emin	Emax
9	1577	567	2817
12	1385	496	2865
15	1190	505	1826

Mainly in the above graph we can see that it breaks all the previous nature of the graphs. Because ,here is no similarities takes place between average and maximum lux levels. In the left figure we can see the graphs of three parameters which are tabulated in the right table and this table is only for the ceiling only for mixed sky condition.

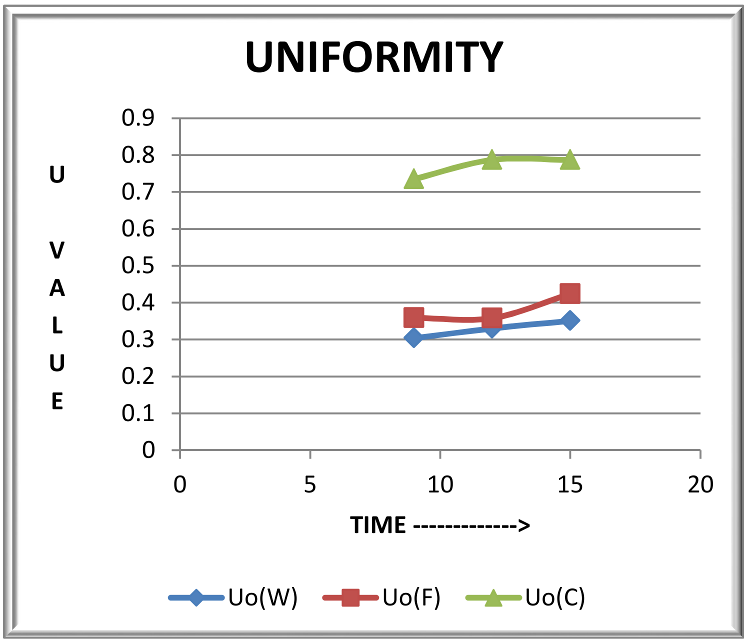
Figure and Table 19.6.3.CEILING VALUE CHART AND GRAPH OF IT



CEILING			
TIME	Eav	Emin	Emax
9	148	109	185
12	124	97	156
15	131	103	170

In mixed sky condition there is a massive change occurred in this part, in the mid of the day all the lux levels are decreased and then gradually it increases. And in below we can see the chart of uniformity as well as its corresponding graphs.

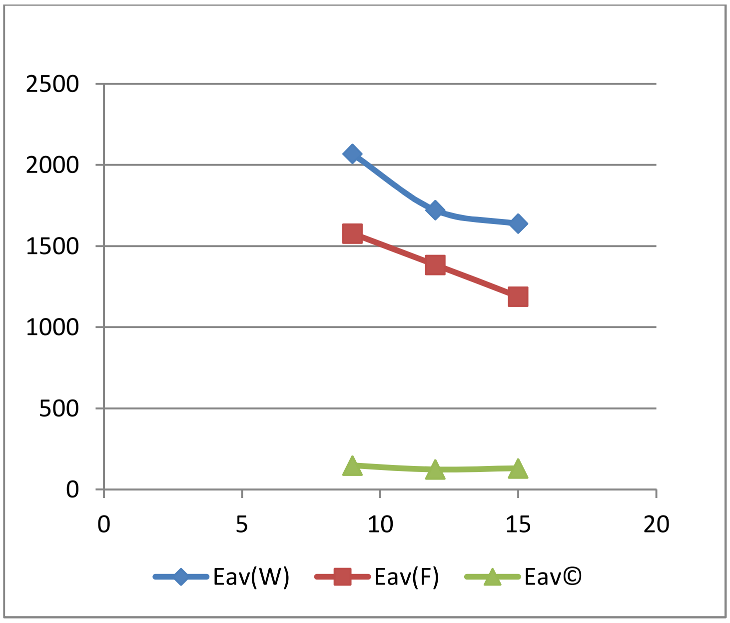
Figure and Table 19.6.4.UNIFORMITY VALUE CHART AND GRAPH OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.304	0.359	0.735
12	0.33	0.358	0.787
15	0.351	0.424	0.787

Again for comparative analysis we have to put all average values in a table and with help of it make a graphical representation of the datas.

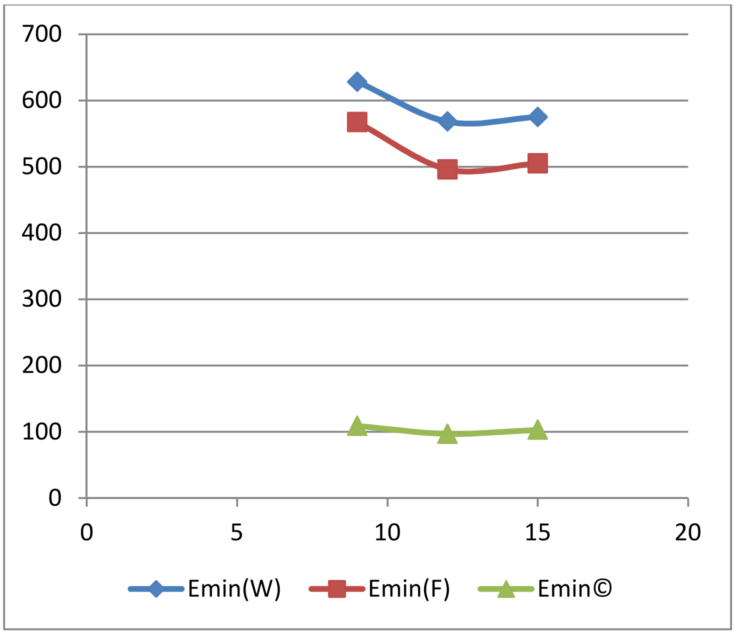
Figure and Table 19.6.5.THE GRAPH AND CHART FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav©
9	2068	1577	148
12	1721	1385	124
15	1638	1190	131

The above graph and the data table are the simulated values from the software for workplane,floor and ceiling of the test room which having the reflective factor of 65-35-05 and all of the average illuminance values are plotted in the above graph which are tabulated in the above table.

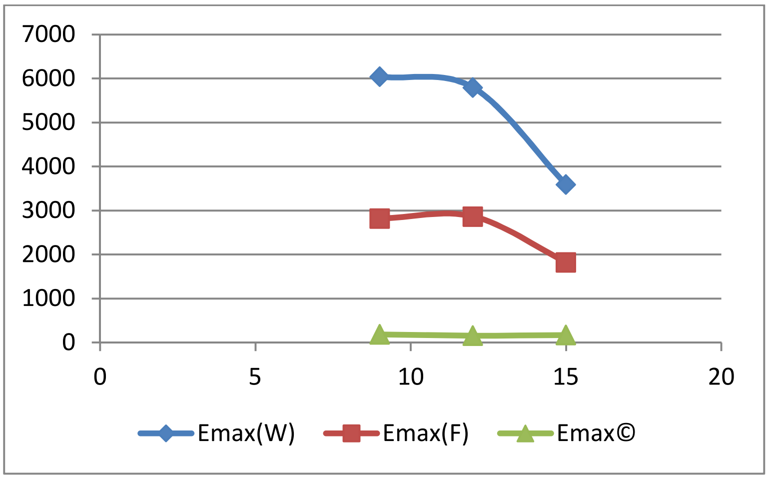
Figure and Table 19.6.6.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	628	567	109
12	568	496	97
15	575	505	103

The above graph and the data table are the simulated values from the software for workplane,floor and ceiling of the test room which having the reflective factor of 65-35-05 and all of the minimum illuminance values are plotted in the above graph which are tabulated in the above table.Here workplane and floor are nearly same as per the pattern of their graphs but ceiling is different from those.

Figure and Table 19.6.7.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



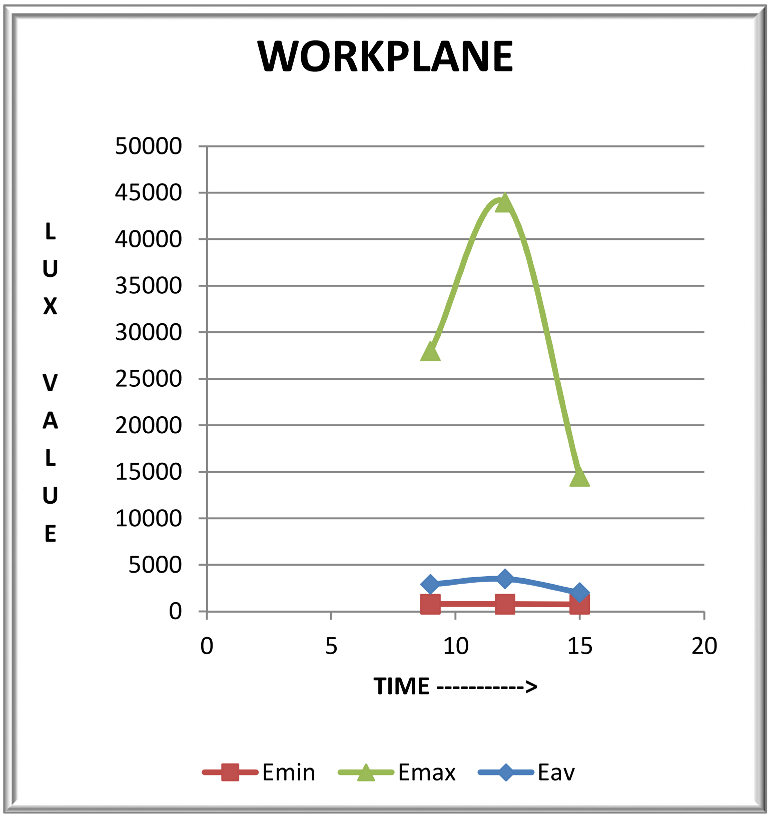
TIME	Emax(W)	Emax(F)	Emax©
9	6040	2817	185
12	5794	2865	156
15	3590	1826	170

CASE :7

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters,which are as follows:When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition.One control group is 50% dimmed and the other one is fully on.

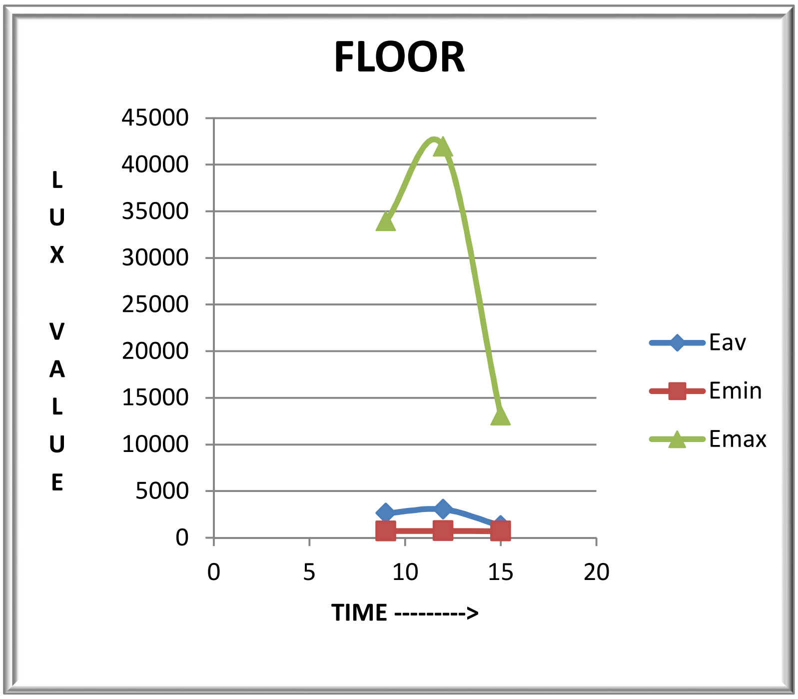
Figure and Table 19.7.1.WORKPLANE VALUE CHART AND GRAPH OF IT



WORKPLANE			
TIME	Eav	Emin	Emax
9	2903	777	27978
12	3483	772	43942
15	1999	769	14483

All the tabulated values are here for the workplane and those values are putted in the graph and the output result shown in the right side.

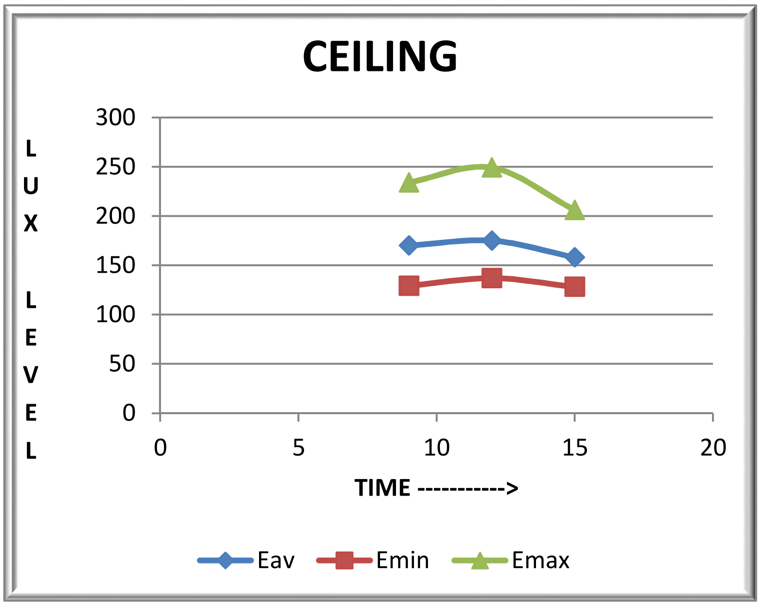
Figure and Table 19.7.2.FLOOR VALUE CHART AND GRAPH OF IT



FLOOR			
TIME	Eav	Emin	Emax
9	2614	718	33915
12	3042	721	41921
15	1273	692	13107

Mainly in the above graph we can see that it breaks all the previous nature of the graphs. Because ,here is no similarities takes place between average and maximum lux levels. In the left figure we can see the graphs of three parameters which are tabulated in the right table and this table is only for the ceiling only for clear sky condition.

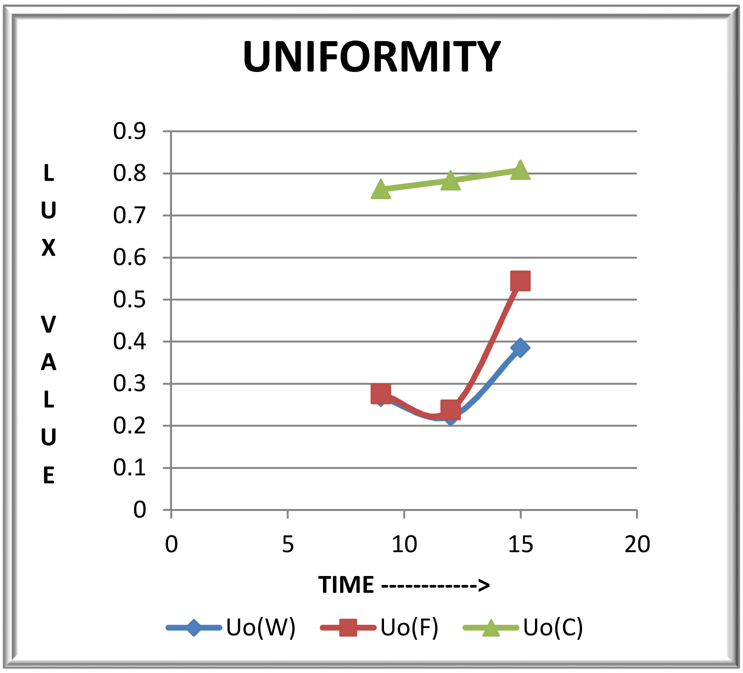
Figure and Table 19.7.3.CEILING VALUE CHART AND GRAPH OF IT



CEILING			
TIME	Eav	Emin	Emax
9	170	129	234
12	175	137	249
15	158	128	206

In clear sky condition there is a change occurred in this part, in the mid of the day all the lux levels are increased and then gradually it decreases. And in the above we can see the chart of all ceilings parameters and as well as its corresponding graphs.

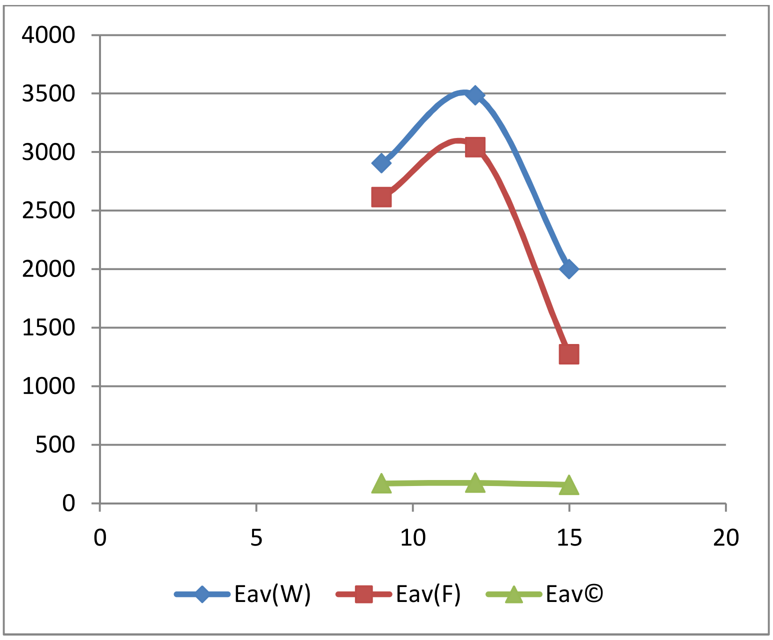
Figure and Table 19.7.4.UNIFORMITY VALUE CHART AND GRAPH OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.268	0.275	0.762
12	0.222	0.237	0.783
15	0.385	0.544	0.808

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated values of uniformity are tabulated in the above table. This simulation considered only for clear sky condition .One control group is 50% dimmed and the other one is fully on.

Figure and Table 19.7.5.THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

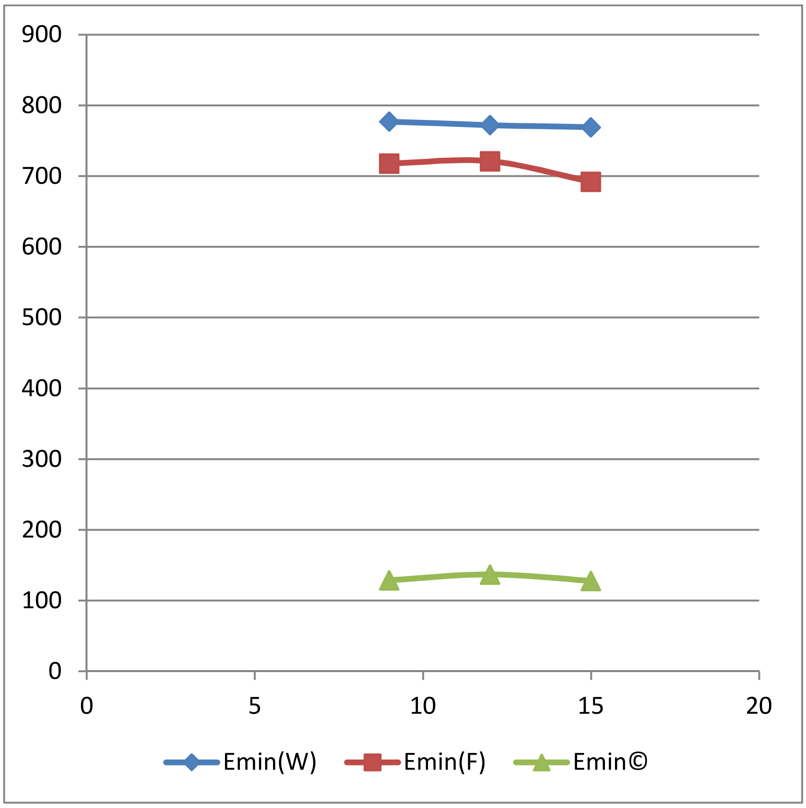


TIME	Eav(W)	Eav(F)	Eav©
9	2903	2614	170
12	3483	3042	175
15	1999	1273	158

The average values for workplane,floor and ceiling are tabulated in the following table.With the help of that table here the graph created and in the graph mainly two curve share the same nature which are for workplane and floor but the graph corresponds with ceiling is linear in nature.

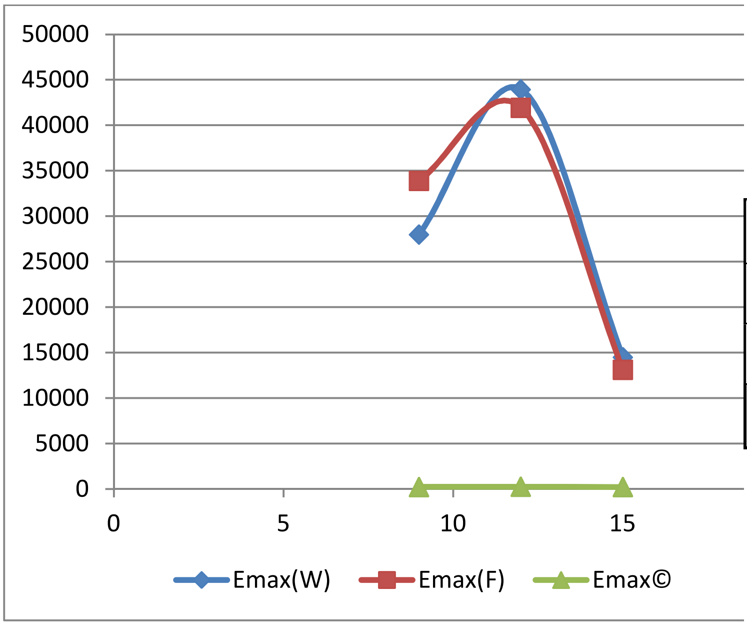
For comparing values here all the minimum datas are tabulated in a single table and with the help of those datas a graph is created which shows below.The graph of workplane is fully linear in nature because of a very small change through out the day.The floor area is also same in this regards,but it has more fluctuating data than workplane,so the curve is bended after 12PM.The lux level is so poor in this case .

Figure and Table 19.7.6.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	777	718	129
12	772	721	137
15	769	692	128

Figure and Table 19.7.7.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	27978	33915	234
12	43942	41921	249
15	14483	13107	206

Same procedure maintained here and for comparison all the maximum values putted together, as a result,a hipped structure of graph generated with respect to workplane and ceiling but the graph of ceiling is linear.

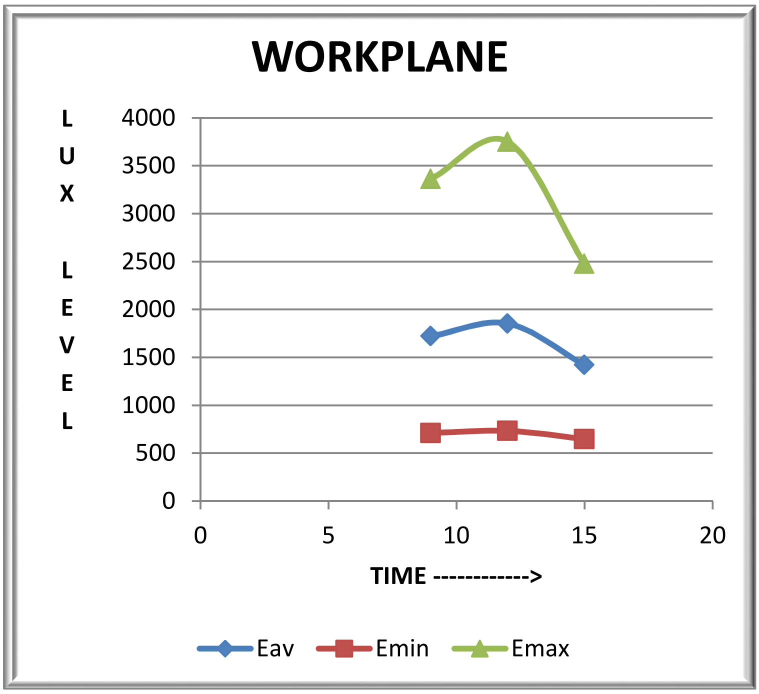
CASE : 8

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters ,which are as follows:

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition. One control group is 50% dimmed and the other one is fully on.

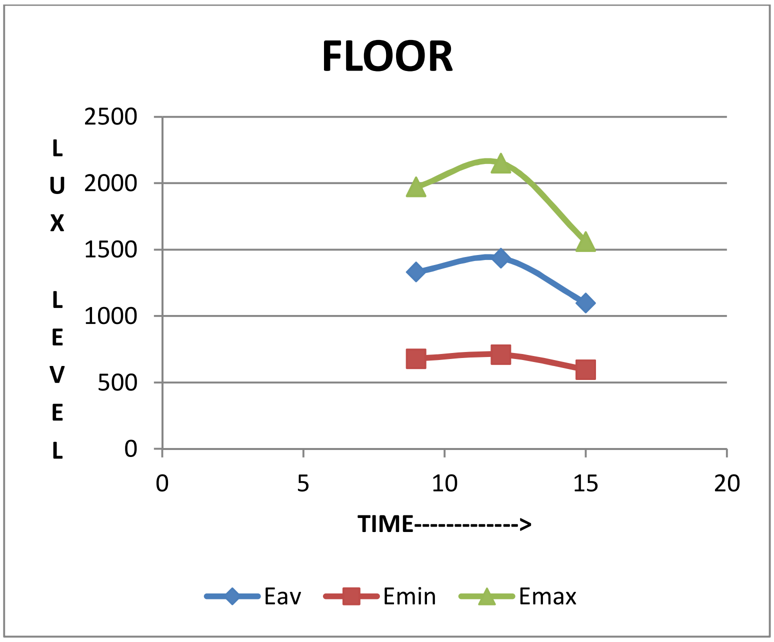
Figure and Table 19.8.1.WORKPLANE VALUE CHART AND GRAPH OF IT



WORKPLANE			
TIME	Eav	Emin	Emax
9	1721	711	3363
12	1853	733	3750
15	1420	648	2476

The workplane value chart and graphs of emax ,emin and eavg when the reflectivity of wall, ceiling and floor are 65-35-05 in overcast sky condition, and one control group is 50% dimmed and the other one is fully on are shown in the above figure and table,where its prominent that the maximum illuminance level is much higher than rest of two parameters.

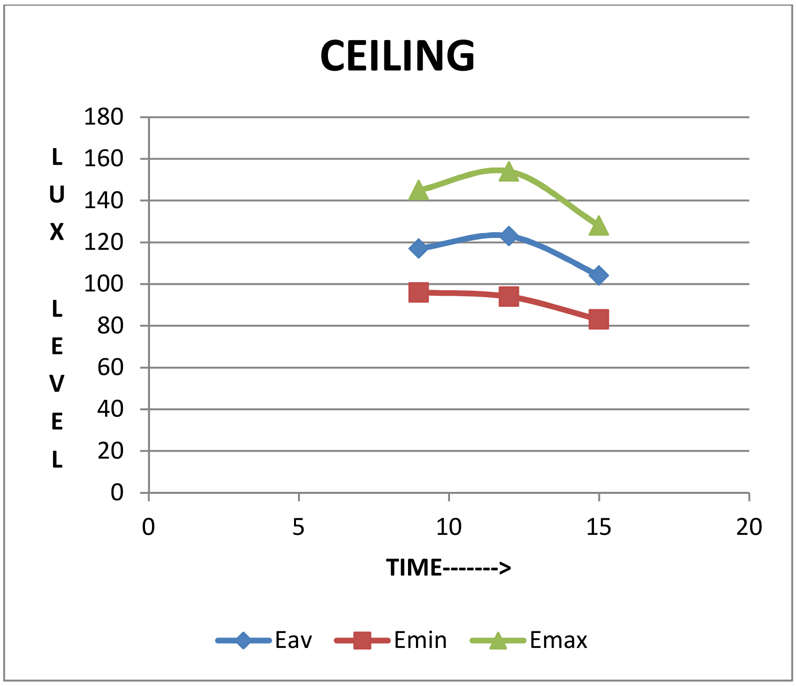
Figure and Table 19.8.2.FLOOR VALUE CHART AND GRAPH OF IT



FLOOR			
TIME	Eav	Emin	Emax
9	1332	680	1973
12	1435	710	2152
15	1098	598	1562

Mainly in the above graph we can see that it has a new nature of floor graph,and there are no similarities takes place with the previous nature of the graphs. Here three parameters are so much similar to each other and create the heaped nature.

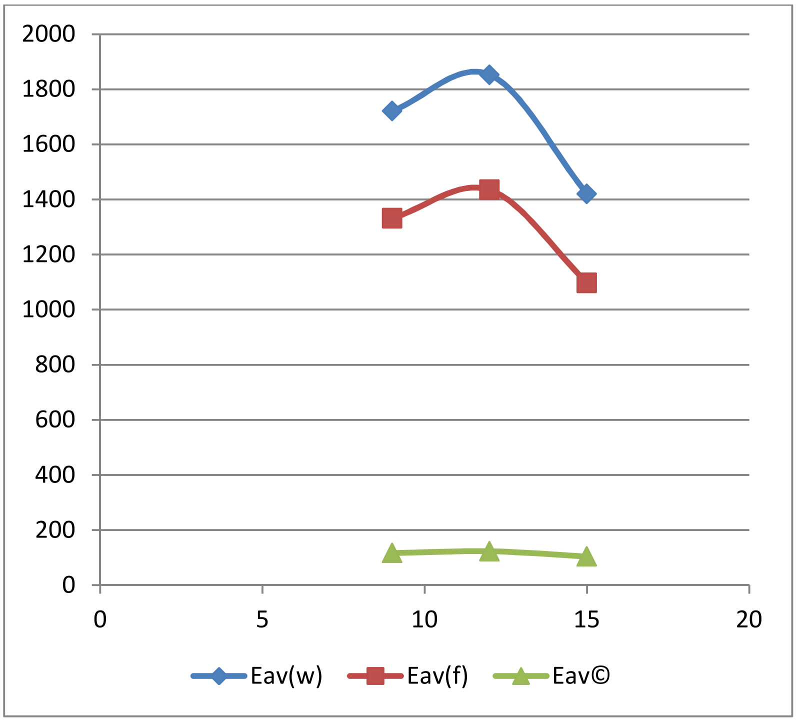
Figure and Table 19.8.3.CEILING VALUE CHART AND GRAPH OF IT



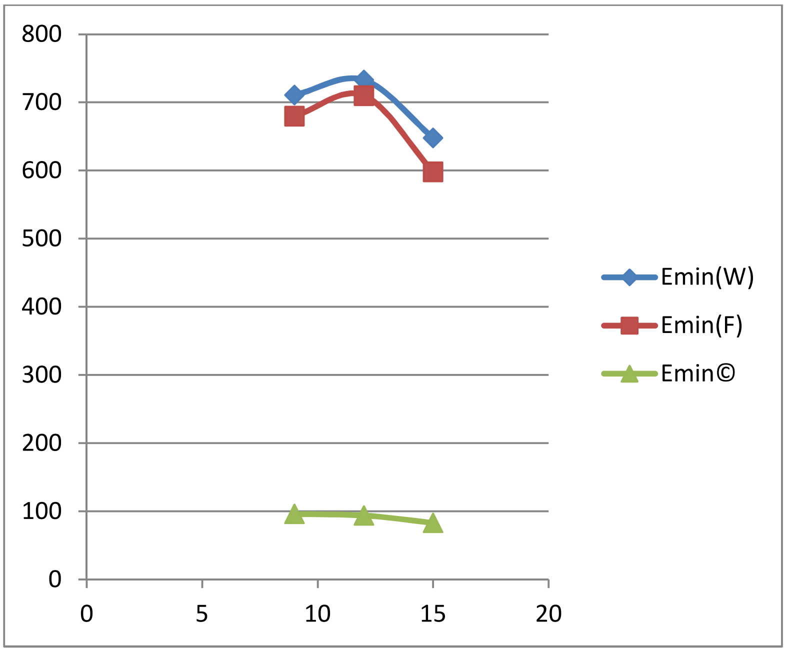
CEILING			
TIME	Eav	Emin	Emax
9	117	96	145
12	123	94	154
15	104	83	128

Figure and Table 19.8.4.THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	1721	1332	117
12	1853	1435	123
15	1420	1098	104

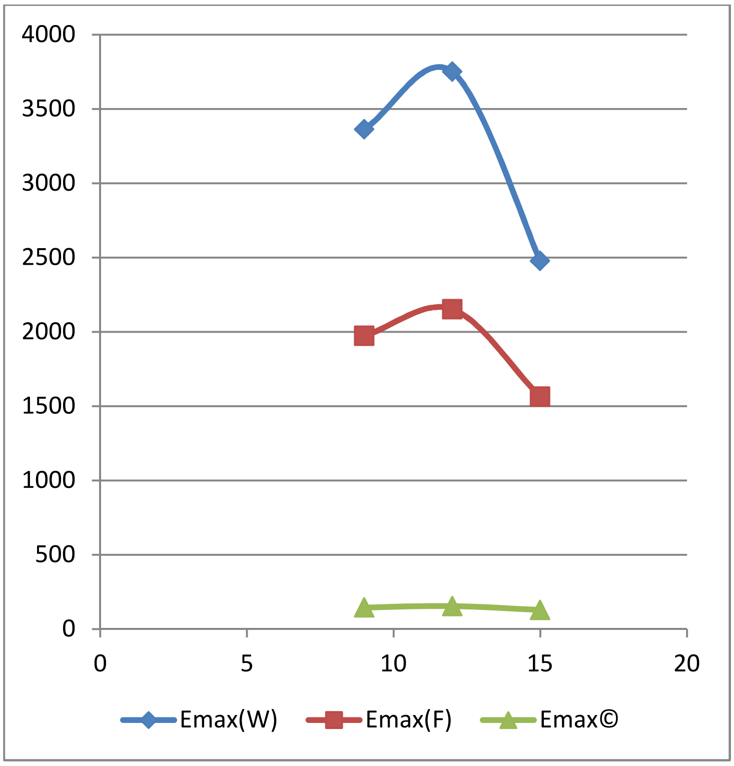


<u>Figure and Table 19.8.5.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING</u>



TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	711	680	96
12	733	710	94
15	648	598	83

Figure and Table 19.8.6.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax	Emax	Emax
9	3363	1973	145
12	3750	2152	154
15	2476	1562	128

In the above three graphs all are the comparative study of maximum,minimum and average lux values,and with the thoroughly observation the conclusion can be made in a line that,in each and every graph there are some similarities takes palce,mainly between workplane and floor.

CASE : 9

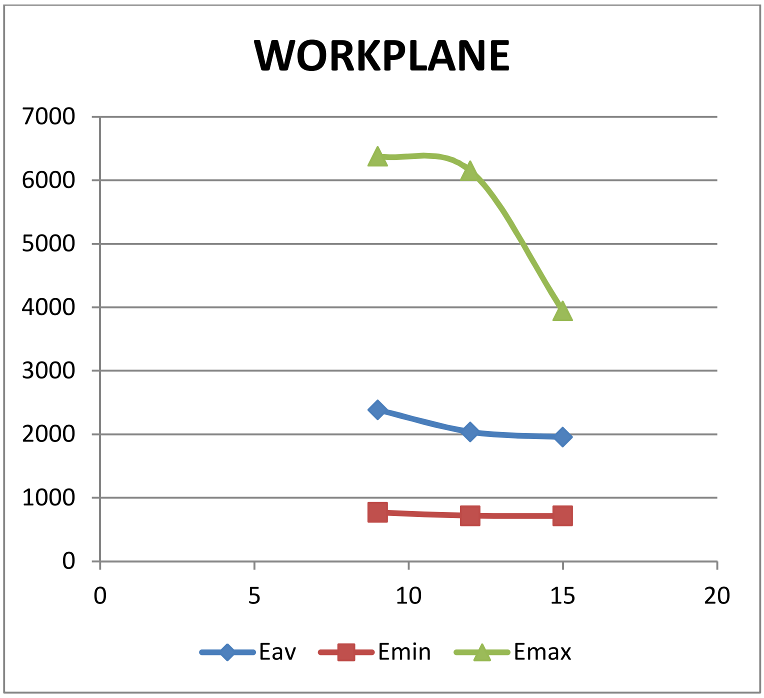
WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters ,which are as follows:

When the reflectivity of wall, ceiling and floor are 65-35-05 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is 50% dimmed and the other one is fully on.

Figure and Table 19.9.1.WORKPLANE VALUE CHART AND GRAPH OF IT

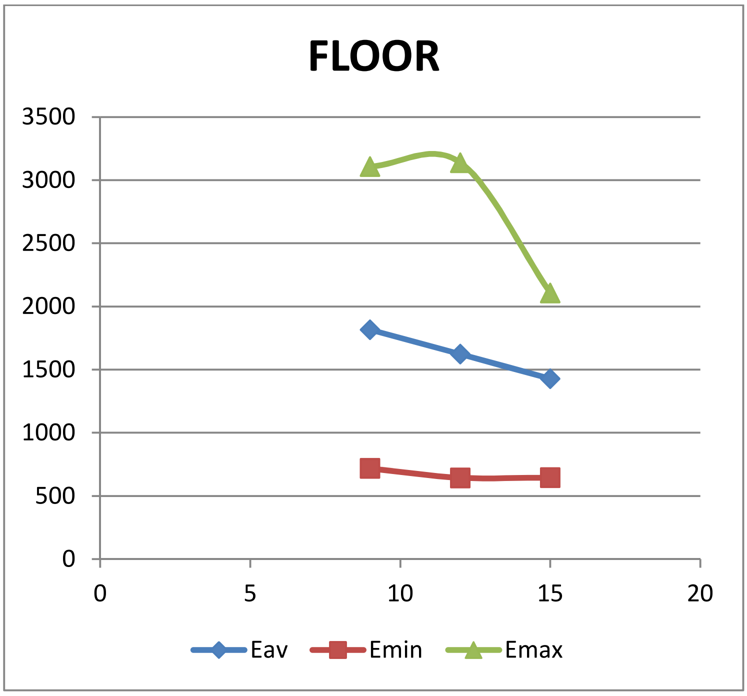
WORKPLANE



TIME	Eav	Emin	Emax
9	2384	771	6377
12	2039	717	6148
15	1954	716	3941

The above diagram shows all three parameters of illuminanace level for workplane,and for that reason the maximum level is much higher than the rest two parameters. And from tha tabulated data and graph it is clear to see that, minimum illuminance doesn't face any abrupt changes through out the day.

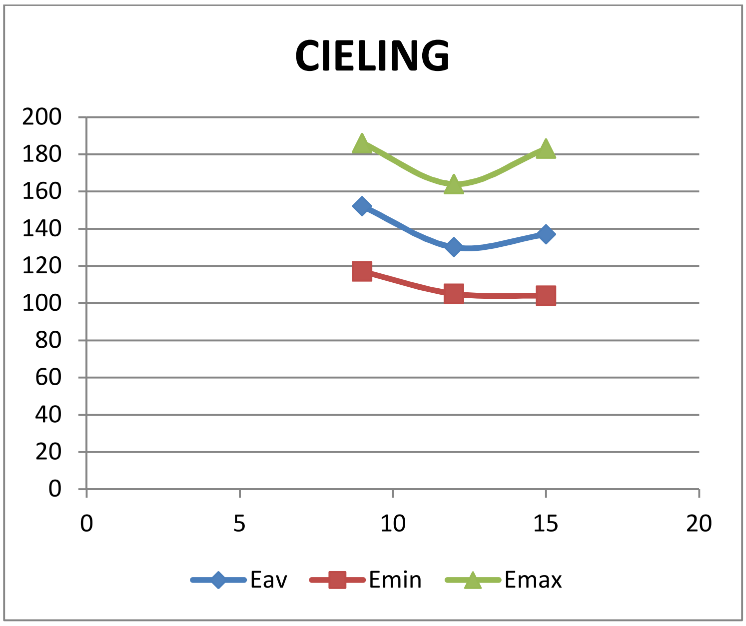
Figure and Table 19.9.2.FLOOR VALUE CHART AND GRAPH OF IT



FLOOR			
TIME	Eav	Emin	Emax
9	1815	718	3108
12	1623	644	3139
15	1428	646	2108

The same nature of the graph for workplane is reflects on the graph for floor also,but in this region all the values are lower than the previous one.

Figure and Table 19.9.3.CIELING VALUE CHART AND GRAPH OF IT



CEILING			
TIME	Eav	Emin	Emax
9	152	117	186
12	130	105	164
15	137	104	183

Position wise ceiling get an extra advantage of even light distribution through out the day,so all three graphs are very much linear to each other.

Figure and Table 19.9.4.THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	2384	1815	152
12	2039	1623	130
15	1954	1428	137

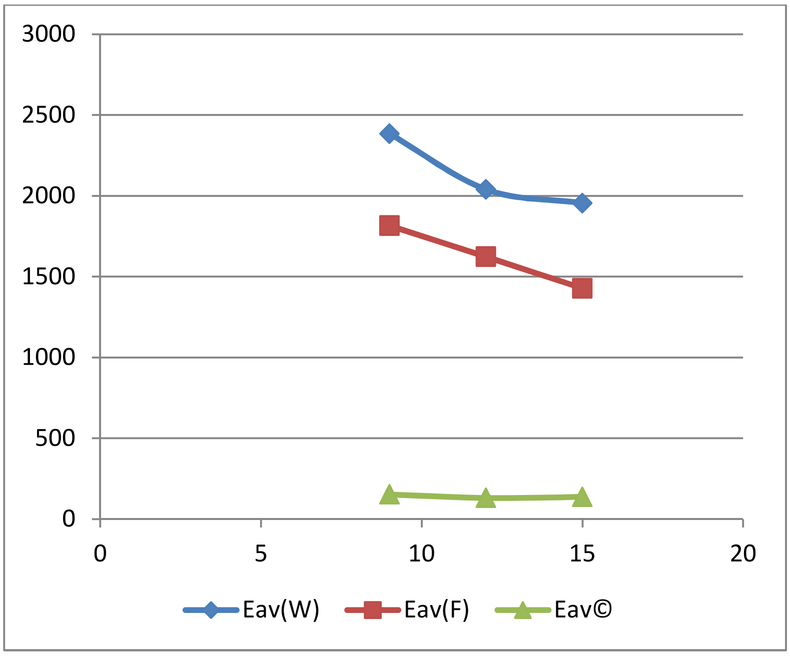
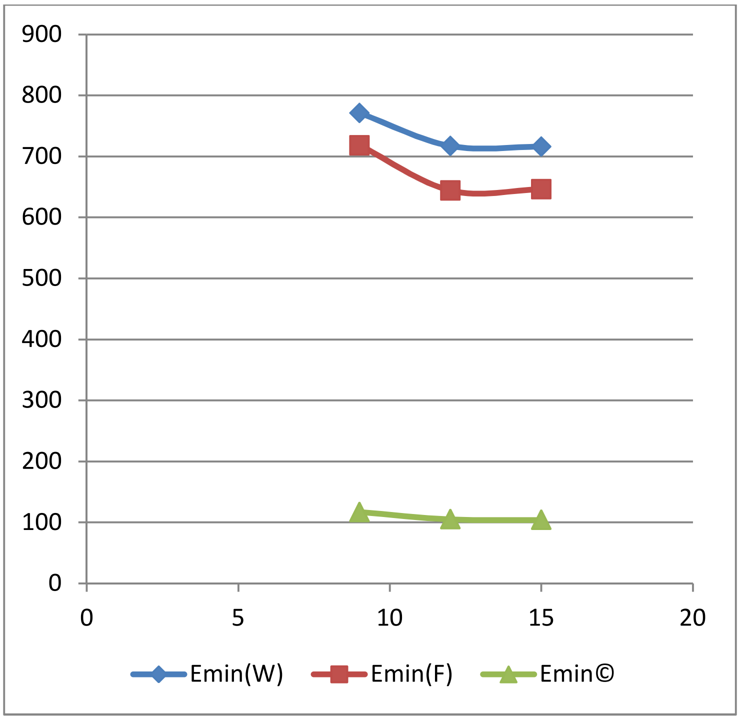
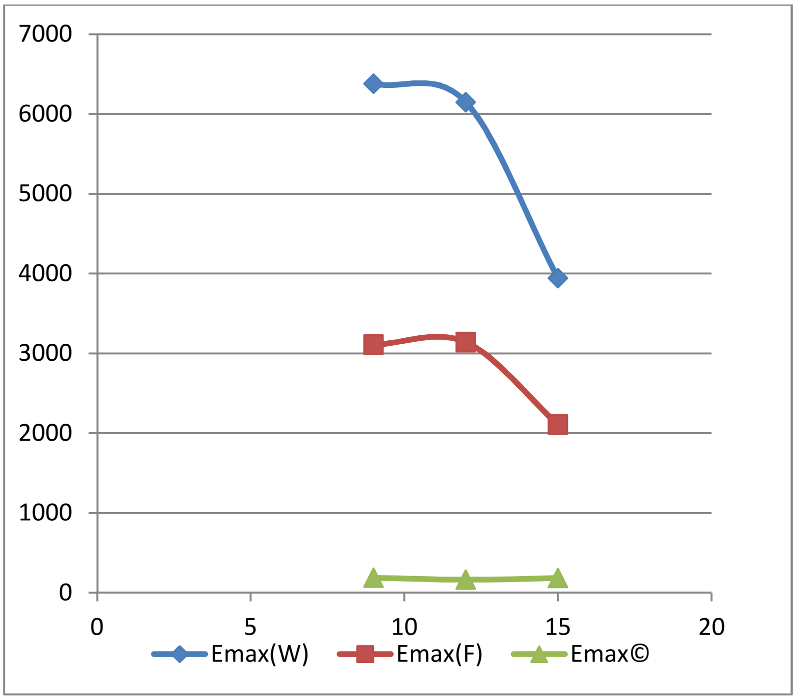


Figure and Table 19.9.5.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	771	718	117
12	717	644	105
15	716	646	104

Figure and Table 19.9.6.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6377	3108	186
12	6148	3139	164
15	3941	2108	183

From the above three graphs and data tables all values are putted together for comparative studies, and here one thing is noticed for all three graphs ,and that is the same nature of workplane and floor and ceiling is different from those two parameters.

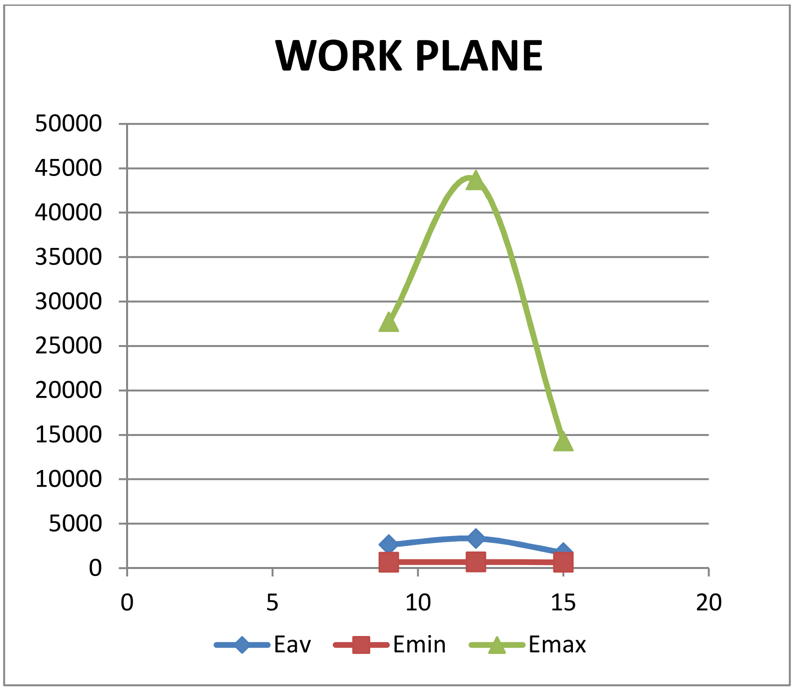
CASE : 10

WORKPLANE ,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 65-35-05 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters ,which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for clear sky condition. One control group is fully off and the other one is fully on.

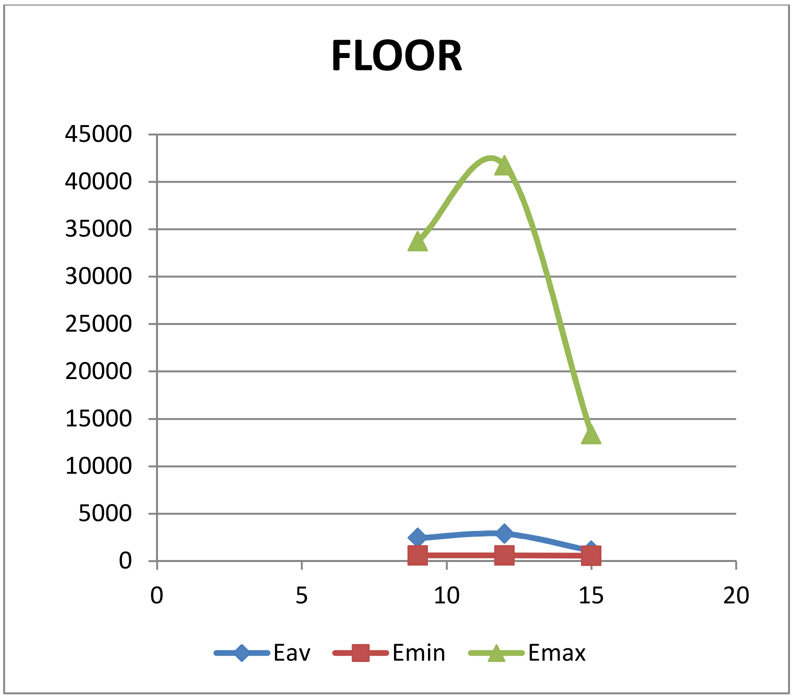
Figure and Table 19.10.1.WORKPLANE VALUE CHART AND GRAPH OF IT



WORKPLANE			
TIME	Eav	Emin	Emax
9	2655	670	27703
12	3329	685	43658
15	1740	658	14276

This simulation considered only for clear sky condition. One control group is fully off and the other one is fully on. due to the range of reflection factor the maximum illuminance level goes much higher than the rest of two parameters.

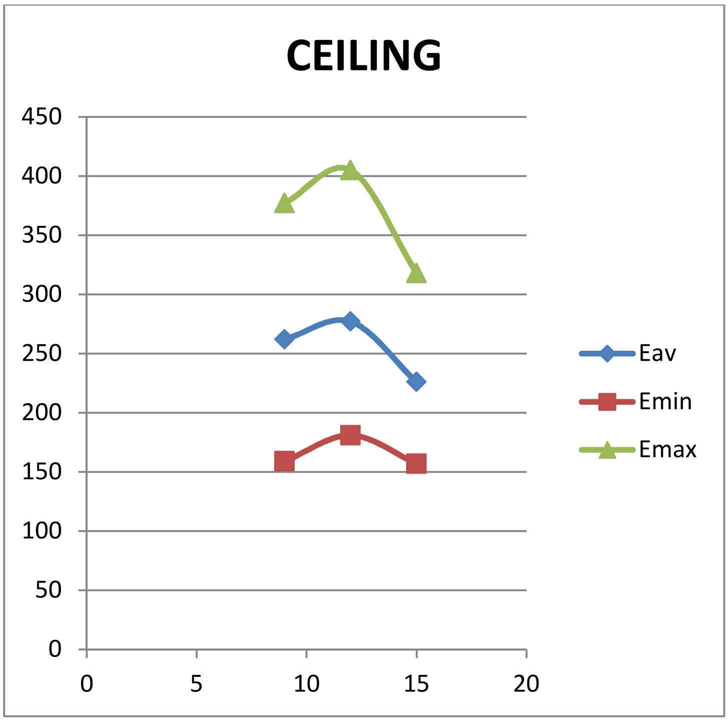
Figure and Table 19.10.2.FLOOR VALUE CHART AND GRAPH OF IT



FLOOR			
TIME	Eav	Emin	Emax
9	2444	610	33748
12	2875	599	41731
15	1098	564	13398

The above figure is just a replica of the previous one as per the nature of the graphs and datas.

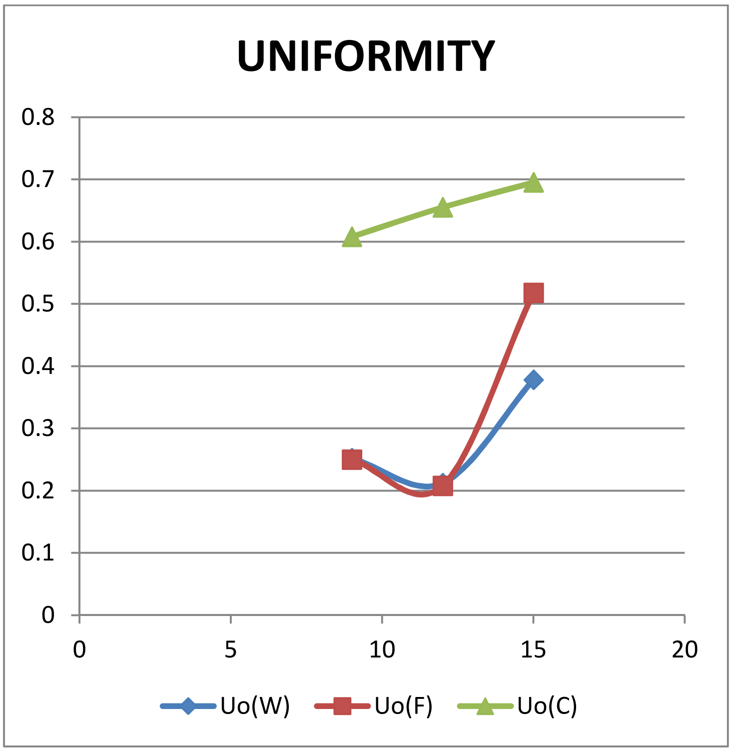
Figure and Table 19.10.3.CEILING VALUE CHART AND GRAPH OF IT



CEILING			
TIME	Eav	Emin	Emax
9	262	159	377
12	277	181	405
15	226	157	318

At 12PM the lux level increased and reached at its optimum values in the ceiling but as because the angle of sun penetration and positions of windows at 3PM the lux level is less than the level achieved at 9AM,due to this a ups and down graph created by those simulated datas.

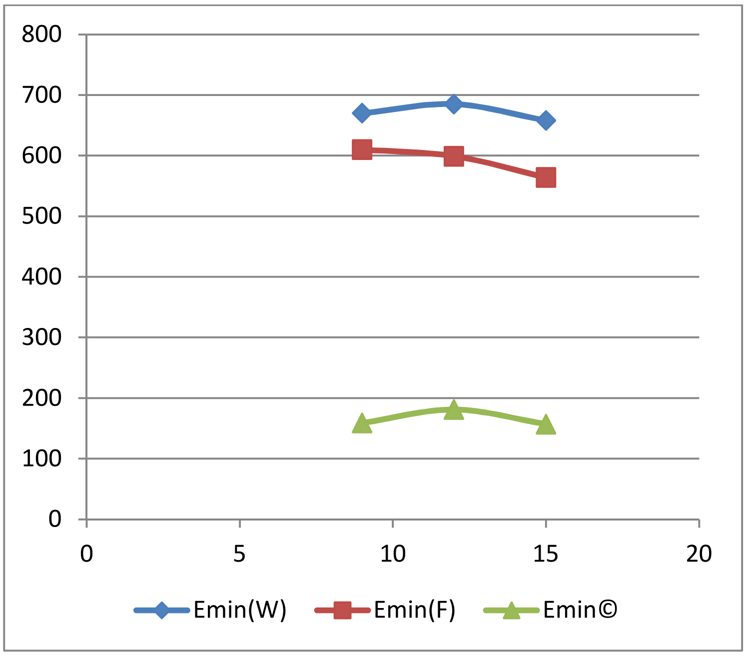
Figure and Table 19.10.4.UNIFORMITY VALUE CHART AND GRAPH OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.252	0.25	0.608
12	0.212	0.208	0.655
15	0.378	0.518	0.695

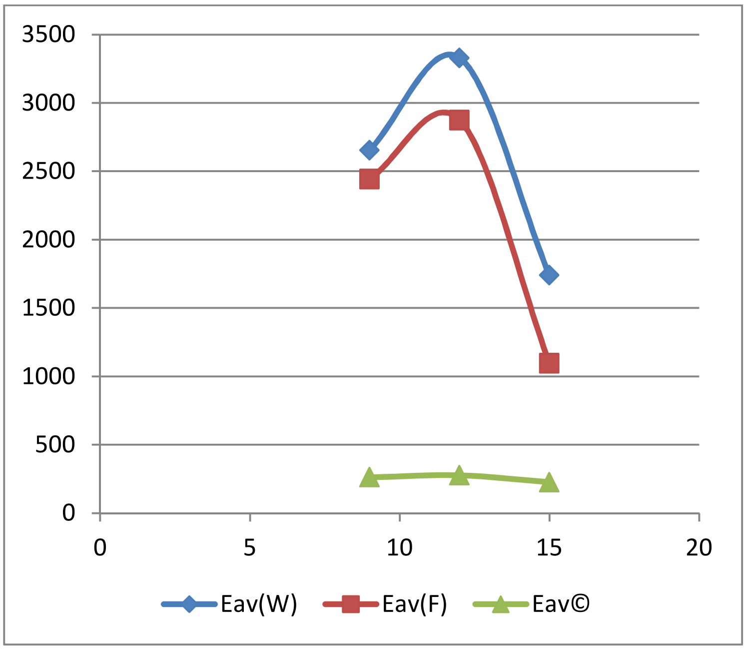
Through out the day the daylight comes in a uneven distributed way for this reason the uniformity is so poor basically in workplane and floor area, and from the above mentioned table the ceiling is illuminated with more or less same kind of daylight distribution and it makes a better graph for ceilings uniformity.

Figure and Table 19.10.5.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



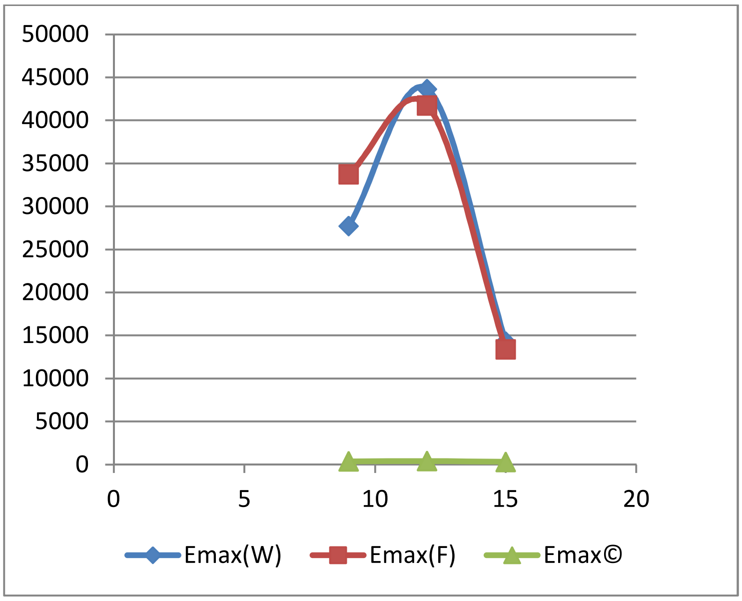
TIME	Emin(W)	Emin(F)	Emin©
9	670	610	159
12	685	599	181
15	658	564	157

Figure and Table 19.10.6.THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav©
9	2655	2444	262
12	3329	2875	277
15	1740	1098	226

Figure and Table 19.10.7.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	27703	33748	377
12	43658	41731	405
15	14276	13398	318

Following the prior method here also comparisons takes place,in the graph of Emin and Eav there is a prior mentioned similarities occurred which is alike for workplane and floor but the ceiling is diff3ernt from them and values are not in the same range of those two parameters also.In the case of Emax there is a overlapping occurred due to the daylight integrations on workplane and floor area,but for the ceiling portion it make a linear graph of maximum values.

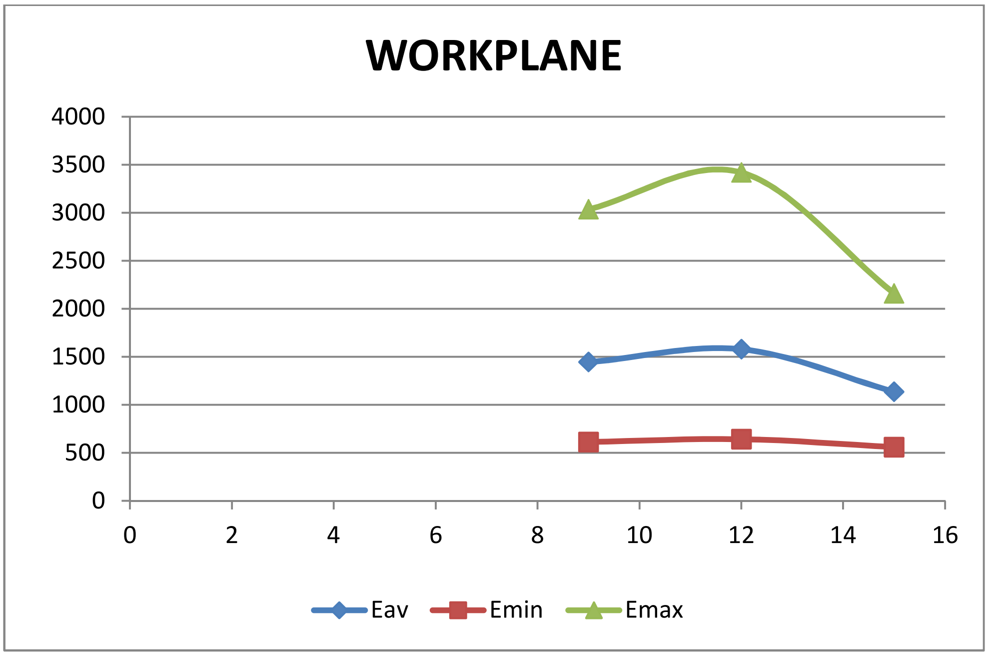
CASE: 11

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 70-40-10 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for overcast sky condition. One control group is fully off and the other one is fully on

11.1. WORKPLANE VALUE GRAPH OF IT

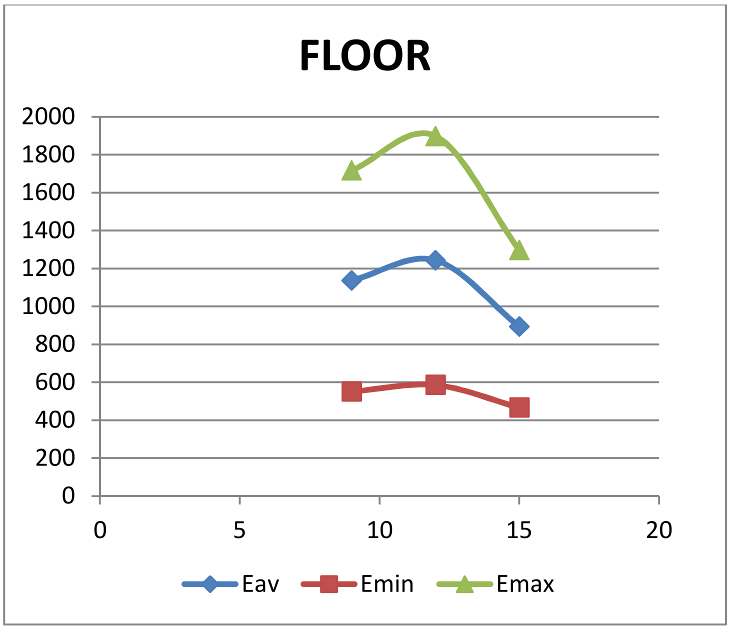


11.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1444	613	3036
12	1579	642	3420
15	1136	559	2159

Due to the increasing values of reflective factor and dimming values of luminaires, here the graph achieved a better response in order to the prior workplane graph. The distance between maximum and average lux level reduces the space, means its a indication of good uniformity can be achieved.

11.2. FLOOR VALUE GRAPH OF IT

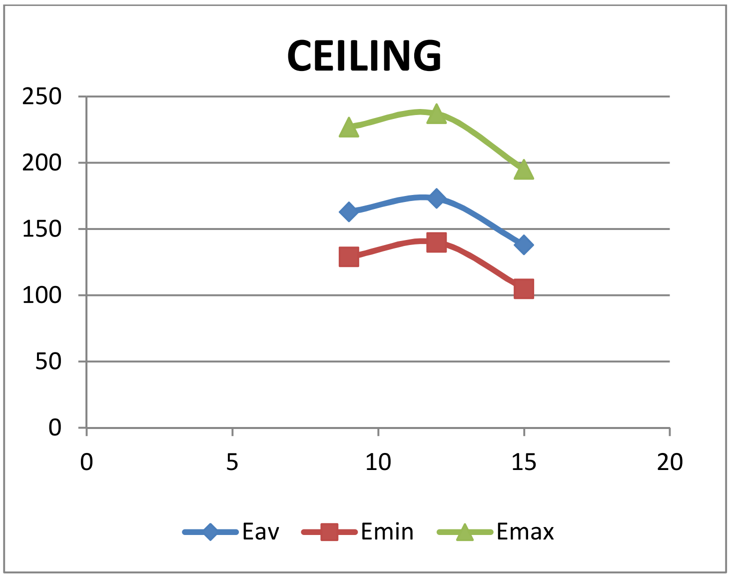


11.2.FLOOR VALUE CHART OF IT

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1136	550	1716
12	1243	585	1898
15	893	466	1297

Due to the overcast sky condition the maximum lux level achieved at 12PM the lux level increased and reached at its optimum values in the floor area but as because the positions of windows and dimming control, at 3PM the lux level is much less than the level achieved at 9AM,due to this a ups and down graph created by those simulated data's.

11.3. CEILING VALUE GRAPH

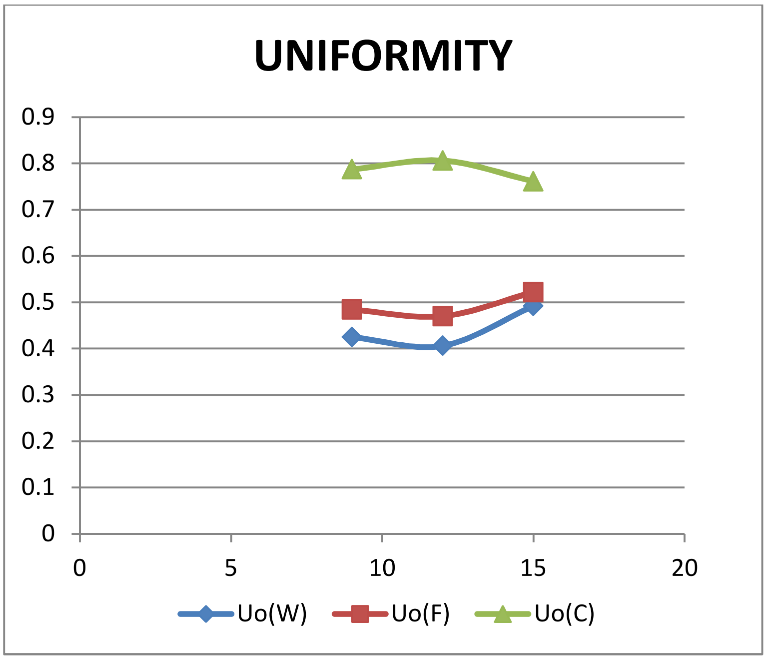


11.3. CEILING VALUE CHART

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	163	129	227
12	173	140	237
15	138	105	195

Here the same nature remains unchanged, so the small heaped nature of graphs are alike as it is in the prior cases, so there is no such a change reflects due to the change in reflection factors, sky condition along with the dimming control.

11.4 UNIFORMITY VALUE GRAPH

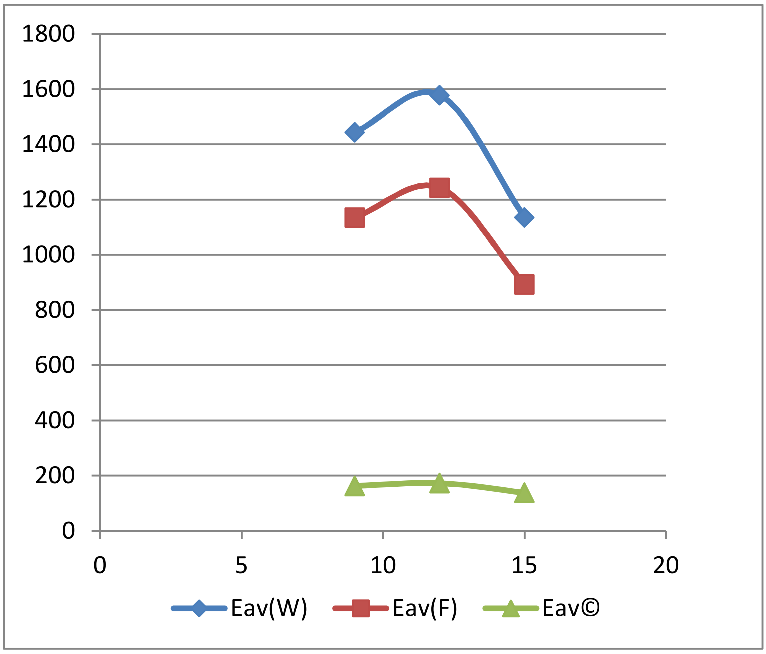


11.4.UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.425	0.484	0.787
12	0.406	0.47	0.806
15	0.492	0.522	0.761

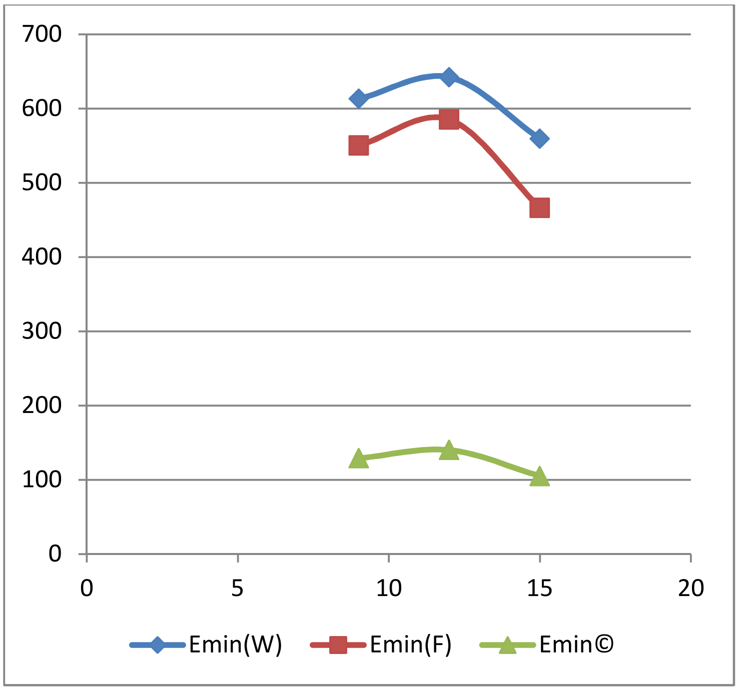
Here workplane and floor shows the same nature of graphs but they are very poor and having lower uniformity but just opposite of this graph generated for ceiling values.

11.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



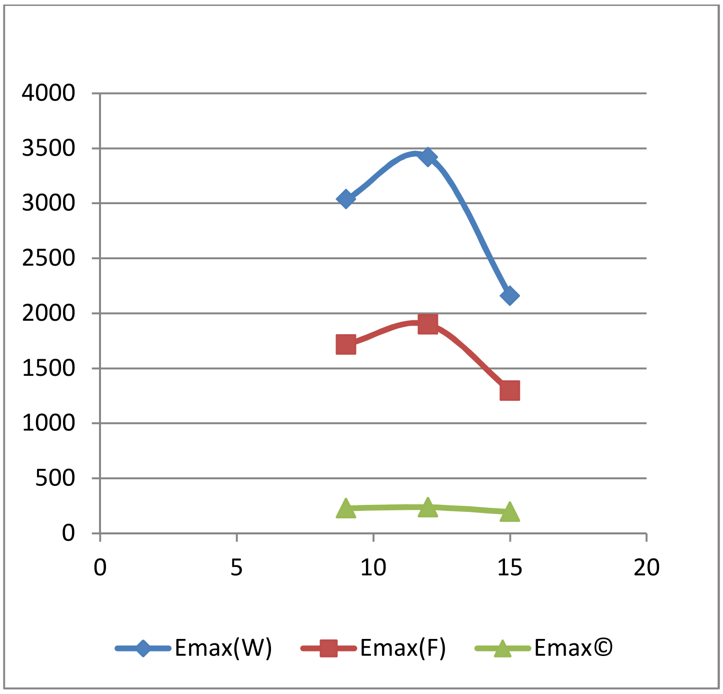
TIME	Eav(W)	Eav(F)	Eav©
9	1444	1136	163
12	1579	1243	173
15	1136	893	138

11.6.THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	613	550	129
12	642	585	140
15	559	466	105

11.7.THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	3036	1716	227
12	3420	1898	237
15	2159	1297	195

From all these above graphs one identical observation occurred that, the graph for workplane and floor, distance between these two are continuously reduced, the gap is highest for all the Emax values in three parameters, then the gap is smaller in Eav values and the graph reduced their difference in Emin. But for the study of the above in these three comparative graphs one thing is more or less same is the nature of the graph of ceiling.

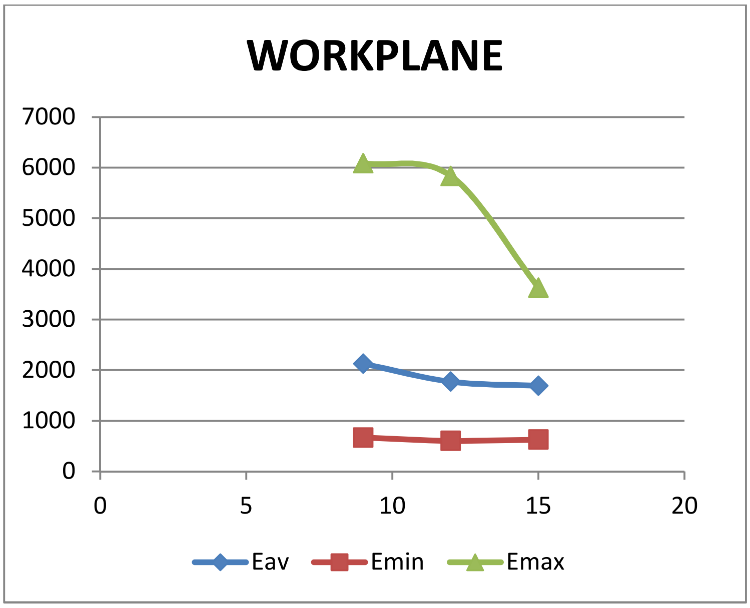
CASE: 12

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 70-40-10 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for mixed sky condition. One control group is fully off and the other one is fully on.

12.1. WORKPLANE VALUE GRAPH OF IT

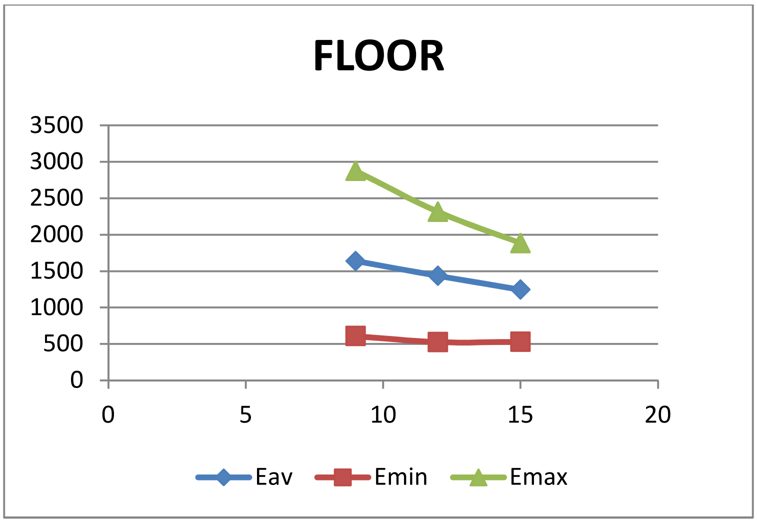


12.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	2127	668	6086
12	1771	603	5835
15	1690	626	3630

This simulation considered only for mixed sky condition. . One control group is fully off and the other one is fully on. Due to the range of reflection factor the maximum illuminance level goes much higher than the rest of two parameters. When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables.

12.2.FLOOR VALUE GRAPH OF IT

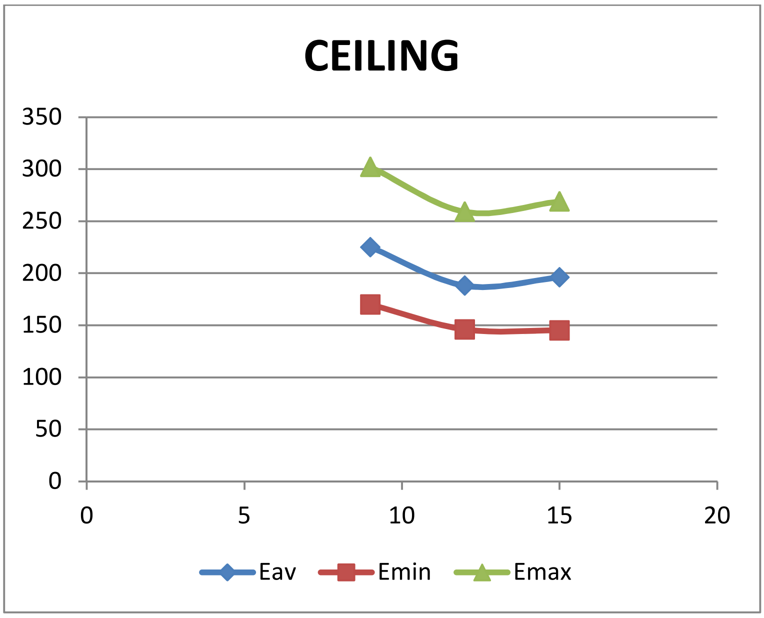


12.2.FLOOR VALUE CHART OF IT

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1639	607	2876
12	1435	525	2313
15	1244	528	1885

Mainly in the above graph we can see that it breaks all the previous nature of the graphs. Because, here the first sloping graph arrises. In the left figure we can see the graphs of three parameters which are tabulated in the right table and this table is only for the floor only for mixed sky condition.

12.3. GRAPH AND CHART FOR CEILING VALUE

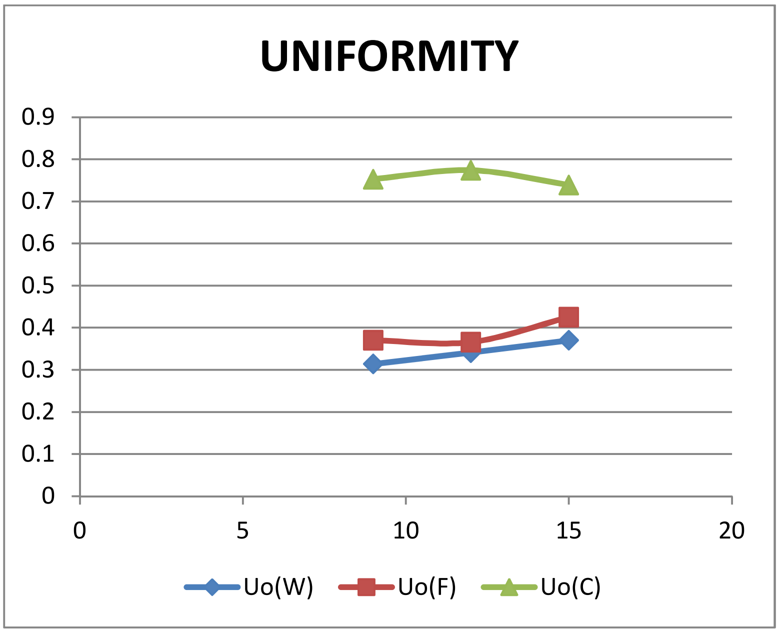


CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	225	170	302
12	188	146	259
15	196	145	269

In mixed sky condition there is a massive change occurred in this part, in the mid of the day all the lux levels are decreased and then gradually it increases. And in below we can see the chart of uniformity as well as its corresponding graphs.

12.4.UNIFORMITY VALUE GRAPH OF IT

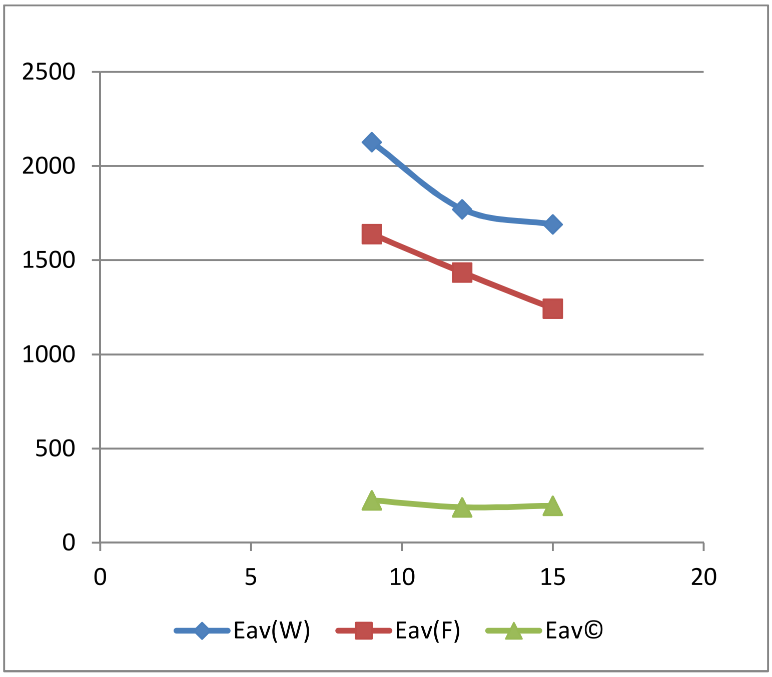
12.4.UNIFORMITY VALUE CHART OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.314	0.37	0.753
12	0.341	0.366	0.774
15	0.37	0.425	0.739

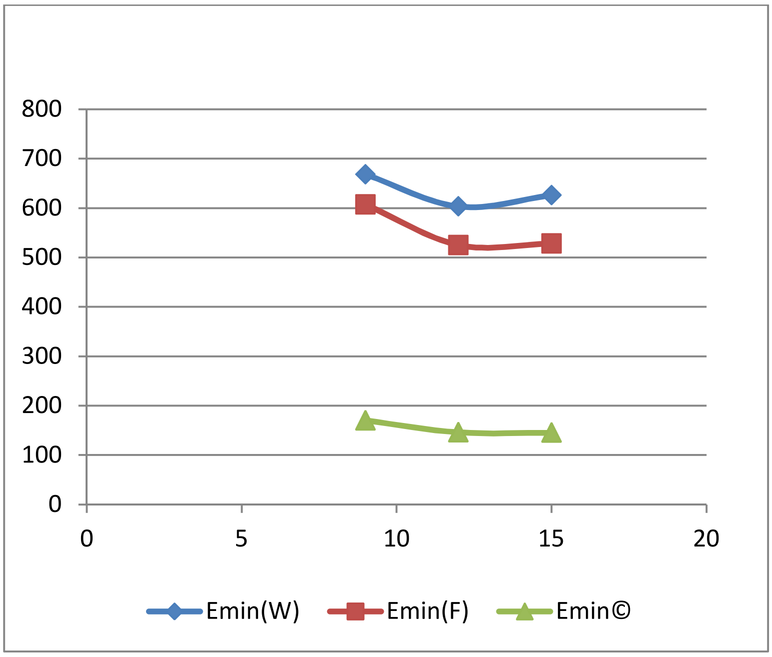
Here workplane and floor shows the same nature of graphs but they are very poor and having lower uniformity and an intersecting points also happened and the common cut off region occurred at 12PM but just opposite of this graph generated for ceiling values.

12.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



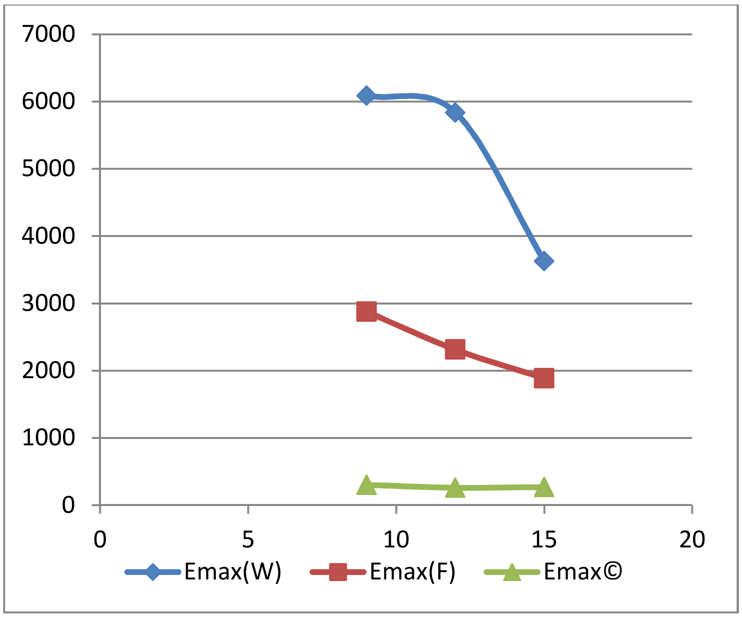
TIME	Eav(W)	Eav(F)	Eav©
9	2127	1639	225
12	1771	1435	188
15	1690	1244	196

12.6.THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING 12.6.THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	668	607	170
12	603	525	146
15	626	528	145

12.7. THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6086	2876	302
12	5835	2313	259
15	3630	1885	269

The sharp slope nature of the graphs of workplane and floor occurred in the Eav region and then the maximum values pointed at 9AM but then the average values reduces gradually, and for the minimum values these same observation is obtained but in the range of maximum values the pick illuminance level hit at 9AM but then it falls down sharply for workplane and floor area. In these three graph one thing is remain unchanged according to the nature of it, that is the ceiling graphs.

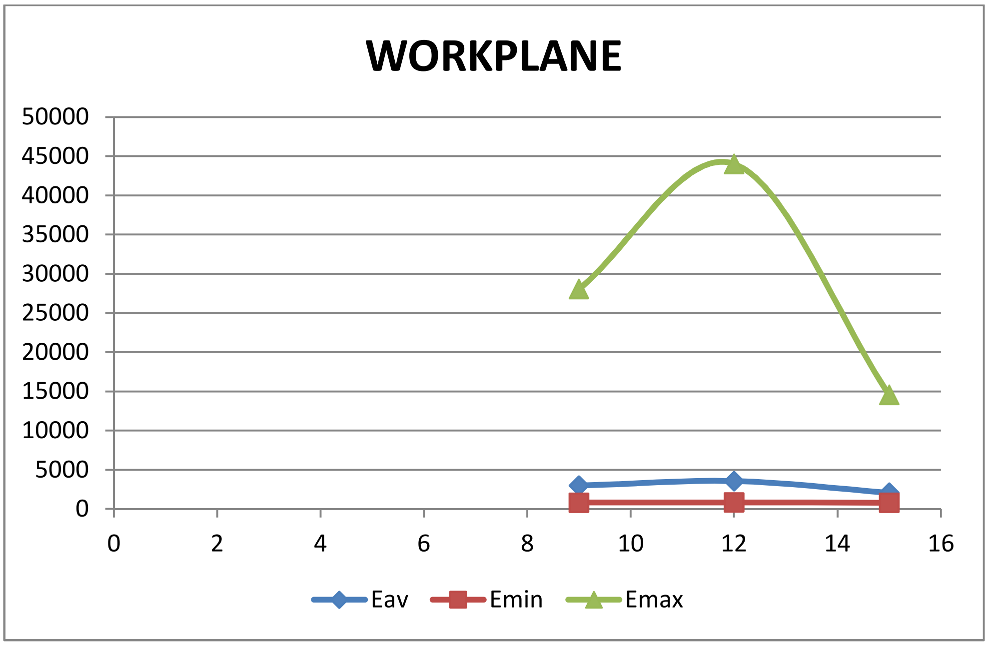
CASE: 13

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 70-40-10 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for clear sky condition. One control group is 50% dimmed and the other one is fully on.

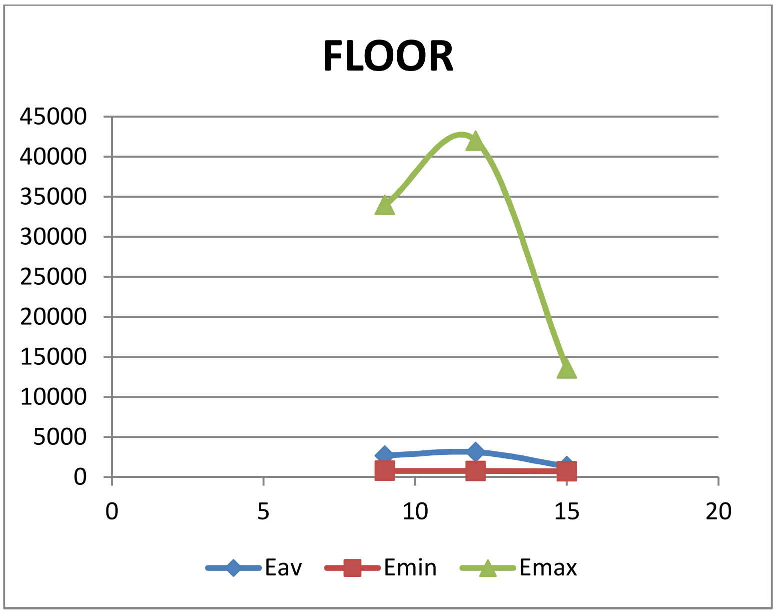
13.1.WORKPLANE VALUE GRAPH OF IT



13.1.WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	Eav	Emin	Emax
9	2980	818	28052
12	3564	841	44012
15	2067	807	14547

13.2.FLOOR VALUE GRAPH CHART



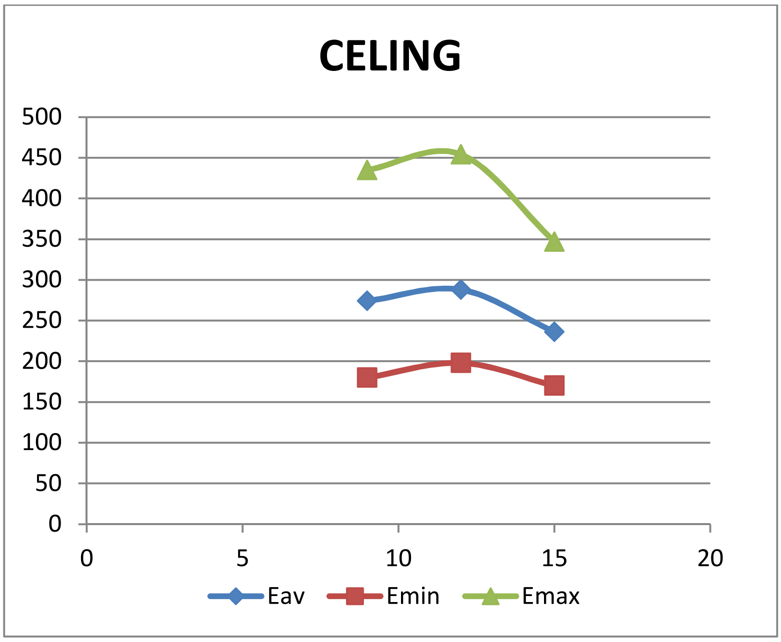
13.2.FLOOR VALUE

FLOOR			
TIME	Eav	Emin	Emax
9	2692	785	34007
12	3121	770	42005
15	1344	729	13575

The above two data tables are created with the simulated data's for clear sky condition, in a condition, when one control group is 50% dimmed and the other one is fully on, then just same observation happened as it shows in the case ,where, the reflectivity of wall, ceiling and floor are 70-40-10 for overcast sky condition. One control group is fully off and the other one is fully on.

13.3.CEILING VALUE GRAPH CHART

13.3.CEILING VALUE

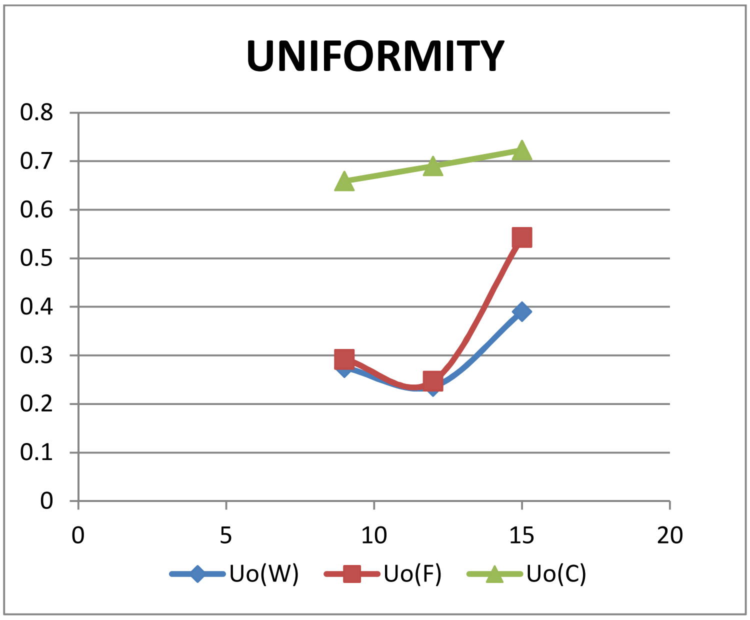


CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	274	180	435
12	288	198	454
15	236	170	347

Now for comparison we have to put all the average, minimum, maximum lux level in a table, and make a graph of them and if we look into this graph then there is a symmetrical graphs takes place for ceiling but in the data table we also see that a wide range of lux values are tabulated against these two, but mainly in ceiling there is a moderate changes takes place with the changes of time.

13.4.UNIFORMITY VALUE GRAPH

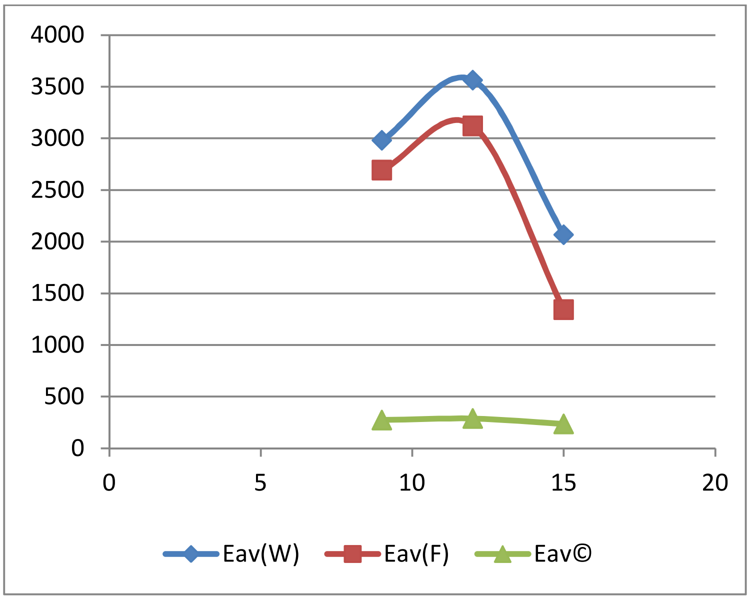
13.4.UNIFORMITY VALUE CHART



UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.275	0.292	0.659
12	0.236	0.247	0.69
15	0.39	0.543	0.723

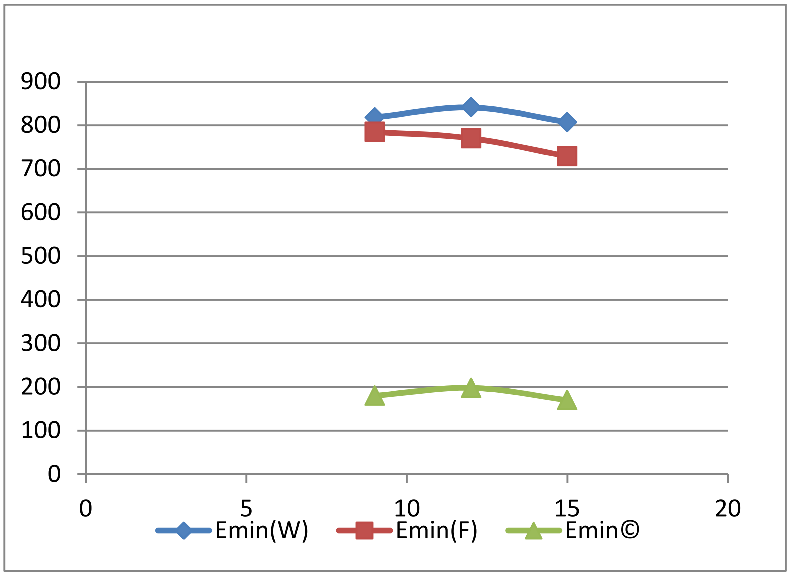
When we consider this new parameter then we can see a new phenomenon arrive which is the common point between workplane and floor on the same time of a particular day. The uniformity enhanced with the time cause as much as we increased the artificial lighting instead of day light we will get greater uniformity. In this case, upto 12 PM the graphs are overlapping in nature, but after that particular time two graph shifted into a new path.

13.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



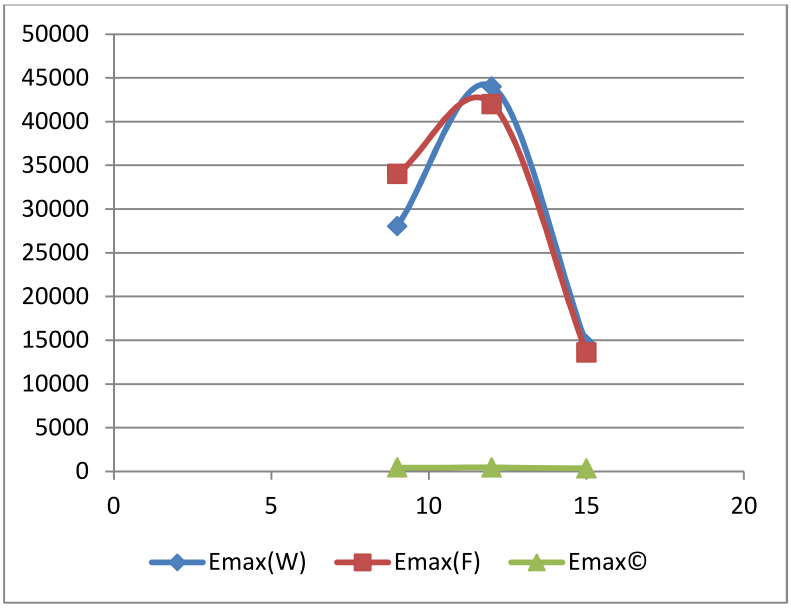
TIME	Eav(W)	Eav(F)	Eav©
9	2980	2692	274
12	3564	3121	288
15	2067	1344	236

13.6. THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	818	785	180
12	841	770	198
15	807	729	170

13.7. THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	28052	34007	435
12	44012	42005	454
15	14547	13575	347

Following the prior method here also comparisons takes place, in the graph of ceiling shows the prior mentioned similarities, but there is a difference occurred in the range of rest two parameters. In the case of Emax there is a overlapping occurred due to the daylight integrations on workplane and floor area, but for the ceiling portion it make a linear graph of maximum lux level. But the nature of the graphs for workplane and floor changed in minimum range.

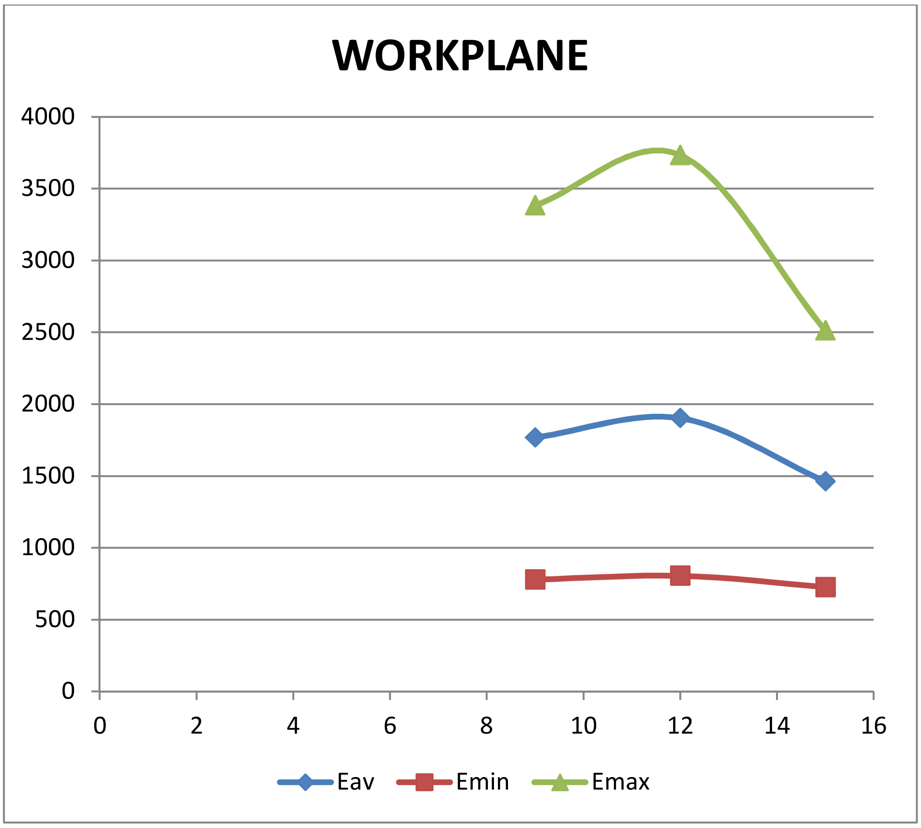
CASE: 14

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 70-40-10 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for overcast sky condition. One control group is 50% dimmed and the other one is fully on.

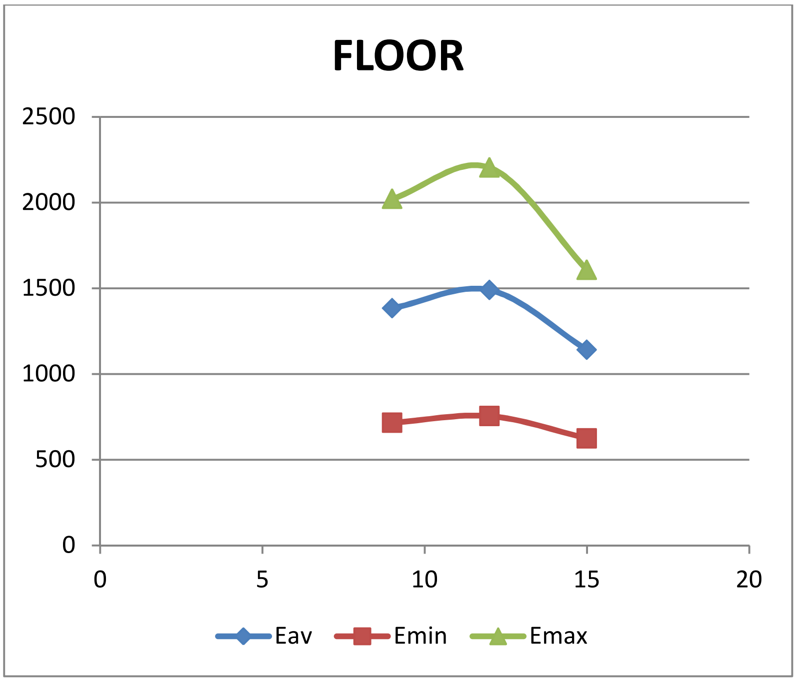
14.1. WORKPLANE VALUE GRAPH OF IT



14.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1768	779	3384
12	1902	805	3733
15	1462	726	2512

14.2. FLOOR VALUE GRAPH

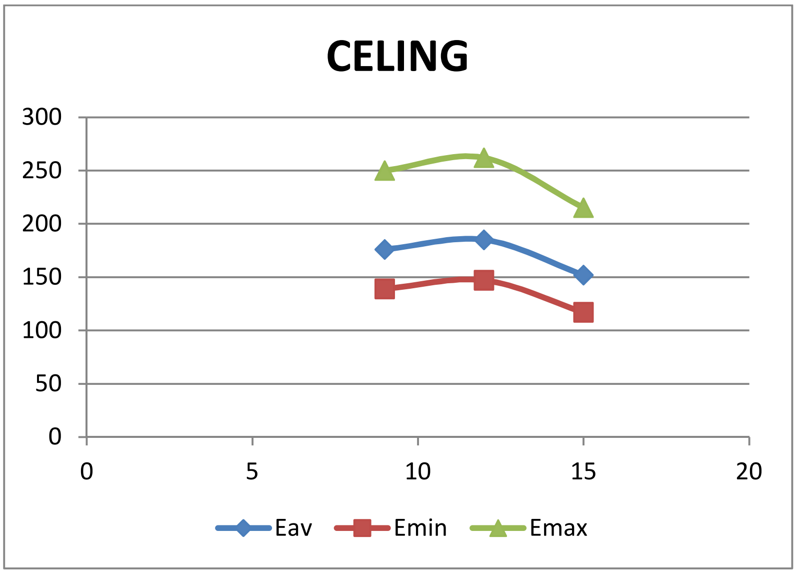


14.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	1383	715	2021
12	1489	754	2203
15	1140	624	1606

The heaped natures of these two graphs are prominent in these two areas. When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for overcast sky condition and one control group is 50% dimmed and the other one is fully on, then the maximum pick value obtained in mid of the day,where lower value shows at 9AM and the middle value is at 3PM of that particular day.

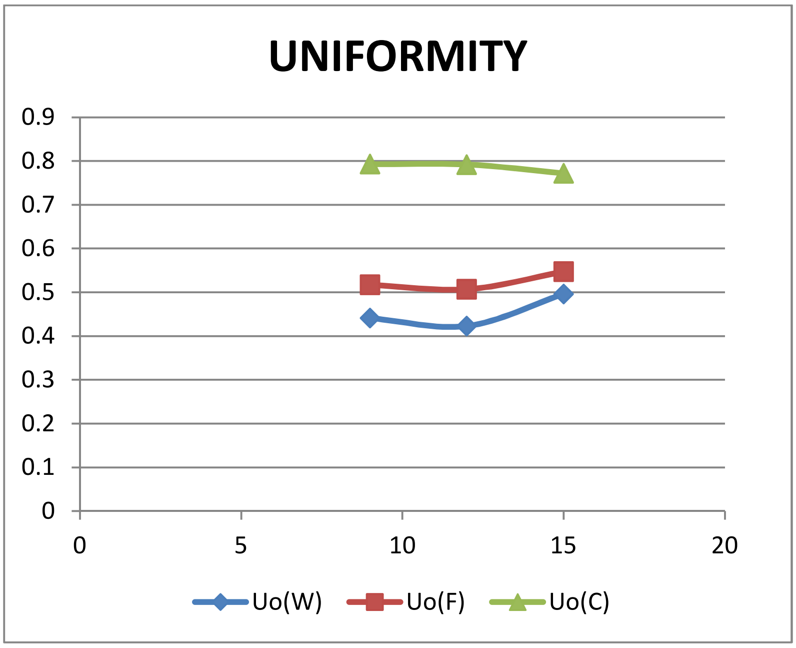
14.3. CELING VALUE GRAPH



14.3. CELING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	176	139	250
12	185	147	262
15	152	117	215

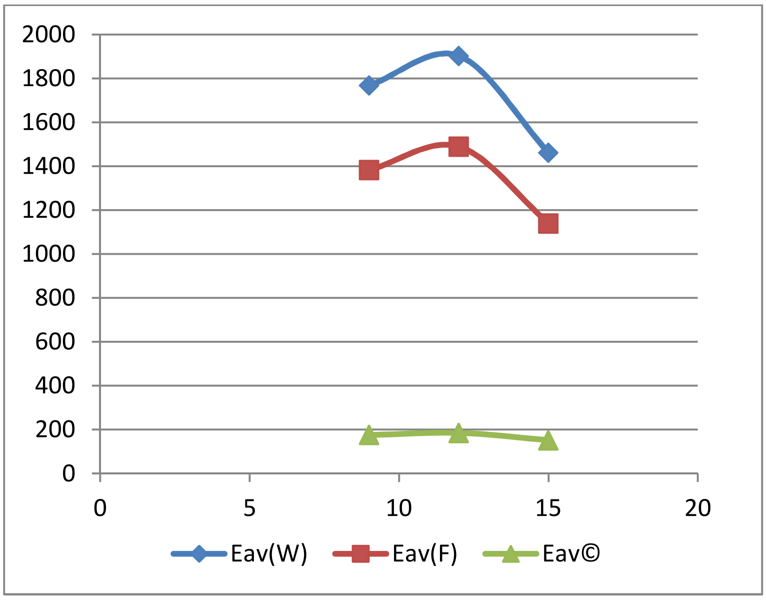
14.4.THE GRAPH AND CHART FOR UNIFORMITY VALUE



UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.441	0.517	0.793
12	0.423	0.507	0.792
15	0.496	0.547	0.772

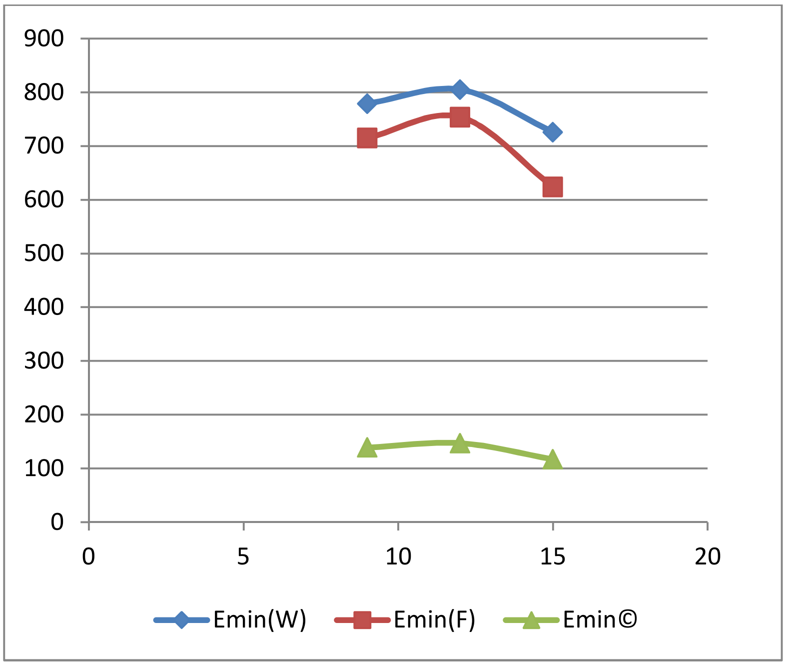
Through out the day the daylight comes in a uneven distributed way for this reason the uniformity is so poor basically in workplane and floor area, and from the above mentioned table the ceiling is illuminated with more or less same kind of daylight distribution and it makes a better graph for ceilings uniformity.

14.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	1768	1383	176
12	1902	1489	185
15	1462	1140	152

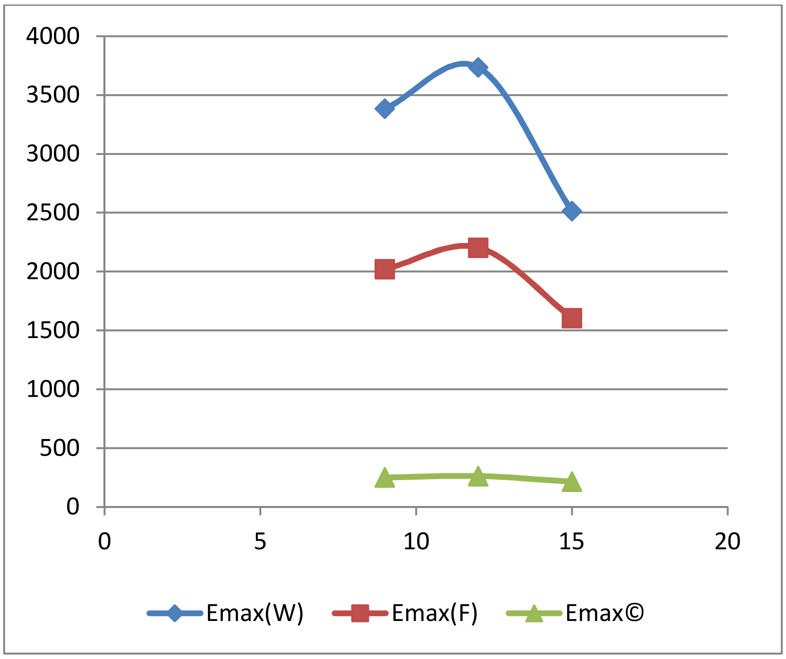
14.6. THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	779	715	139
12	805	754	147
15	726	624	117

14.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

14.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	3384	2021	250
12	3733	2203	262
15	2512	1606	215

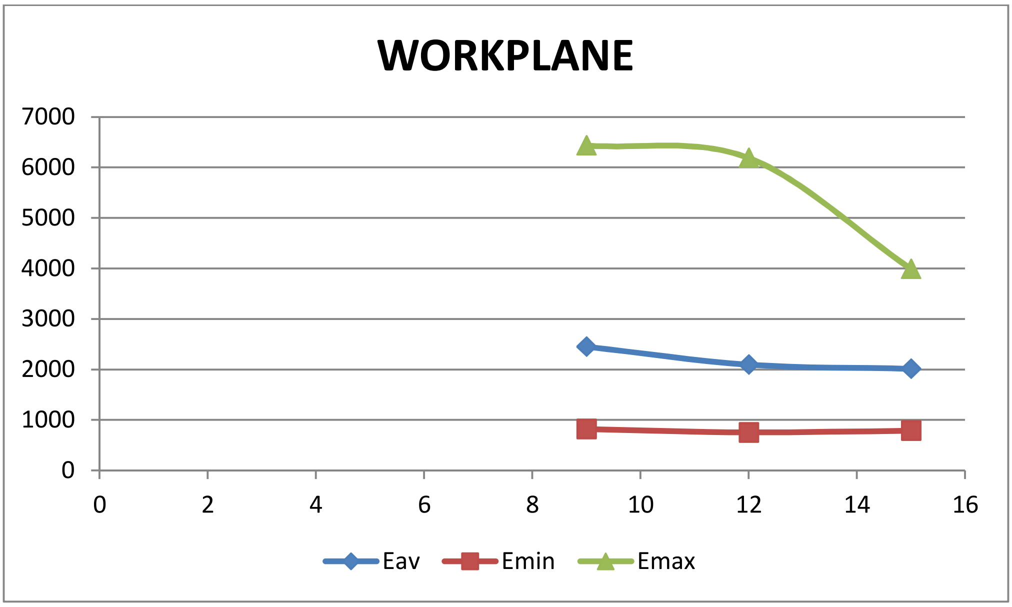
CASE: 15

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 70-40-10 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are then the simulated lux levels are tabulated in the 70-40-10 following tables. This simulation considered only for mixed sky condition. One control group is 50% dimmed and the other one is fully on.

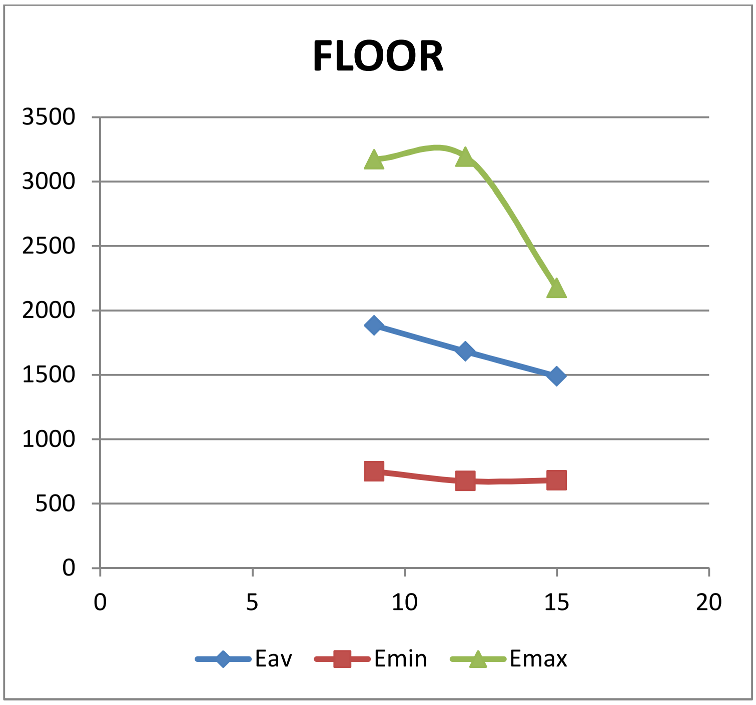
15.1. WORKPLANE VALUE GRAPH



15.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	2450	821	6436
12	2095	754	6187
15	2012	788	3988

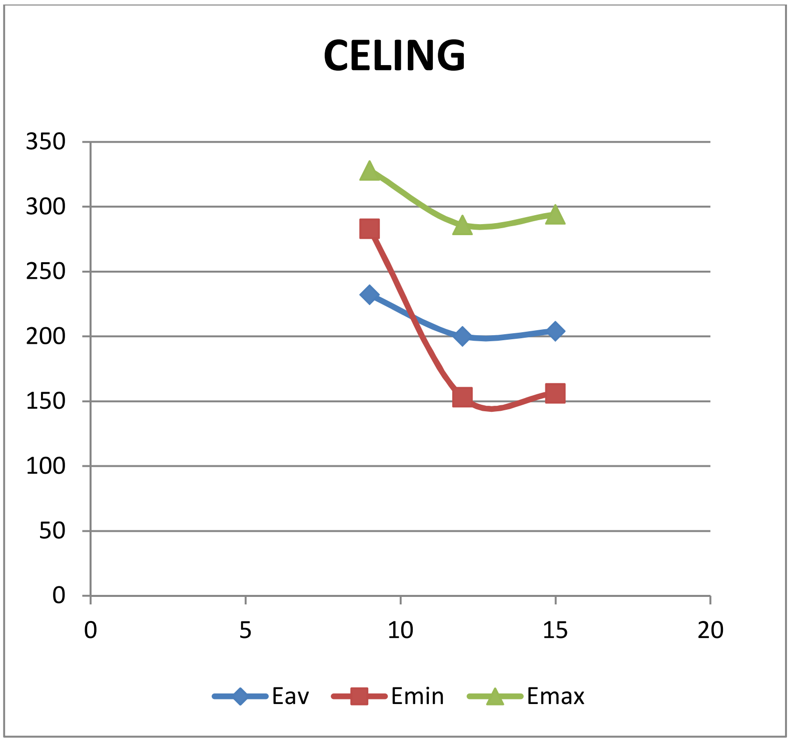
15.2. FLOOR VALUE GRAPH OF IT IT



15.2. FLOOR VALUE CHART OF

FLOOR			
TIME	Eav	Emin	Emax
9	1884	750	3173
12	1681	675	3193
15	1489	681	2173

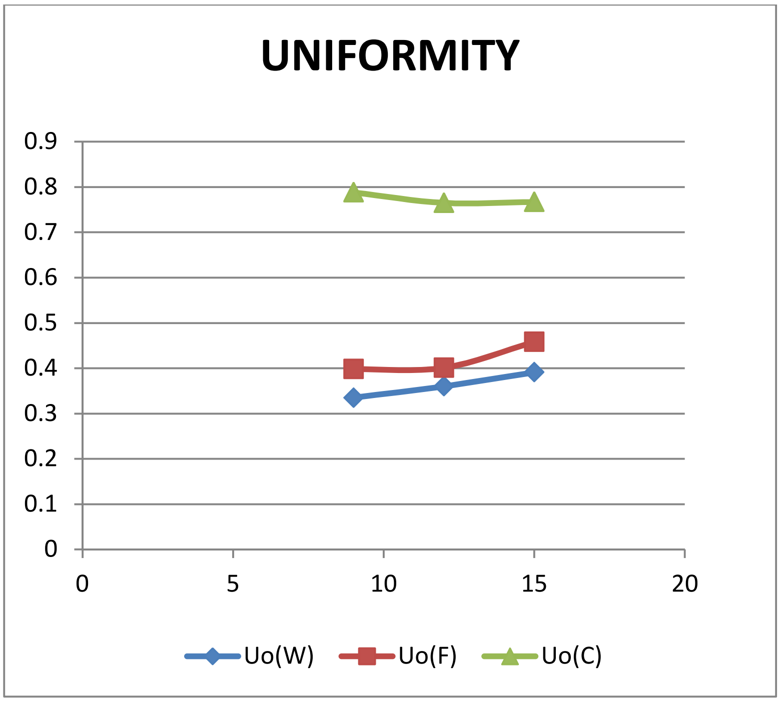
15.3. CEILING VALUE GRAPH OF IT IT



15.3.CEILING VALUE CHART OF

CEILING			
TIME	Eav	Emin	Emax
9	232	283	328
12	200	153	286
15	204	156	294

15.4. UNIFORMITY VALUE GRAPH

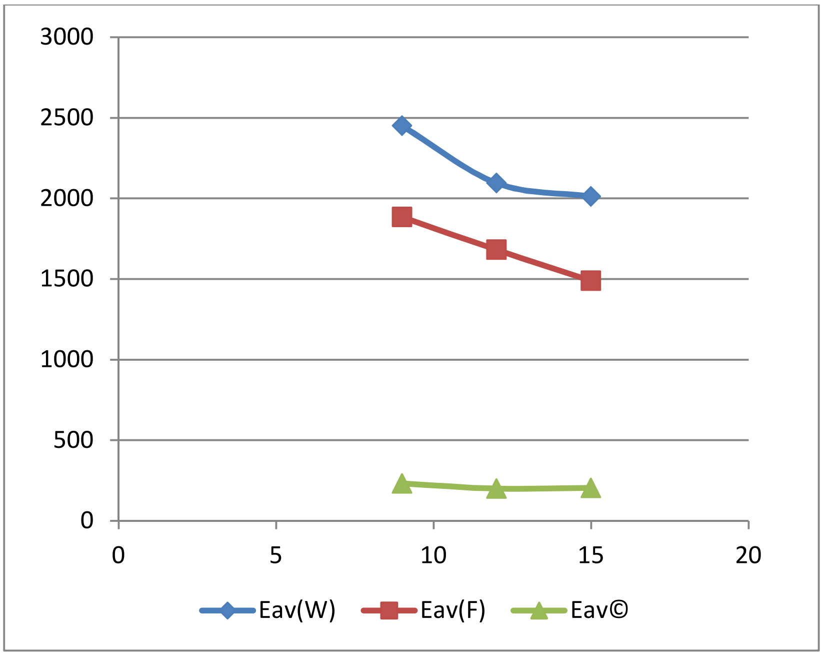


15.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.335	0.398	0.788
12	0.36	0.401	0.765
15	0.391	0.458	0.767

Due to the sky conditions and reflection factor the uniformity is enriched with its value through out all the day in the ceiling, but the same factor is very poor for the workplane and floor.

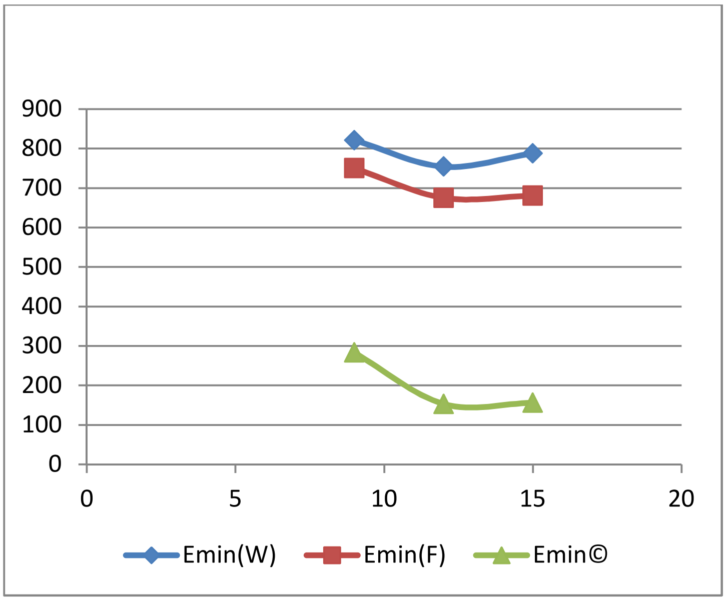
15.5 THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav©
9	2450	1884	232
12	2095	1681	200
15	2012	1489	204

15.6.THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

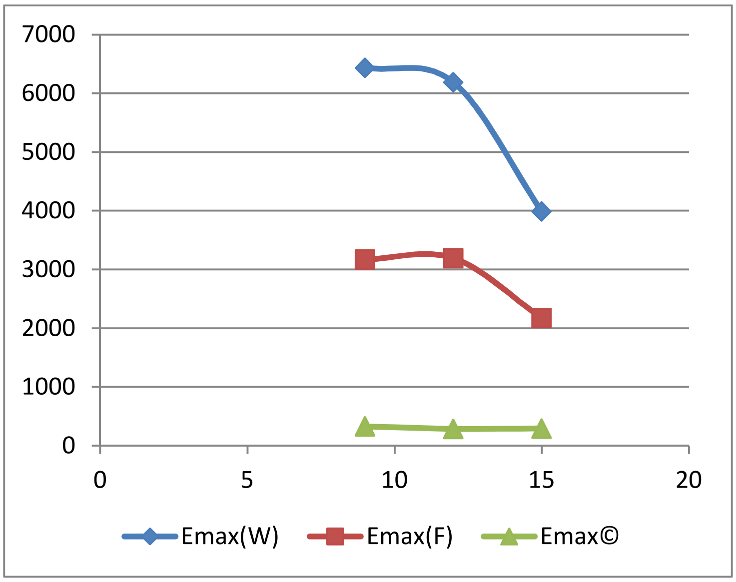
15.6.THE CHART FOR ALL Emin VALUES FOR WORKPLANE, AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	821	750	283
12	754	675	153
15	788	681	156

15.7.THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

15.7.THE CHART FOR ALL Emax VALUES FOR WORKPLANE, AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6436	3173	328
12	6187	3193	286
15	3988	2173	294

For comparison, all the average values are putted in one graph and in that graph workplane graph is tilted and slowly decreasing in nature, floor graph is sharply decreasing in nature and the graph for ceiling is linear with respect to the change. But in the case of minimum values all of these three parameters shows more or less shame nature, particularly identical graphs are shown by workplane and floor. Maximum lux level is abruptly decresing for workplaneare, gradually decreasing for floor area and linear for ceiling area shows in the above figures.

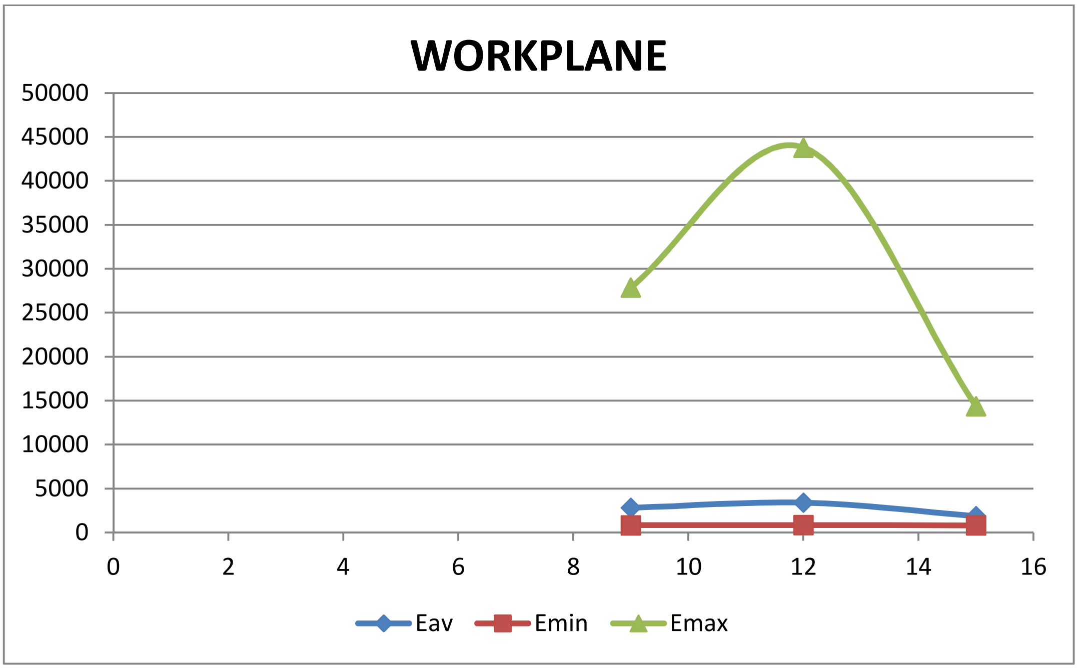
CASE: 16

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN CLEAR SKY CONDITION, AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition. One control group is fully off and the other one is fully on.

16.1. WORKPLANE VALUE GRAPH OF IT

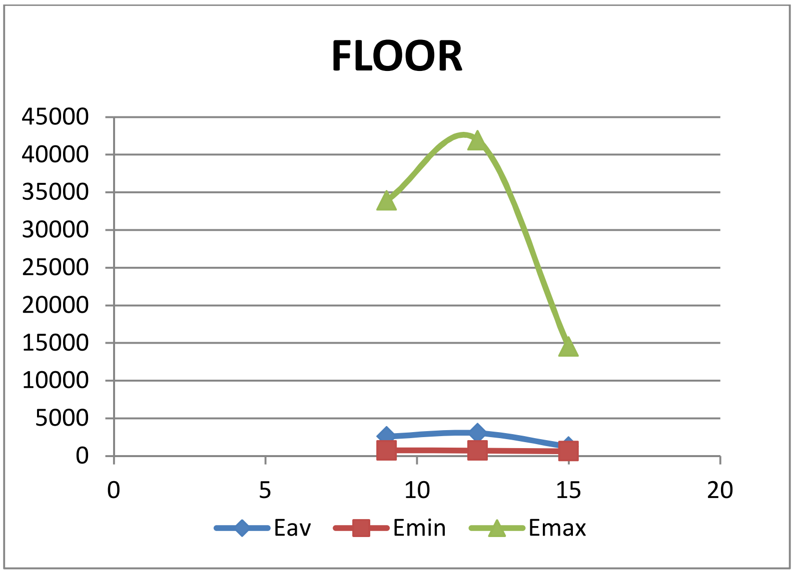


16.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	2802	824	27850
12	3391	843	43795
15	1862	801	14377

The above tabulated data's are placed into the above graph for their graphical presentation, all the data's of maximum, minimum and average lux levels of workplane grafted here. The nature and range of average and minimum lux levels are almost alike, but the range of maximum illuminance is much more higher than these two parameters.

16.2. FLOOR VALUE GRAPH OF IT

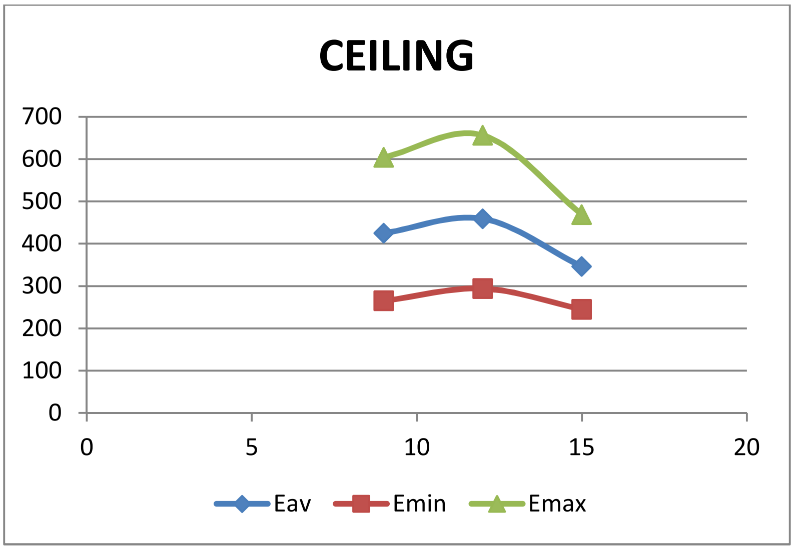


16.2. FLOOR VALUE CHART OF

FLOOR			
TIME	Eav	Emin	Emax
9	2601	746	33935
12	3039	727	41926
15	1239	640	14530

As the graph of workplane shows the heaped nature of maximum graph, and almost same nature of rest two parameters, here also same thing occurred. But for the floor area, the maximum illuminance level is sharply fall down after 12PM and for the average value also, the gradual increasing graph fall down after that certain time period.

16.3. CEILING VALUE GRAPH OF IT

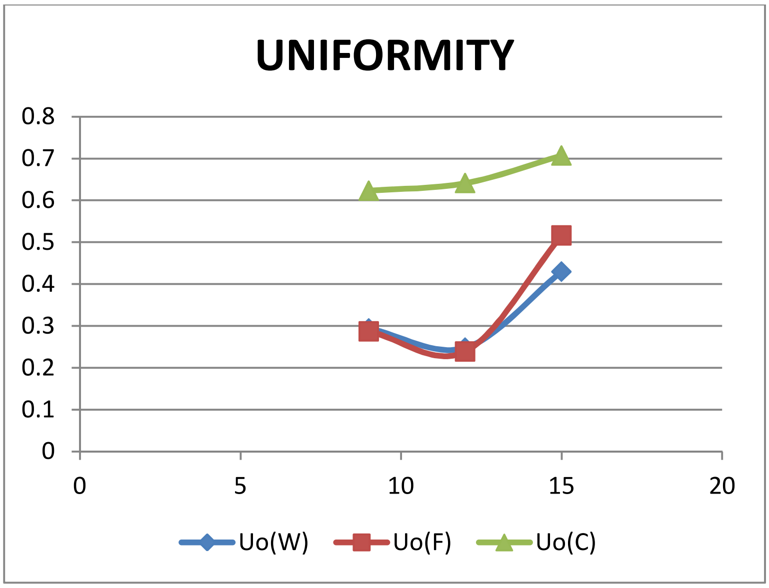


16.3. CEILING VALUE CHART OF IT

CEILING			
TIME	Eav	Emin	Emax
9	425	265	604
12	459	294	656
15	346	245	469

Nature of graphs and the ranges of all three parameters of ceiling maintain a very small range of variations, hence the graphical presentation shows a very good quality of curves, all of these three values depicted here and the gradually increased graph fall down after 12PM, the pick value reached at its utmost position at 12PM and in the least value at 3PM.

16.4.UNIFORMITY VALUE GRAPH OF IT   16.4.UNIFORMITY VALUE CHART OF IT

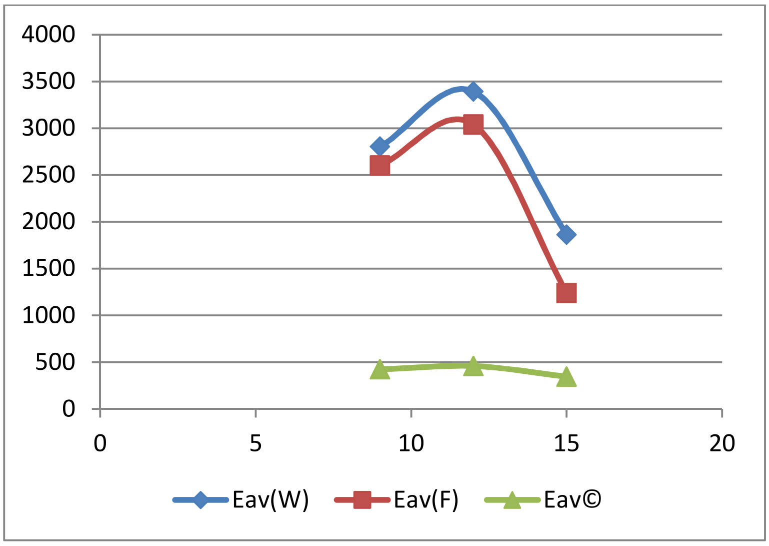


UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.294	0.287	0.623
12	0.248	0.239	0.641
15	0.43	0.516	0.707

As we all know,in daylight there are less amount of uniformity takes place because of the uneven daylight distribution and this theory reflects on the tabulated data's as well as on the graphs, for this in daylight conditions the uniformity of workplane and floor are very poor, and they intersect with each others.

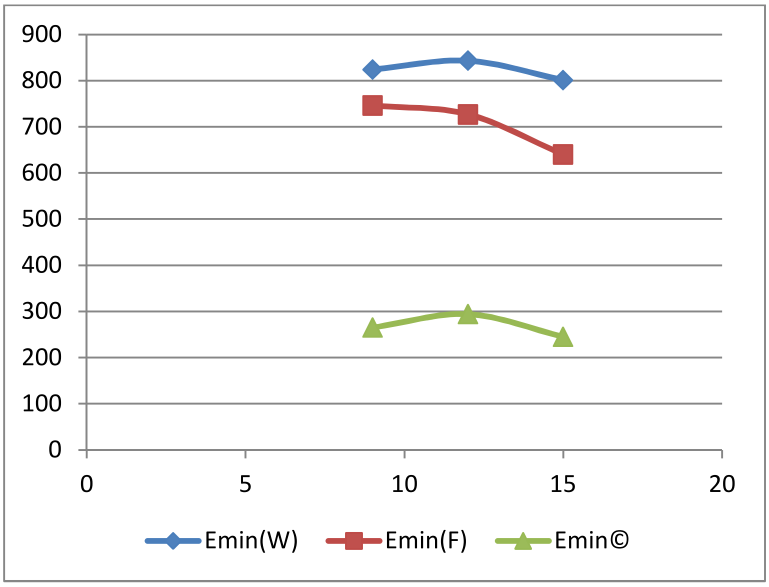
16.5.THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

16.5.THE CHART FOR ALL Eav VALUES FOR WORKPLANE, AND CEILING



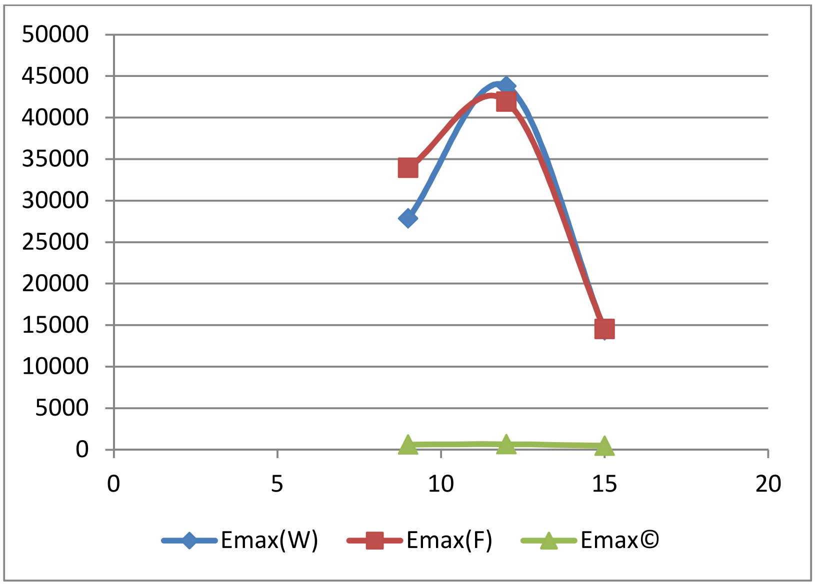
TIME	Eav(W)	Eav(F)	Eav©
9	2802	2601	425
12	3391	3039	459
15	1862	1239	346

16.6. THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	824	746	265
12	843	727	294
15	801	640	245

16.7. THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	27850	33935	604
12	43795	41926	656
15	14377	14530	469

The sharp slope nature of the graphs of workplane and floor occurred in the Eav region and then the maximum values pointed at 12PM but then the average values reduces sharply ,and for the minimum values these same observation is obtained but in minimum range of area all the values are in a small variation of ranges, as a results no sharp fall down occurred here. And in the case of maximum value graphs there is a overlapping happened between workplane and floor, the values of these two are overlapped with each other after 9AM onwards.

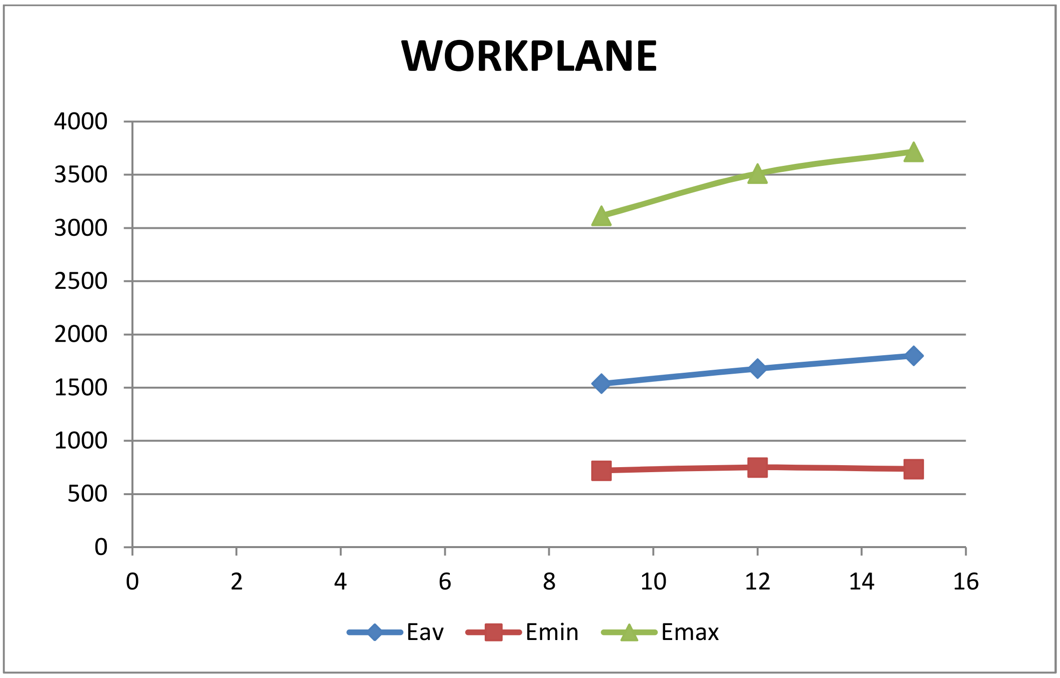
CASE: 17

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax , Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

In this case study we follow the following parameters, which are as follows:

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition. One control group is fully off and the other one is fully on.

17.1. WORKPLANE VALUE CHART OF IT

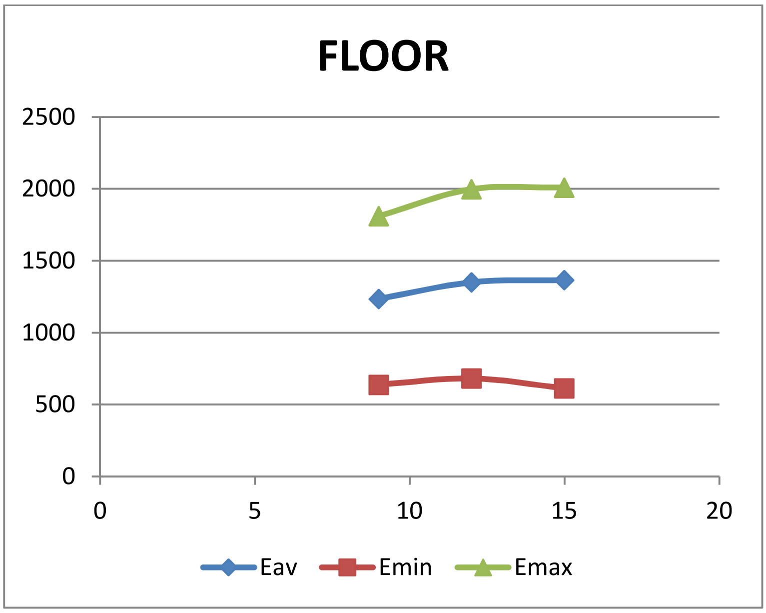


17.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	Eav	Emin	Emax
9	1536	721	3114
12	1677	750	3512
15	1800	735	3717

This simulation happened in the standard suggest range of reflection factor, where an indoor should be designed.

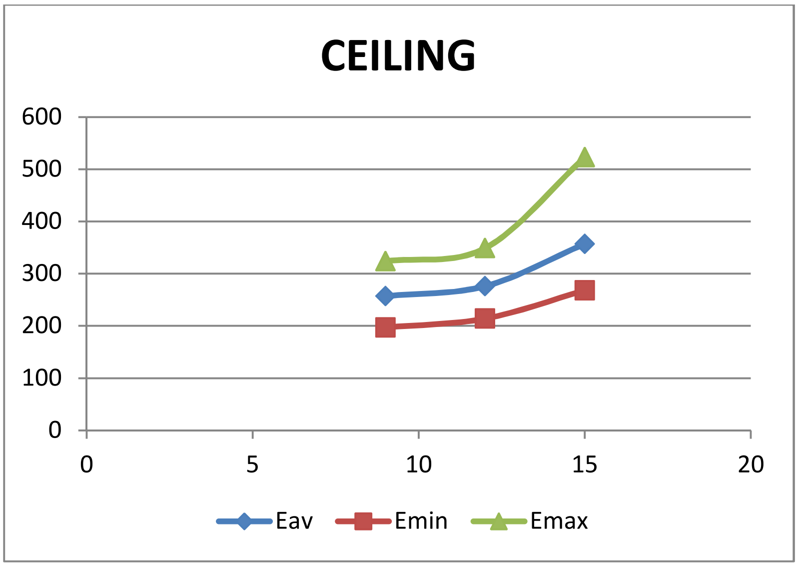
17.2. FLOOR VALUE GRAPH



17.2. FLOOR VALUE CHART

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1235	638	1810
12	1350	682	1998
15	1366	613	2009

17.3. CEILING VALUE GRAPH



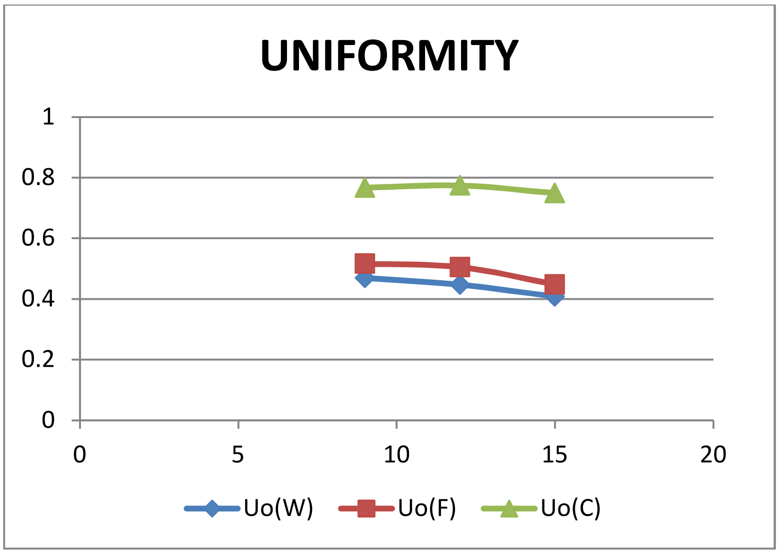
17.3. CEILING VALUE CHART

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	257	197	324
12	276	214	349
15	357	268	523

As because total simulation takes place depending upon reflection factor that's the reason behind so symmetric graph created in this part, and all the tabulated values are in the range of standard values, in the cases of workplane, floor and ceiling.

17.4. UNIFORMITY VALUE GRAPH

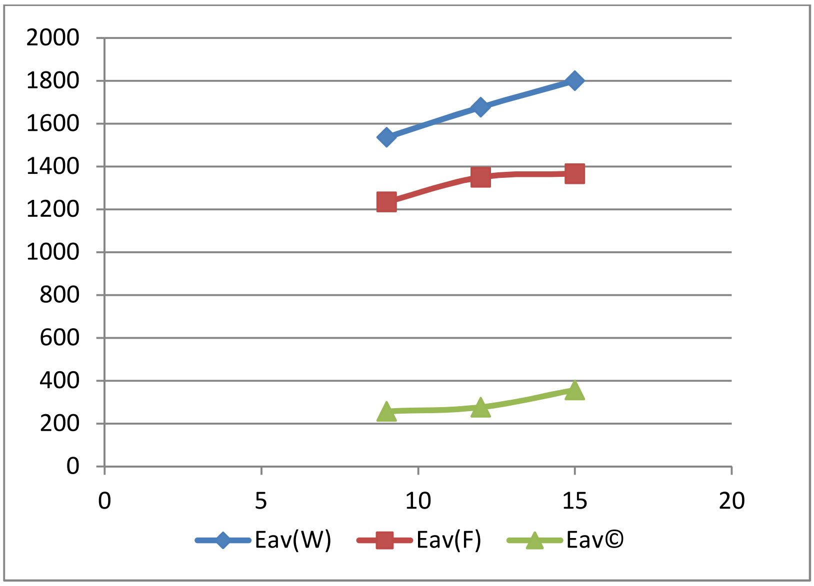
17.4. UNIFORMITY VALUE CHART



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.469	0.516	0.767
12	0.447	0.505	0.774
15	0.408	0.448	0.749

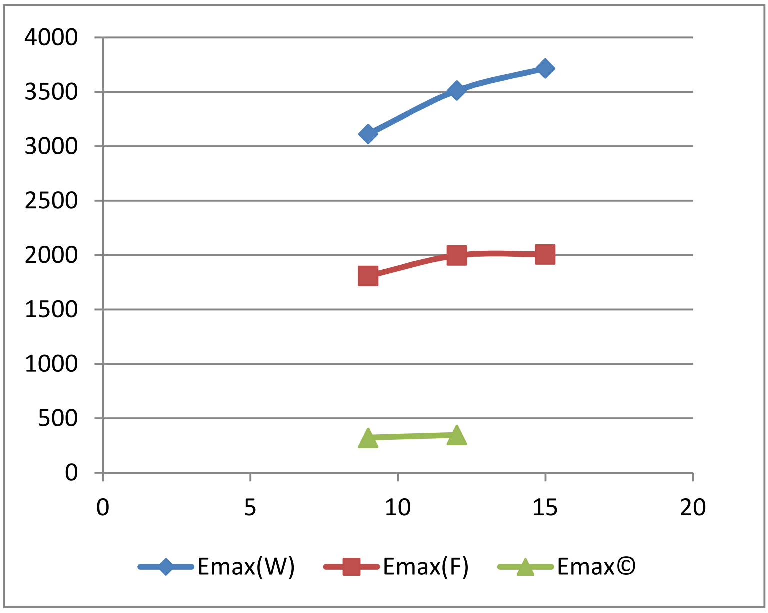
Uniformity improves its value due to the reflection factor, but for dimming control and the sky condition the values are not in the range of standard suggested range but for ceiling its obey the range and produce a linear graph of it.

17.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



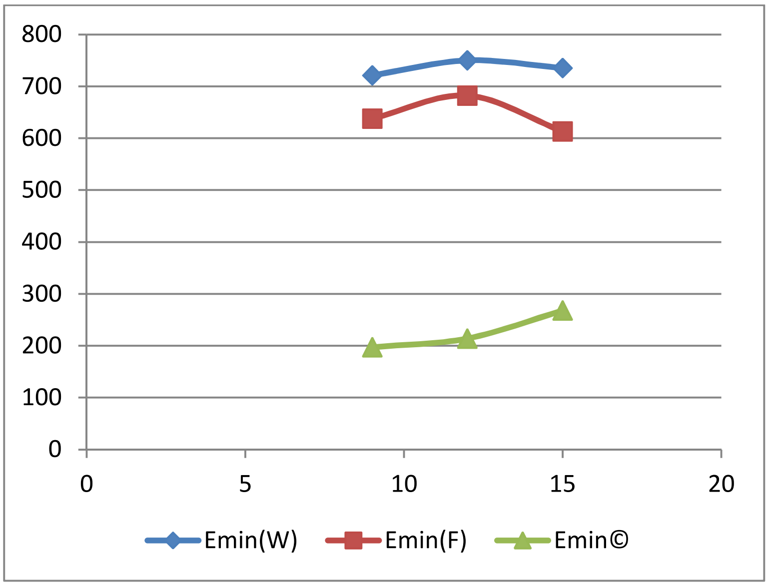
TIME	Eav(W)	Eav(F)	Eav©
9	1536	1235	257
12	1677	1350	276
15	1800	1366	357

17.6. THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	3114	1810	324
12	3512	1998	349
15	3717	2009	523

17.7. THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	721	638	197
12	750	682	214
15	735	613	268

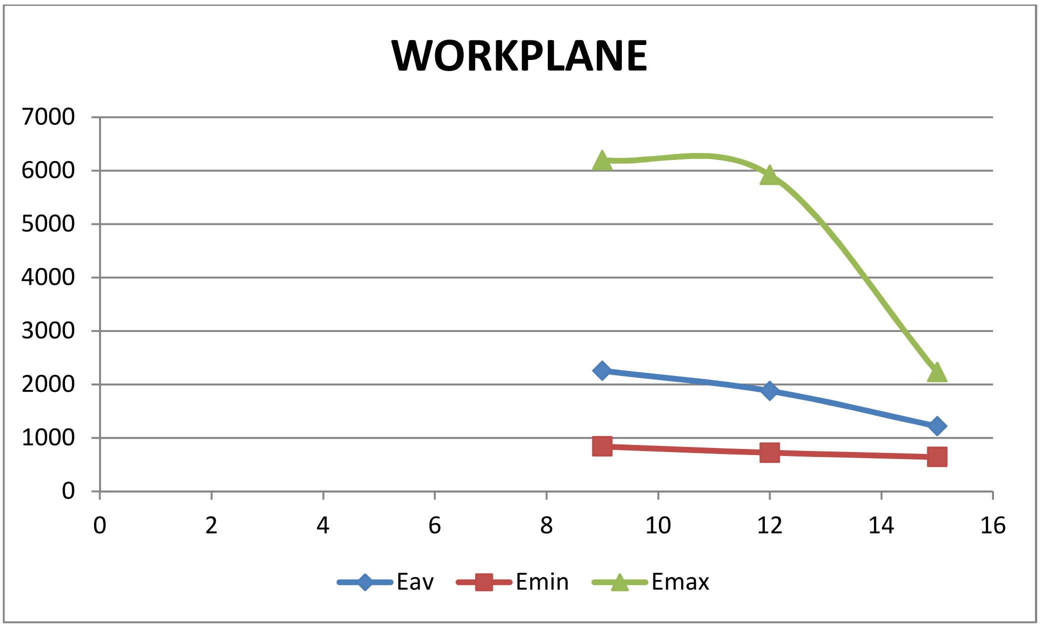
These comparisons graphs also show the standard variations, but some times it drifted form its regions due to the boundary conditions.

CASE: 18

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is fully off and the other one is fully on.

18.1. WORKPLANE VALUE GRAPH OF IT

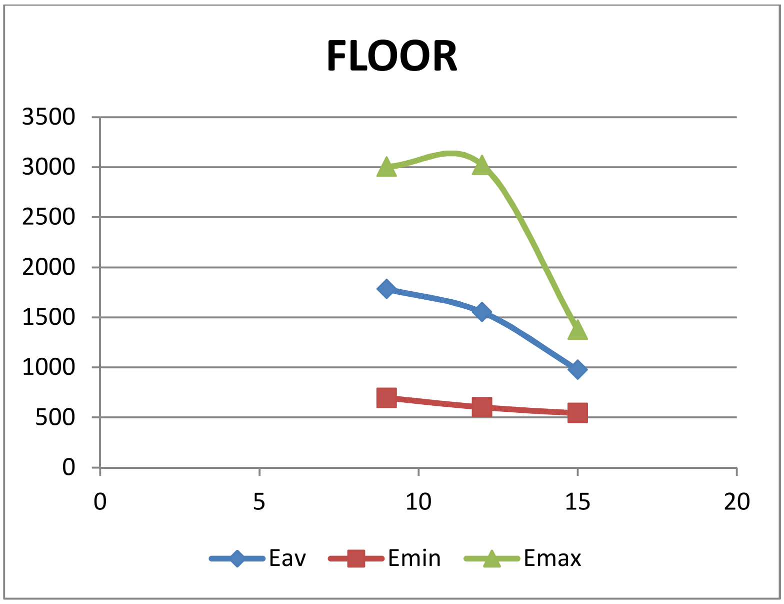


18.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	2254	838	6195
12	1877	722	5917
15	1215	641	2227

In the mixed sky condition, the average values shown a new tendency of the graphs which are generated for the workplane area, is that, the highest values are generated at the early of the day and that values has a tendency of decreasing continuously.

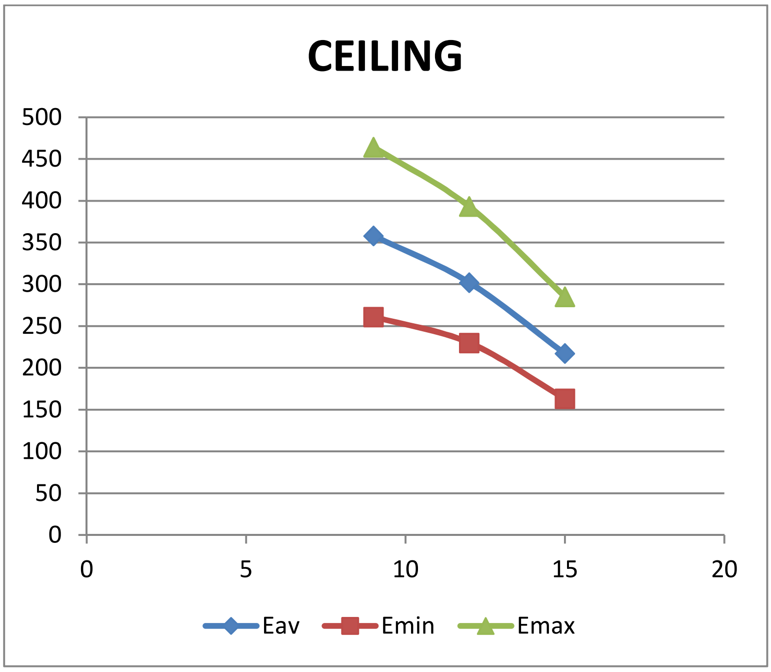
18.2. FLOOR VALUE GRAPH OF IT



18.2. FLOOR VALUE CHART OF IT

FLOOR			
TIME	Eav	Emin	Emax
9	1782	696	3006
12	1552	601	3021
15	975	543	1376

18.3. CEILING VALUE GRAPH OF IT

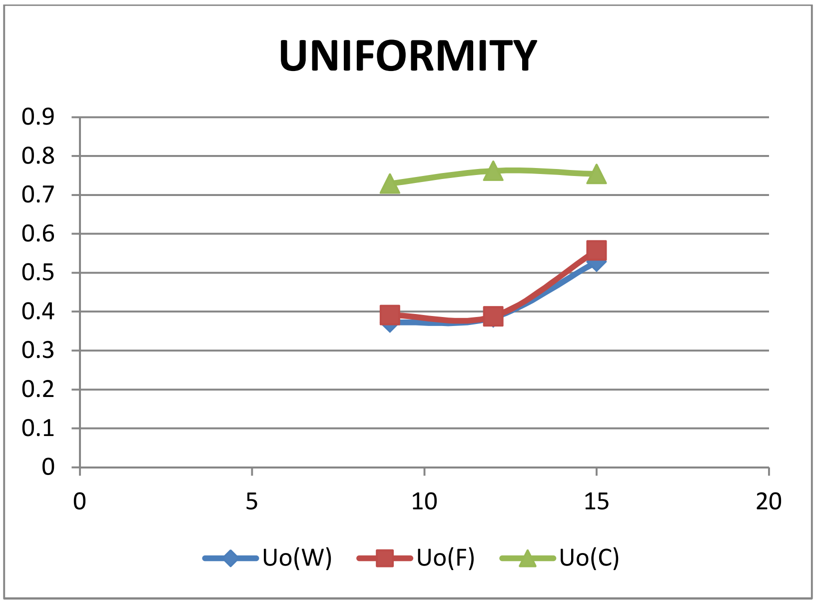


18.3. CEILING VALUE CHART OF IT

CEILING			
TIME	Eav	Emin	Emax
9	358	261	464
12	302	230	393
15	217	163	285

Floor graph is almost follow the same nature of workplane, but in a small version, cause all the illuminance values are lower in his region in the respect to the workplane. For the ceiling all three graphs which indicated the maximum, minimum and average values are sharply bended downwards, as because the highest values of this part occurs at 9AM and the least value occurs at 3PM.

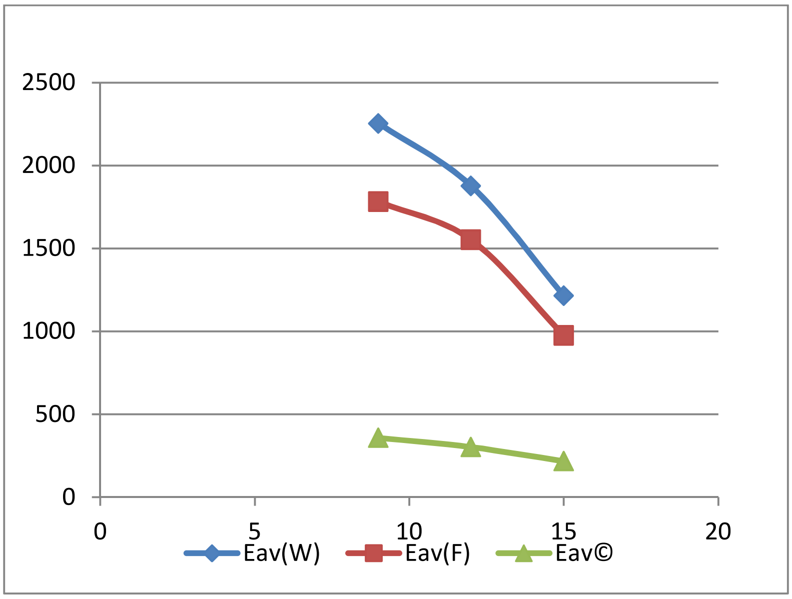
18.4. UNIFORMITY VALUE GRAPH OF IT 18.4. UNIFORMITY VALUE CHART OF IT



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.372	0.391	0.729
12	0.385	0.388	0.762
15	0.528	0.557	0.754

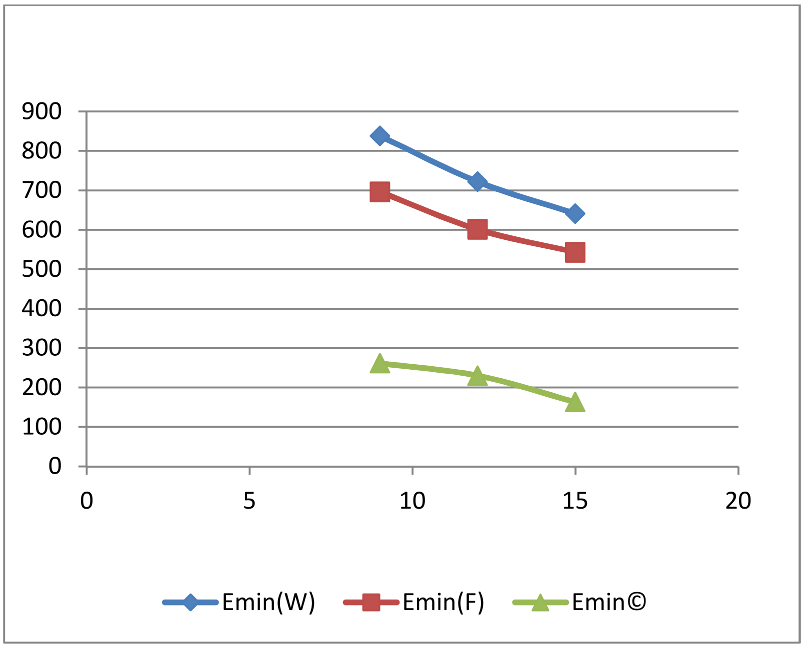
Uniformity improves its value due to the reflection factor, but for dimming control and the sky condition the values are not in the range of standard suggested range but for ceiling its obey the range and produce a linear graph of it., and here an overlapping occurred, and that remain through out the day.

18.5. THE GRAPH AND CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Eav(W)	Eav(F)	Eav©
9	2254	1782	358
12	1877	1552	302
15	1215	975	217

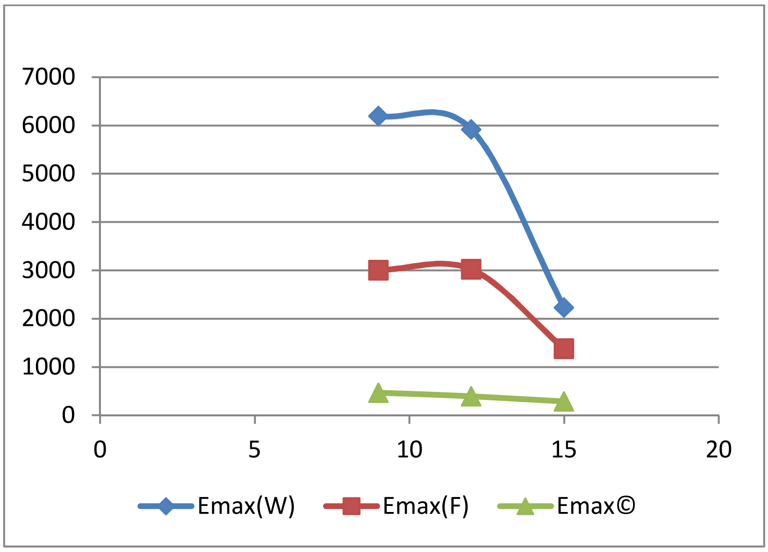
18.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING



18.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	838	696	261
12	722	601	230
15	641	543	163

18.7. THE GRAPH AND CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6195	3006	464
12	5917	3021	393
15	2227	1376	285

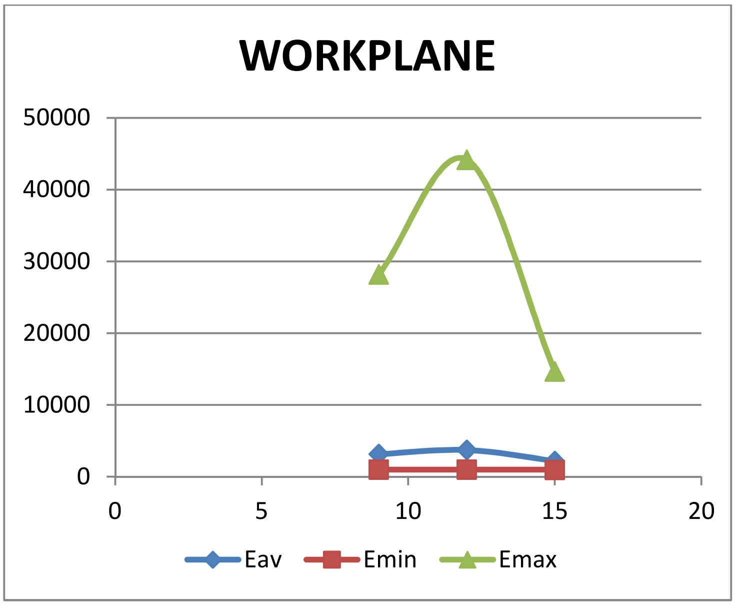
The sharp slope nature of the graphs of workplane and floor occurred in the Eav region and then the maximum values pointed at 9AM but then the average values reduces sharply, and for the minimum values these same observation is obtained but in minimum range of area all the values are in a small variation of ranges, as a results no sharp fall down occurred here. And in the case of maximum value graphs there is a linear graph created against ceiling, a tilted graph created due to workplane, cause after the mid of the day, the graph fall down sharply.

CASE: 19

WORKPLANE , FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition. One control group is 50%dimmed and the other one is fully on.

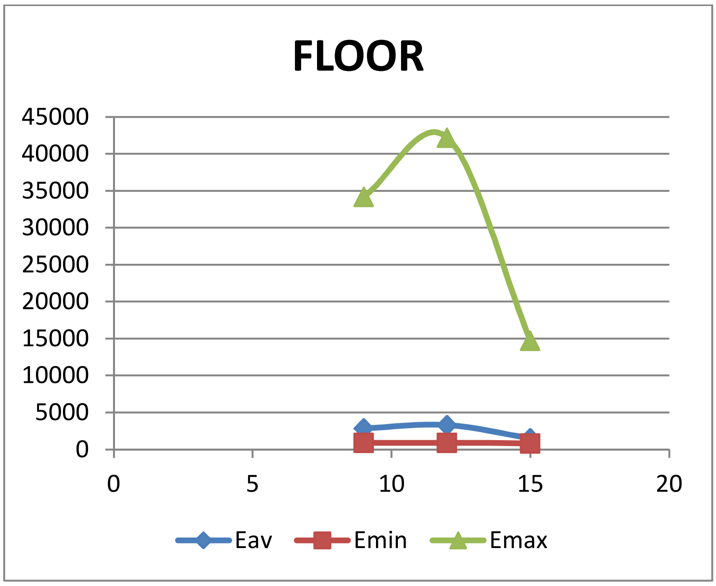
19.1. WORKPLANE VALUE GRAPH OF IT



19.1. WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	3139	1000	28204
12	3728	1013	44148
15	2195	978	14646

19.2. FLOOR VALUE GRAPH OF IT



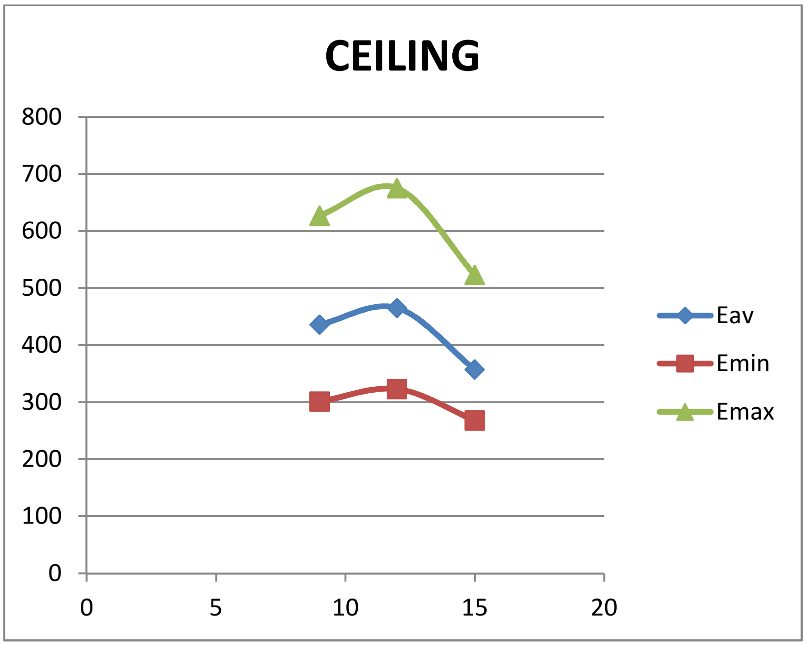
19.2. FLOOR VALUE CHART OF IT

FLOOR			
TIME	Eav	Emin	Emax
9	2859	896	34204
12	3296	906	42209
15	1498	816	14723

19.3. CEILING VALUE GRAPH OF IT

19.3. CEILING VALUE CHART OF

IT

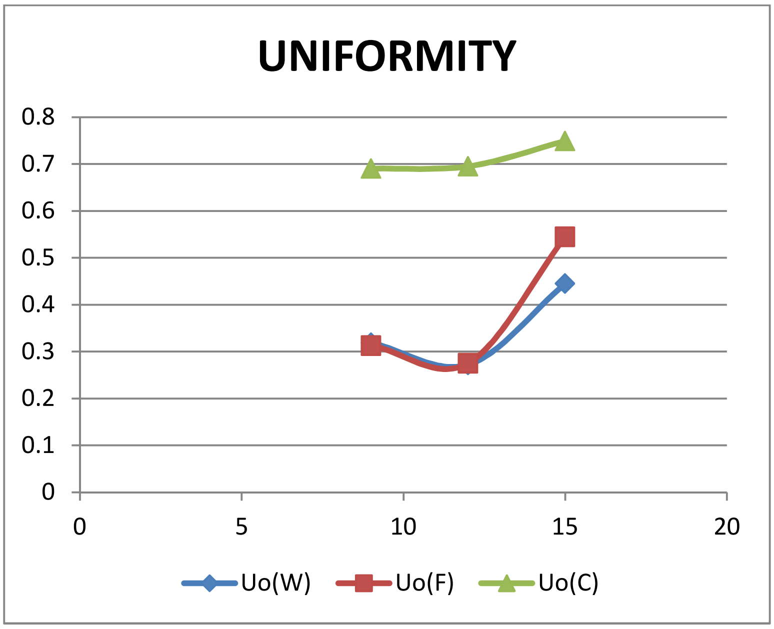


CEILING			
TIME	Eav	Emin	Emax
9	436	301	627
12	465	323	675
15	357	268	523

In the clear sky condition, the average values shown the same tendency of the graphs which are generated for the workplane area, is that, the highest values are generated at the mid of the day and that values has a tendency of decreasing continuously, but early morning this graph rises significantly. Same thing happened in the case of floor area also. And in the case of ceiling it remain unchanged and create heaped structure of graphs for all the three parameters.

19.4. UNIFORMITY VALUE GRAPH

19.4. UNIFORMITY VALUE CHART

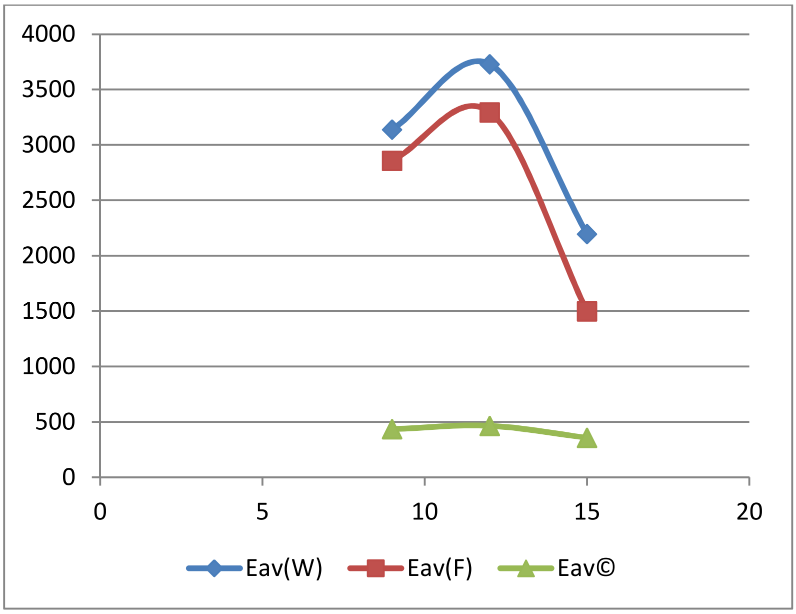


UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.319	0.313	0.69
12	0.272	0.275	0.695
15	0.445	0.545	0.749

Uniformity improves its value due to the reflection factor and sky condition, but for dimming control the values are not in the range of standard suggested range but for ceiling its obey the range and produce a curved but linear graph of it., and here an overlapping occurred, and that remain mid of the day, but then it drifted it paths.

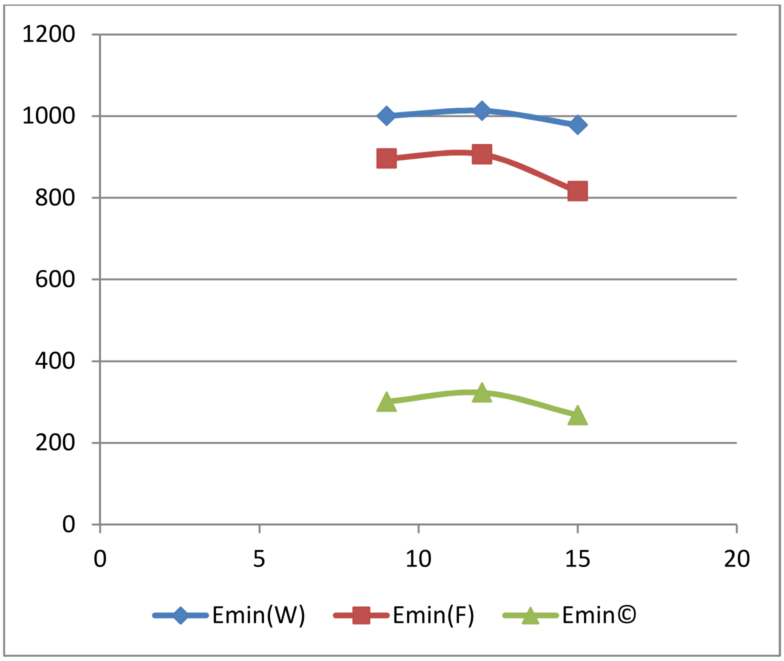
19.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

19.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

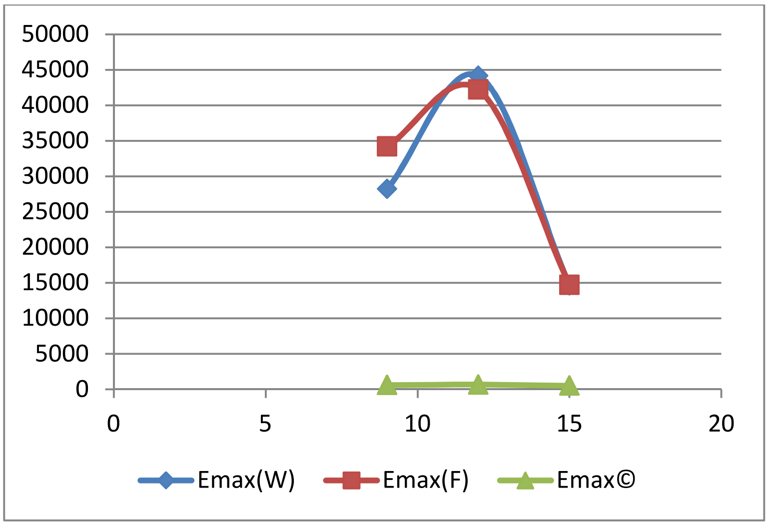


TIME	Eav(W)	Eav(F)	Eav©
9	3139	2859	436
12	3728	3296	465
15	2195	1498	357

19.6. THE GRAPH AND CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	1000	896	301
12	1013	906	323
15	978	816	268



TIME	Emax(W)	Emax(F)	Emax©
9	28204	34204	627
12	44148	42209	675
15	14646	14723	523

The sharp slope nature of the graphs of workplane and floor occurred in the Eav region and then the maximum values pointed at 12PM but then the average values reduces sharply, and for the minimum values the observation shows a change and it creates a slow curved, but in minimum range of area all the values are in a small variation of ranges, as a results no sharp fall down occurred here. And in the case of maximum value graphs there is a overlapping happened between workplane and floor, the values of these two are overlapped with each other after 9AM onwards.

CASE: 20

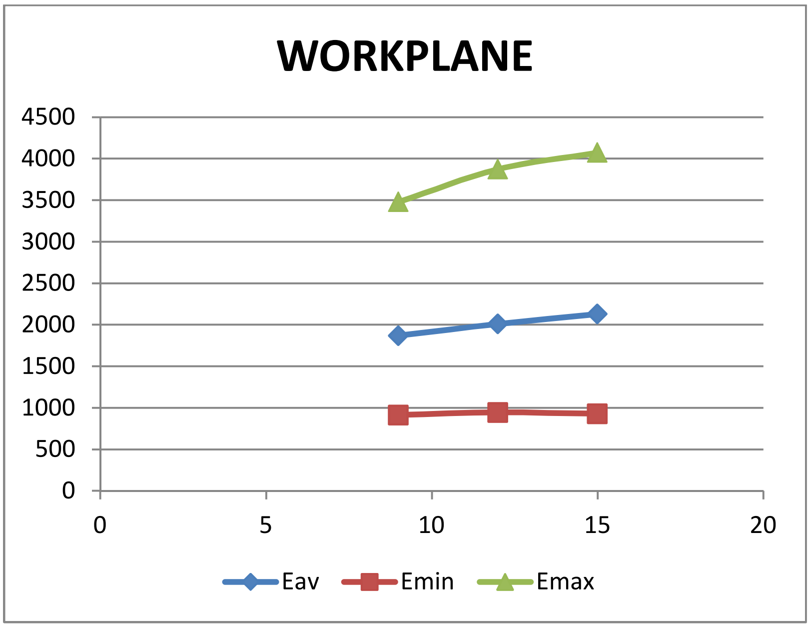
WORKPLANE,FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables.

This simulation considered only for overcast sky condition.

One control group is 50%dimmed and the other one is fully on.

20.1. WORKPLANE VALUE GRAPH



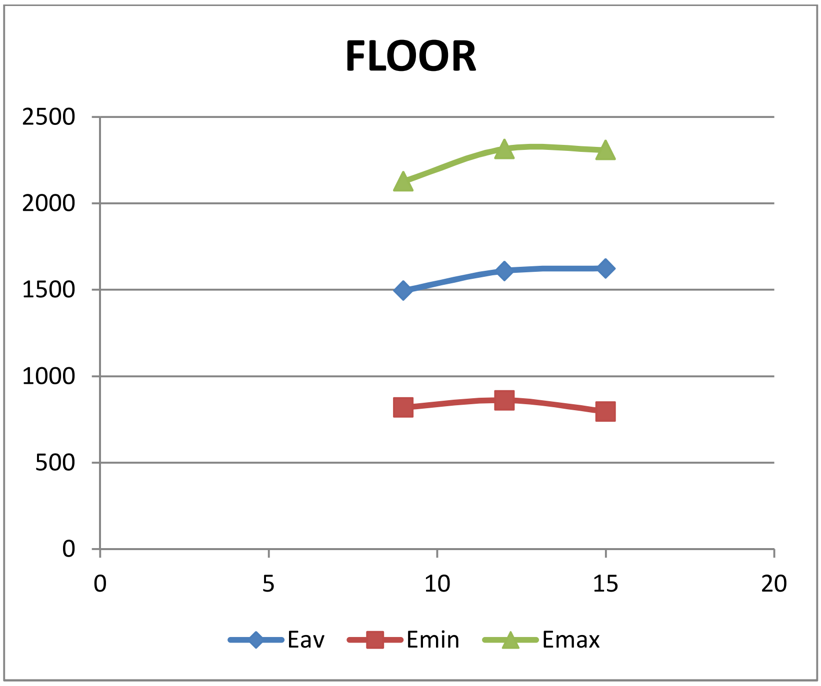
20.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1870	915	3479
12	2010	945	3873
15	2130	929	4071

This simulation happened in the standard suggest range of reflection factor, where an indoor should be designed for this, and three graphs made as per the standard values, and more or lessly they are linear curved.

20.2. FLOOR VALUE GRAPH OF IT

20.2. FLOOR VALUE CHART OF IT

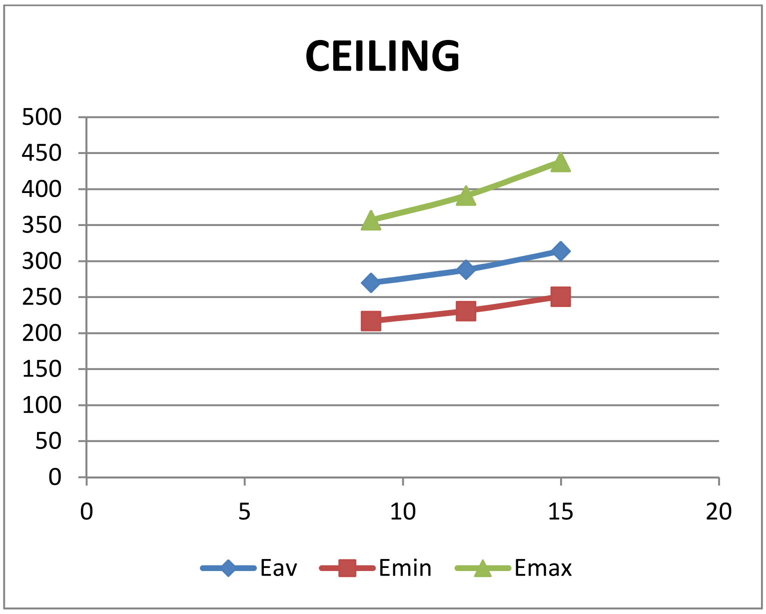


FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1495	820	2128
12	1609	861	2315
15	1624	797	2309

For floor area the graphs are maintained the same nature as of the workplane.

20.3. CEILING VALUE GRAPH OF IT

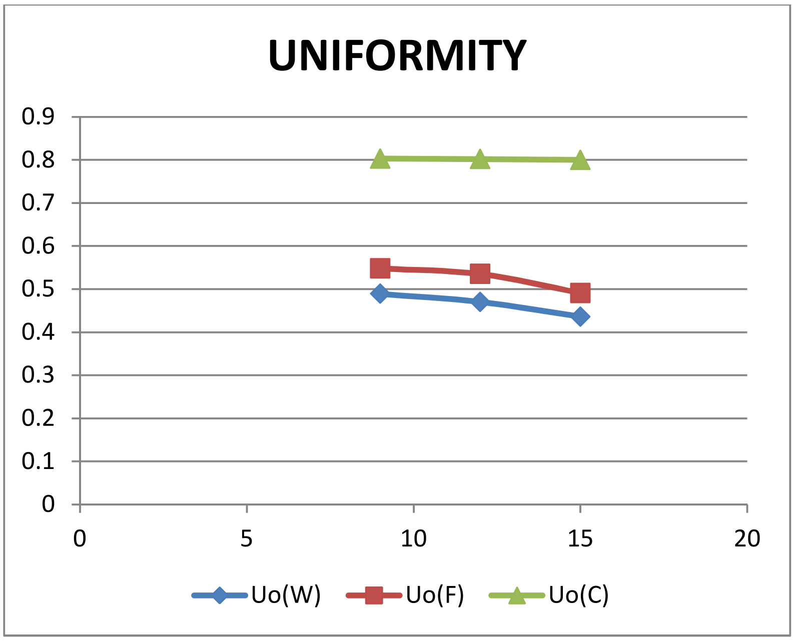
20.3. CEILING VALUE CHART OF IT



CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	270	217	357
12	288	231	391
15	314	251	438

20.4. UNIFORMITY VALUE GRAPH

20.4. UNIFORMITY VALUE CHART



UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.489	0.548	0.803
12	0.47	0.535	0.802
15	0.436	0.491	0.8

As because total simulation takes place depending upon reflection factor that's the reason behind so symmetric graph created in this part, and all the tabulated values are in the range of standard values, in the case of ceiling..

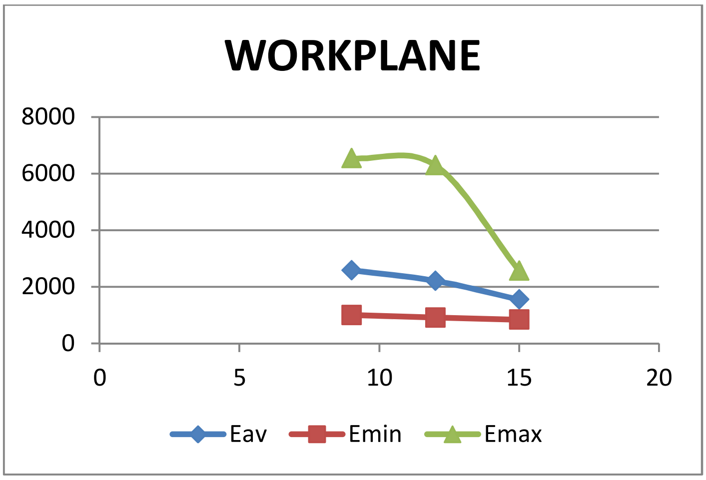
For the uniformity, workplane and floor are follow the same tendency, but they are in lower value of standard suggest values, and in the case of ceilings uniformity the graph is linear and its slightly above the standard values.

CASE: 21

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 80-50-20 IN MIXED SKY CONDITION, AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 80-50-20 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is 50%dimmed and the other one is fully on.

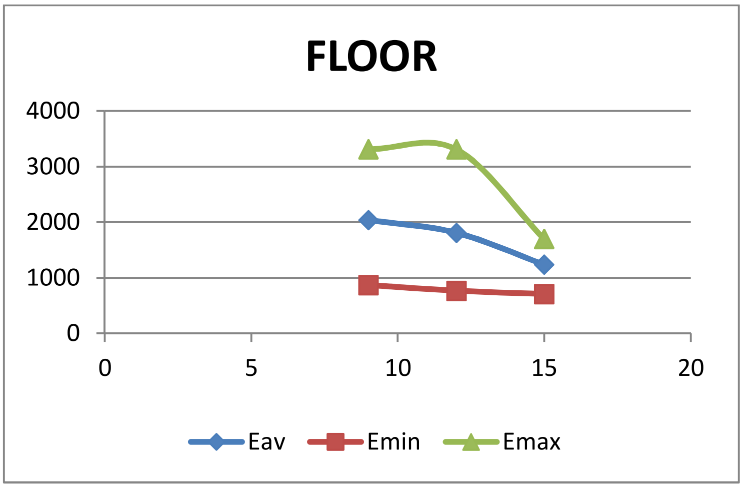
21.1.WORKPLANE VALUE GRAPH OF IT



21.1.WORKPLANE VALUE CHART OF IT

WORKPLANE			
TIME	Eav	Emin	Emax
9	2584	1004	6542
12	2211	917	6295
15	1550	840	2577

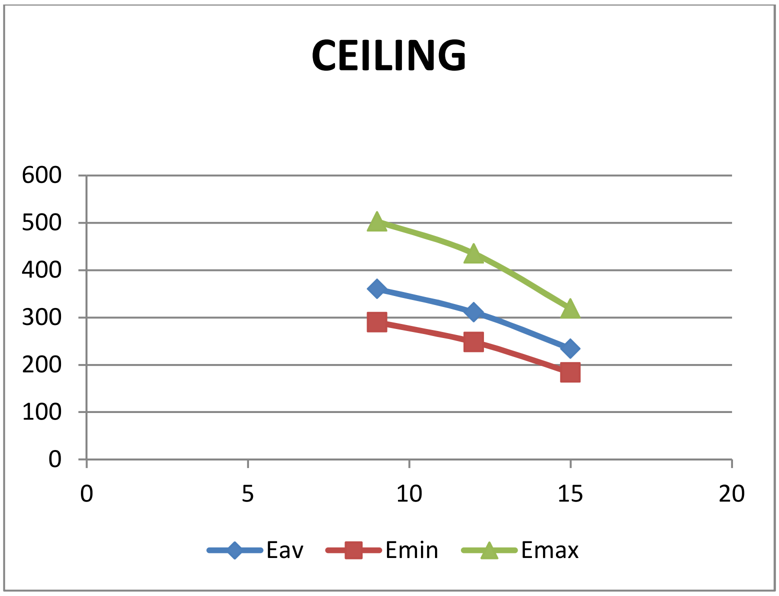
21.2. FLOOR VALUE GRAPH OF IT



21.2. FLOOR VALUE CHART OF IT

FLOOR			
TIME	Eav	Emin	Emax
9	2038	870	3311
12	1810	767	3311
15	1237	709	1698

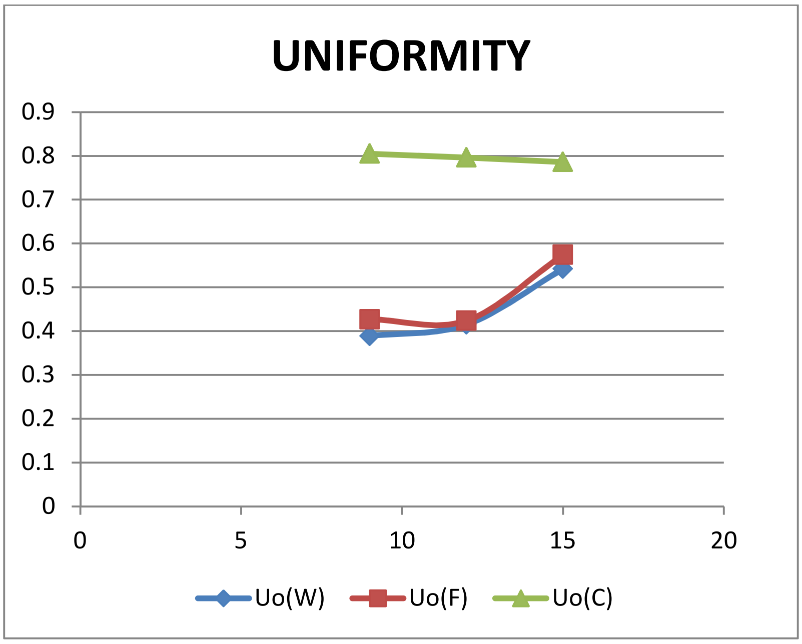
21.3. CEILING VALUE GRAPH OF IT



21.3. CEILING VALUE CHART OF IT

CEILING			
TIME	Eav	Emin	Emax
9	360	290	503
12	311	248	435
15	234	184	319

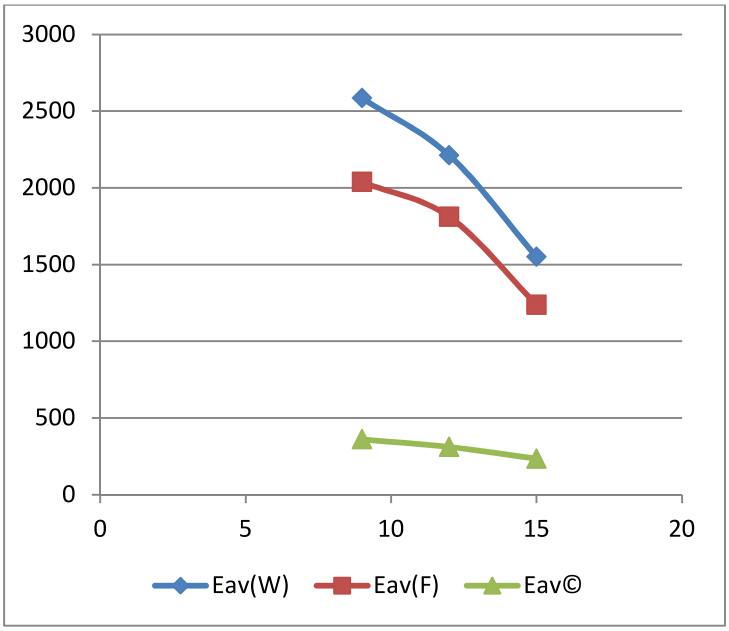
21.4.UNIFORMITY VALUE GRAPH OF IT



21.4.UNIFORMITY VALUE CHART OF IT

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.389	0.427	0.805
12	0.415	0.424	0.796
15	0.542	0.574	0.786

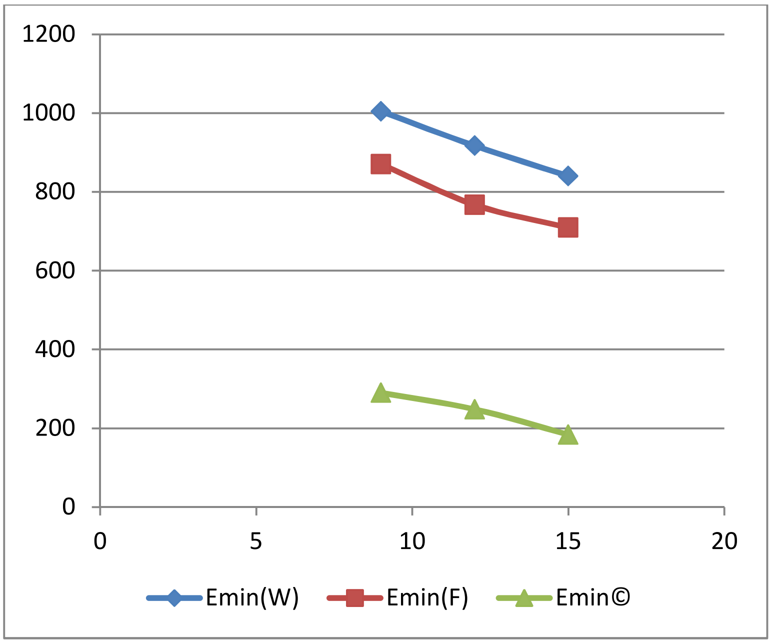
21.5. THE GRAPH FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING



21.5. THE CHART FOR ALL Eavg VALUES FOR WORKPLANE, AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	2584	2038	360
12	2211	1810	311
15	1550	1237	234

21.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

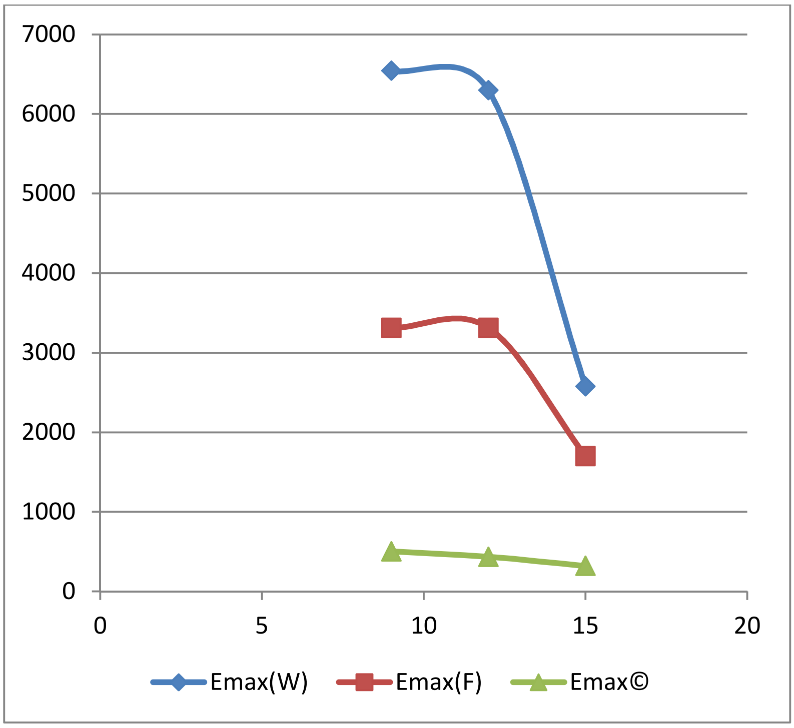


21.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1004	870	290
12	917	767	248
15	840	709	184

21.7.THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

21.7.THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6542	3311	503
12	6295	3311	435
15	2577	1698	319

CASE: 22

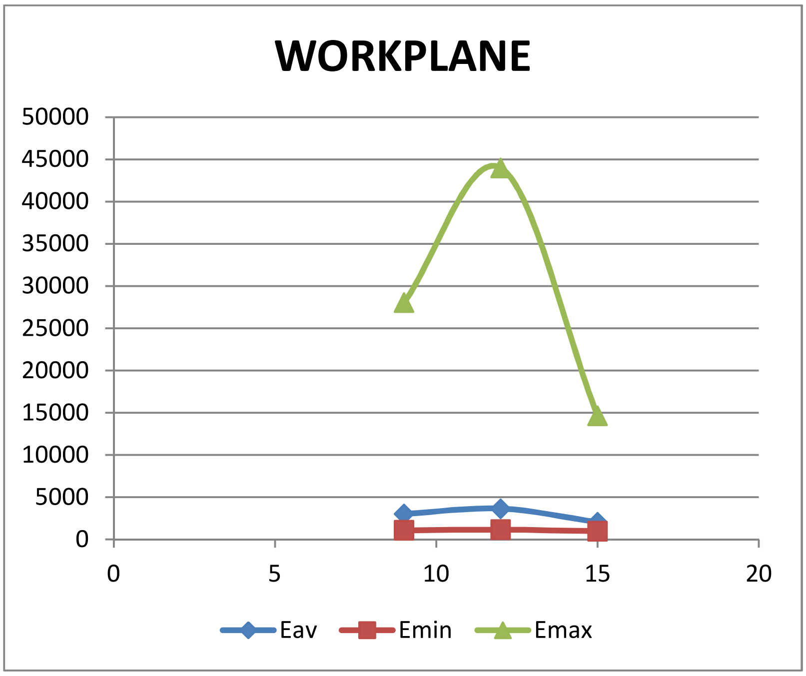
WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables.

This simulation considered only for clear sky condition.

One control group is fully off and the other one is fully on.

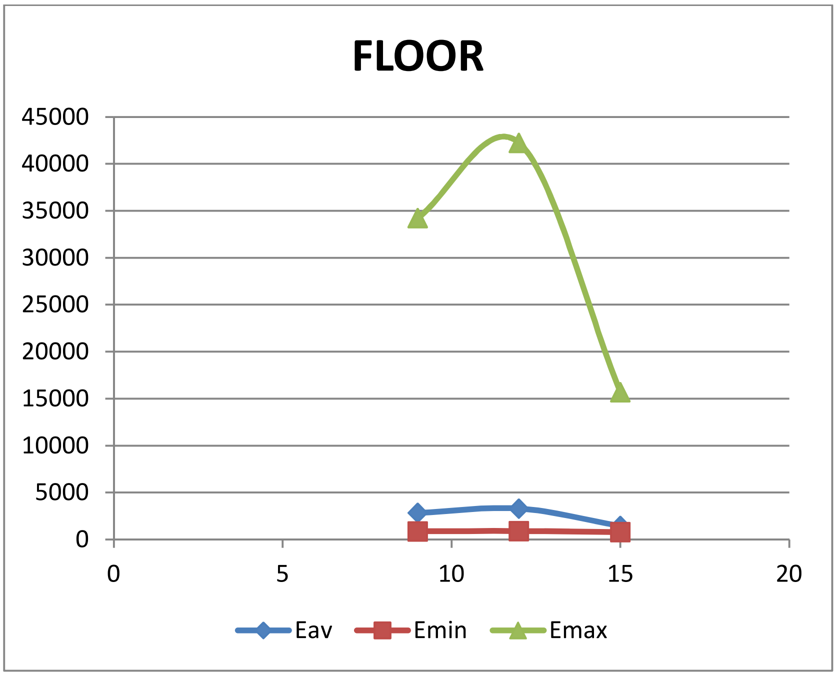
22.1. WORKPLANE VALUE GRAPH



22.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	3024	1076	28046
12	3634	1144	43975
15	2038	979	14617

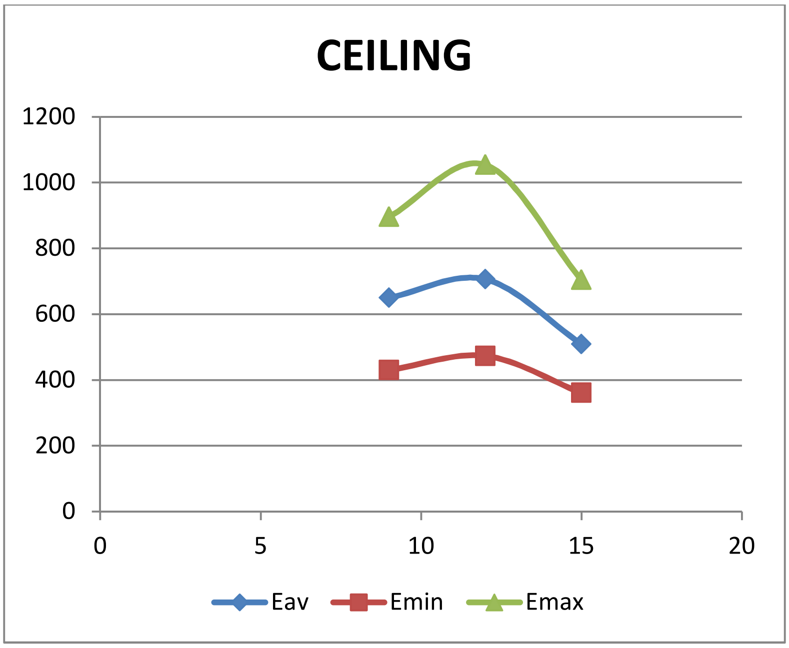
22.2. FLOOR VALUE GRAPH



22.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	2837	877	34225
12	3290	901	42233
15	1439	790	15682

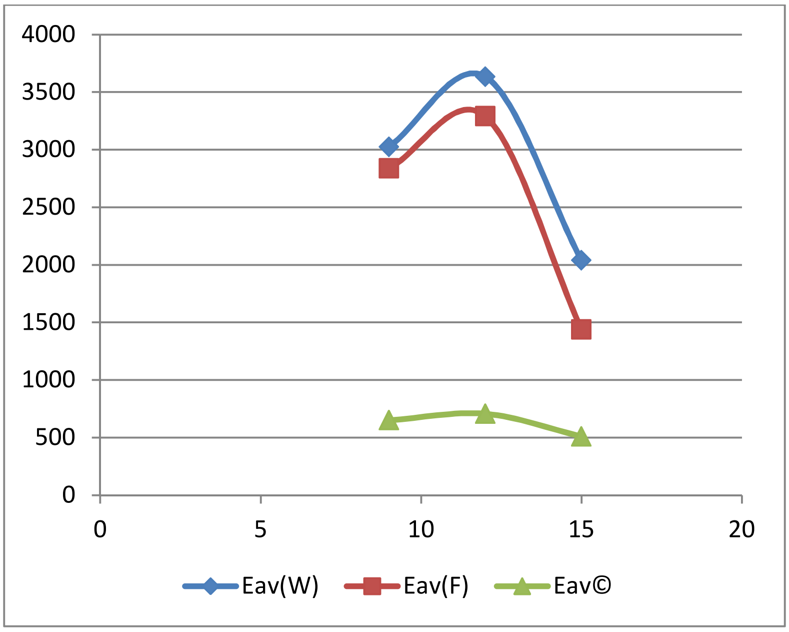
22.3. CEILING VALUE GRAPH



22.3.CEILING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	650	430	896
12	706	473	1054
15	509	361	704

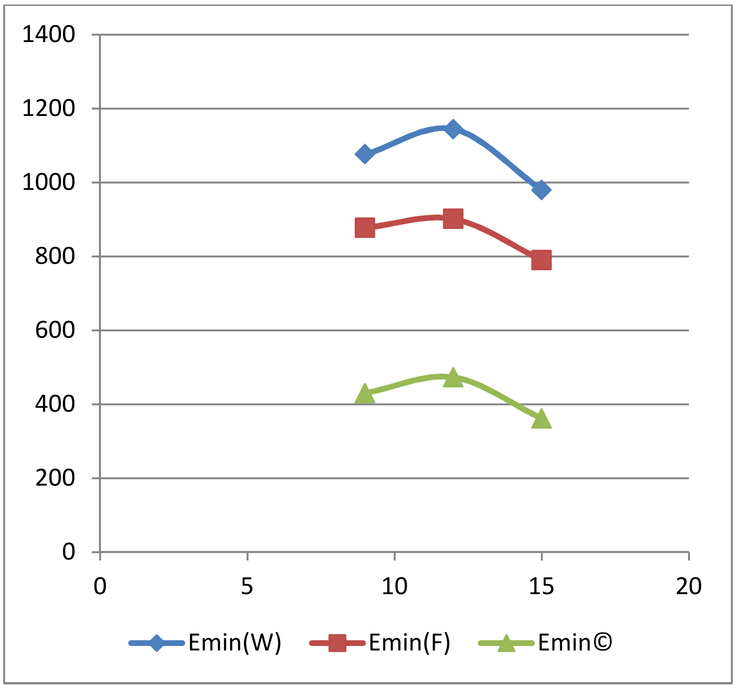
22.4. UNIFORMITY VALUE GRAPH



22.4. UNIFORMITY VALUE CHART

TIME	Eav(W)	Eav(F)	Eav©
9	3024	2837	650
12	3634	3290	706
15	2038	1439	509

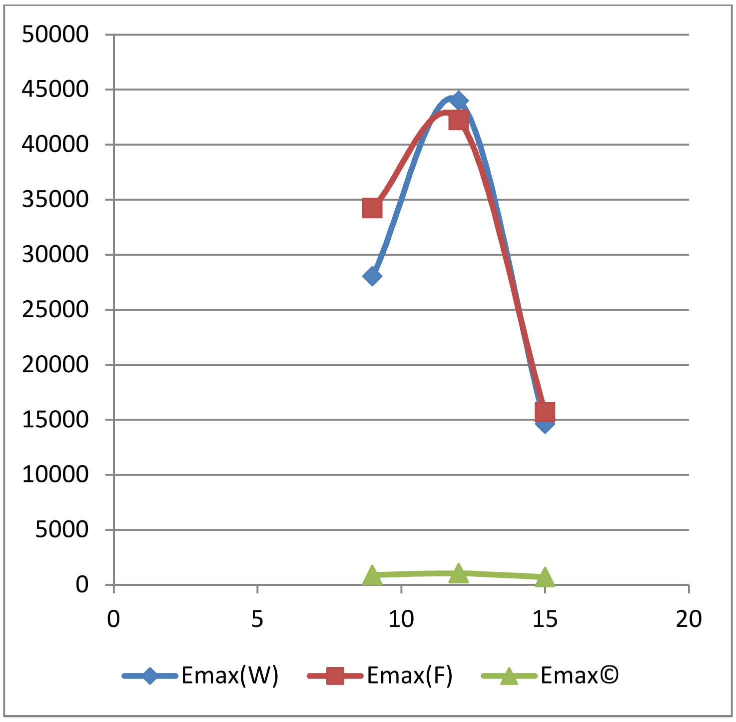
22.5. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR



22.5. THE CHART FOR ALL Emin VALUES FOR ALL OF THEM

TIME	Emin(W)	Emin(F)	Emin©
9	1076	877	430
12	1144	901	473
15	979	790	361

22.6. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



22.6. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emax(W)	Emax(F)	Emax©
9	28046	34225	896
12	43975	42233	1054
15	14617	15682	704

CASE: 23

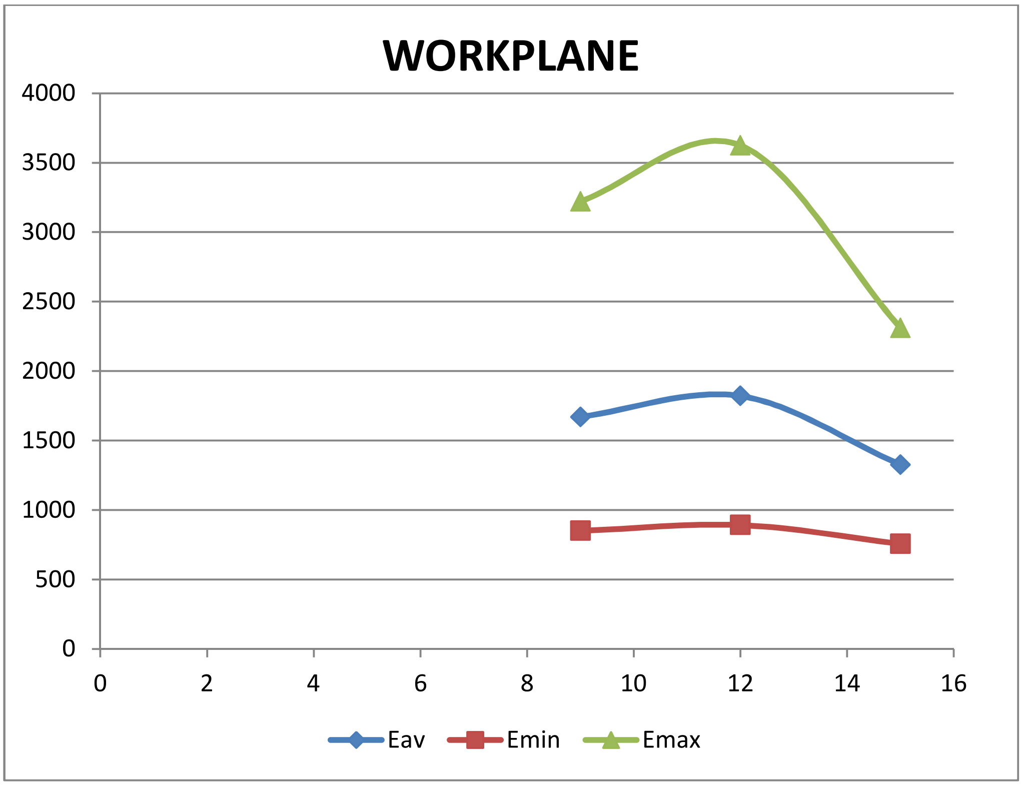
WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables.

This simulation considered only for overcast sky condition.

One control group is fully off and the other one is fully on.

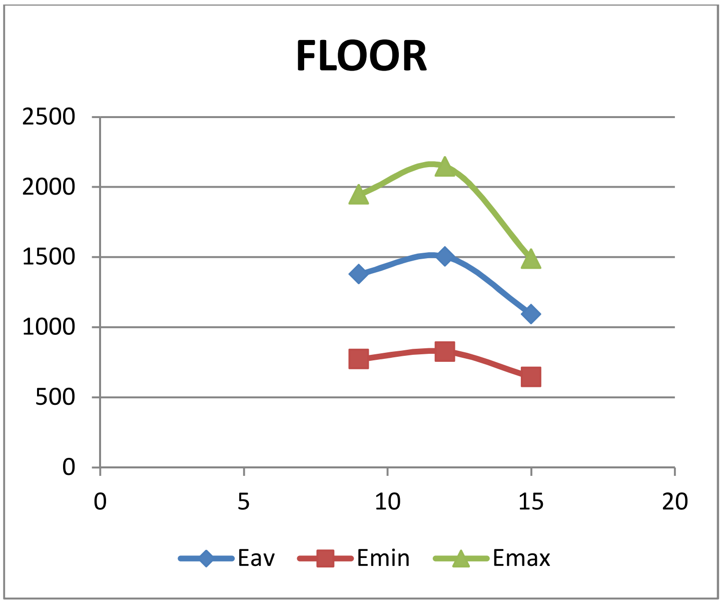
23.1. WORKPLANE VALUE GRAPH



23.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1671	851	3222
12	1821	892	3625
15	1327	757	2311

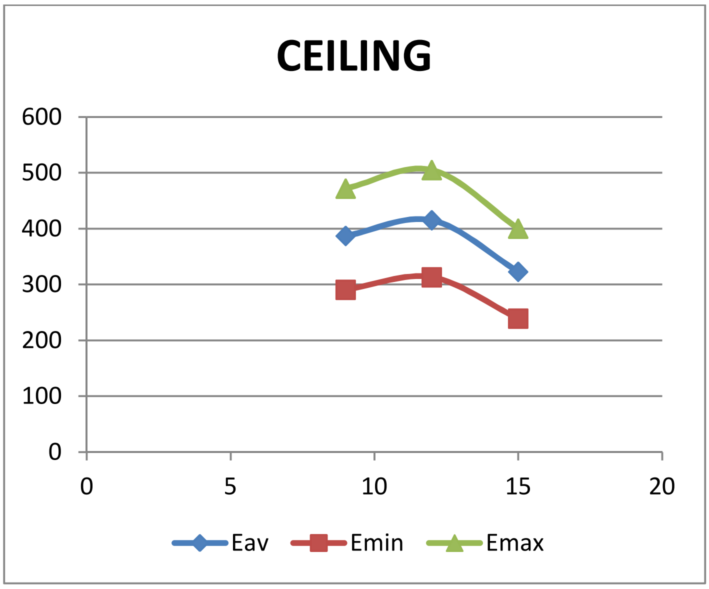
23.2. FLOOR VALUE GRAPH



23.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	1379	773	1948
12	1504	826	2147
15	1093	645	1489

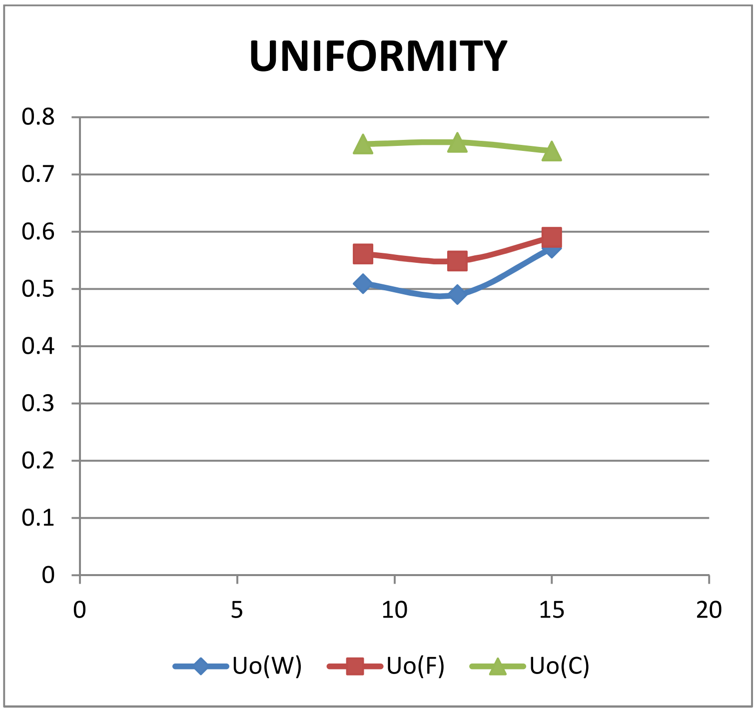
23.3. CEILING VALUE GRAPH



23.3. CEILING VALUE CHART OF

CEILING			
TIME	Eav	Emin	Emax
9	387	291	472
12	415	313	505
15	323	239	400

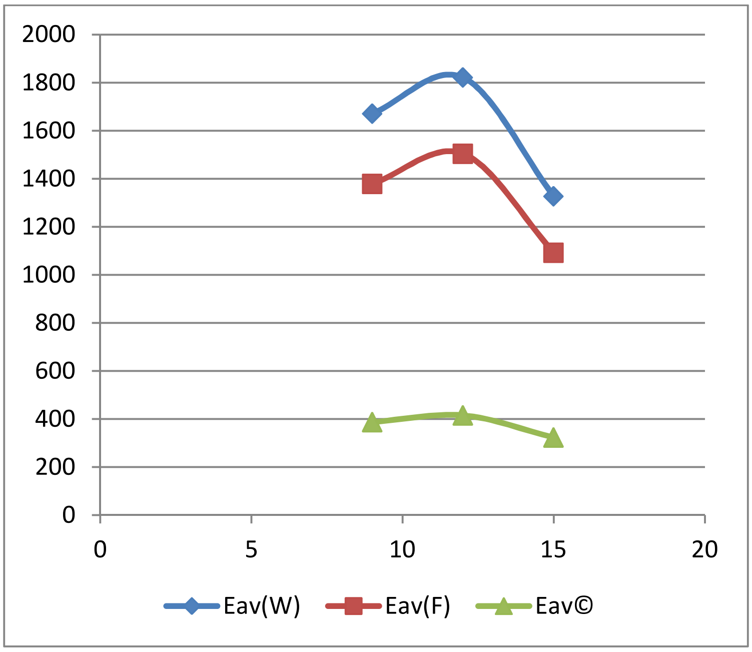
23.4. UNIFORMITY VALUE GRAPH



23.4.UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.509	0.561	0.753
12	0.49	0.549	0.756
15	0.571	0.59	0.741

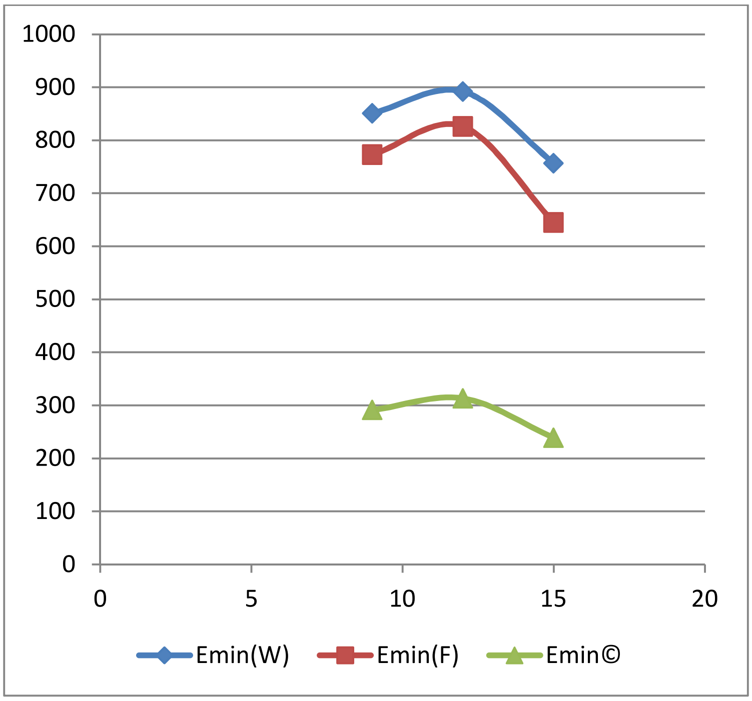
23.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



23.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	1671	1379	387
12	1821	1504	415
15	1327	1093	323

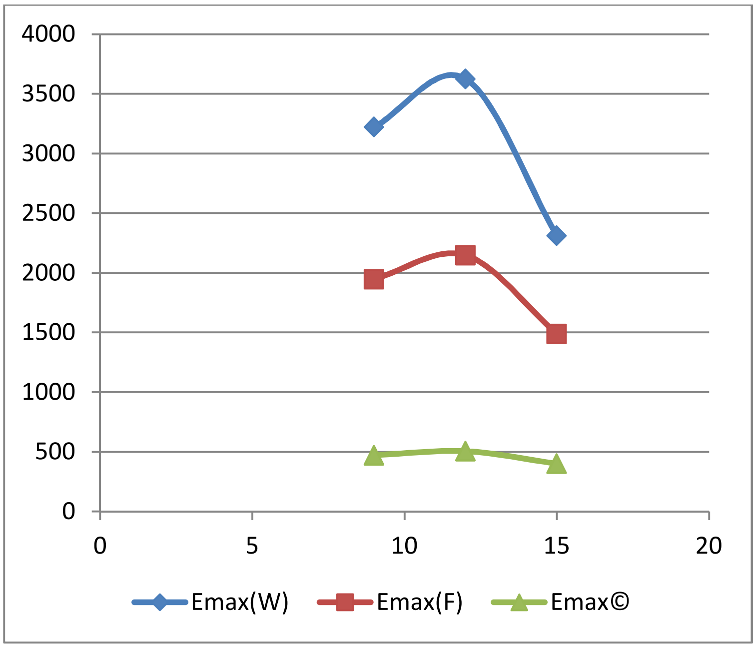
23.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



23.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	851	773	291
12	892	826	313
15	757	645	239

23.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



23.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

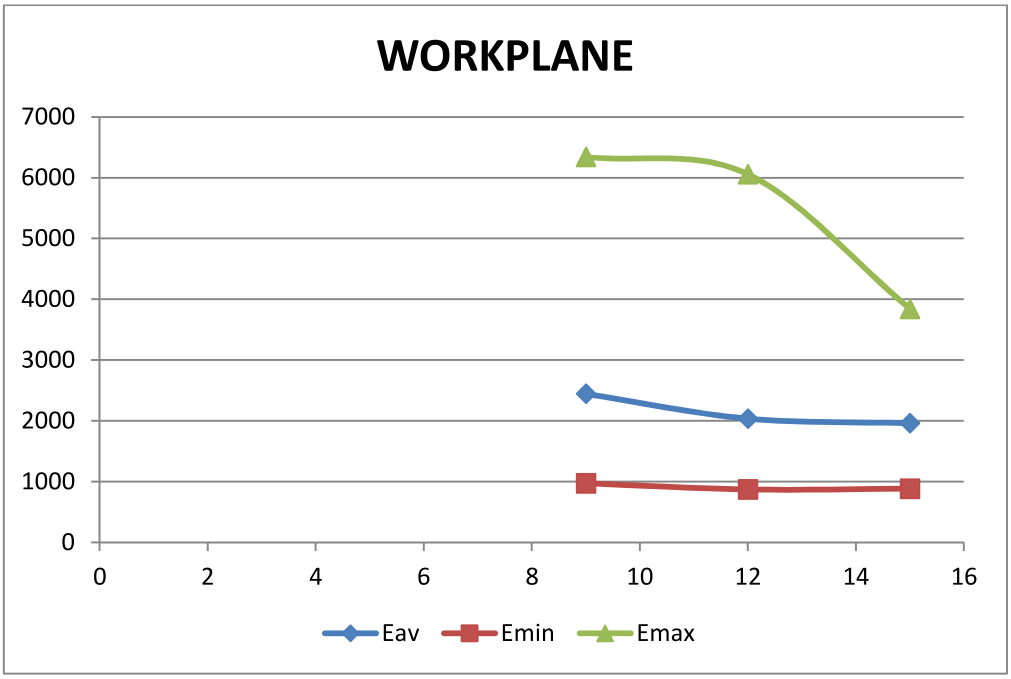
TIME	Emax(W)	Emax(F)	Emax©
9	3222	1948	472
12	3625	2147	505
15	2311	1489	400

CASE: 24

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN MIXED SKY CONDITION, AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is fully off and the other one is fully on.

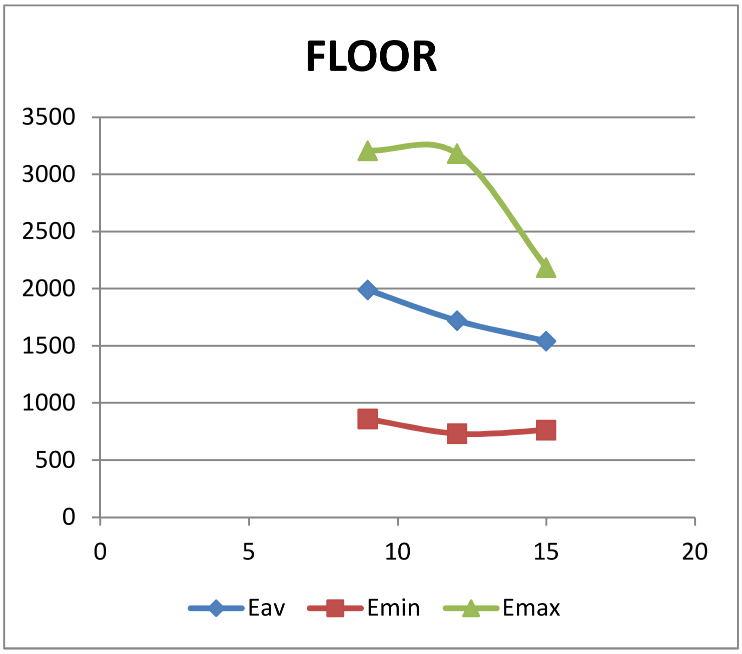
24.1. WORKPLANE VALUE GRAPH



24.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	2444	974	6341
12	2036	871	6058
15	1961	883	3844

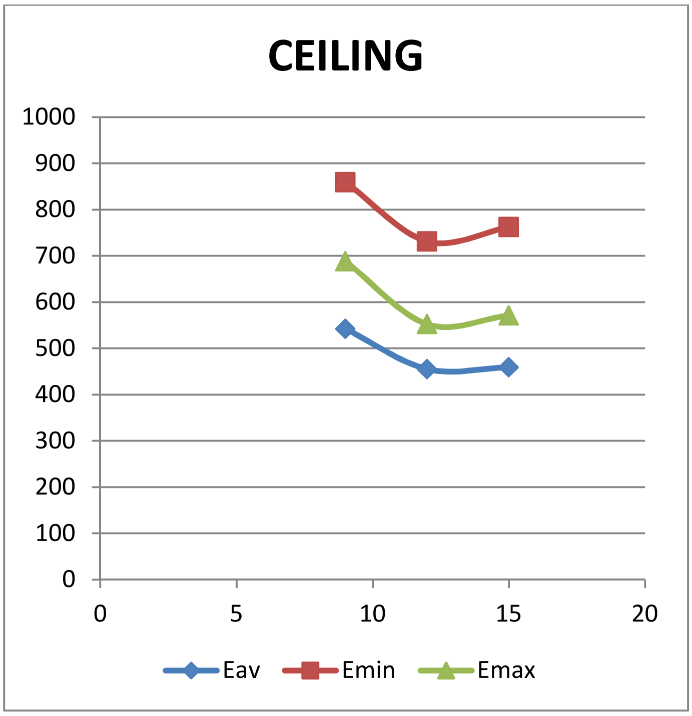
24.2. FLOOR VALUE GRAPH



24.2. FLOOR VALUE CHART

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1989	859	3207
12	1720	731	3180
15	1541	762	2185

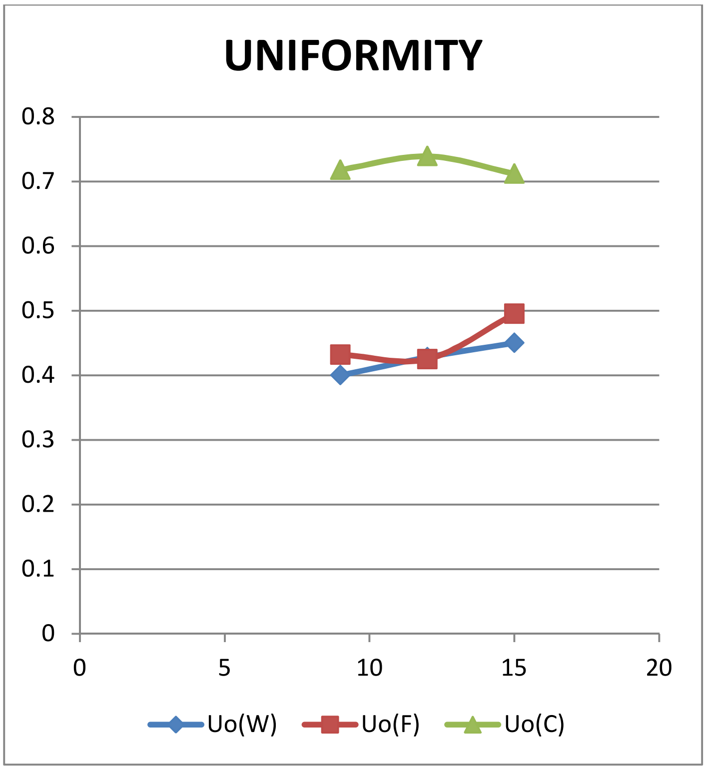
24.3. CEILING VALUE GRAPH



24.3. CEILING VALUE CHART

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	542	859	688
12	455	731	552
15	459	762	571

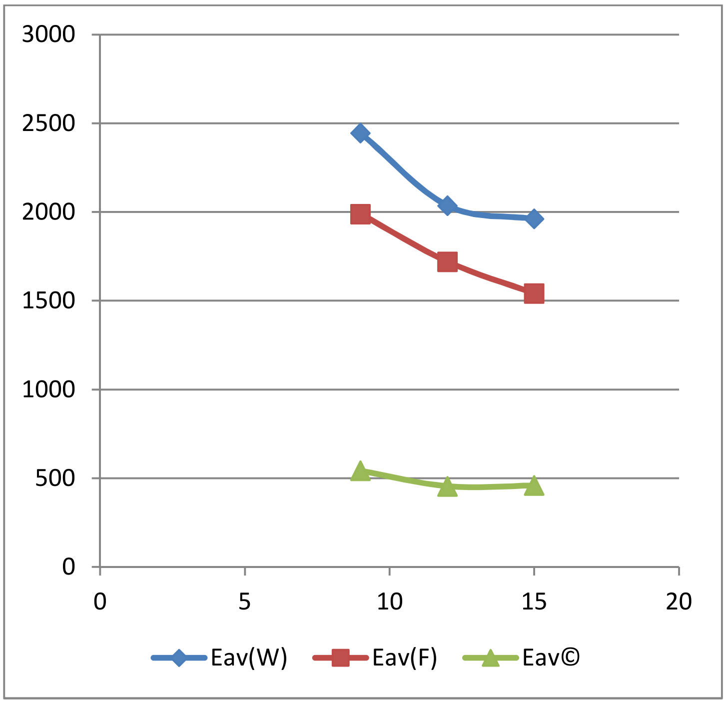
24.4. UNIFORMITY VALUE GRAPH



24.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.3999	0.432	0.718
12	0.428	0.425	0.739
15	0.45	0.495	0.712

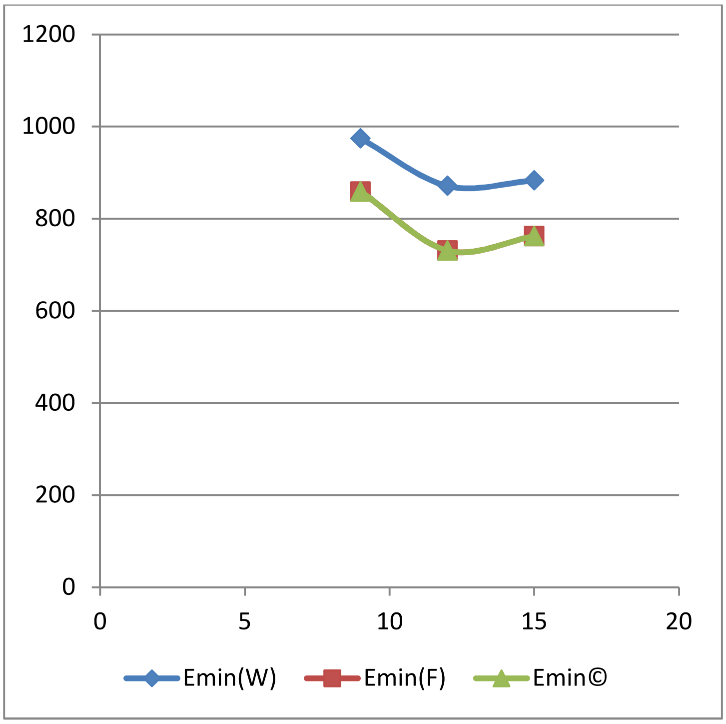
24.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



24.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	2444	1989	542
12	2036	1720	455
15	1961	1541	459

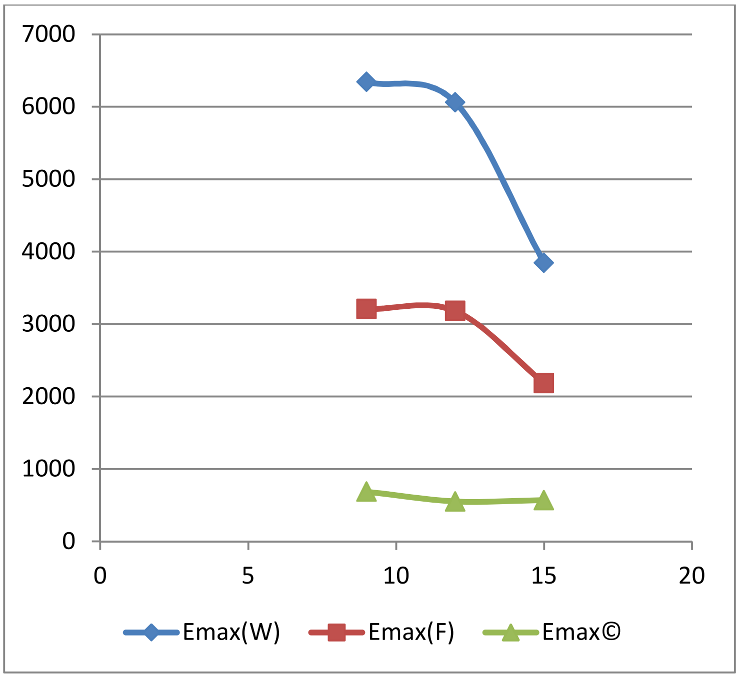
24.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



24.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	974	859	859
12	871	731	731
15	883	762	762

24.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



24.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

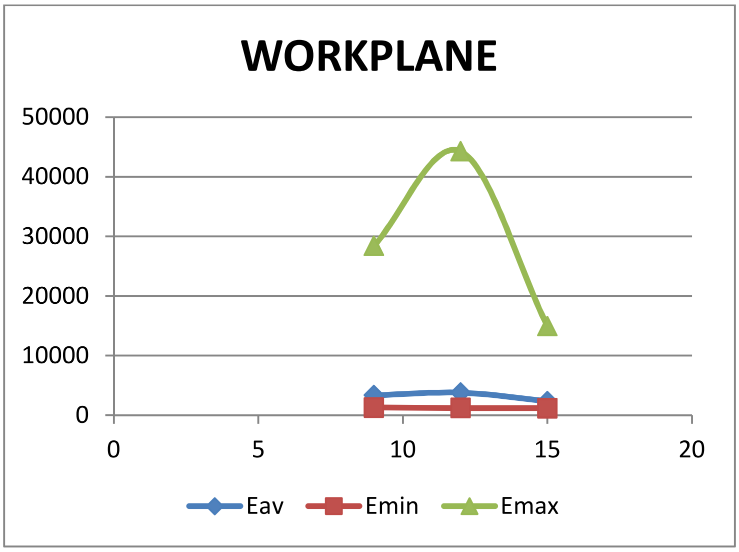
TIME	Emax(W)	Emax(F)	Emax©
9	6341	3207	688
12	6058	3180	552
15	3844	2185	571

CASE: 25

WORKPLANE , FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear skycondition.One control group is 50% dimmed and the other one is fully on.

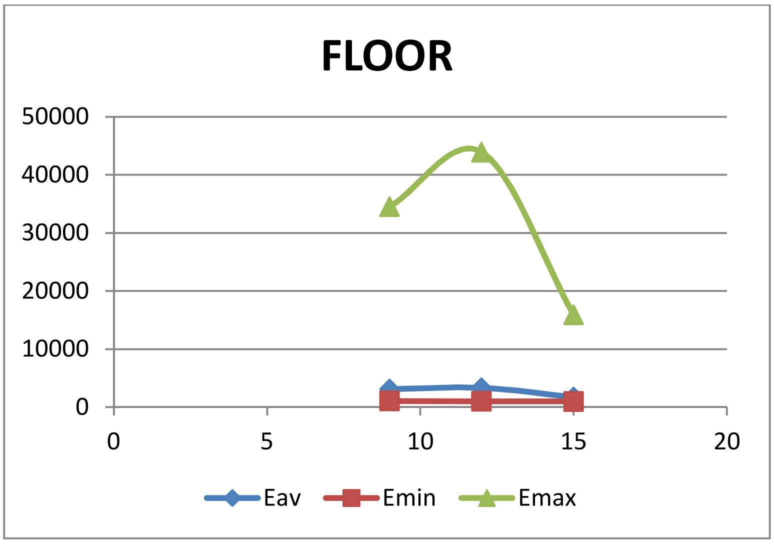
25.1. WORKPLANE VALUE GRAPH



25.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	3360	1301	28420
12	3784	1205	44259
15	2380	1179	14907

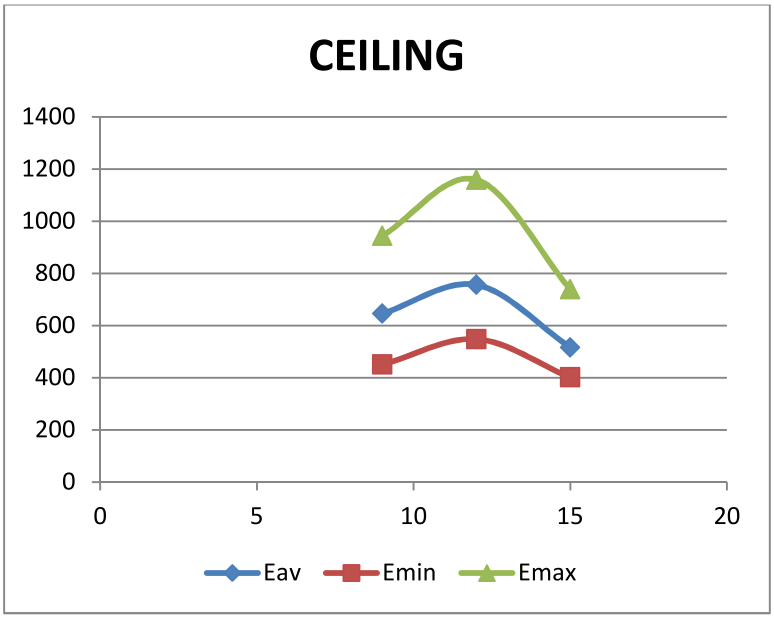
25.2. FLOOR VALUE GRAPH



25.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	3104	1068	34508
12	3320	1011	43896
15	1713	985	15904

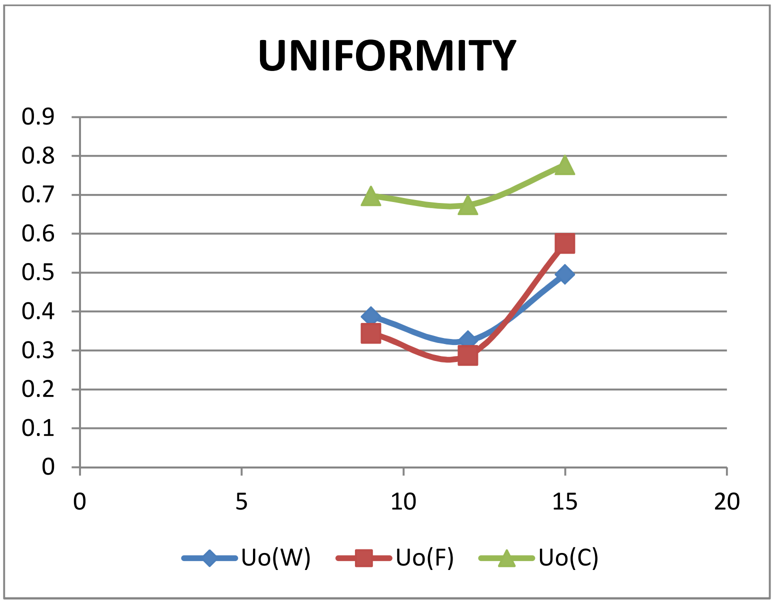
25.3 CEILING VALUE GRAPH



25.3 CEILING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	646	450	944
12	756	548	1159
15	516	401	739

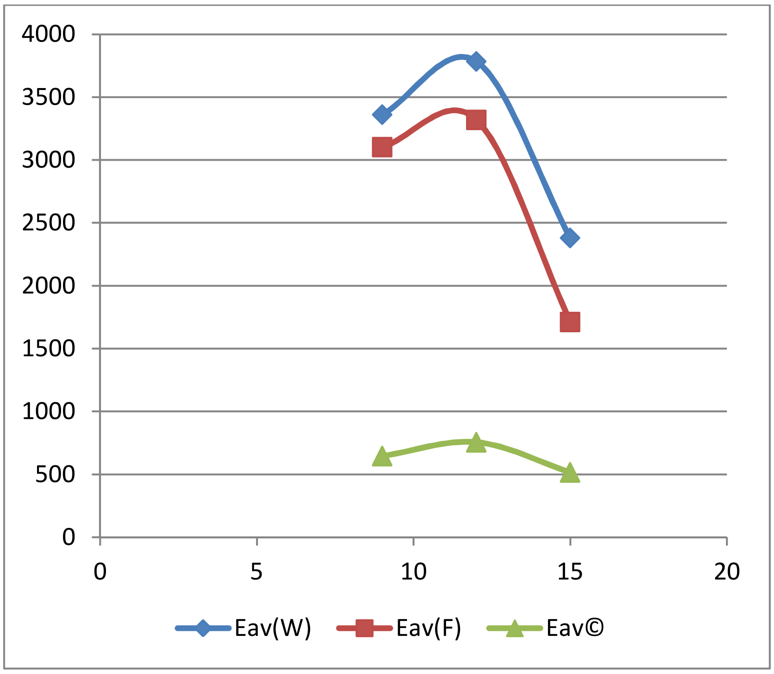
25.4. UNIFORMITY VALUE GRAPH



25.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.387	0.344	0.697
12	0.325	0.287	0.674
15	0.495	0.575	0.777

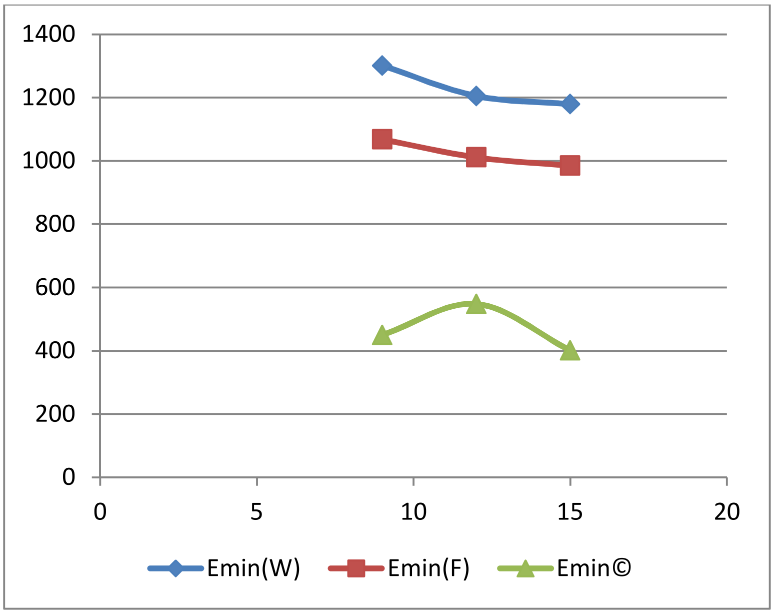
25.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



25.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	3360	3104	646
12	3784	3320	756
15	2380	1713	516

25.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

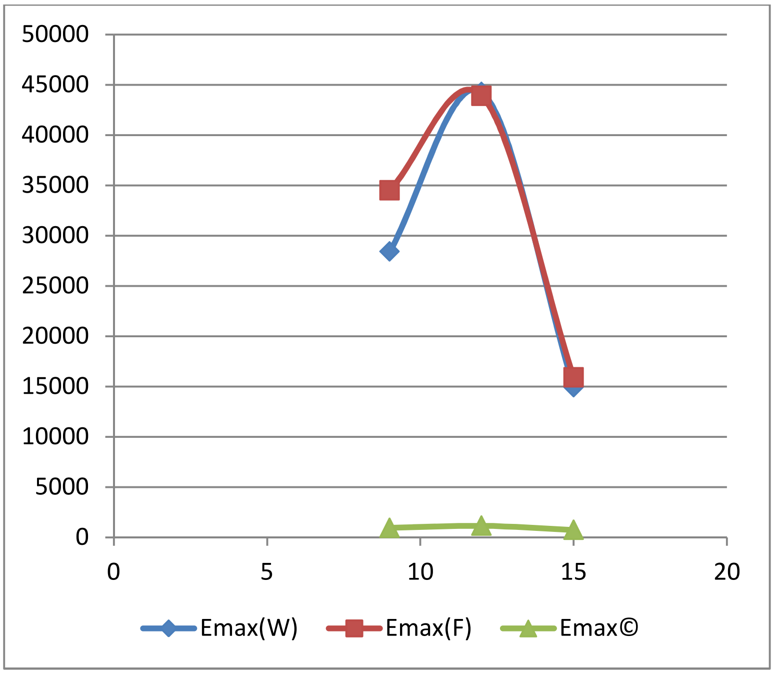


25.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1301	1068	450
12	1205	1011	548
15	1179	985	401

25.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

25.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



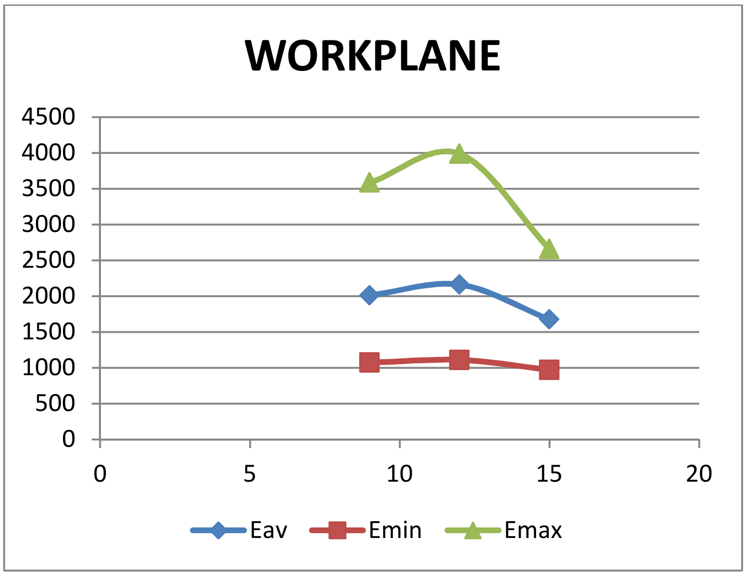
TIME	Emax(W)	Emax(F)	Emax©
9	28420	34508	944
12	44259	43896	1159
15	14907	15904	739

CASE: 26

WORKPLANE , FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN OVERCAST SKY CONDITION, AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition. One control group is 50% dimmed and the other one is fully on.

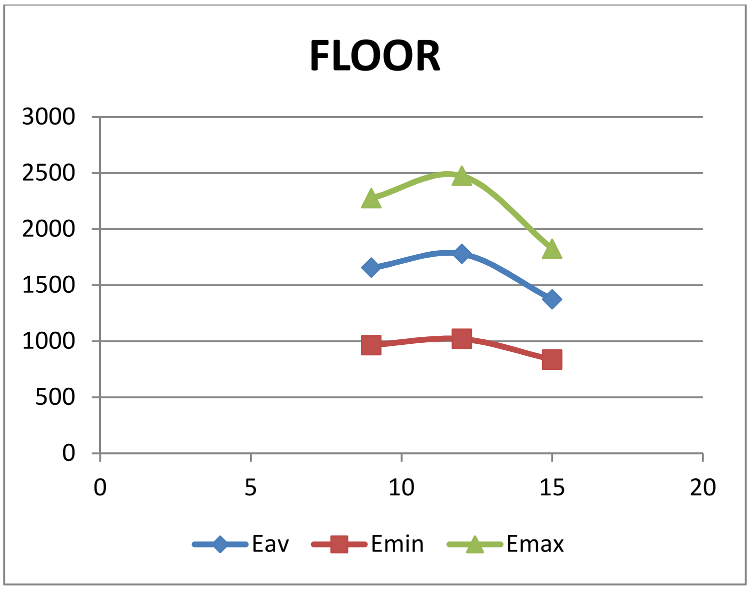
26.1. WORKPLANE VALUE GRAPH



26.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	2013	1073	3585
12	2162	1111	3987
15	1675	973	2656

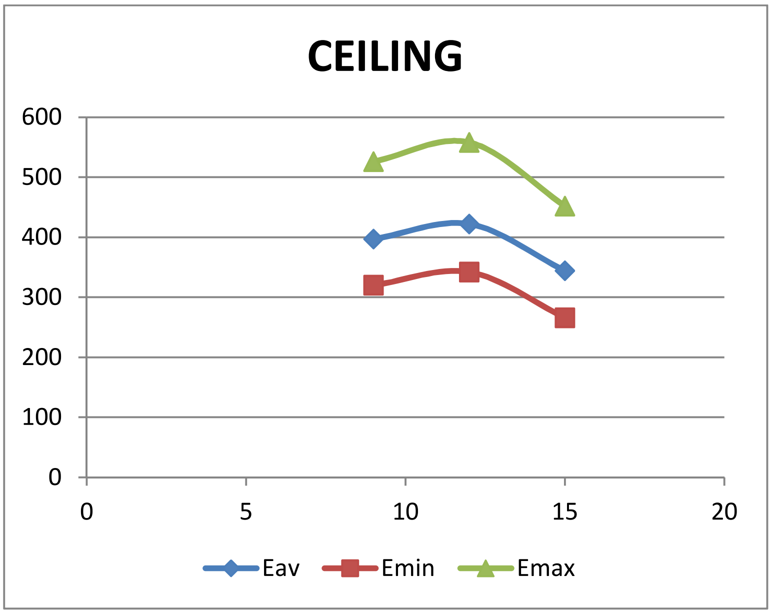
26.2. FLOOR VALUE GRAPH



26.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	1654	964	2276
12	1778	1019	2474
15	1372	835	1824

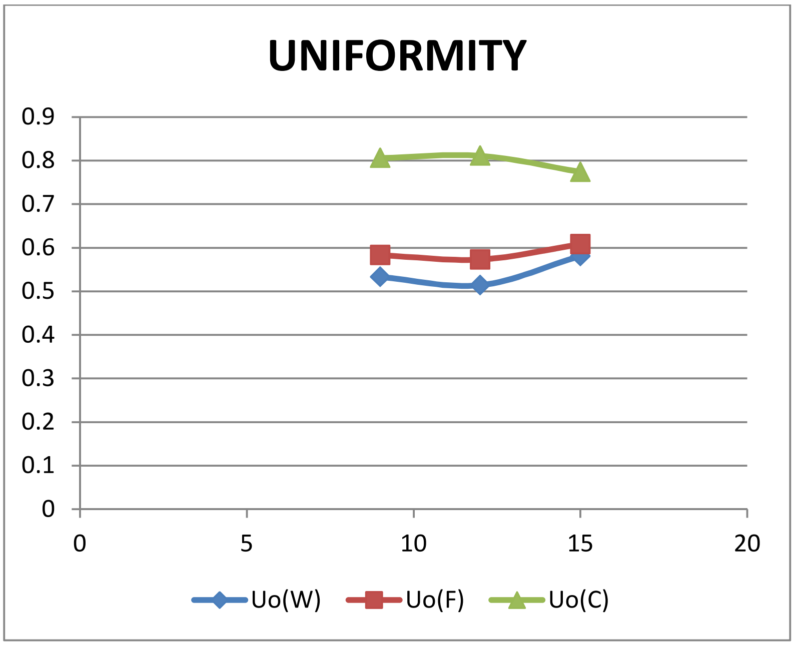
26.3. CEILING VALUE GRAPH



26.3. CEILING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	397	320	526
12	422	342	558
15	344	266	452

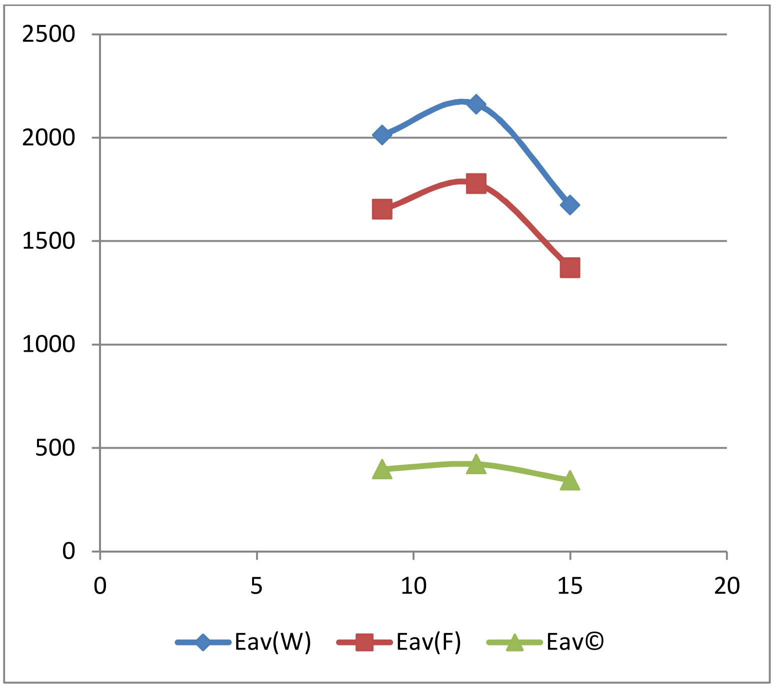
26.4. UNIFORMITY VALUE GRAPH



26.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.533	0.583	0.806
12	0.514	0.573	0.811
15	0.581	0.608	0.774

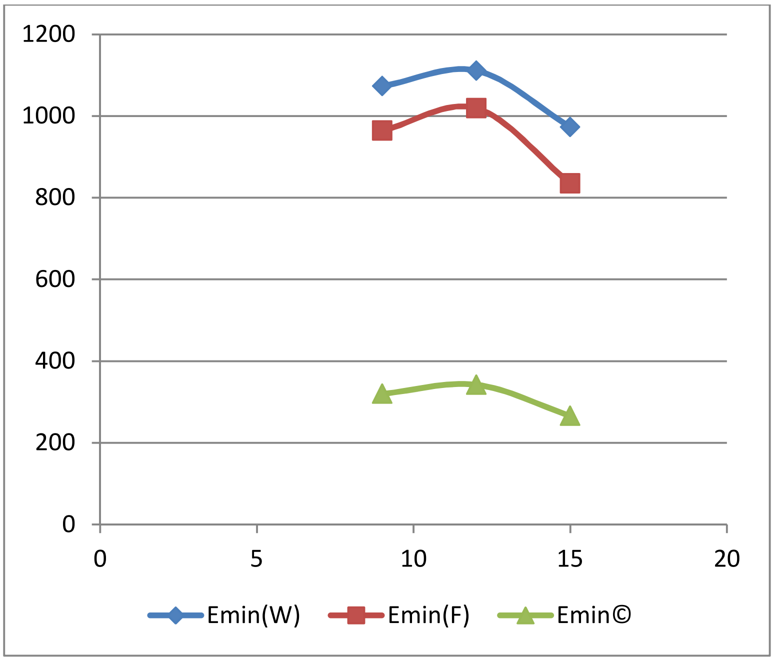
26.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



26.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	2013	1654	397
12	2162	1778	422
15	1675	1372	344

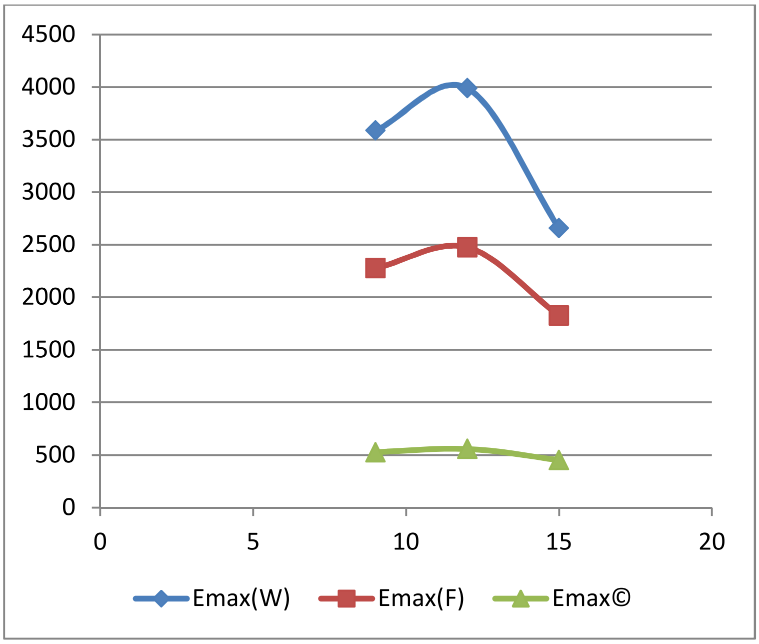
26.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



26.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1073	964	320
12	1111	1019	342
15	973	835	266

26.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



26.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

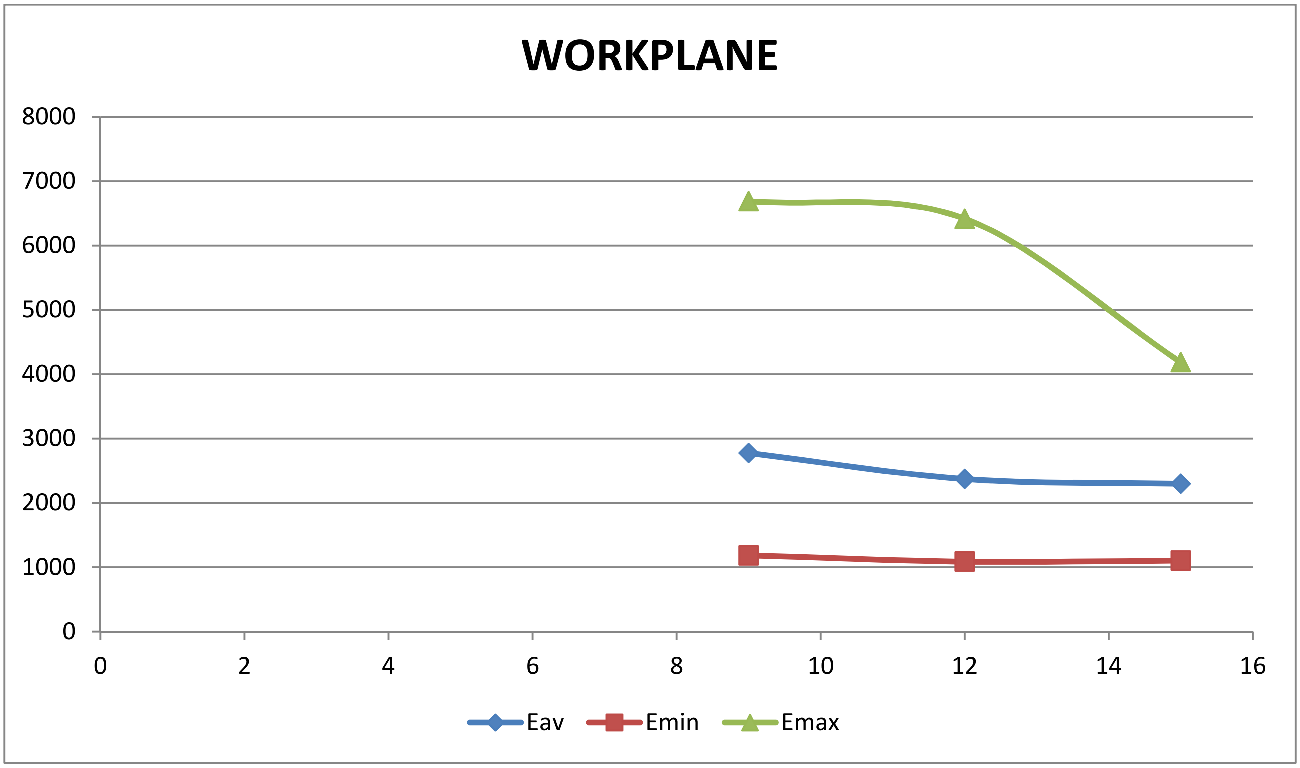
TIME	Emax(W)	Emax(F)	Emax©
9	3585	2276	526
12	3987	2474	558
15	2656	1824	452

CASE: 27

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 90-60-30 IN MIXED SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 90-60-30 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is 50% dimmed and the other one is fully on.

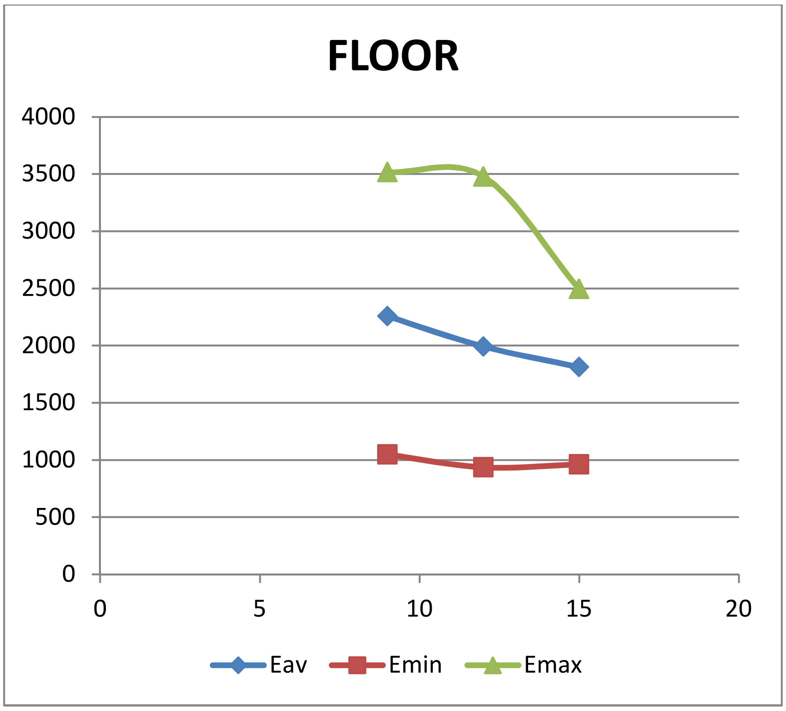
27.1. WORKPLANE VALUE GRAPH



27.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	2775	1185	6689
12	2373	1088	6416
15	2297	1104	4184

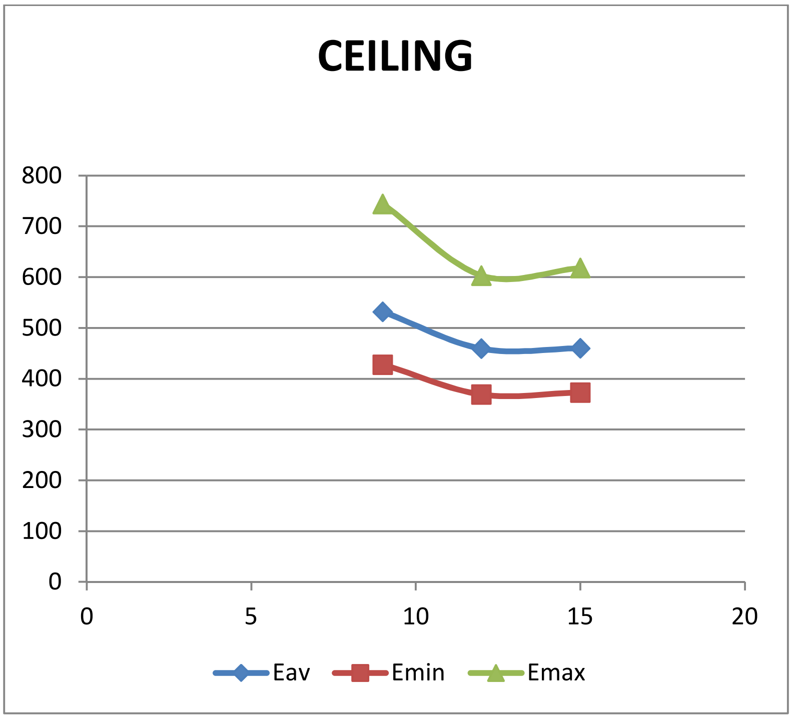
27.2. FLOOR VALUE GRAPH



27.2. FLOOR VALUE CHART

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	2256	1048	3517
12	1992	935	3478
15	1812	962	2494

27.3. CEILING VALUE GRAPH

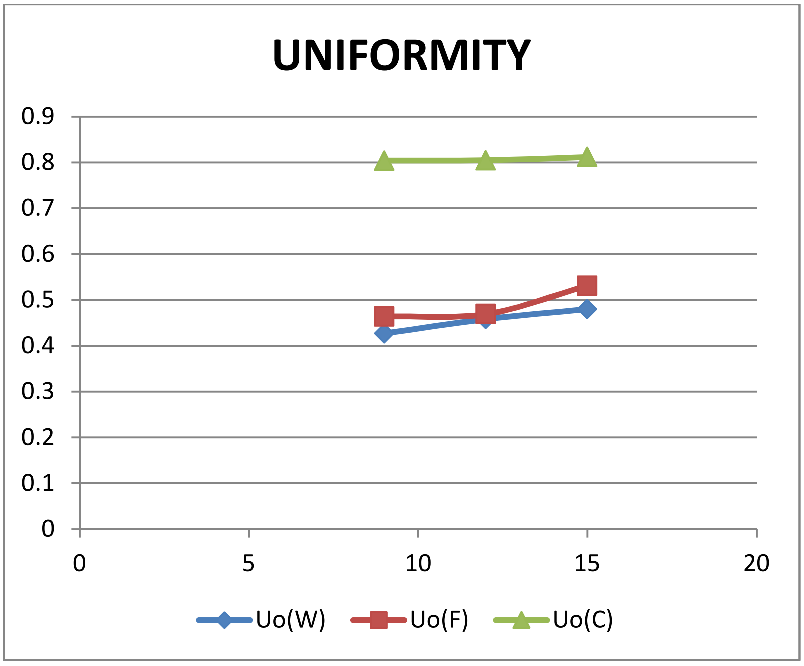


27.3. CEILING VALUE CHART

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	532	428	744
12	459	369	603
15	460	373	618

27.4. UNIFORMITY VALUE GRAPH

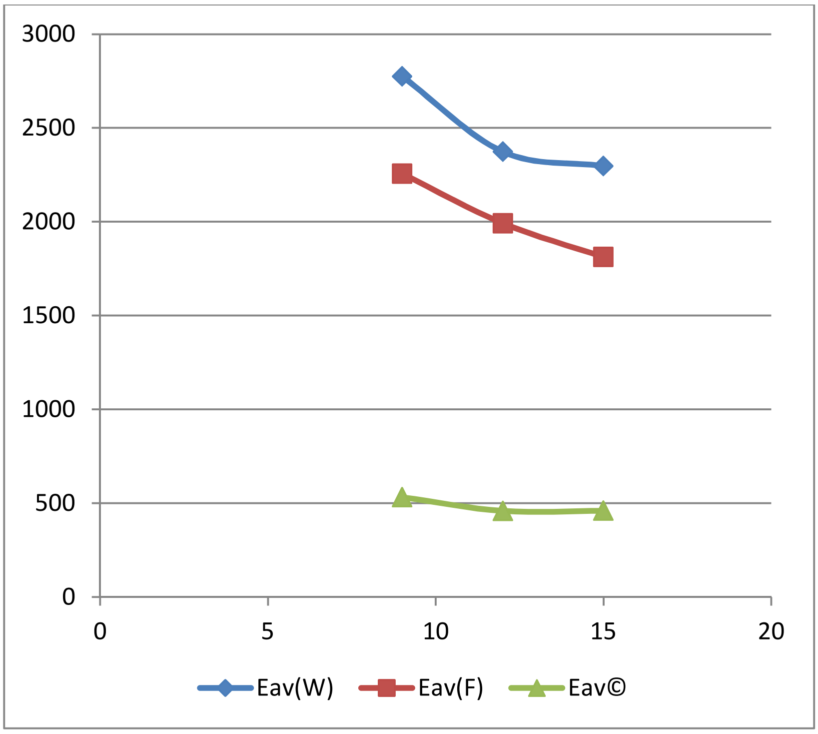
27.4. UNIFORMITY VALUE CHART



UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.427	0.464	0.804
12	0.458	0.469	0.8046
15	0.48	0.531	0.812

27.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

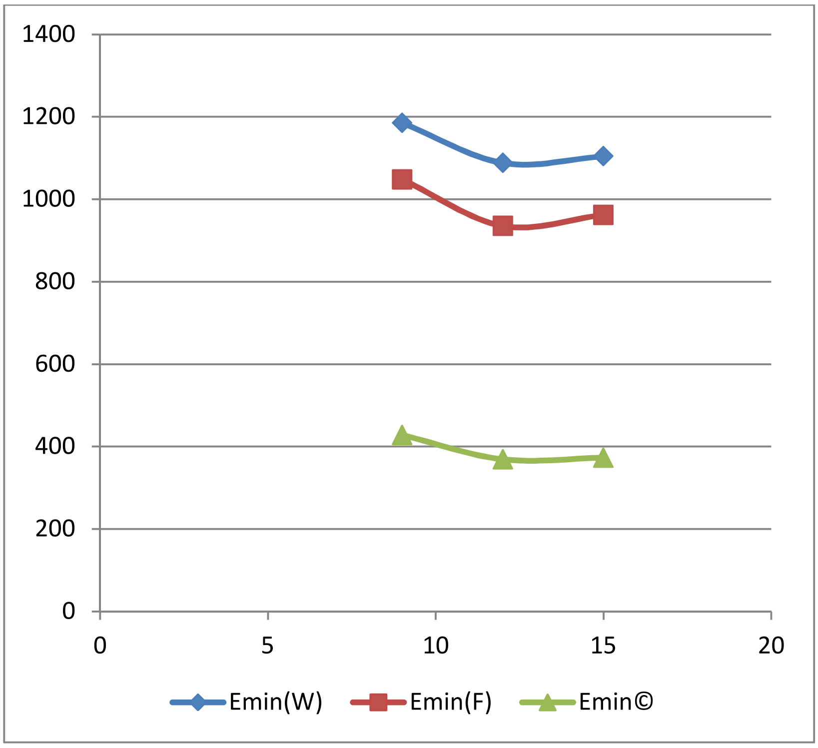
27.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, AND CEILING



TIME	Eav(W)	Eav(F)	Eav©
9	2775	2256	532
12	2373	1992	459
15	2297	1812	460

27.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

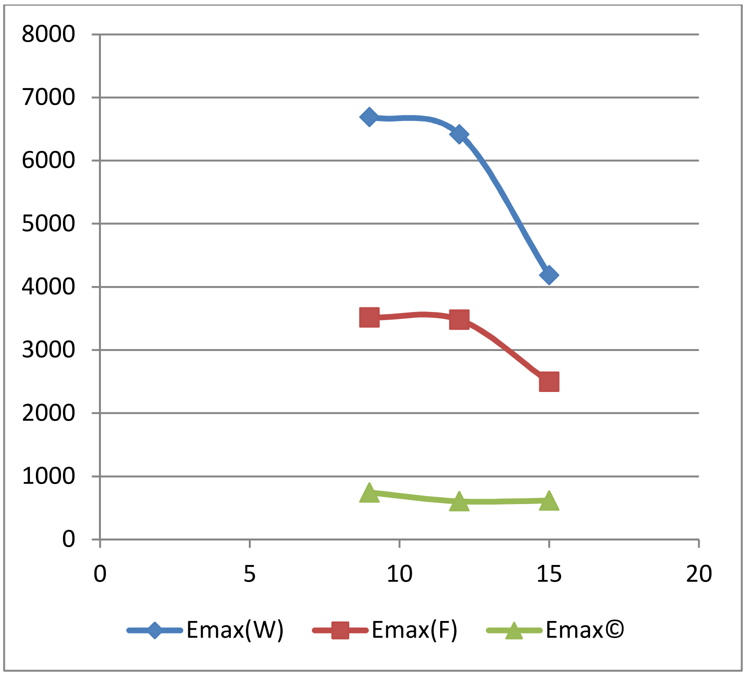
27.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	1185	1048	428
12	1088	935	369
15	1104	962	373

27.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

27.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



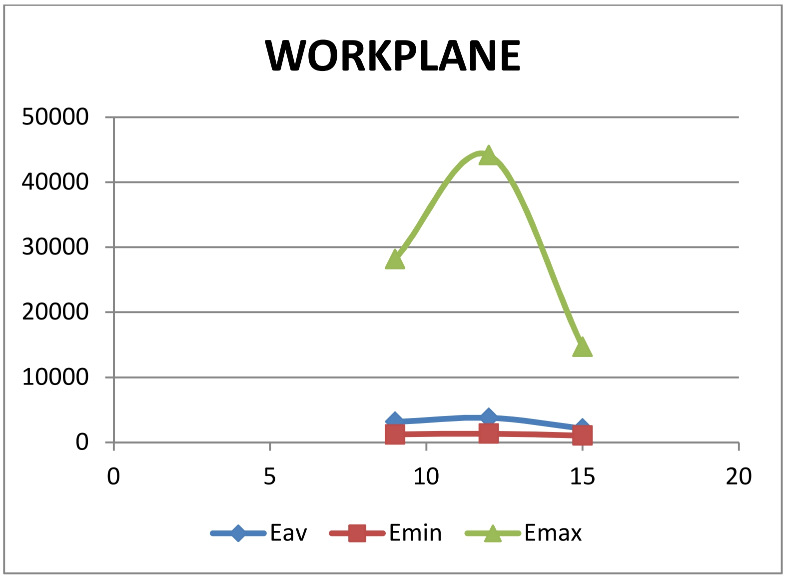
TIME	Emax(W)	Emax(F)	Emax©
9	6689	3517	744
12	6416	3478	603
15	4184	2494	618

CASE: 28

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN CLEAR SKY CONDITION, AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition. One control group is fully off and the other one is fully on.

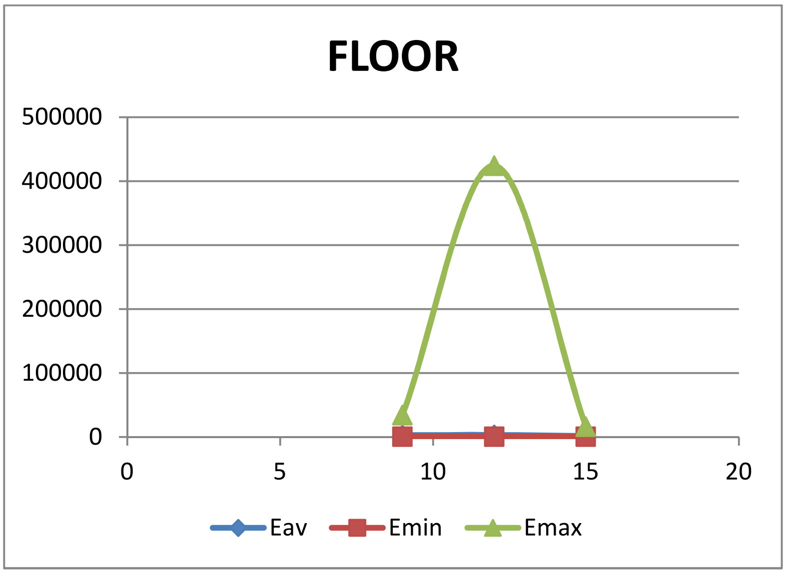
28.1. WORKPLANE VALUE GRAPH



28.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	3143	1215	28167
12	3764	1327	44154
15	2133	1042	14701

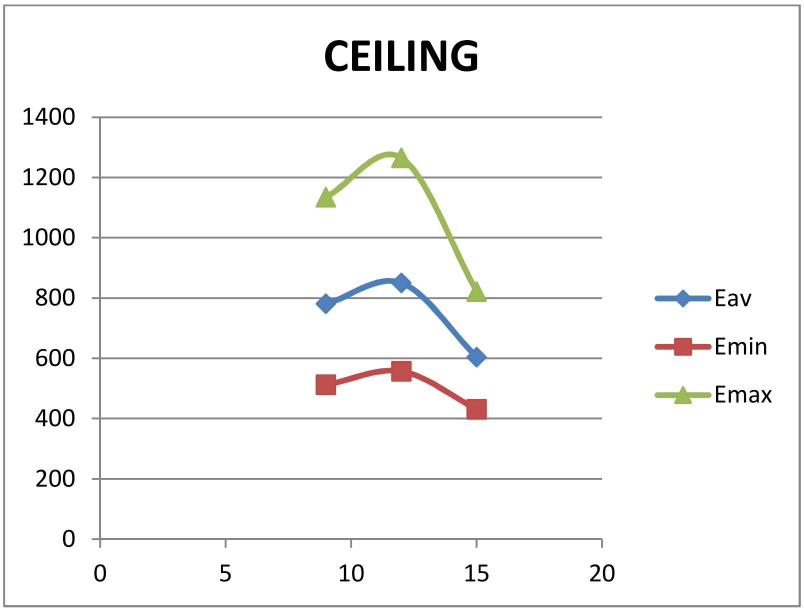
28.2. FLOOR VALUE GRAPH OF IT



28.2. FLOOR VALUE CHART OF IT

FLOOR			
TIME	Eav	Emin	Emax
9	2971	987	34387
12	3432	1018	423999
15	1549	879	16274

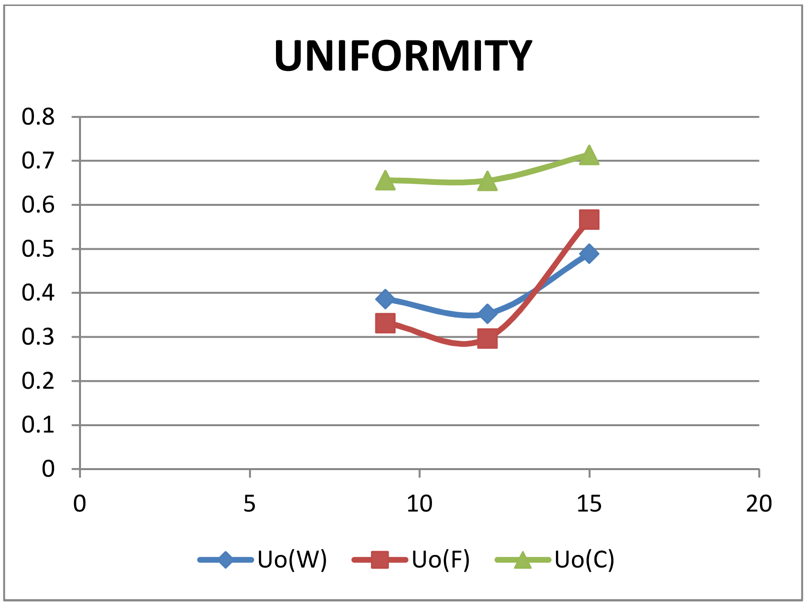
28.3. CEILING VALUE GRAPH



28.3. CEILING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	781	512	1135
12	850	557	1265
15	604	431	822

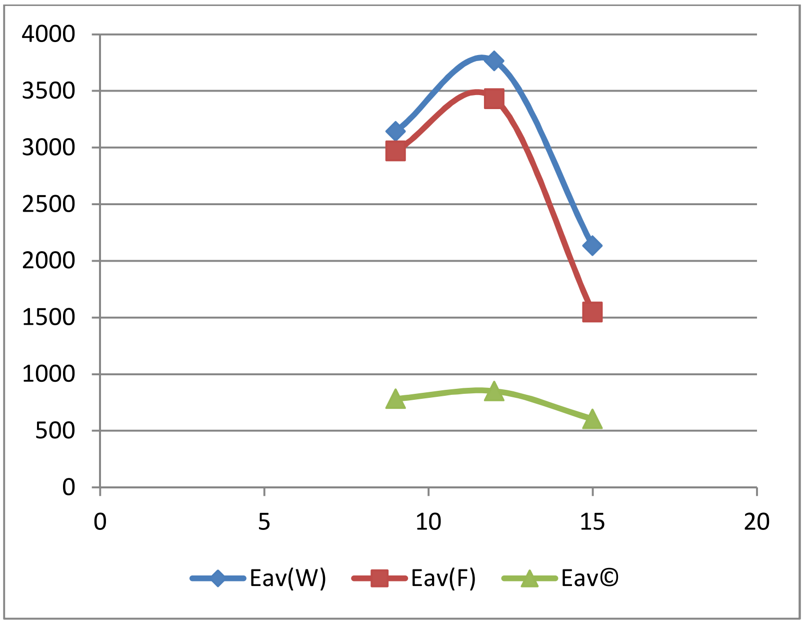
28.4. UNIFORMITY VALUE GRAPH



28.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.386	0.332	0.656
12	0.353	0.297	0.655
15	0.489	0.567	0.714

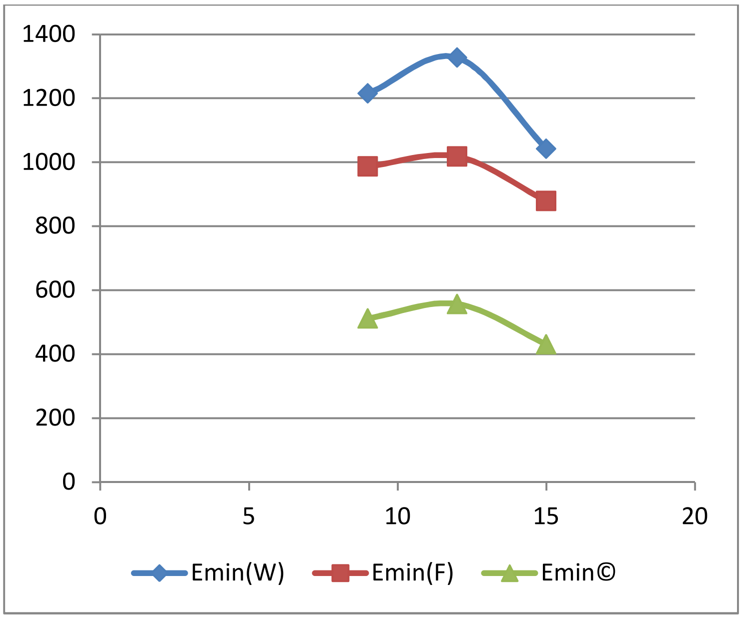
28.5. THE GRAPH FOR ALL Eav
Eav VALUES FOR WORKPLANE, FLOOR
FLOOR AND CEILING



28.5. THE CHART FOR ALL
VALUES FOR WORKPLANE,
AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	3143	2971	781
12	3764	3432	850
15	2133	1549	604

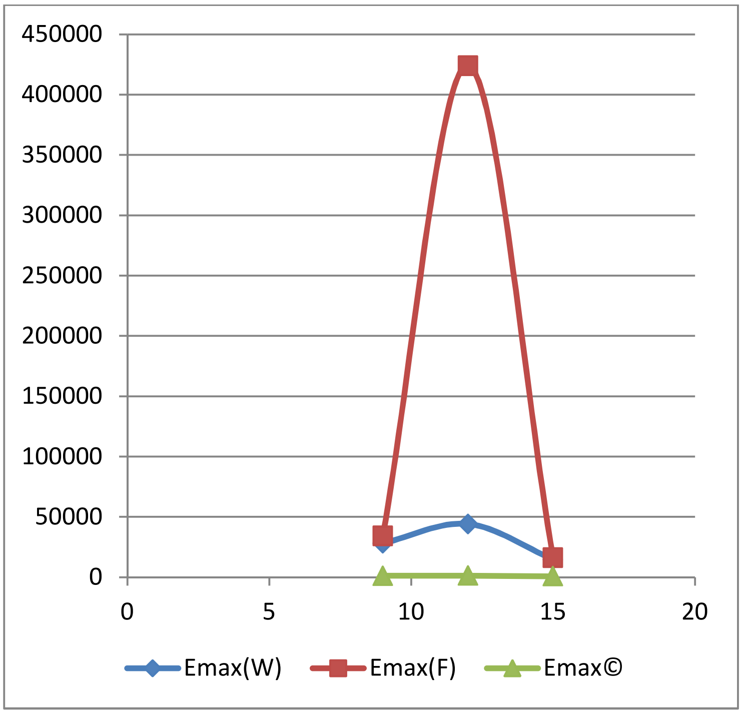
28.6. THE GRAPH FOR ALL Emin
VALUES FOR WORKPLANE, FLOOR
AND CEILING



28.6. THE CHART FOR ALL Emin
VALUES FOR WORKPLANE, FLOOR
AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1215	987	512
12	1327	1018	557
15	1042	879	431

28.7. THE GRAPH FOR ALL Emax Emax VALUES FOR WORKPLANE, FLOOR CEILING



28.7. THE CHART FOR ALL VALUES FOR THEM

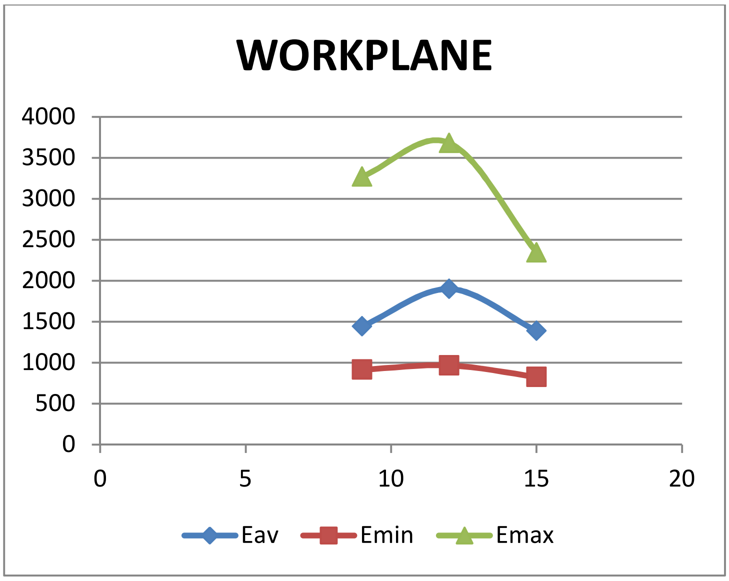
TIME	Emax(W)	Emax(F)	Emax©
9	28167	34387	1135
12	44154	423999	1265
15	14701	16274	822

CASE: 29

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN OVERCAST SKY CONDITION, AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition. One control group is fully off and the other one is fully on.

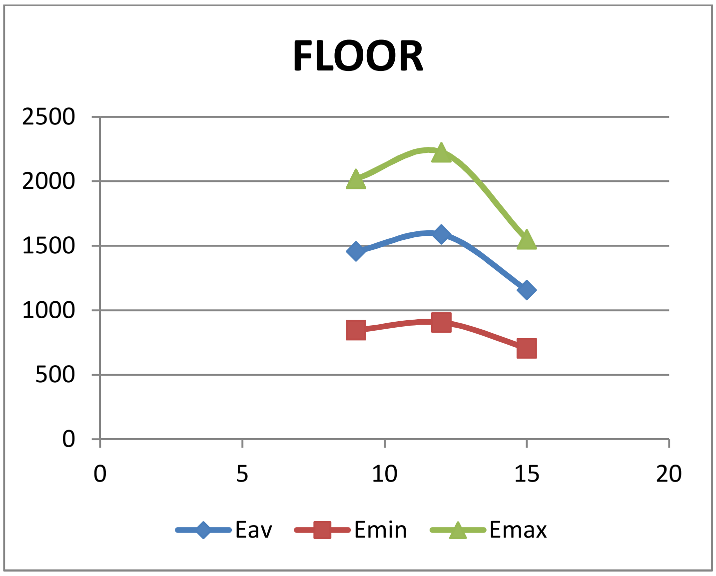
29.1. WORKPLANE VALUE GRAPH



29.1.WORKPLANE VALUE CHART

WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	1442	915	3270
12	1898	965	3681
15	1387	825	2343

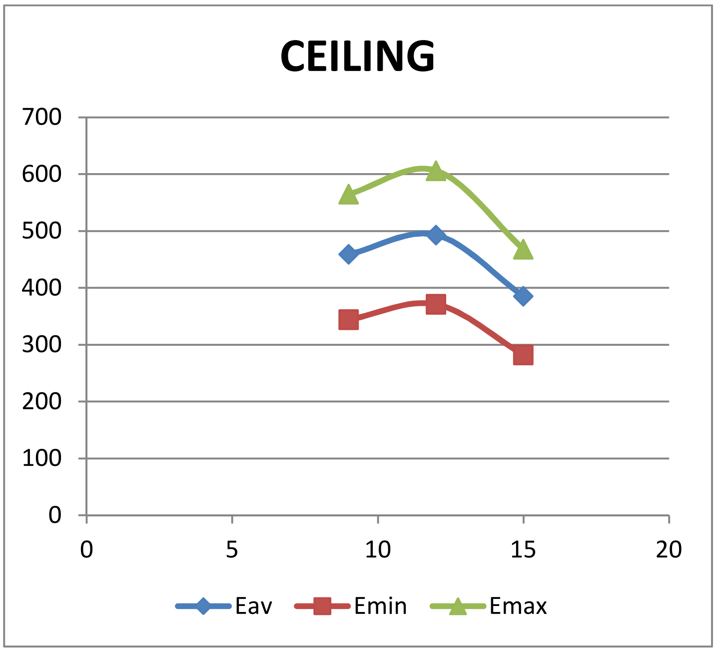
29.2. FLOOR VALUE GRAPH



29.2. FLOOR VALUE CHART

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1457	846	2020
12	1588	906	2226
15	1158	706	1550

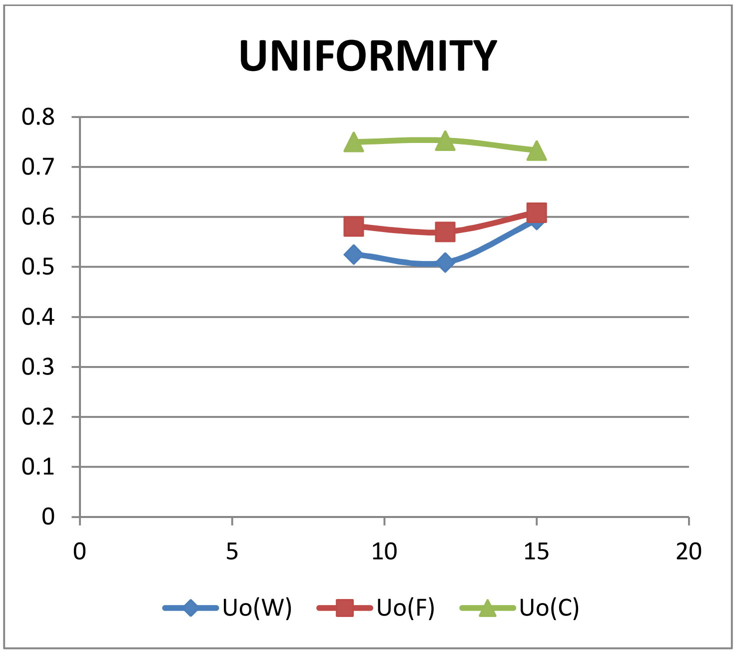
29.3. CEILING VALUE GRAPH



29.3. CEILING VALUE CHART

CEILING			
TIME	Eav	Emin	Emax
9	459	344	565
12	493	371	606
15	385	282	468

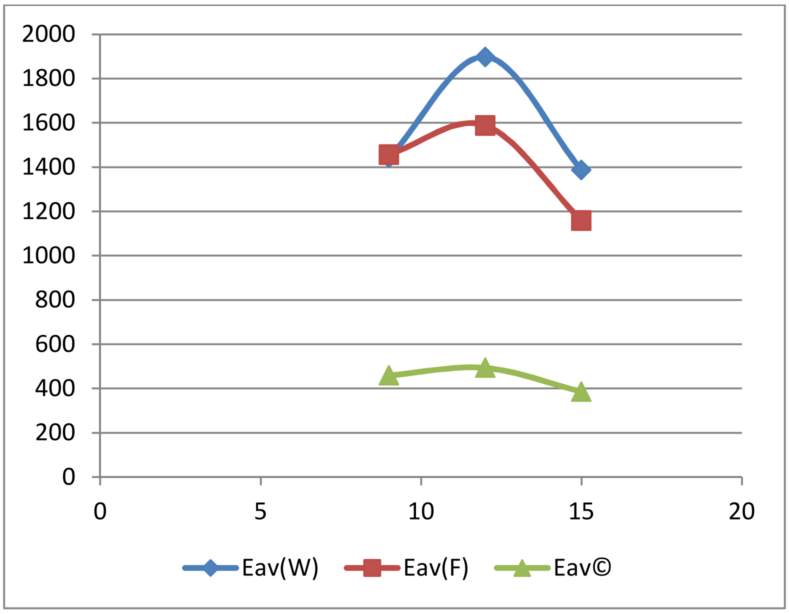
29.4. UNIFORMITY VALUE GRAPH



29.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.525	0.581	0.75
12	0.509	0.57	0.753
15	0.594	0.609	0.733

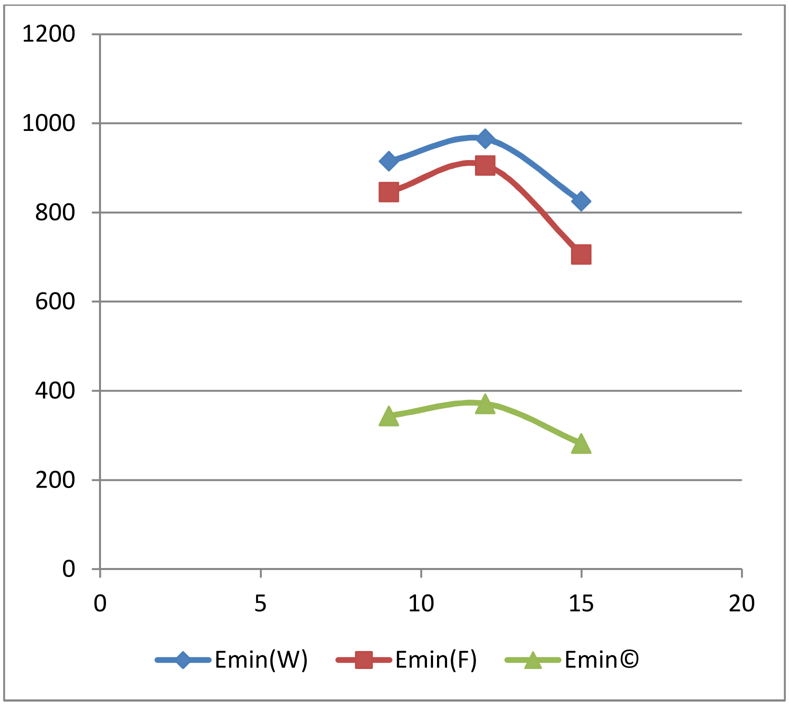
29.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



29.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	1442	1457	459
12	1898	1588	493
15	1387	1158	385

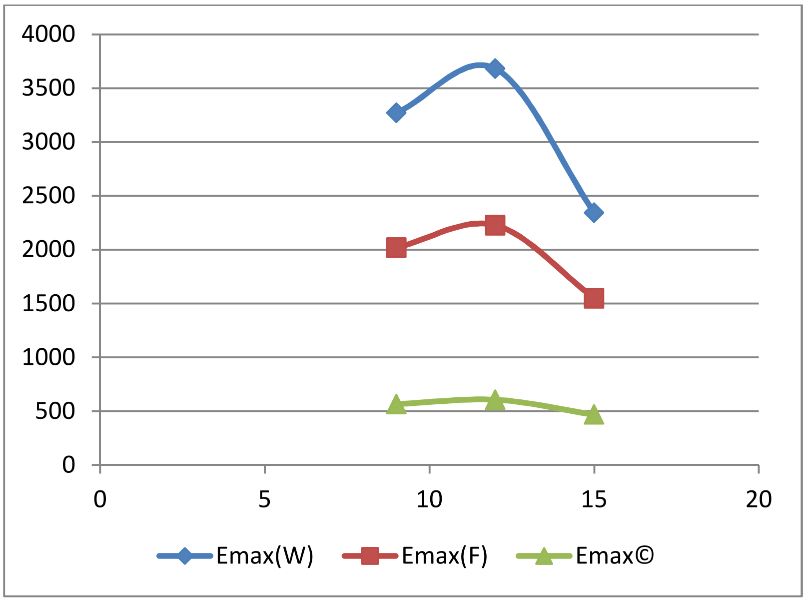
29.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING



29.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	915	846	344
12	965	906	371
15	825	706	282

29.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



29.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

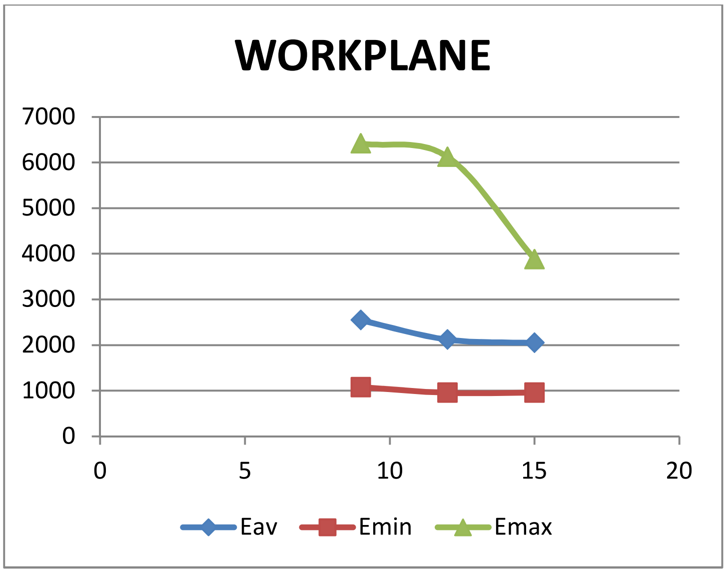
TIME	Emax(W)	Emax(F)	Emax©
9	3270	2020	565
12	3681	2226	606
15	2343	1550	468

CASE: 30

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN MIXED SKY CONDITION, AND ONE CONTROL GROUP IS FULLY OFF AND THE OTHER ONE IS FULLY ON.

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is fully off and the other one is fully on.

30.1. WORKPLANE VALUE GRAPH .

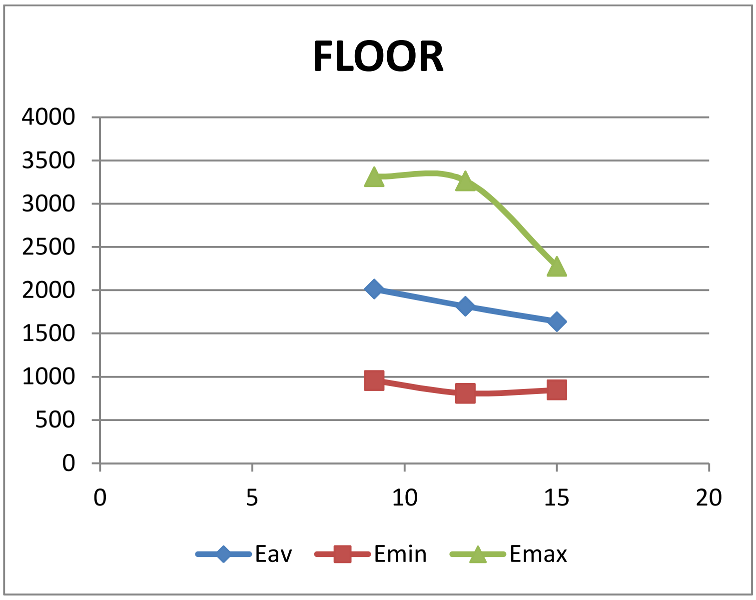


30.1. WORKPLANE VALUE CHART .

WORKPLANE			
TIME	Eav	Emin	Emax
9	2545	1079	6419
12	2120	954	6122
15	2047	958	3883

30.2. FLOOR VALUE GRAPH .

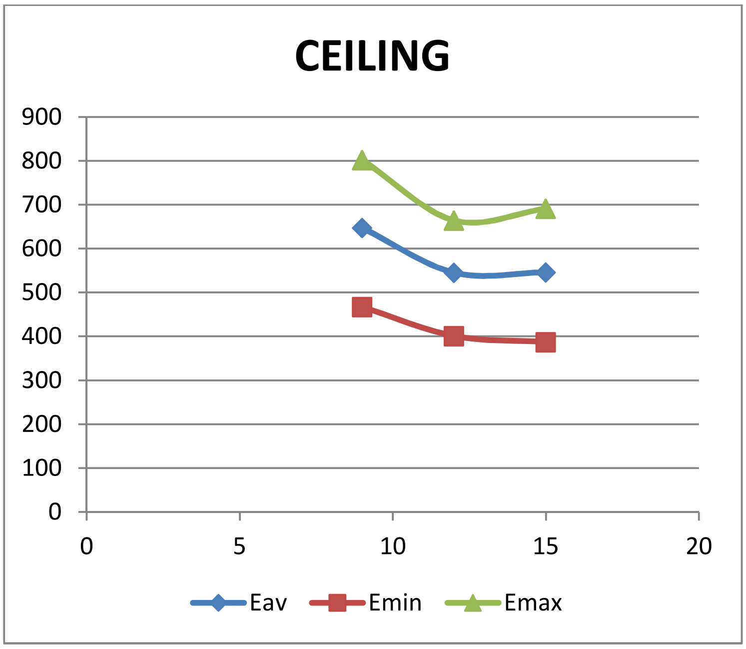
30.2. FLOOR VALUE CHART .



FLOOR			
TIME	Eav	Emin	Emax
9	2013	955	3314
12	1814	808	3266
15	1637	847	2278

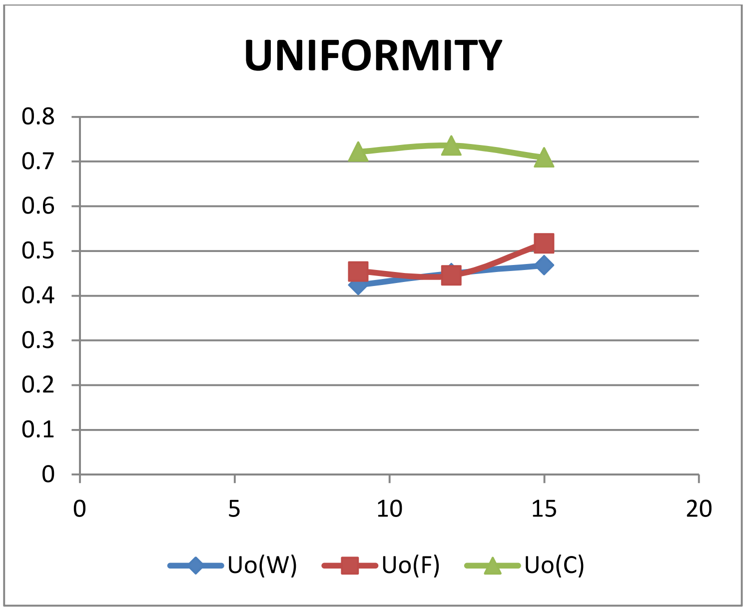
30.3. CEILING VALUE GRAPH .

30.3. CEILING VALUE CHART .



CEILING			
TIME	Eav	Emin	Emax
9	647	467	802
12	545	401	664
15	546	387	691

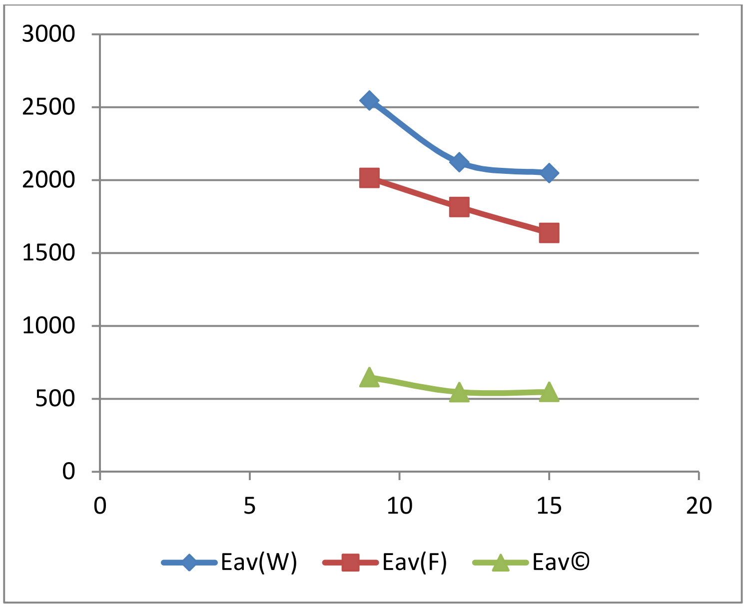
30.4. UNIFORMITY VALUE GRAPH .



30.4. UNIFORMITY VALUE CHART .

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.424	0.454	0.722
12	0.45	0.445	0.736
15	0.468	0.517	0.709

30.5. THE GRAPH FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING

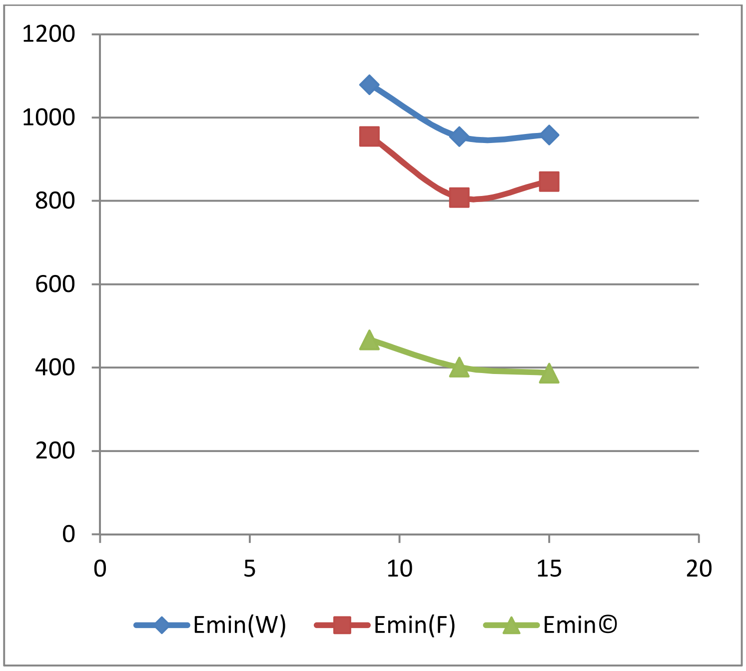


30.5. THE CHART FOR ALL Eavg VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2545	2013	647
12	2120	1814	545
15	2047	1637	546

30.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

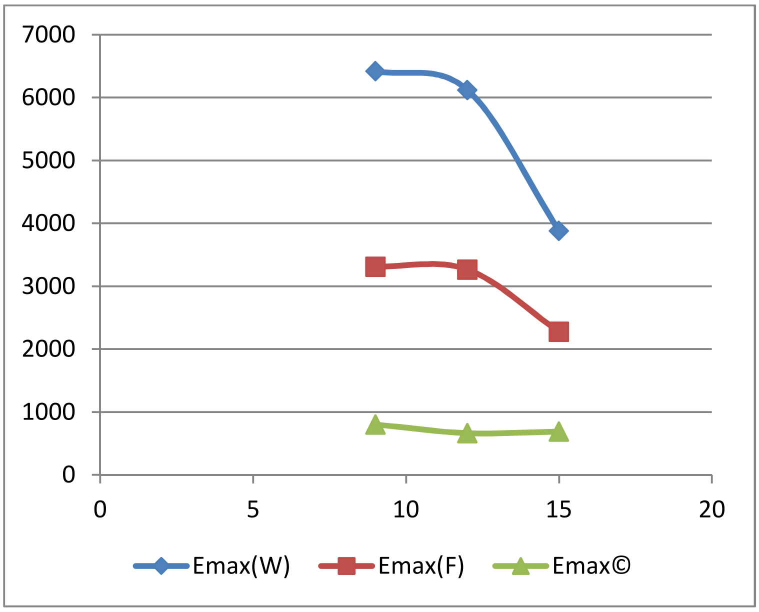
30.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



TIME	Emin(W)	Emin(F)	Emin©
9	1079	955	467
12	954	808	401
15	958	847	387

30.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR FLOOR AND CEILING

30.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, AND CEILING



TIME	Emax(W)	Emax(F)	Emax©
9	6419	3314	802
12	6122	3266	664
15	3883	2278	691

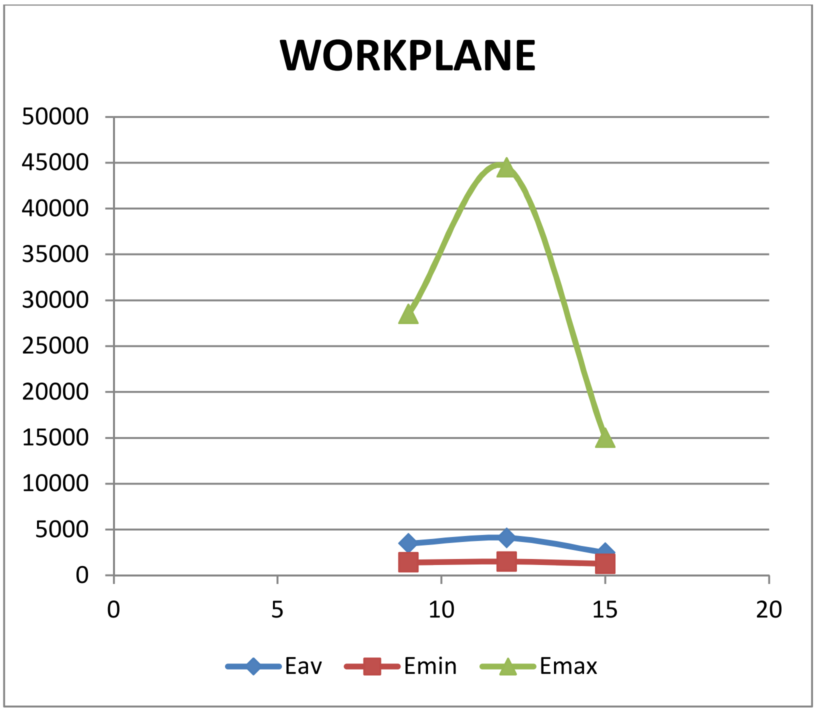
CASE: 31

WORKPLAN, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax ,Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN CLEAR SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for clear sky condition. One control group is 50%dimmed and the other one is fully on.

31.1. WORKPLANE VALUE CHART .

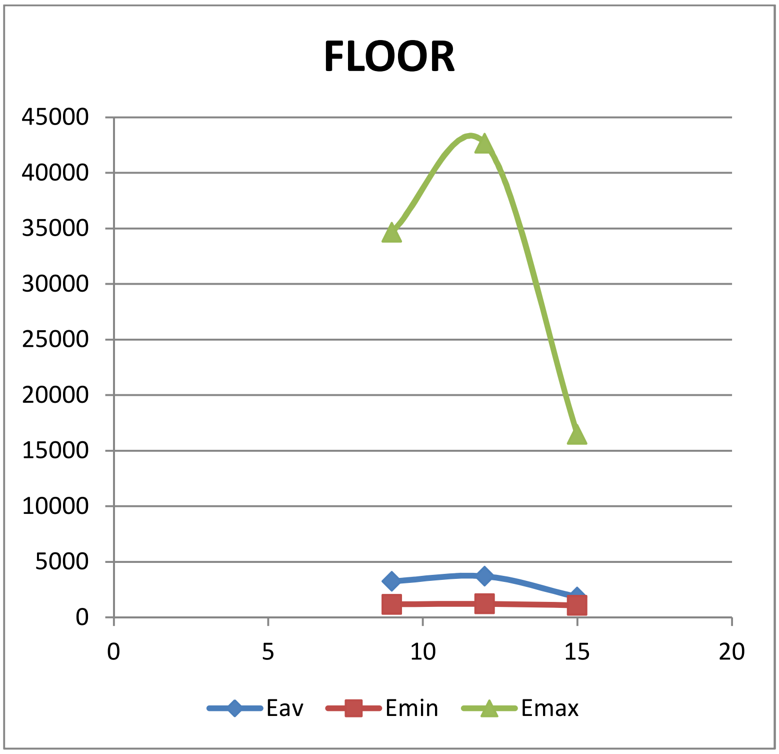
31.1. WORKPLANE VALUE CHART .



WORKPLANE			
TIME	Eav	Emin	Emax
9	3477	1414	28523
12	4094	1502	44501
15	2475	1268	15002

In the above figure we can find out the maximum, minimum and average lux values on workplane, as because in the design we integrated the daylight part so the maximum lux level is much more higher than the rest of those parameters.

31.2. FLOOR VALUE GRAPH .

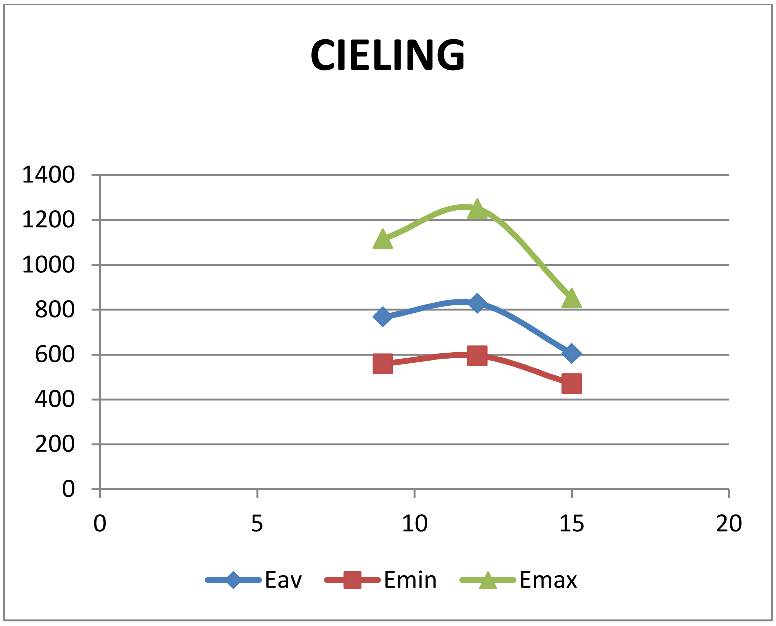


31.2. FLOOR VALUE CHART .

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	3244	1183	34670
12	3701	1217	42684
15	1829	1078	16486

In the top left images we can find the graph of floor area where three parameters are plotted, and there is a similarities of the prior part of workplane. And the graphs are plotted with the help of data's which are tabulated in the right side.

31.3. CEILING VALUE GRAPH .

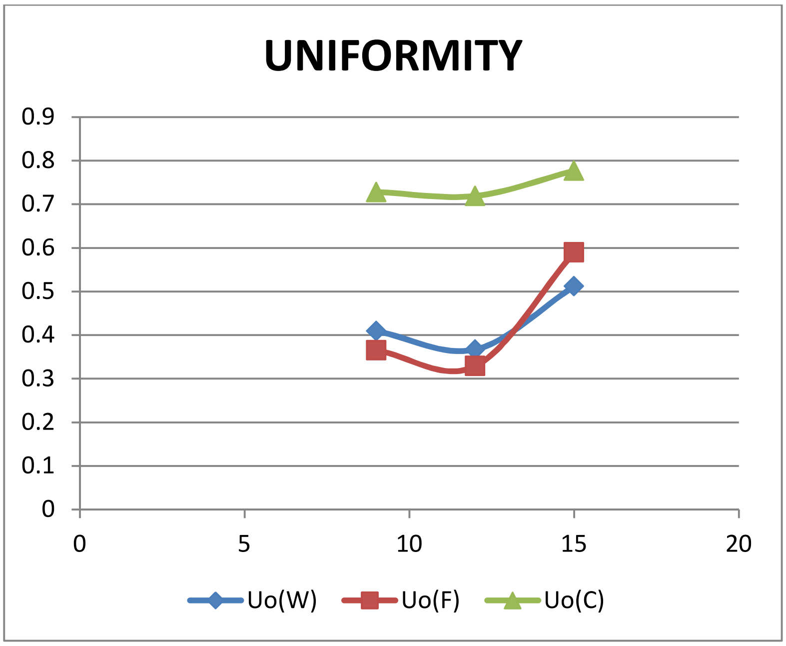


31.3.CEILING VALUE CHART

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	768	559	1116
12	828	595	1250
15	605	470	852

As because the reflectivity and dimmed control groups are assigned together then the ceiling has more soothing graphs. And the gap between three parameters are properly maintained and well distributed lux level can be find here.

31.4. UNIFORMITY VALUE GRAPH .

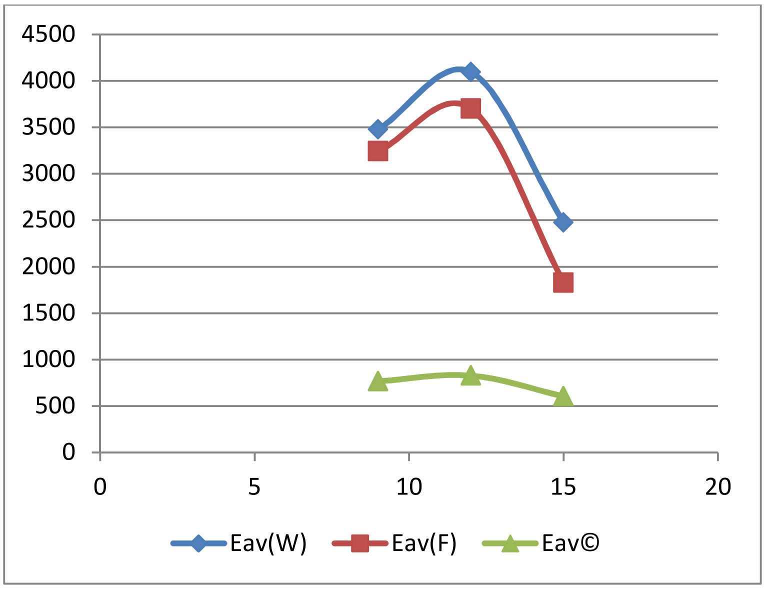


31.4.UNIFORMITY VALUE CHART .

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.409	0.365	0.728
12	0.367	0.329	0.719
15	0.512	0.59	0.777

As per the above discussion there is a similarity between workplane and floor and that reflects on the uniformity curve also, so two graphs intersect with each others but in this graph uniformity of ceiling is also plotted and it plotted against the time and through out the day it maintained a good amount of uniformity.

31.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

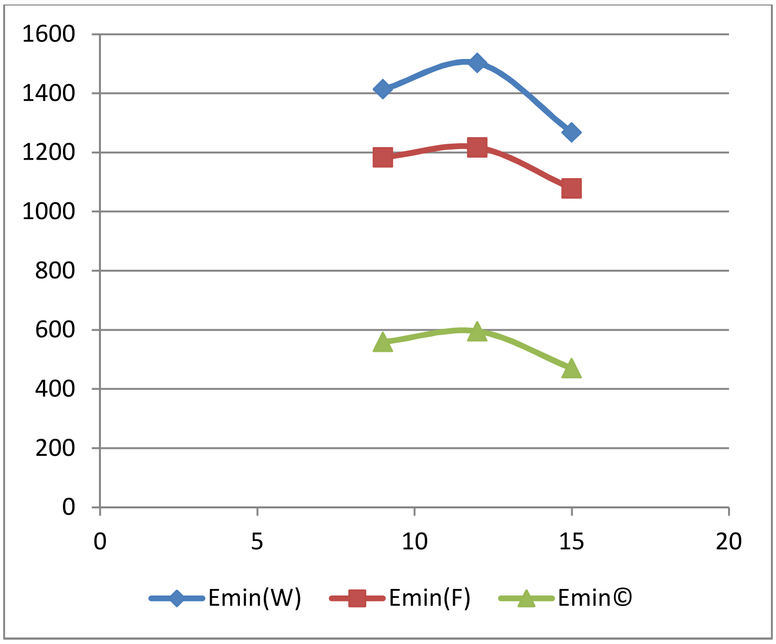


31.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	3477	3244	768
12	4094	3701	828
15	2475	1829	605

For comparative study here we put all the average data's and make a graph with the help of those stimulated data's.

31.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

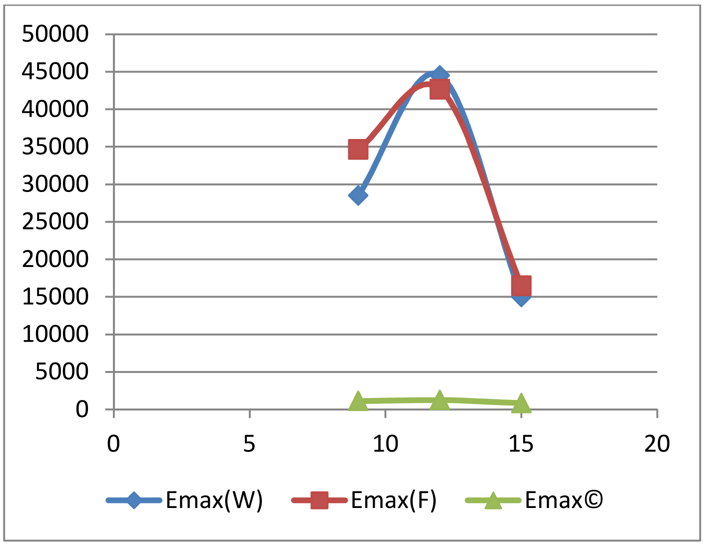


31.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1414	1183	559
12	1502	1217	595
15	1268	1078	470

In the above graph there are three plotted takes place and there is a significant changes also shown by this graph which is the similarities between workplane and floor and the ceiling is different as per the above discussion.

31.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



31.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emax(W)	Emax(F)	Emax©
9	28523	34670	1116
12	44501	42684	1250
15	15002	16486	852

Same thing happened in the case of maximum values also and a sharp change in lux level also occurred here and then almost same nature with near by values of workplane and floor. Curve of ceiling is less than those previous parameters.

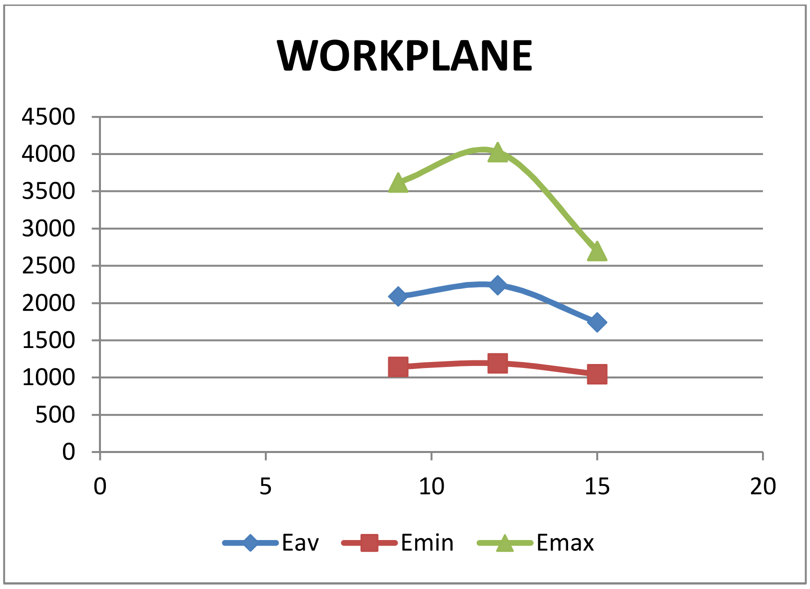
CASE: 32

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax , Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN OVERCAST SKY CONDITION,AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for overcast sky condition.One control group is 50%dimmed and the other one is fully on.

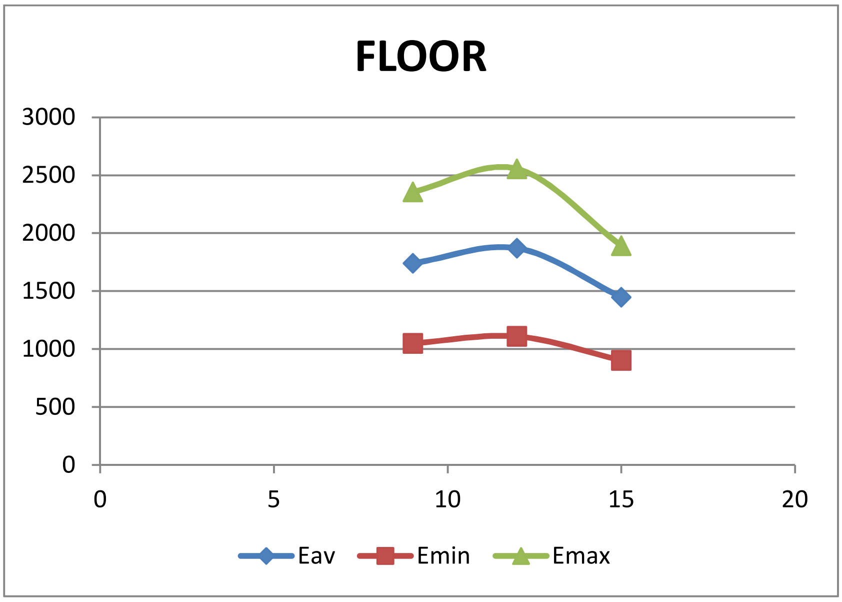
32.1 WORKPLANE VALUE GRAPH

32.1 WORKPLANE VALUE CHART .



WORKPLANE			
TIME	**Eav**	**Emin**	**Emax**
9	2089	1147	3621
12	2241	1191	4027
15	1742	1045	2700

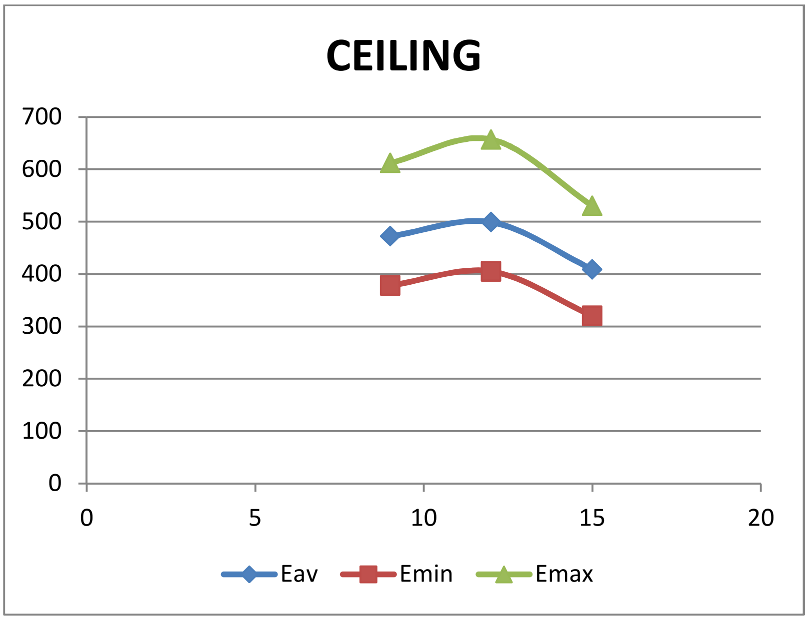
32.2. FLOOR VALUE GRAPH .



32.2. FLOOR VALUE CHART .

FLOOR			
TIME	**Eav**	**Emin**	**Emax**
9	1741	1050	2356
12	1870	1109	2555
15	1448	902	1891

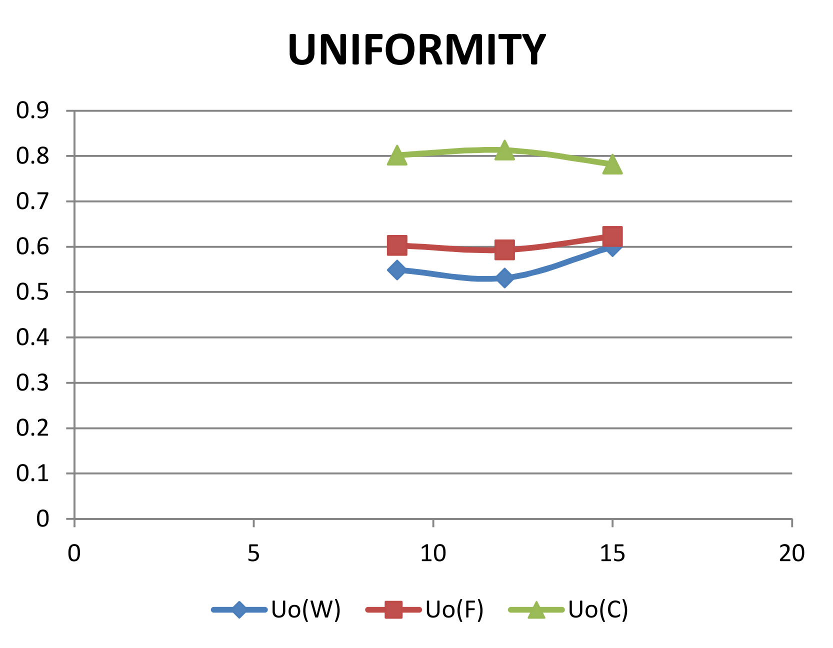
32.3. CEILING VALUE GRAPH .



32.3. CEILING VALUE CHART .

CEILING			
TIME	**Eav**	**Emin**	**Emax**
9	472	378	612
12	499	405	657
15	409	320	530

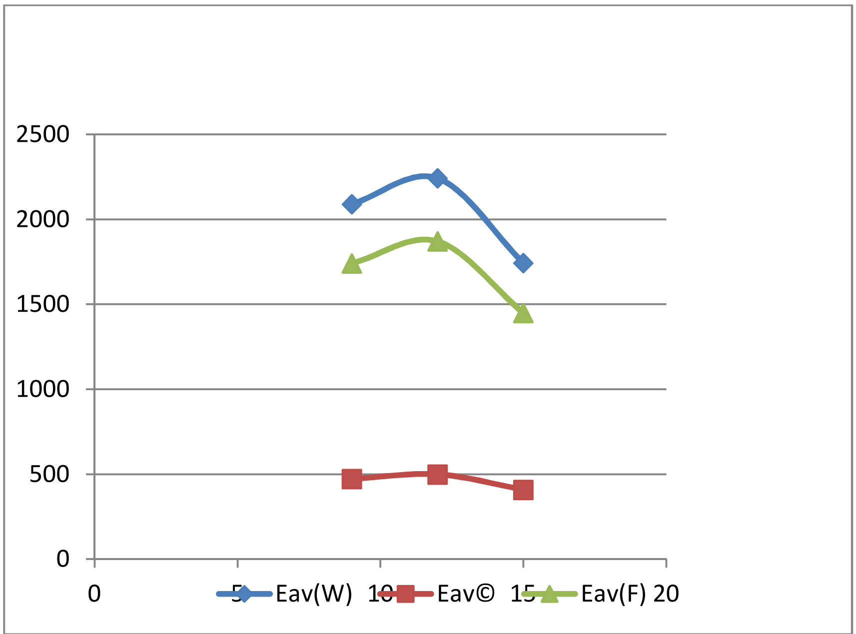
32.4. UNIFORMITY VALUE GRAPH .



32.4. UNIFORMITY VALUE CHART .

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.549	0.603	0.802
12	0.531	0.593	0.813
15	0.6	0.623	0.782

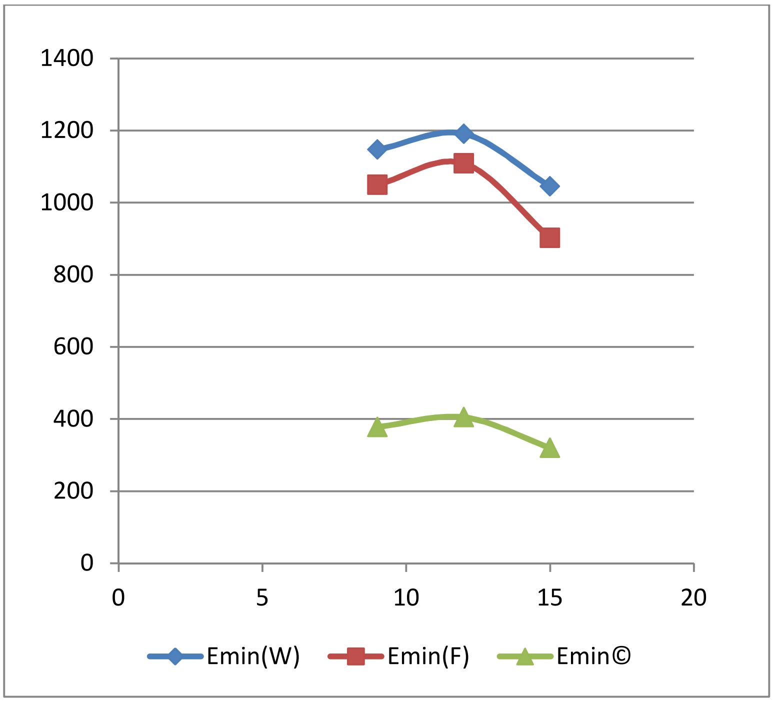
32.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



32.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2089	1741	472
12	2241	1870	499
15	1742	1448	409

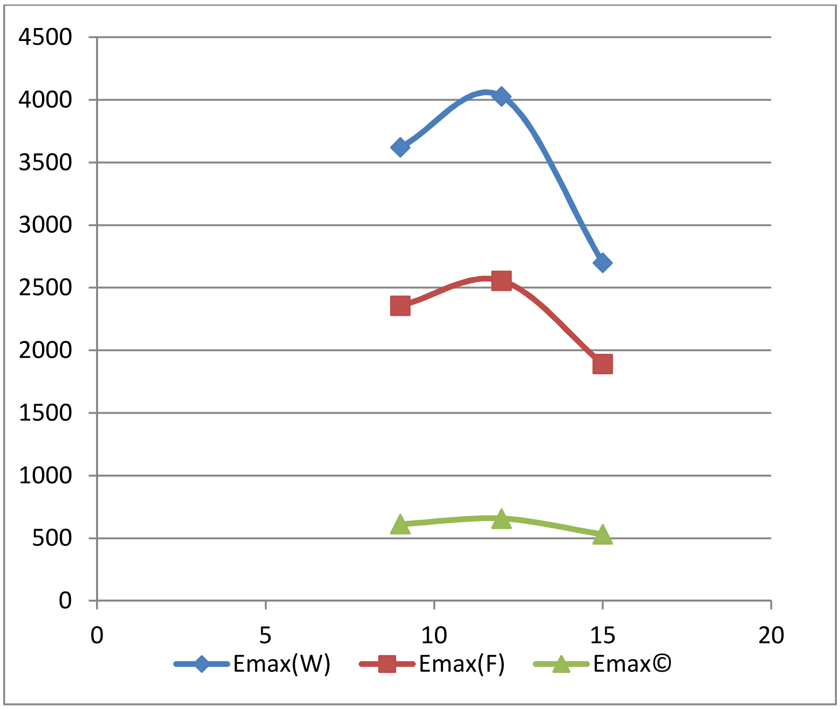
32.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



32.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1147	1050	378
12	1191	1109	405
15	1045	902	320

32.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



32.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

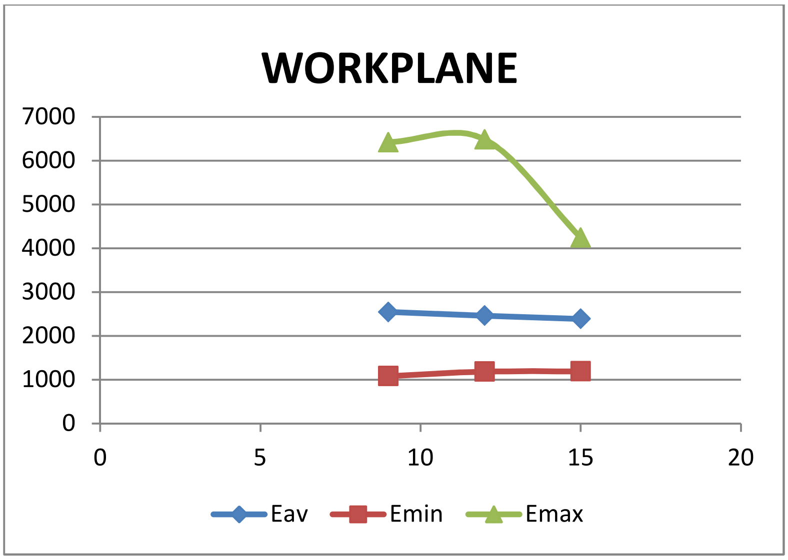
TIME	Emax(W)	Emax(F)	Emax©
9	3621	2356	612
12	4027	2555	657
15	2700	1891	530

CASE: 33

WORKPLANE, FLOOR AND CEILING VALUE CHART AND GRAPHS OF Emax, Emin AND Eavg WHEN THE REFLECTIVITY OF WALL, CEILING AND FLOOR ARE 95-65-35 IN MIXED SKY CONDITION, AND ONE CONTROL GROUP IS 50% DIMMED AND THE OTHER ONE IS FULLY ON

When the reflectivity of wall, ceiling and floor are 95-65-35 then the simulated lux levels are tabulated in the following tables. This simulation considered only for mixed sky condition. One control group is 50%dimmed and the other one is fully on.

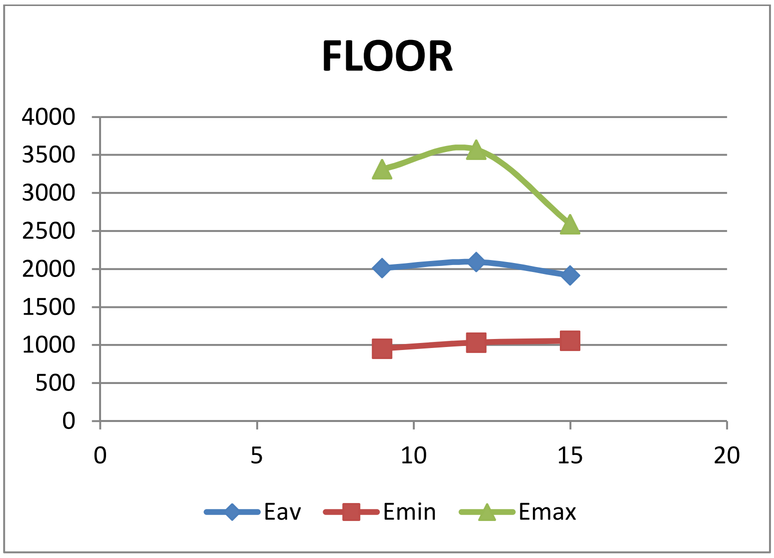
33.1. WORKPLANE VALUE GRAPH



33.1. WORKPLANE VALUE CHART

WORKPLANE			
TIME	Eav	Emin	Emax
9	2545	1079	6419
12	2461	1182	6484
15	2386	1190	4240

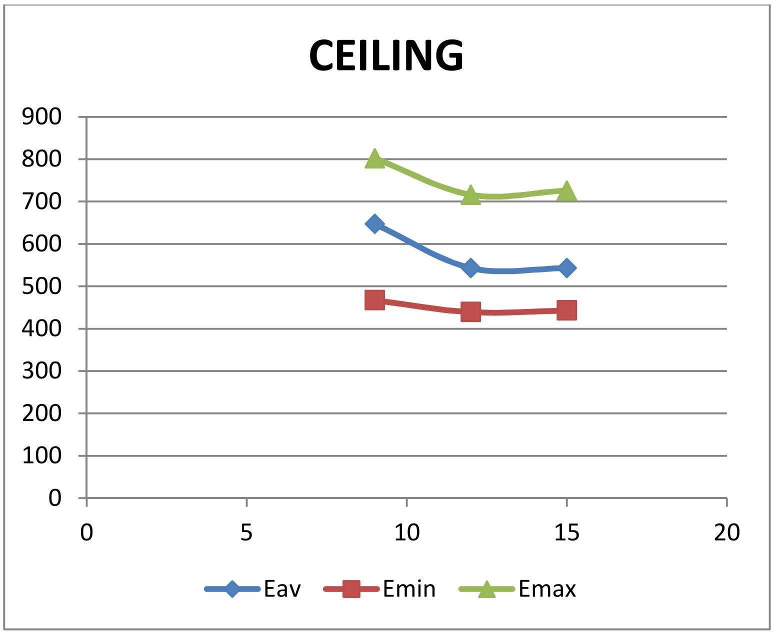
33.2. FLOOR VALUE GRAPH .



33.2. FLOOR VALUE CHART

FLOOR			
TIME	Eav	Emin	Emax
9	2013	955	3314
12	2092	1033	3571
15	1915	1057	2590

33.3. CEILING VALUE GRAPH .

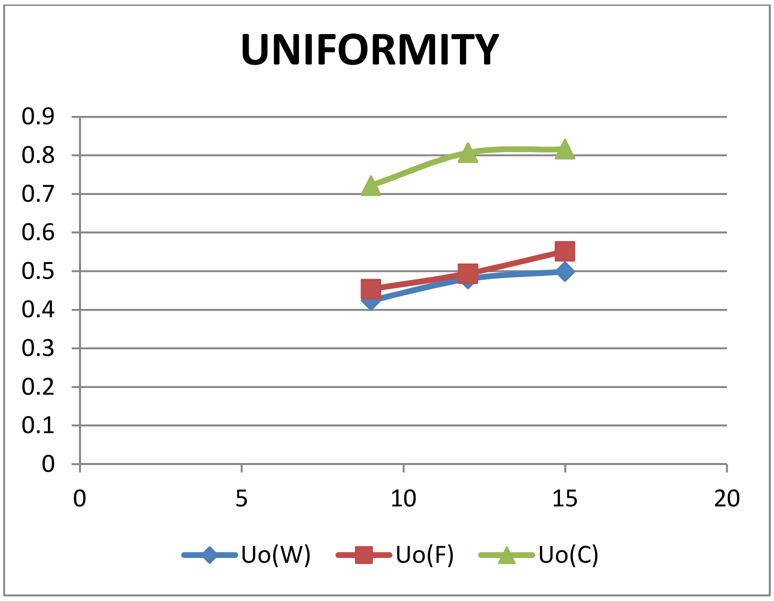


33.3. CEILING VALUE CHART .

CEILING			
TIME	Eav	Emin	Emax
9	647	467	802
12	543	439	716
15	543	443	726

33.4. UNIFORMITY VALUE GRAPH .

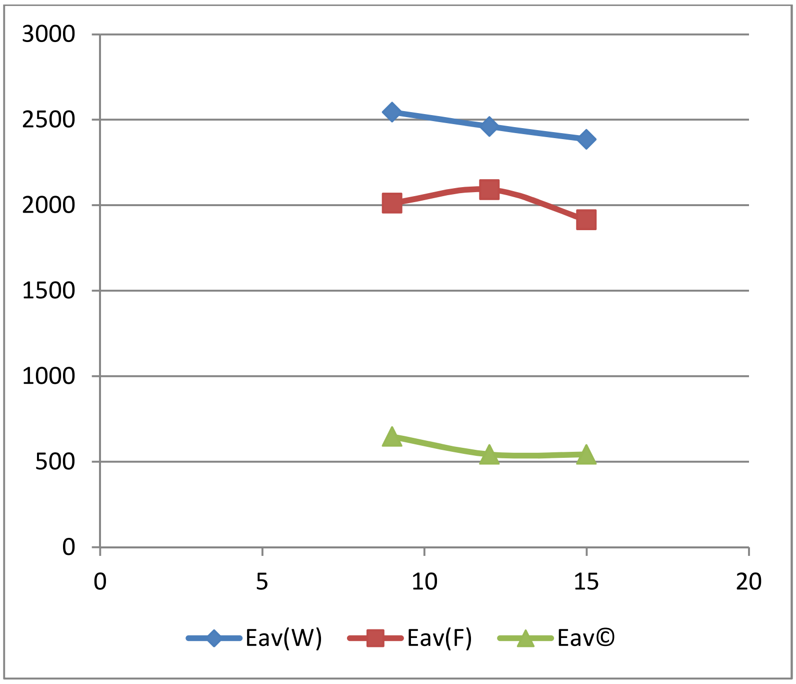
.



33.4. UNIFORMITY VALUE CHART

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.424	0.454	0.722
12	0.48	0.494	0.807
15	0.499	0.552	0.816

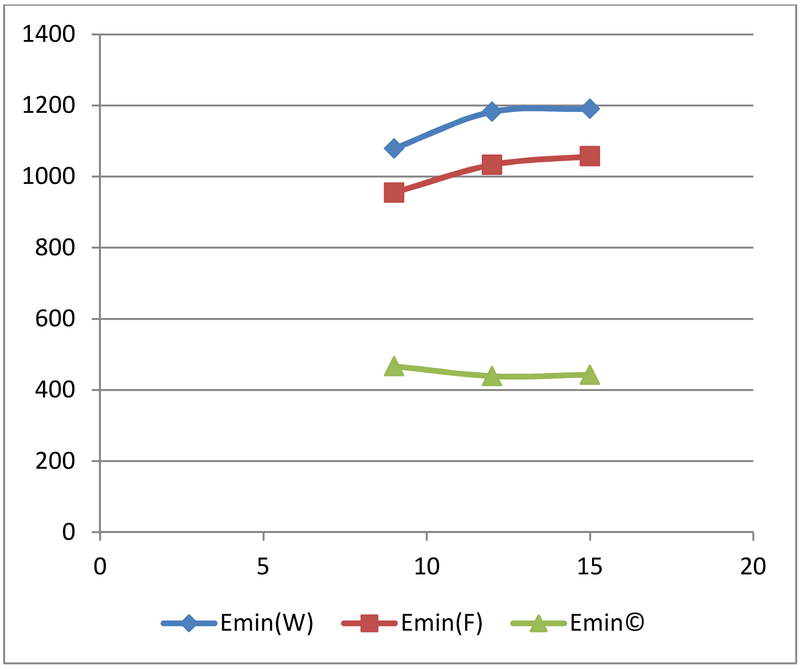
33.5. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



33.5. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Eav(W)	Eav(F)	Eav©
9	2545	2013	647
12	2461	2092	543
15	2386	1915	543

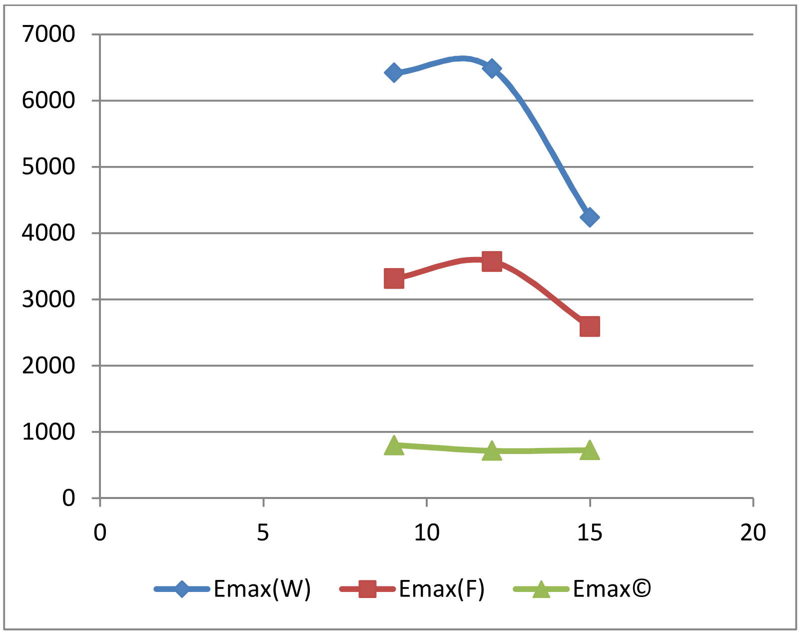
33.6. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



33.6. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emin(W)	Emin(F)	Emin©
9	1079	955	467
12	1182	1033	439
15	1190	1057	443

33.7. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



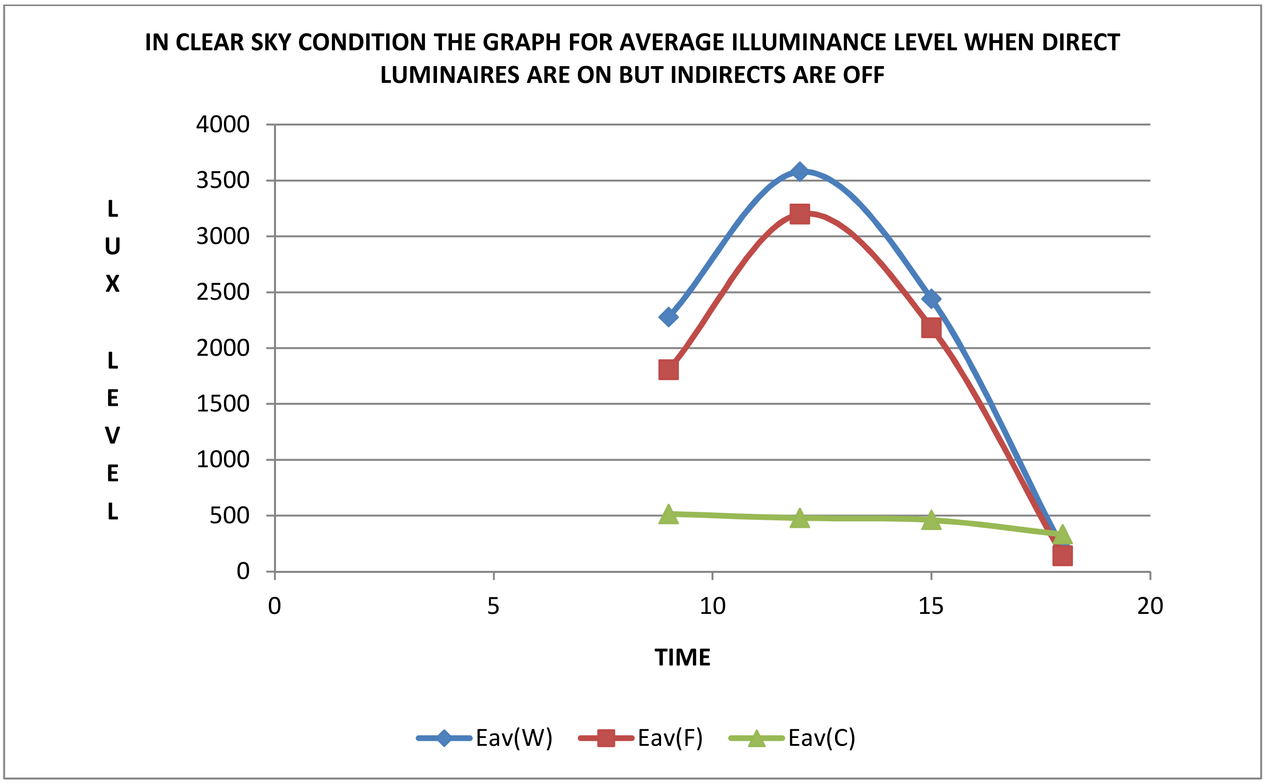
33.7. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

TIME	Emax(W)	Emax(F)	Emax©
9	6419	3314	802
12	6484	3571	716
15	4240	2590	726

CASE: 34

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN DIRECT LUMINAIRES ARE ON BUT INDIRECTS ARE OFF

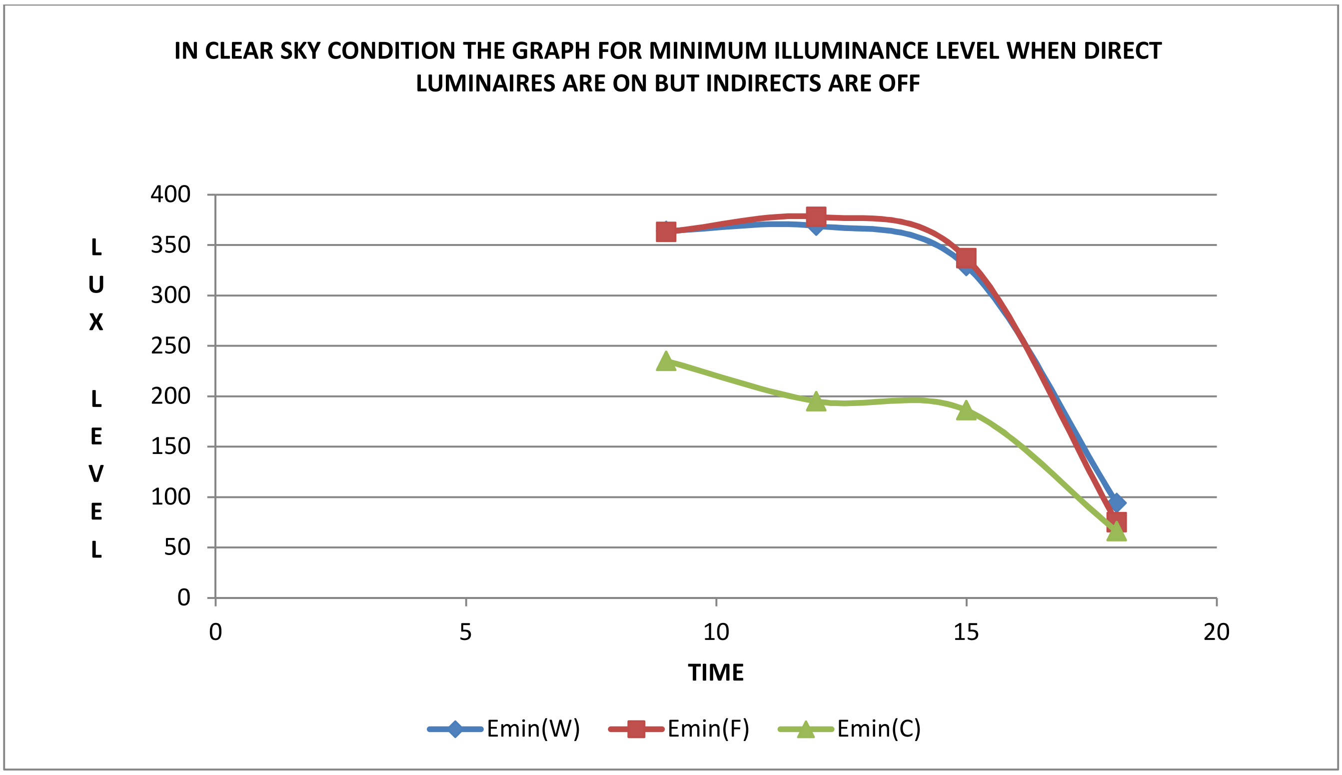
34.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



34.1. THE CHARTS FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav	Eav	Eav
9	2278	1807	515
12	3579	3200	479
15	2440	2182	461
18	207	140	332

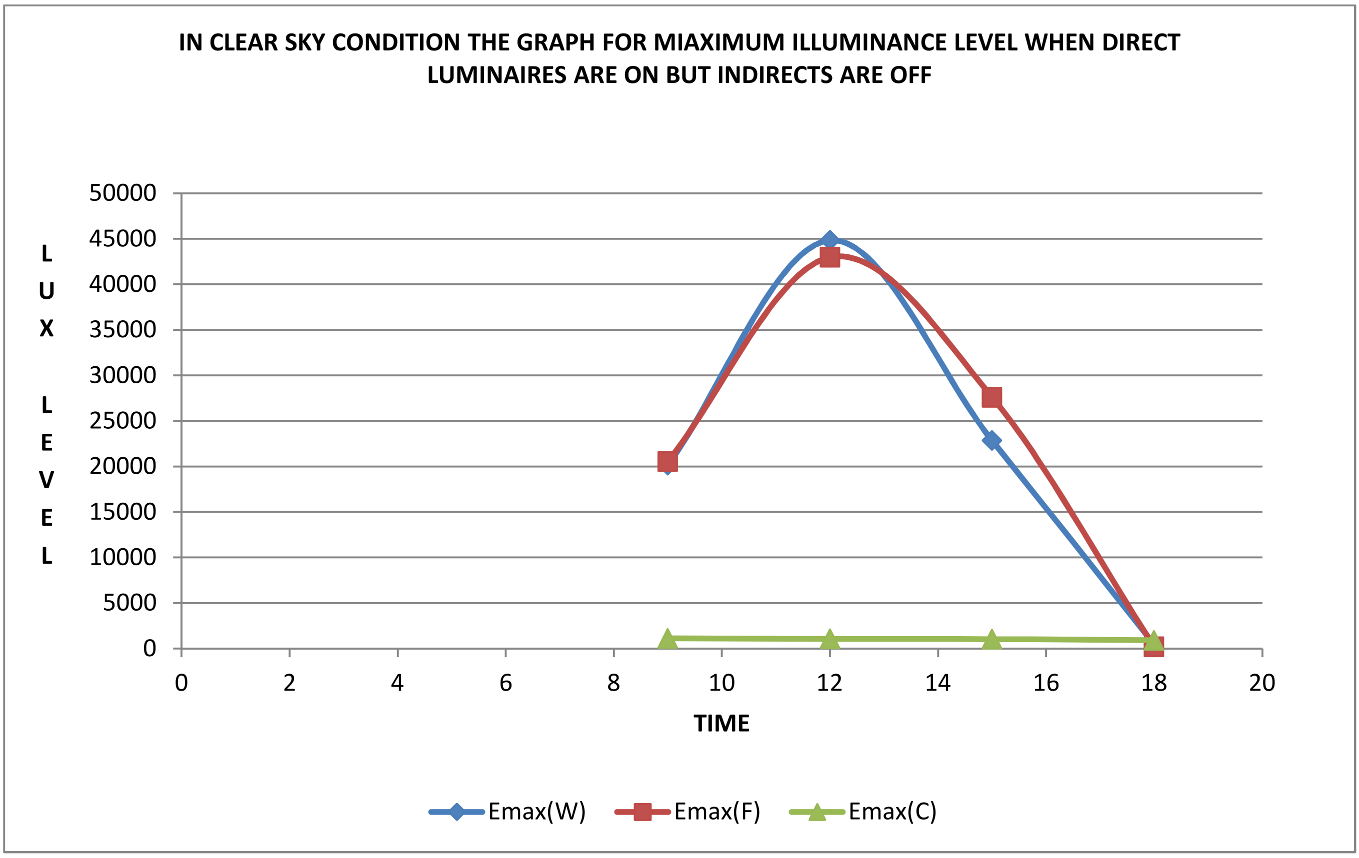
34.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



34.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	Emin	Emin	Emin
9	364	363	235
12	369	378	195
15	329	337	186
18	94	75	66

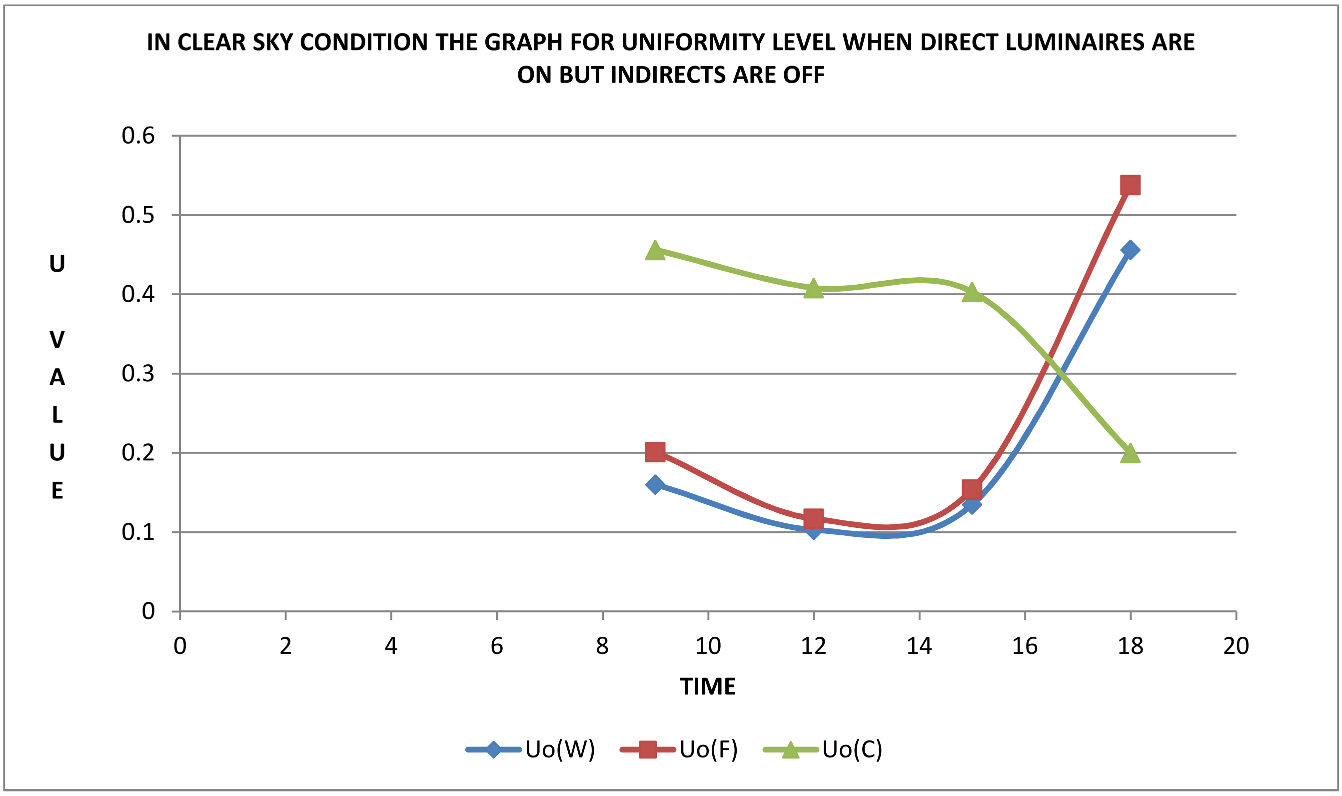
34.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



34.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin**	**Emin**
9	20139	20527	1113
12	44828	42965	1065
15	22841	27610	1036
18	452	195	899

34.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



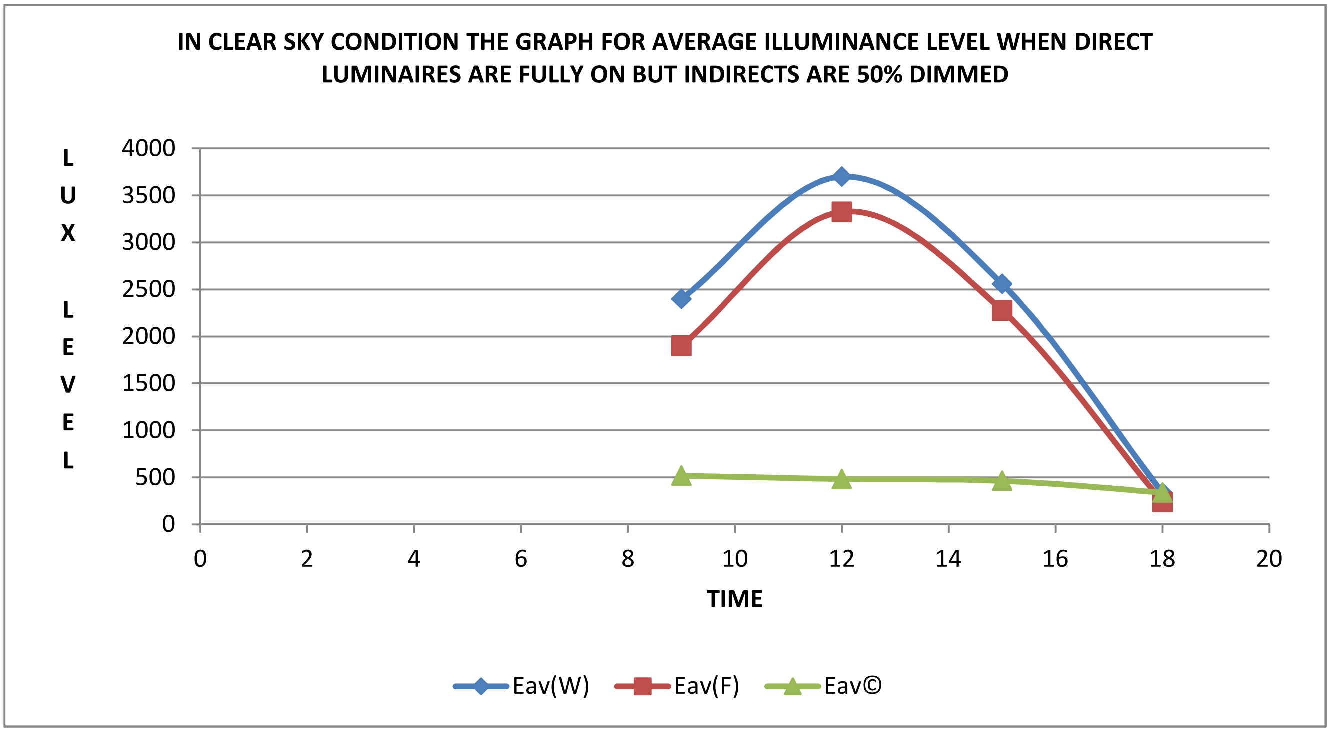
34.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.16	0.201	0.456
12	0.103	0.117	0.408
15	0.135	0.154	0.403
18	0.456	0.538	0.2

CASE: 35

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m, WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE 50% DIMMED

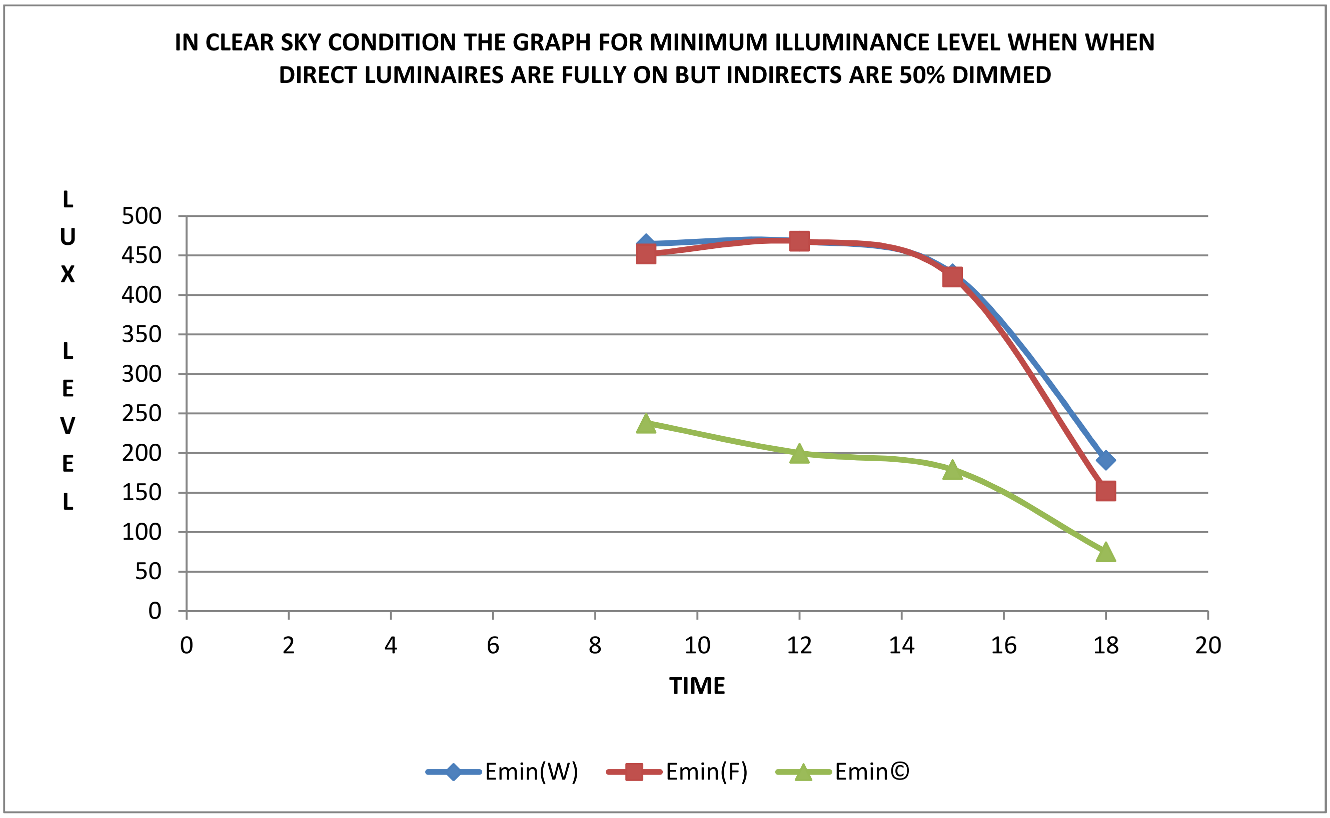
35.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



35.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2398	1902	518
12	3700	3326	482
15	2559	2276	463
18	336	239	339

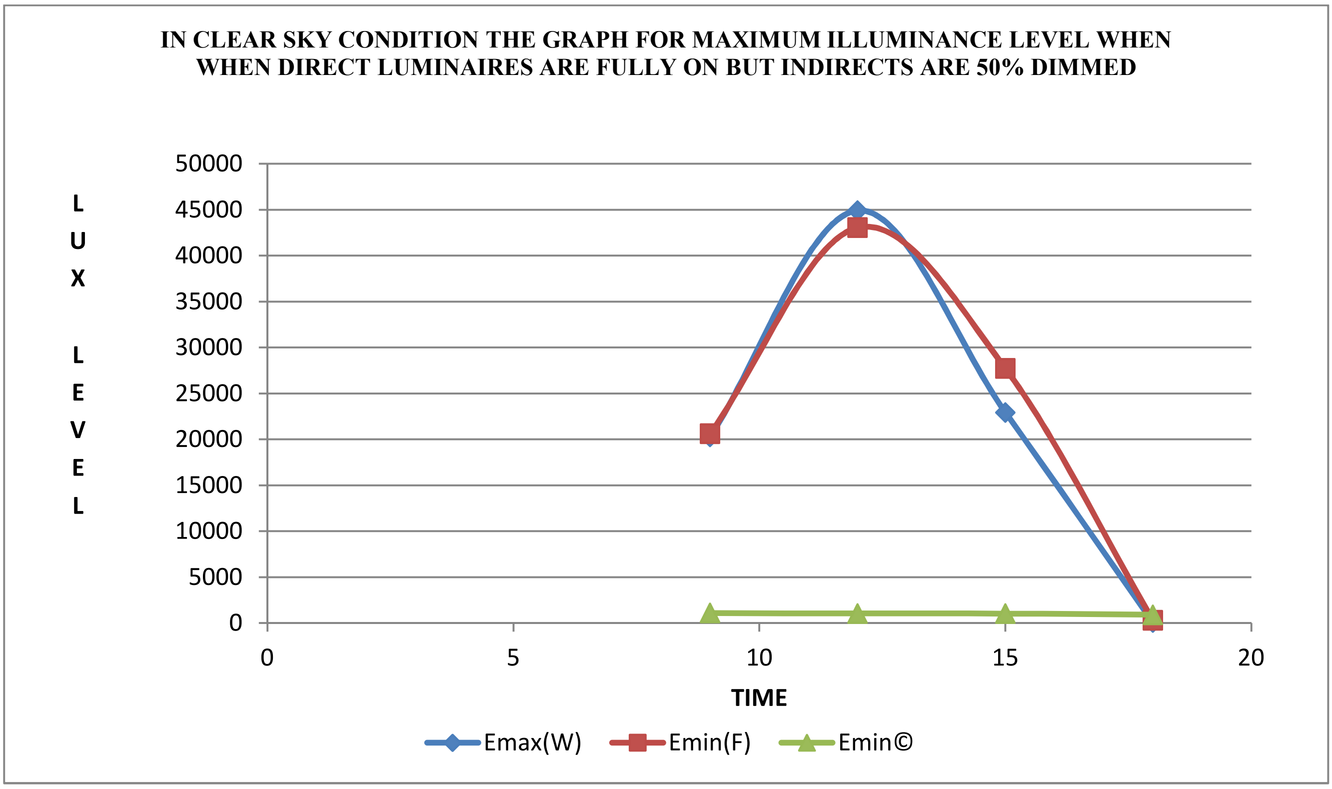
35.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



35.2. THE CHAPTER FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	465	452	238
12	468	468	200
15	427	423	179
18	191	152	75

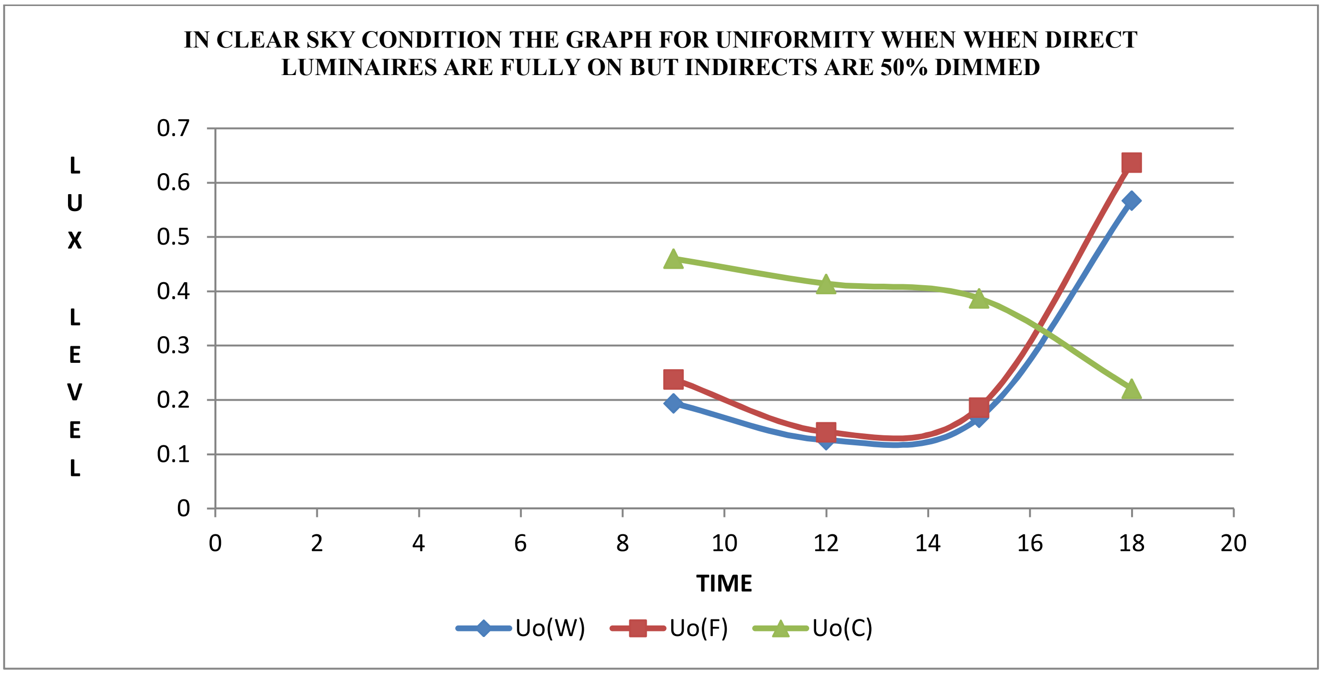
<u>35.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING</u>



<u>35.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING</u>

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20279	20630	1114
12	44919	43063	1050
15	22932	27715	1037
18	61	300	908

35.4.THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



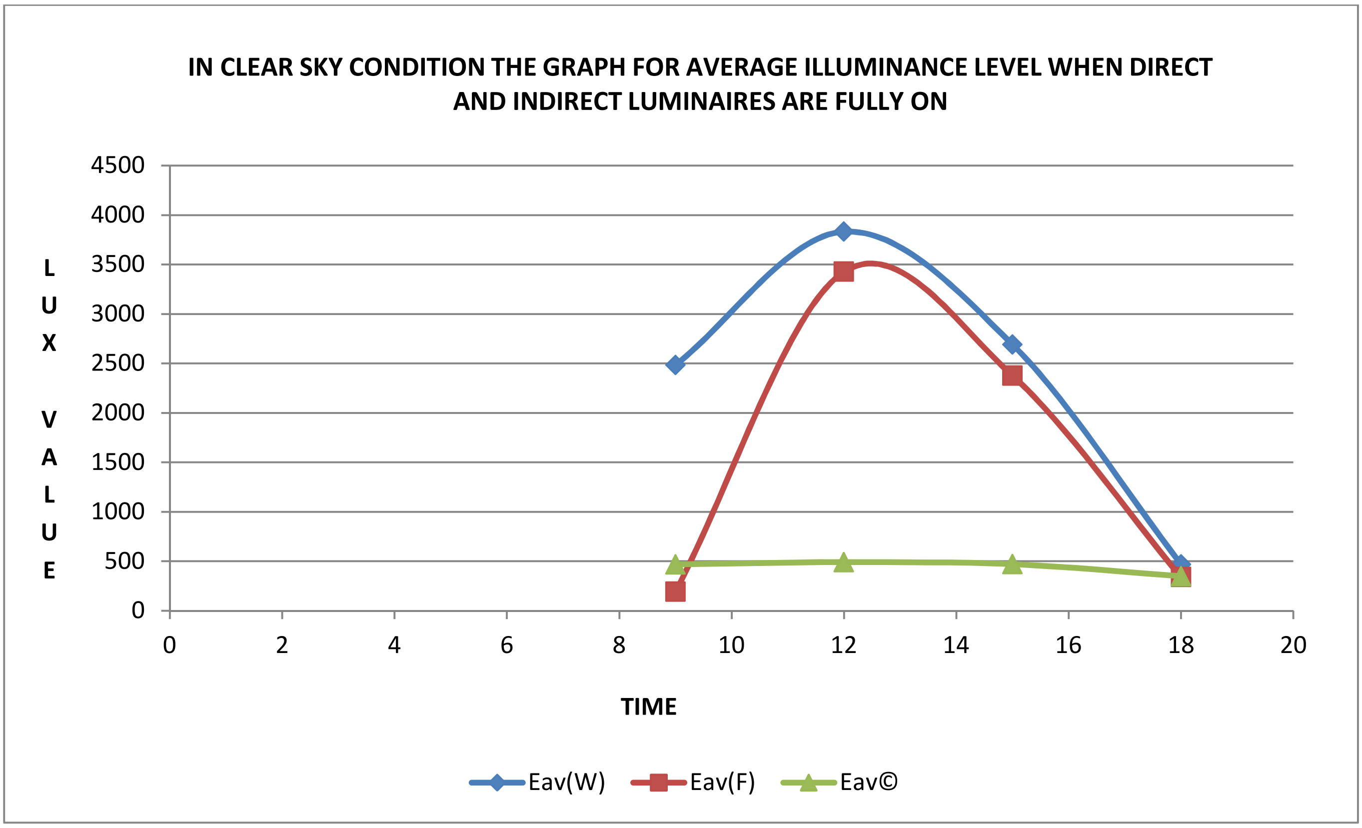
35.4.THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.194	0.238	0.46
12	0.126	0.141	0.414
15	0.167	0.186	0.387
18	0.567	0.637	0.221

CASE: 36

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE 50% DIMMED

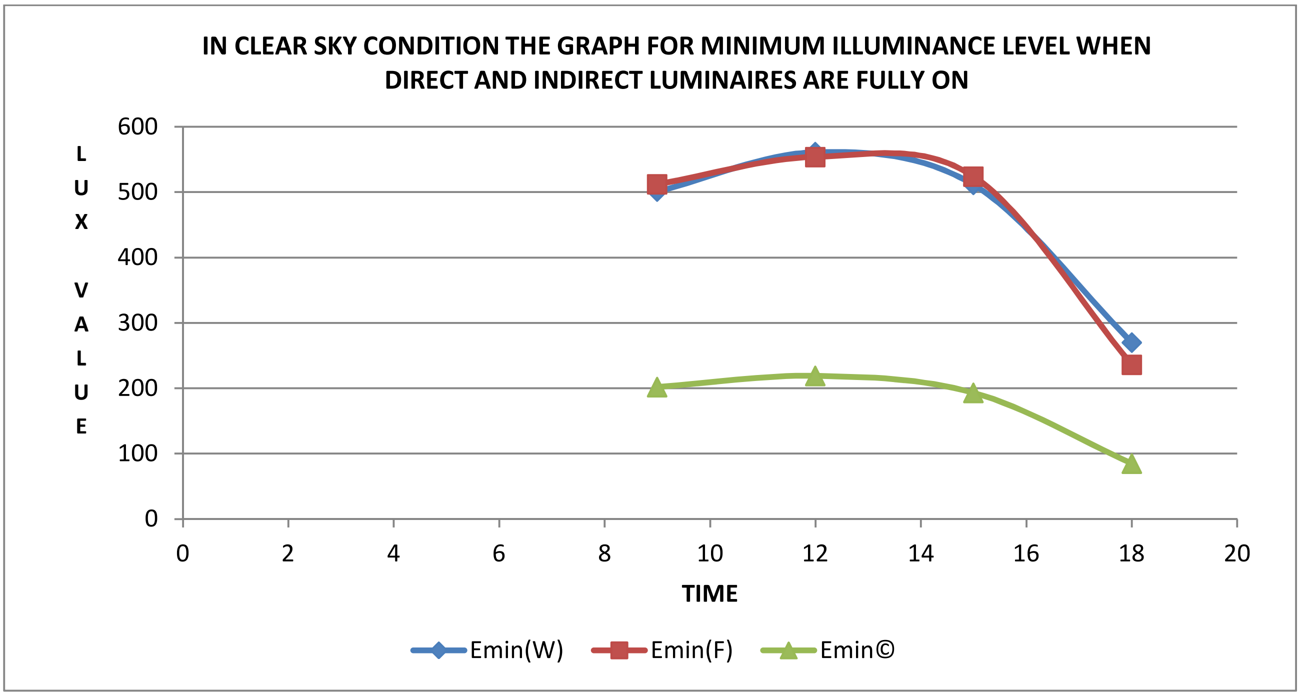
36.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



36.1. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2483	194	469
12	3832	3426	491
15	2690	2376	471
18	469	340	348

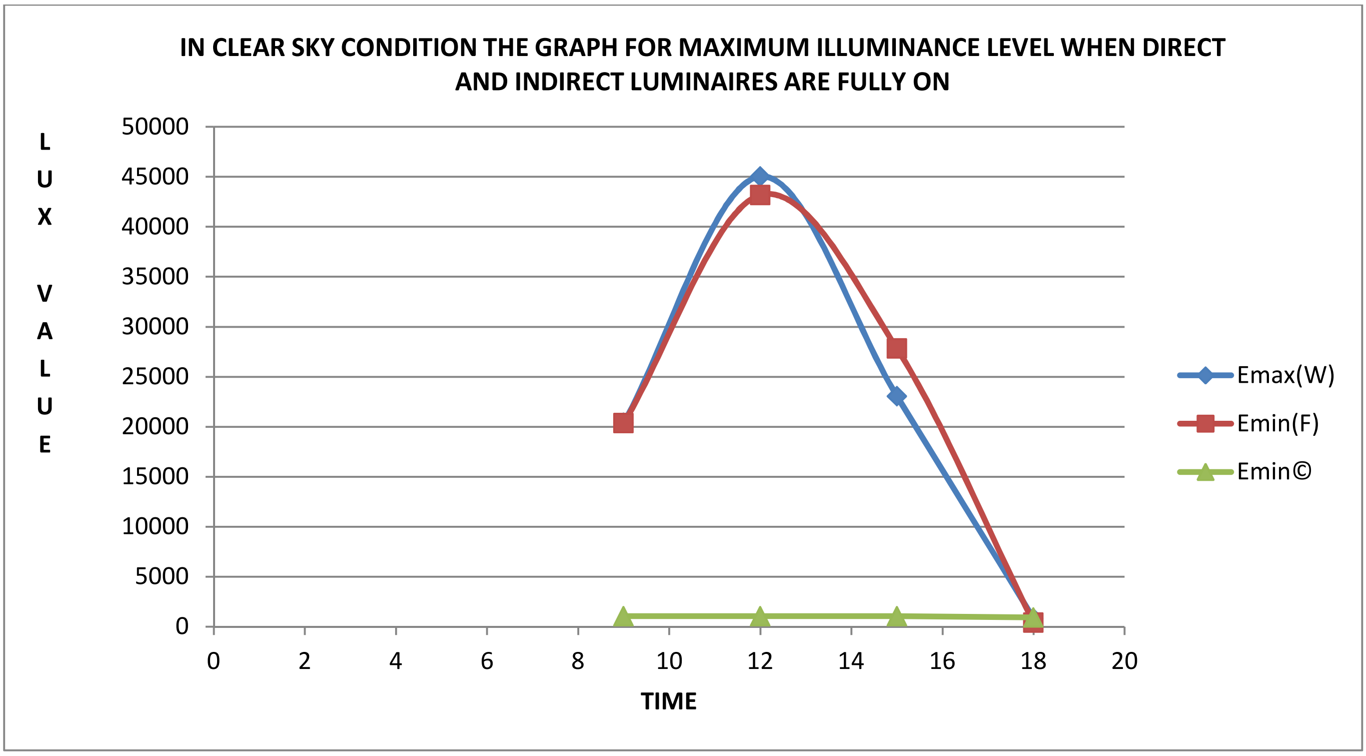
36.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



36.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	Emin(W)	Emin(F)	Emin©
9	501	512	202
12	561	554	219
15	511	524	193
18	270	236	85

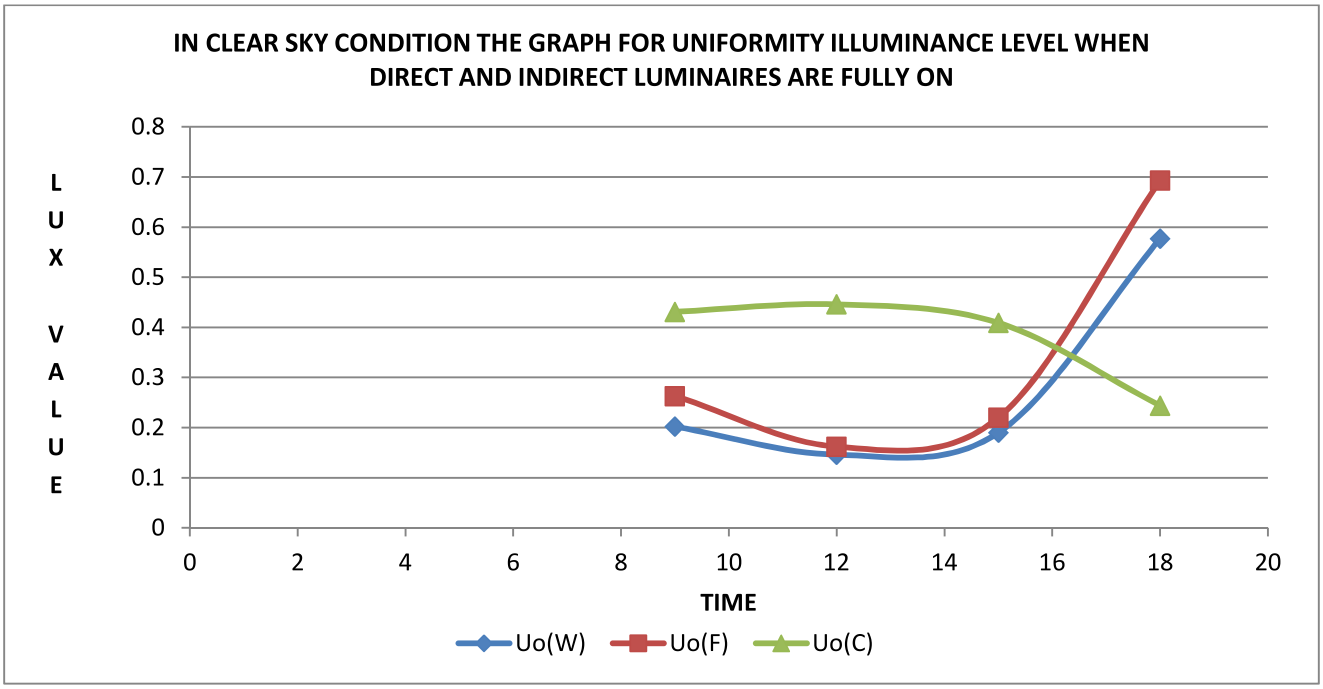
36.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



36.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	5082	2768	177
12	5680	3097	118
15	5644	2996	198
18	604	323	463

35.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



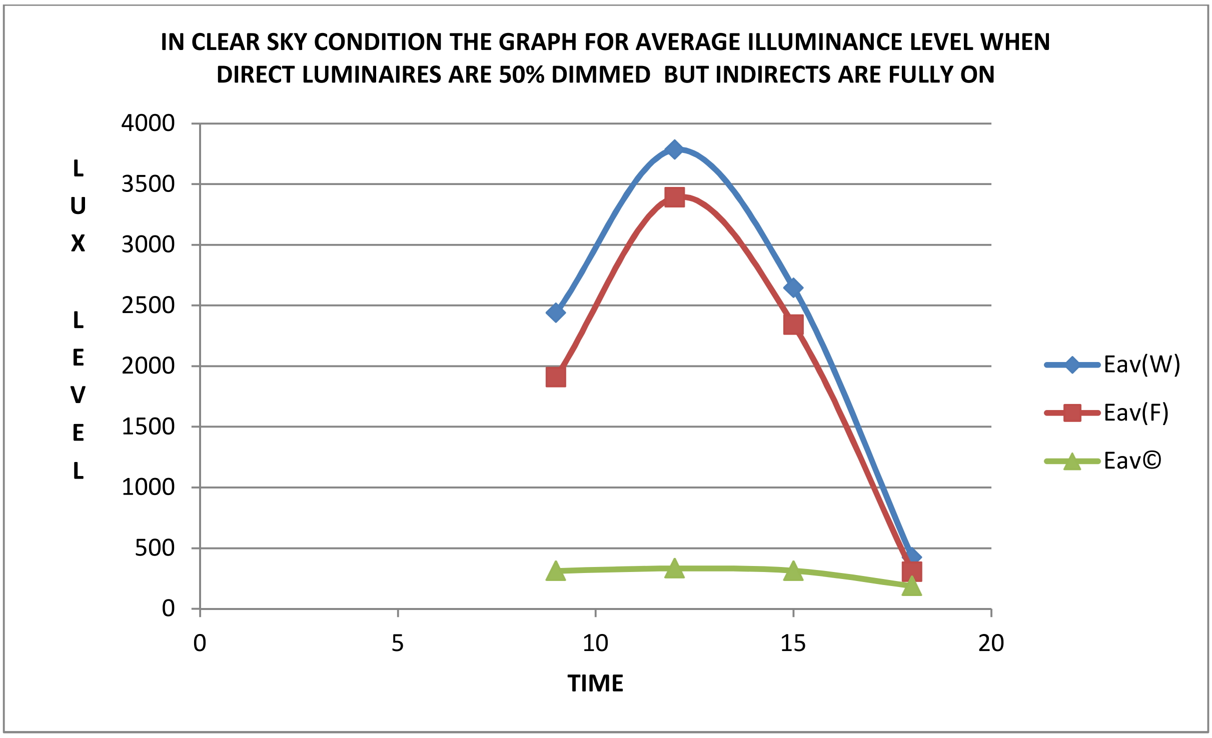
35.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	$U_{0(W)}$	$U_{0(F)}$	$U_{0(C)}$
9	0.202	0.263	0.431
12	0.146	0.162	0.446
15	0.19	0.22	0.409
18	0.577	0.693	0.244

CASE: 36

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN DIRECT LUMINAIRES ARE 50% DIMMED BUT INDIRECTS ARE FULLY ON

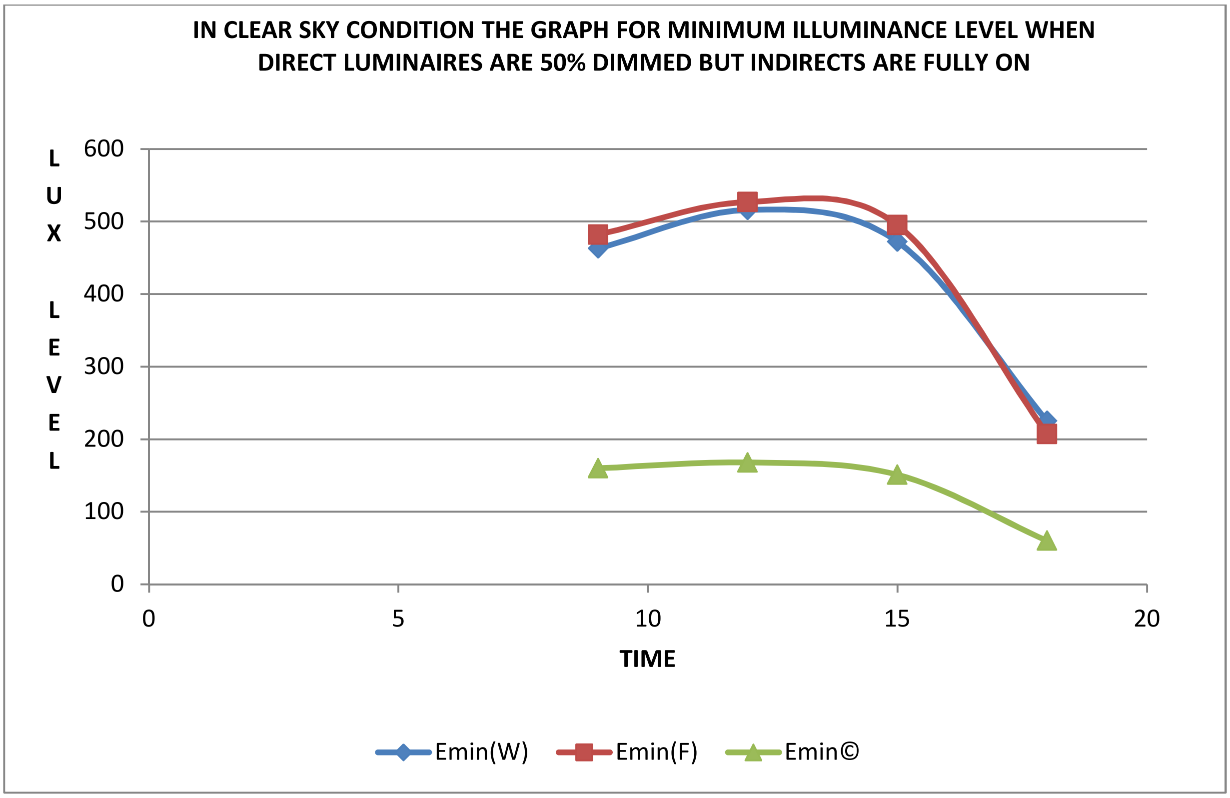
36.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



36.1. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2439	1910	312
12	3785	3391	333
15	2646	2341	314
18	423	305	188

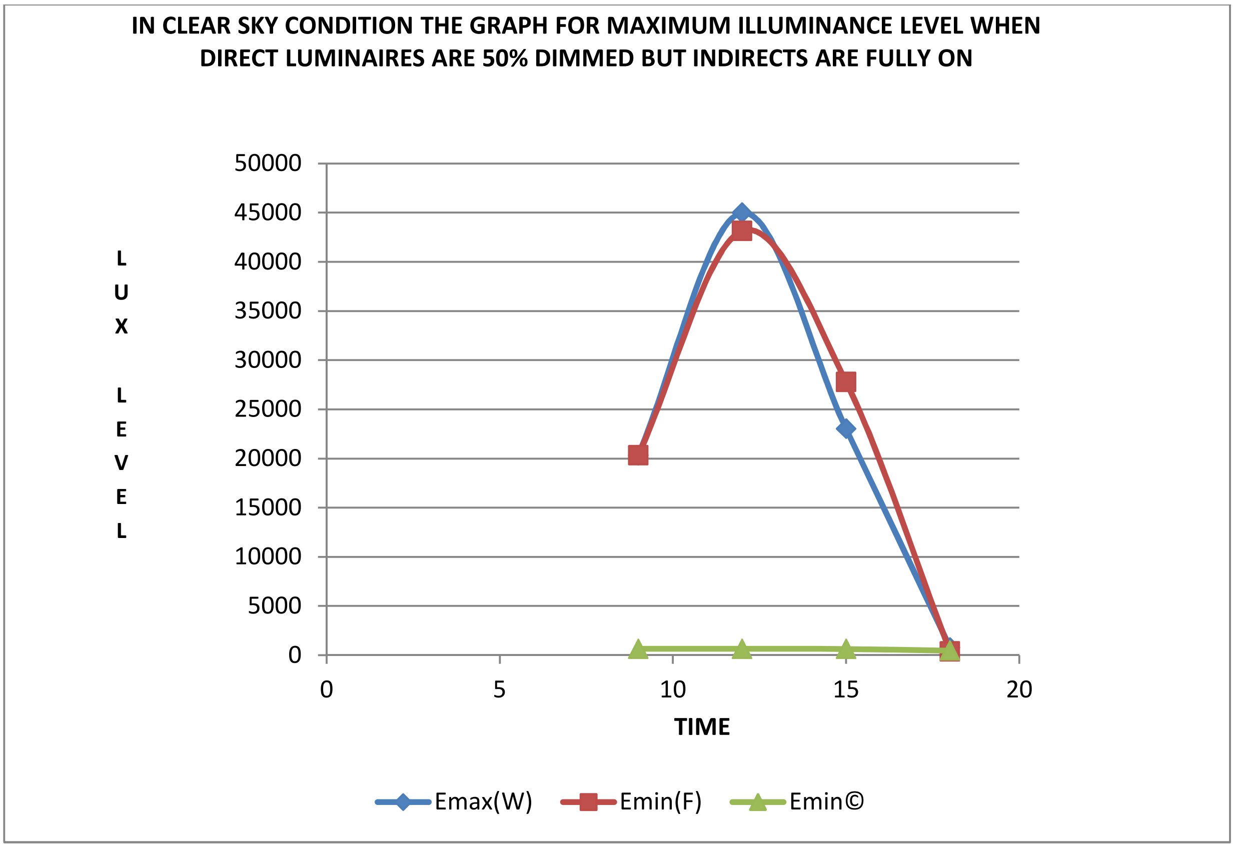
36.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



36.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	Emin(W)	Emin(F)	Emin©
9	463	482	160
12	516	527	168
15	472	495	151
18	225	207	60

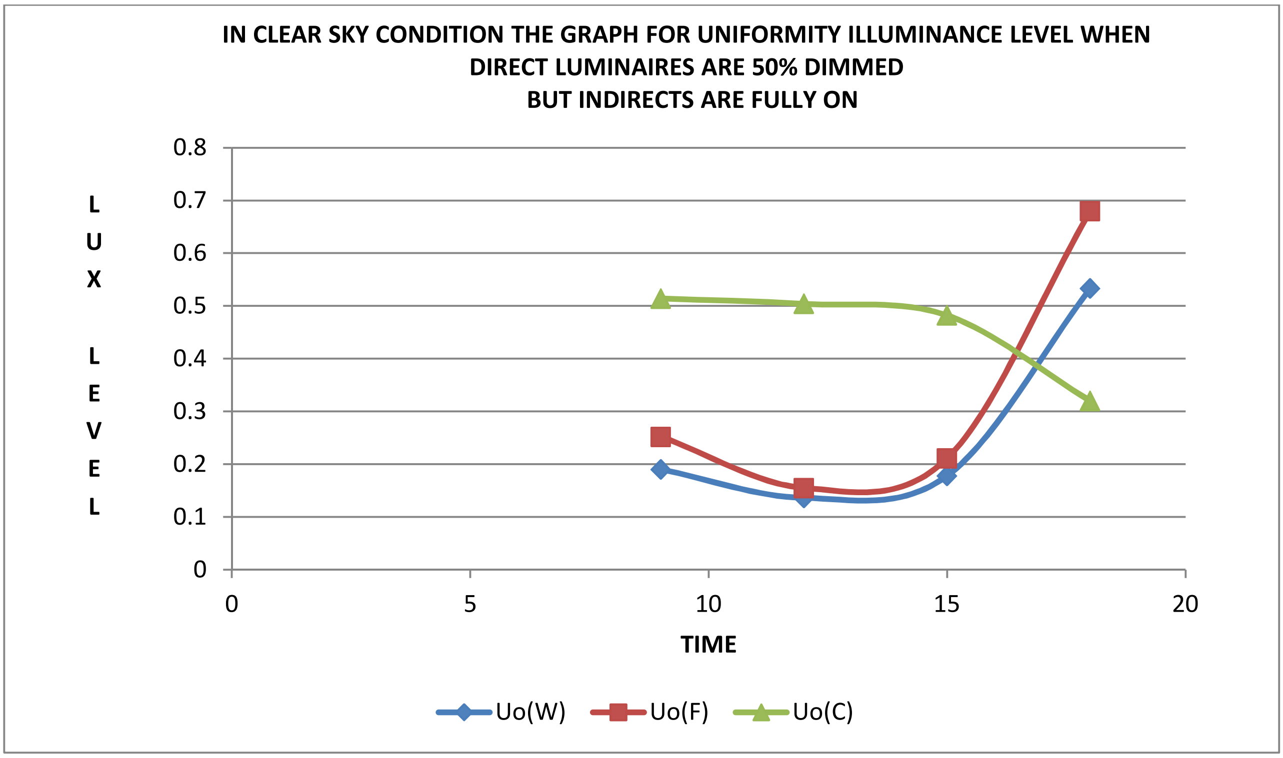
36.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



36.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	Emax(W)	Emin(F)	Emin©
9	20337	20333	639
12	44986	43135	640
15	23015	27784	630
18	774	375	473

36.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



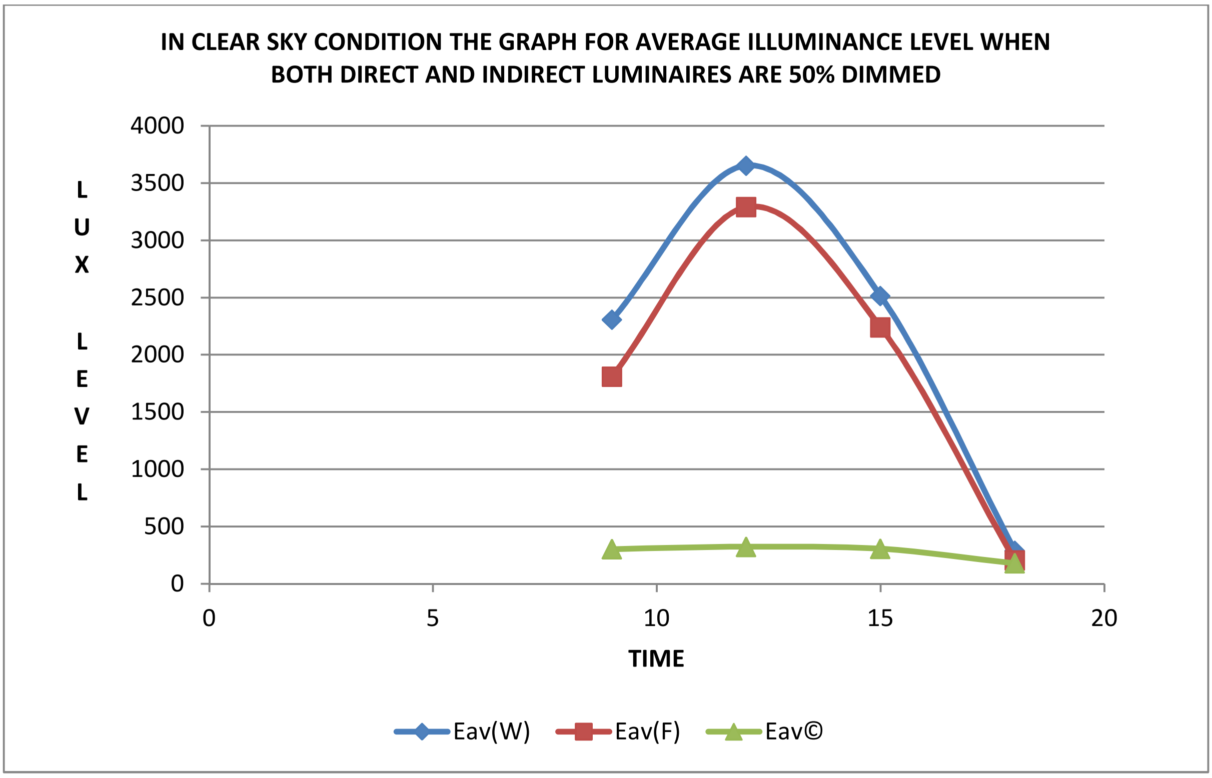
36.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	U_0(W)	U_0(F)	U_0(C)
9	0.19	0.252	0.514
12	0.136	0.155	0.504
15	0.178	0.211	0.482
18	0.533	0.68	0.32

CASE: 37

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE 50% DIMMED

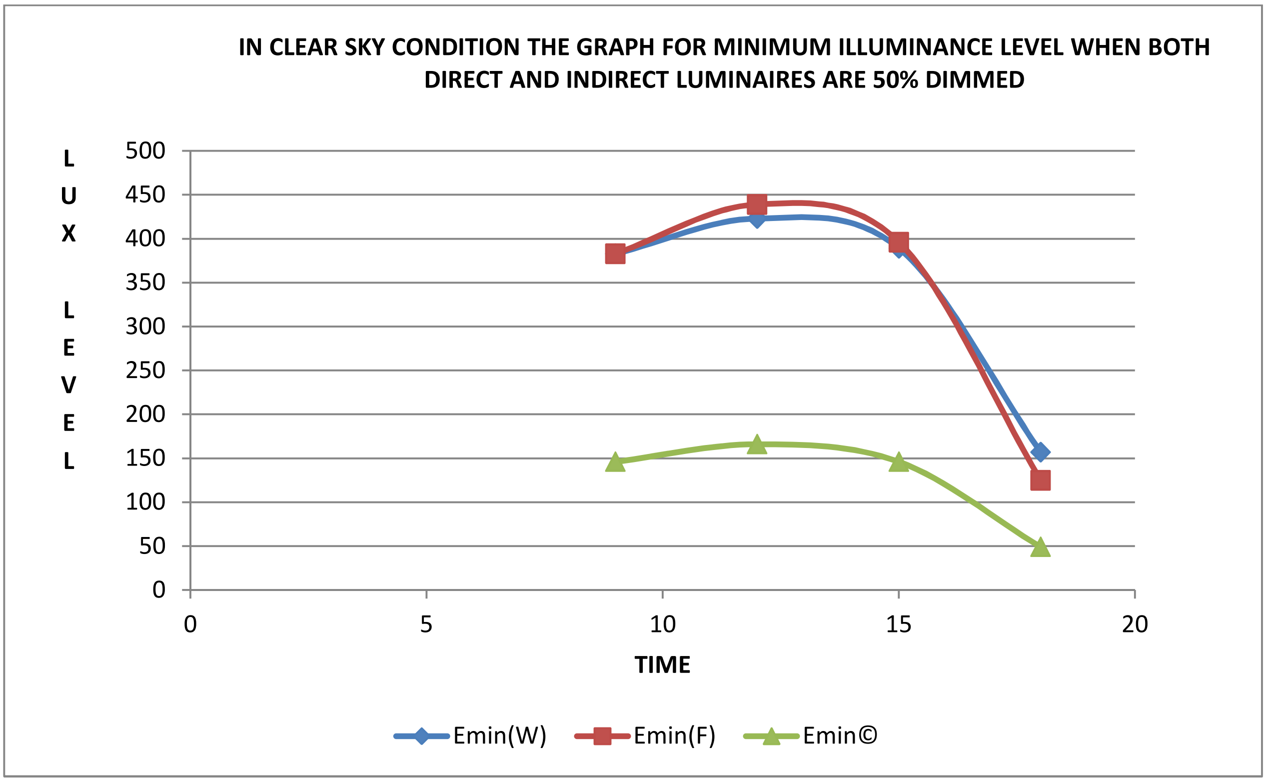
37.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



37.1. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2308	1809	303
12	3653	3290	324
15	2515	2241	306
18	290	204	179

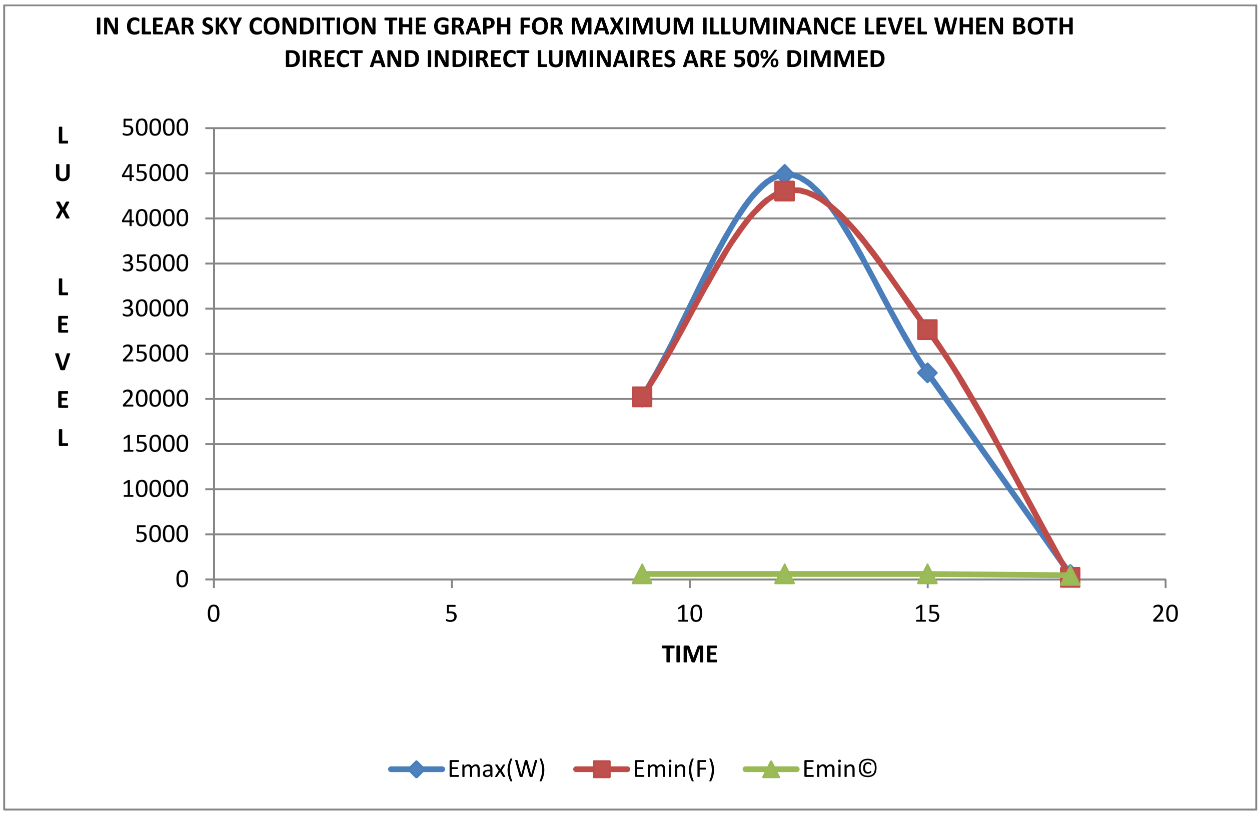
37.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



37.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	383	383	146
12	423	439	166
15	389	396	146
18	157	125	49

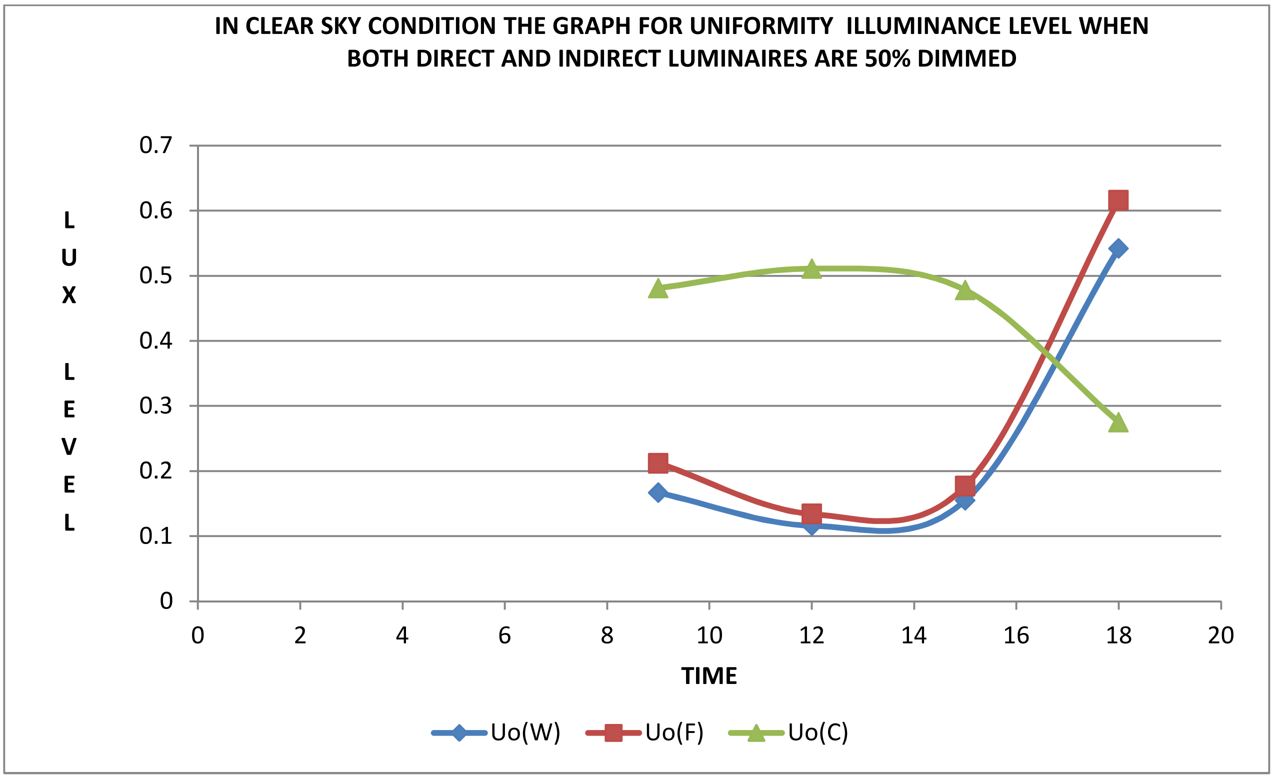
37.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



37.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	Emax(W)	Emin(F)	Emin©
9	20196	20241	629
12	44874	43030	627
15	22892	27677	620
18	571	260	464

37.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



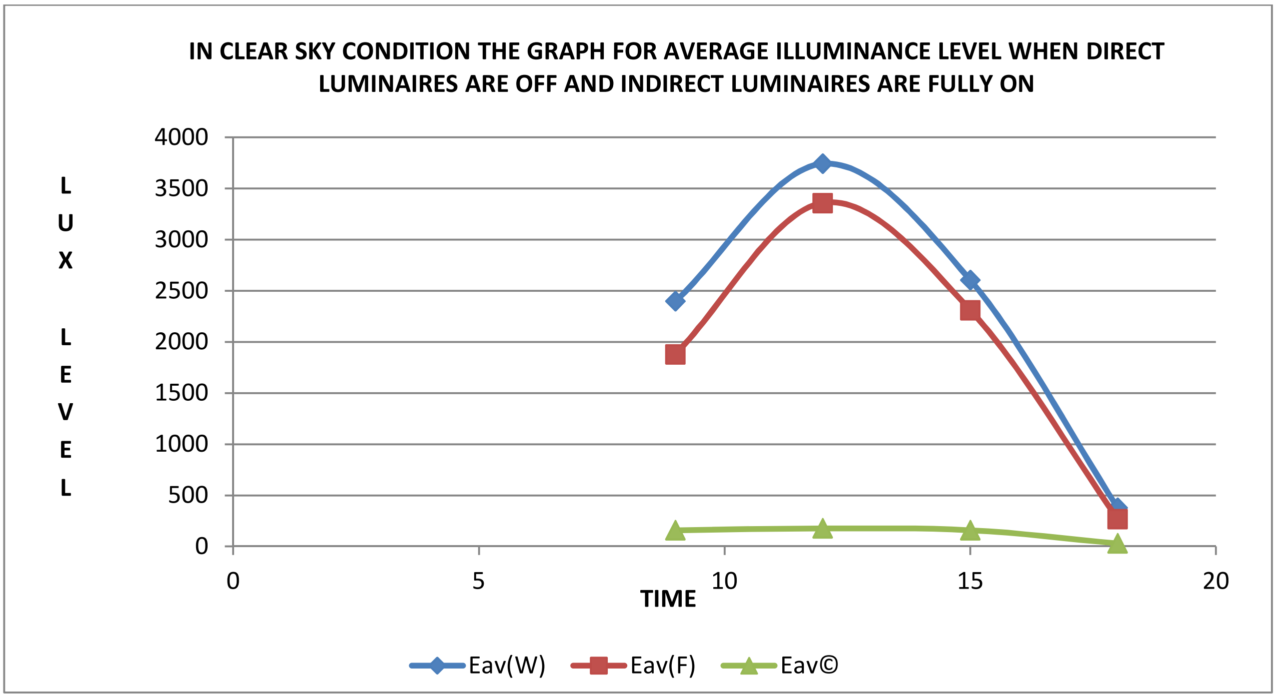
37.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	$U_{0(W)}$	$U_{0(F)}$	$U_{0(C)}$
9	0.1666	0.212	0.481
12	0.116	0.134	0.511
15	0.155	0.177	0.478
18	0.542	0.616	0.275

CASE: 38

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m, WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

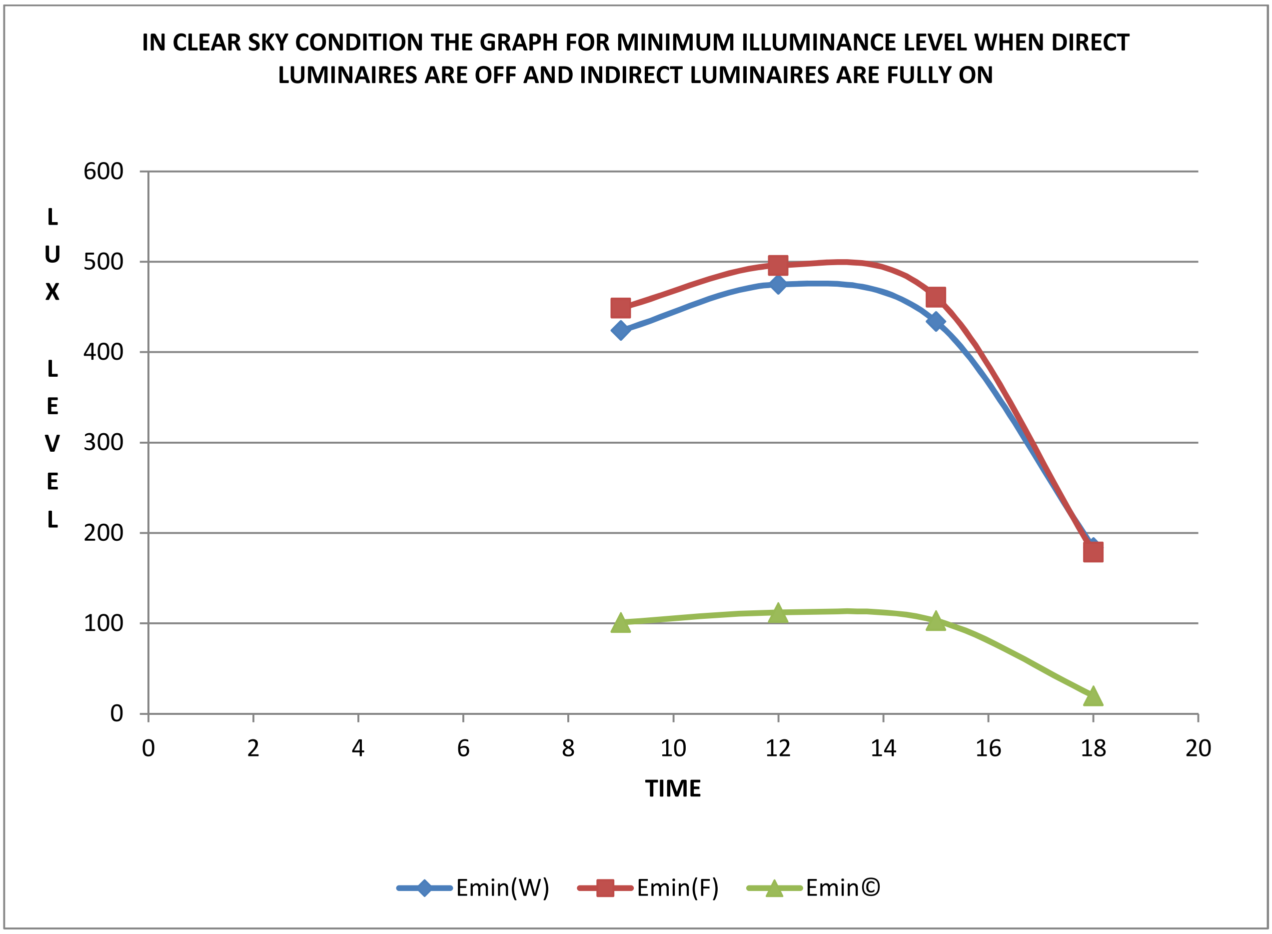
38.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



38.1. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2397	1879	158
12	3741	3359	177
15	2604	2310	159
18	378	270	30

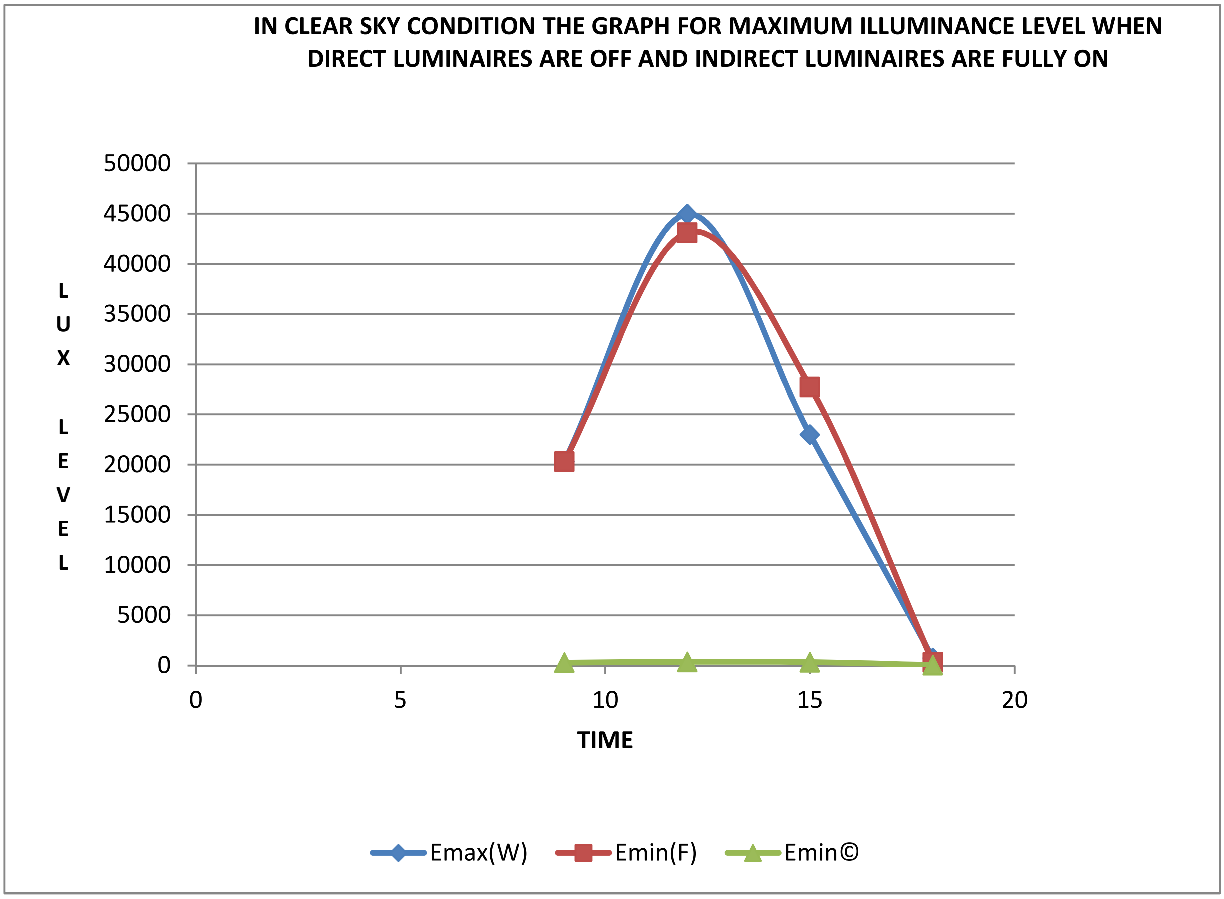
38.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



38.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	Emin(W)	Emin(F)	Emin©
9	424	449	101
12	475	496	112
15	434	461	103
18	184	179	20

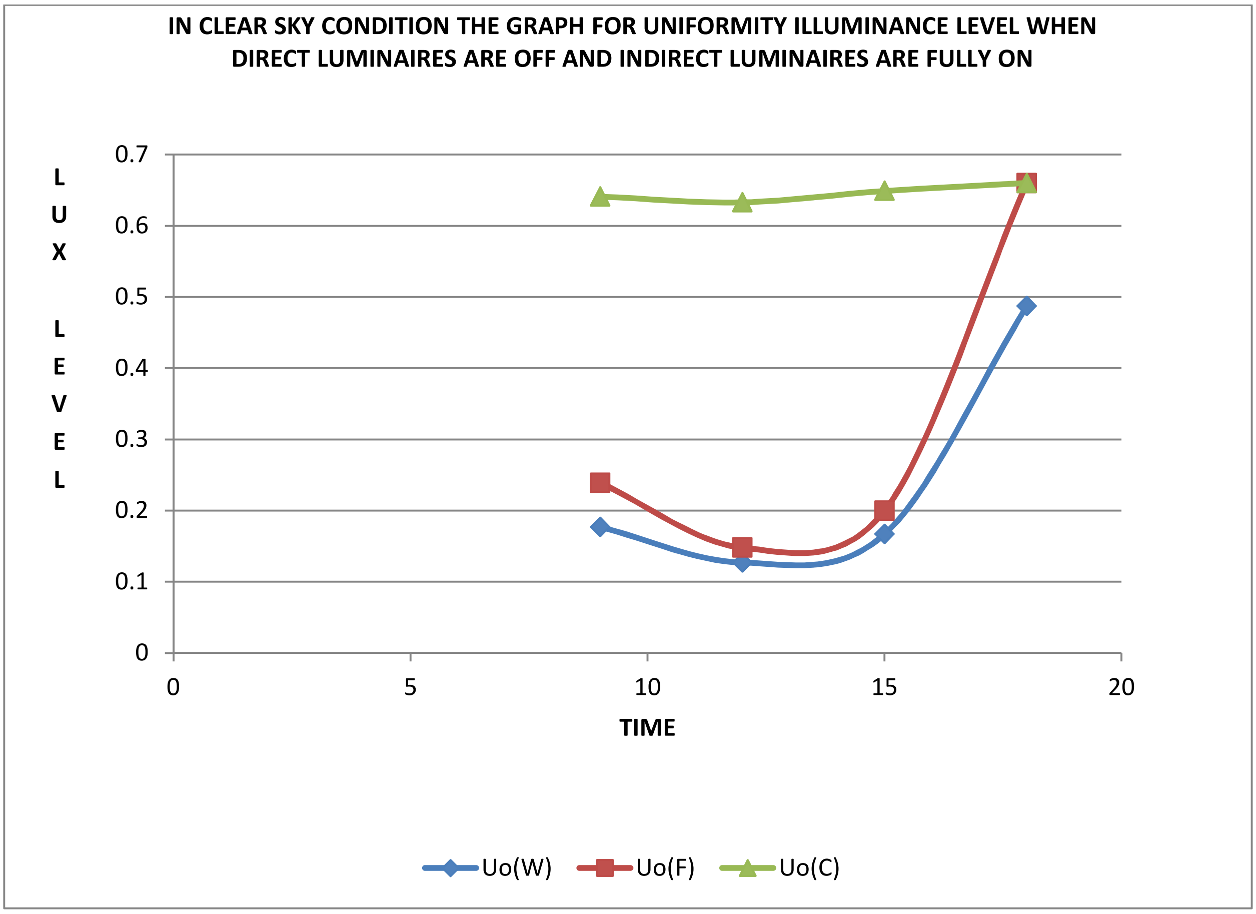
38.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



38.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20295	20297	282
12	44952	43107	354
15	22973	27751	327
18	731	336	38

38.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



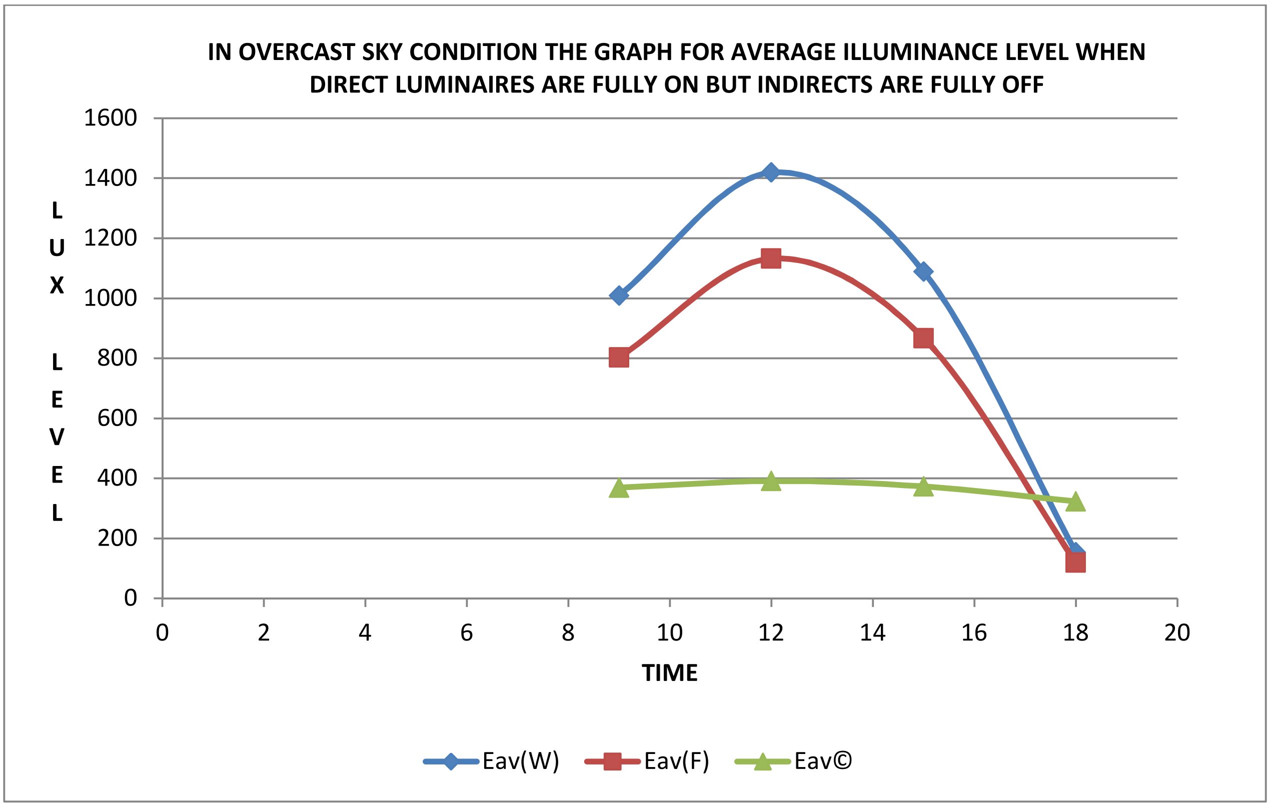
38.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	$U_{0(W)}$	$U_{0(F)}$	$U_{0(C)}$
9	0.177	0.239	0.641
12	0.127	0.148	0.633
15	0.167	0.2	0.649
18	0.487	0.66	0.66

CASE: 39

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE FULLY OFF

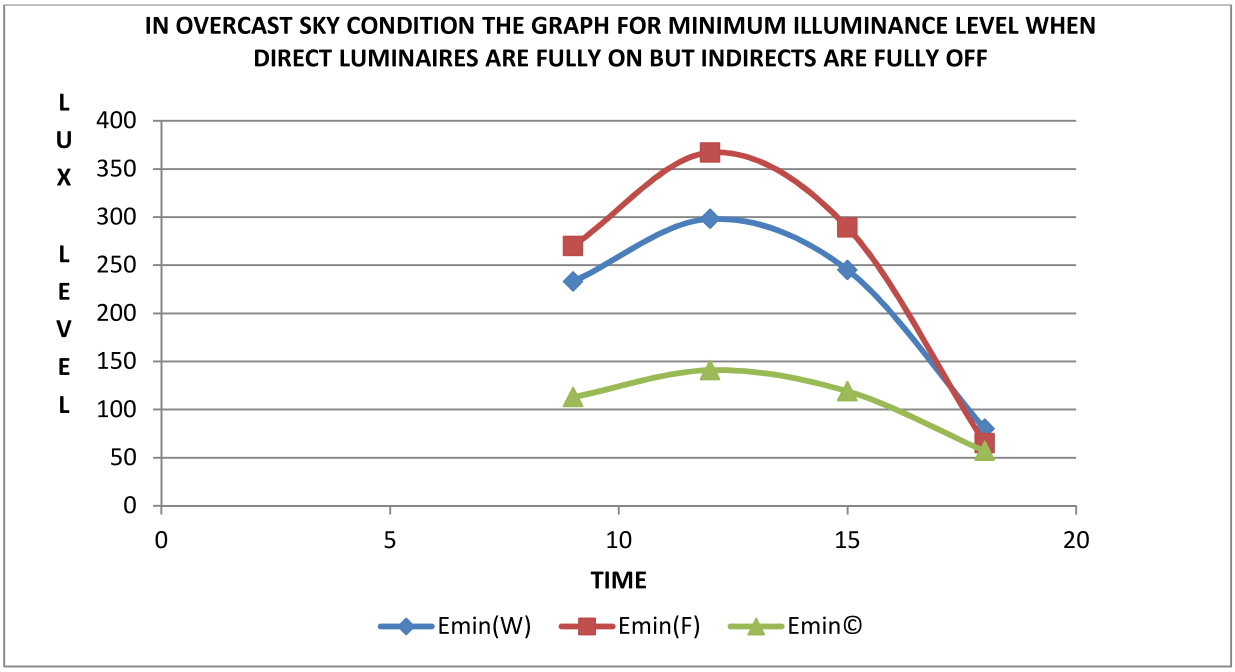
39.1. THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



39.1. THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1009	803	369
12	1419	1132	391
15	1089	867	373
18	153	119	323

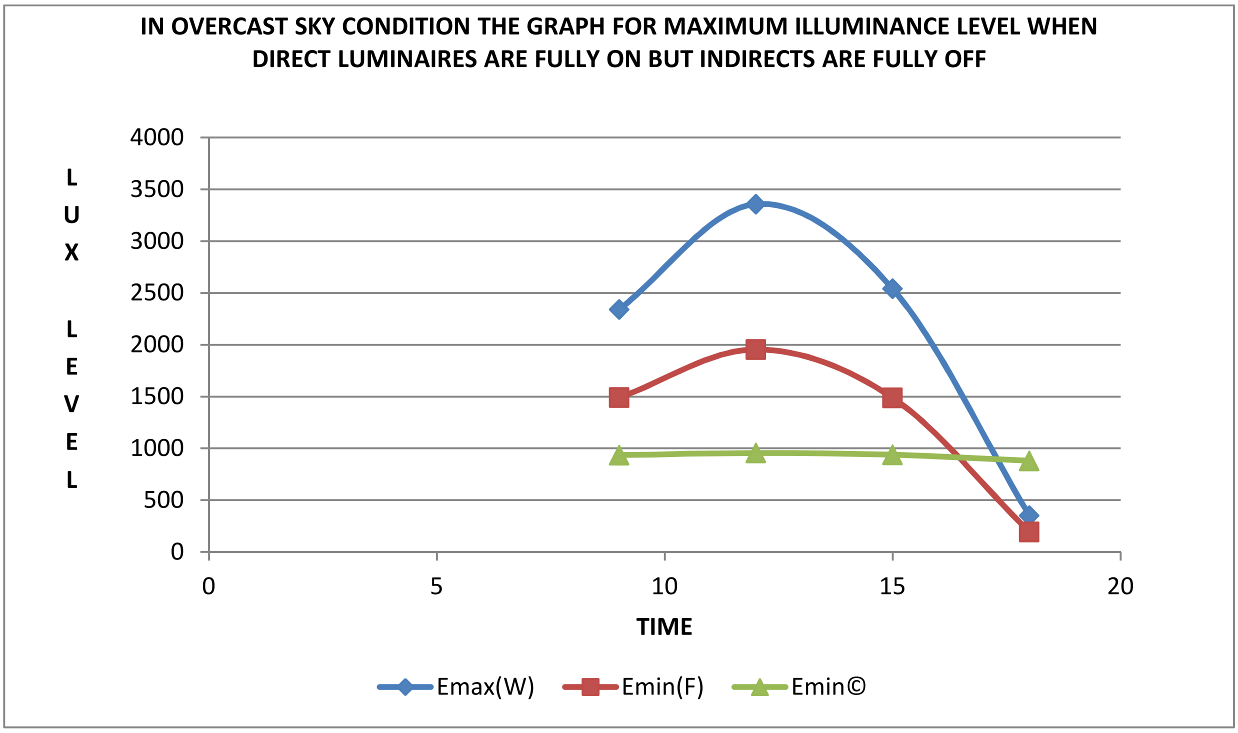
39.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



39.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

MINIMUM LUX LEVEL			
TIME	Emin(W)	Emin(F)	Emin©
9	233	270	113
12	298	367	141
15	245	289	119
18	80	65	57

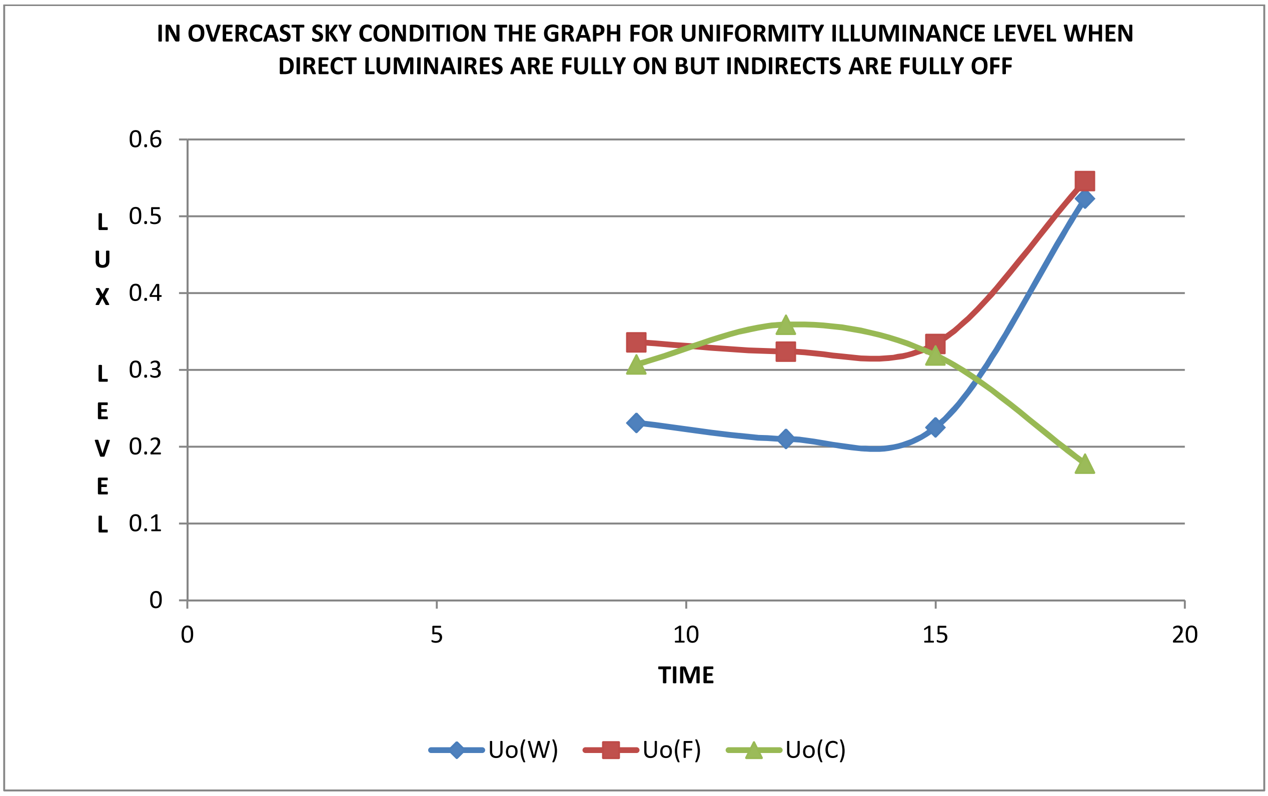
39.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



39.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	Emax(W)	Emin(F)	Emin©
9	2341	1490	935
12	3357	1954	955
15	2540	1488	939
18	352	193	880

39.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



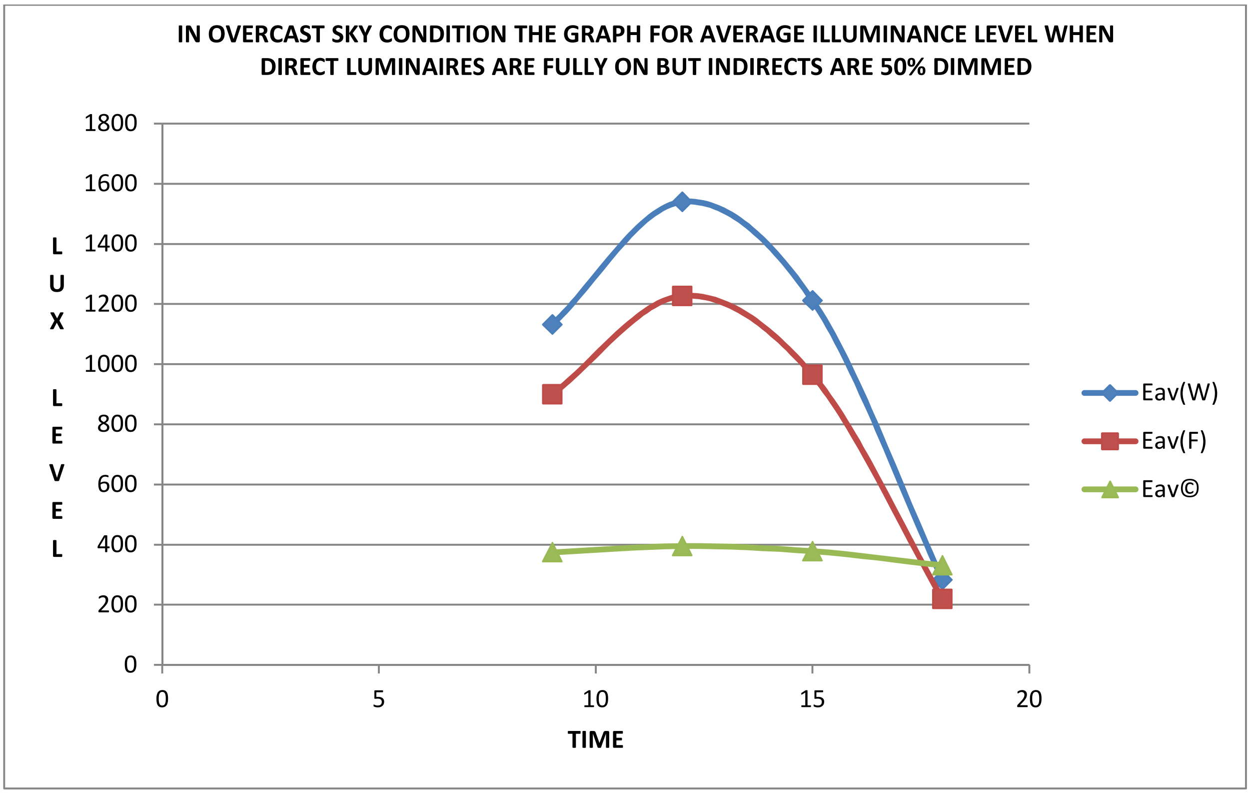
39.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.231	0.336	0.307
12	0.21	0.324	0.359
15	0.225	0.334	0.319
18	0.523	0.546	0.178

CASE: 40

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m , WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE 50% DIMMED

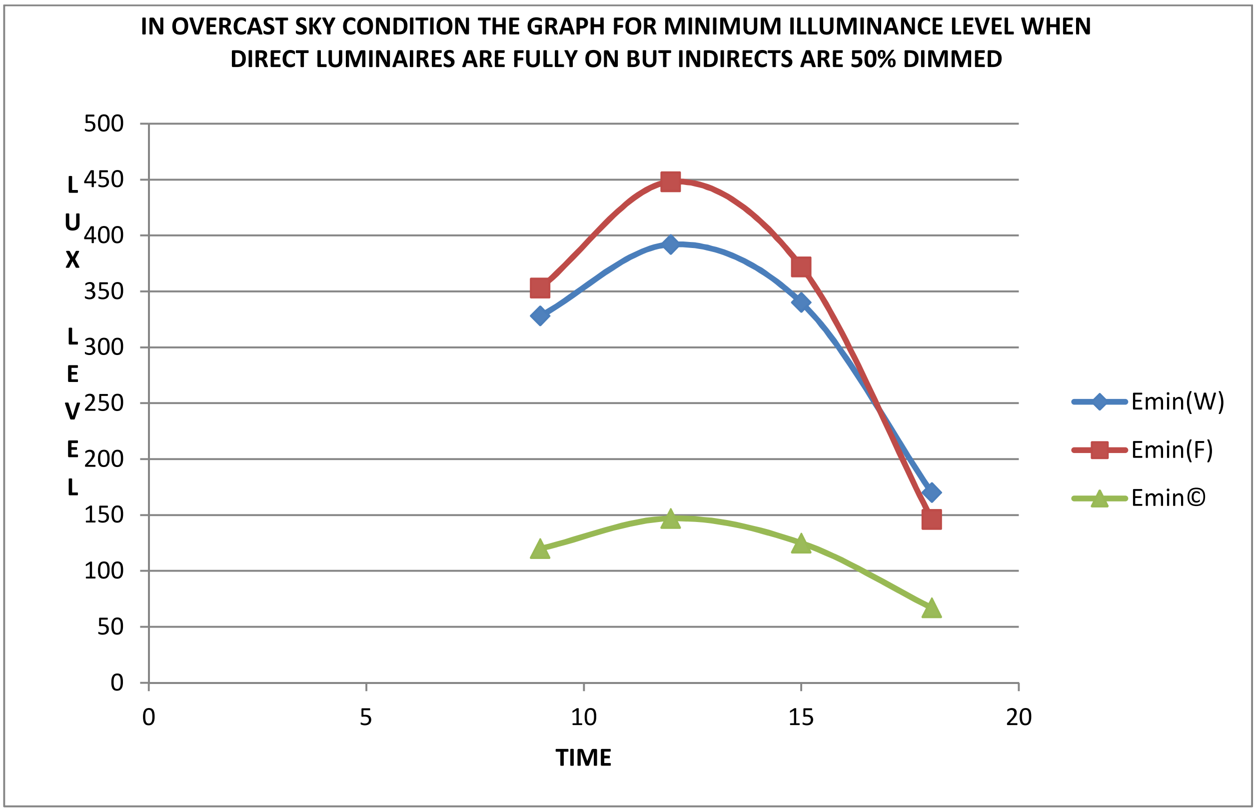
40.1 THE GRAPH FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING



40.1 THE CHART FOR ALL Eav VALUES FOR WORKPLANE, FLOOR AND CEILING

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1132	900	374
12	1540	1227	395
15	1212	964	378
18	283	219	331

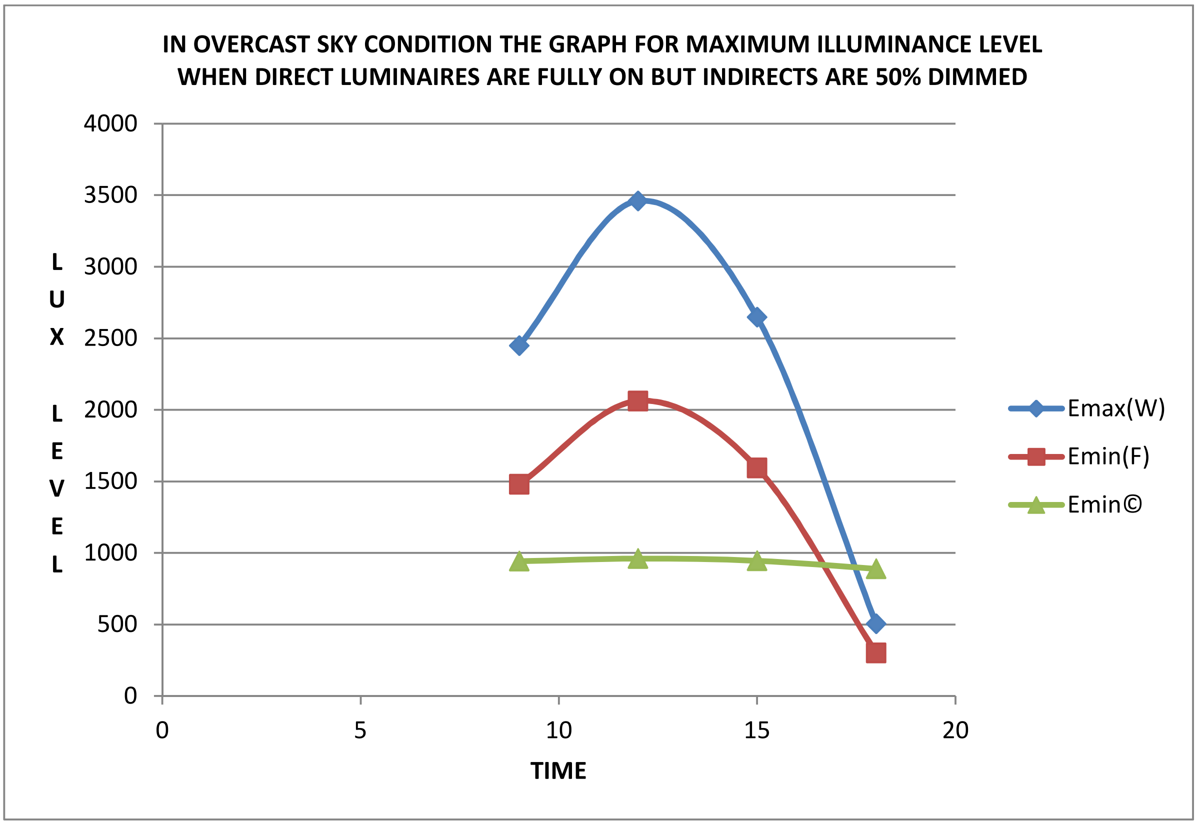
40.2. THE GRAPH FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING



40.2. THE CHART FOR ALL Emin VALUES FOR WORKPLANE, FLOOR AND CEILING

	MINIMUM LUX LEVEL		
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	328	353	120
12	392	448	147
15	340	372	125
18	170	146	67

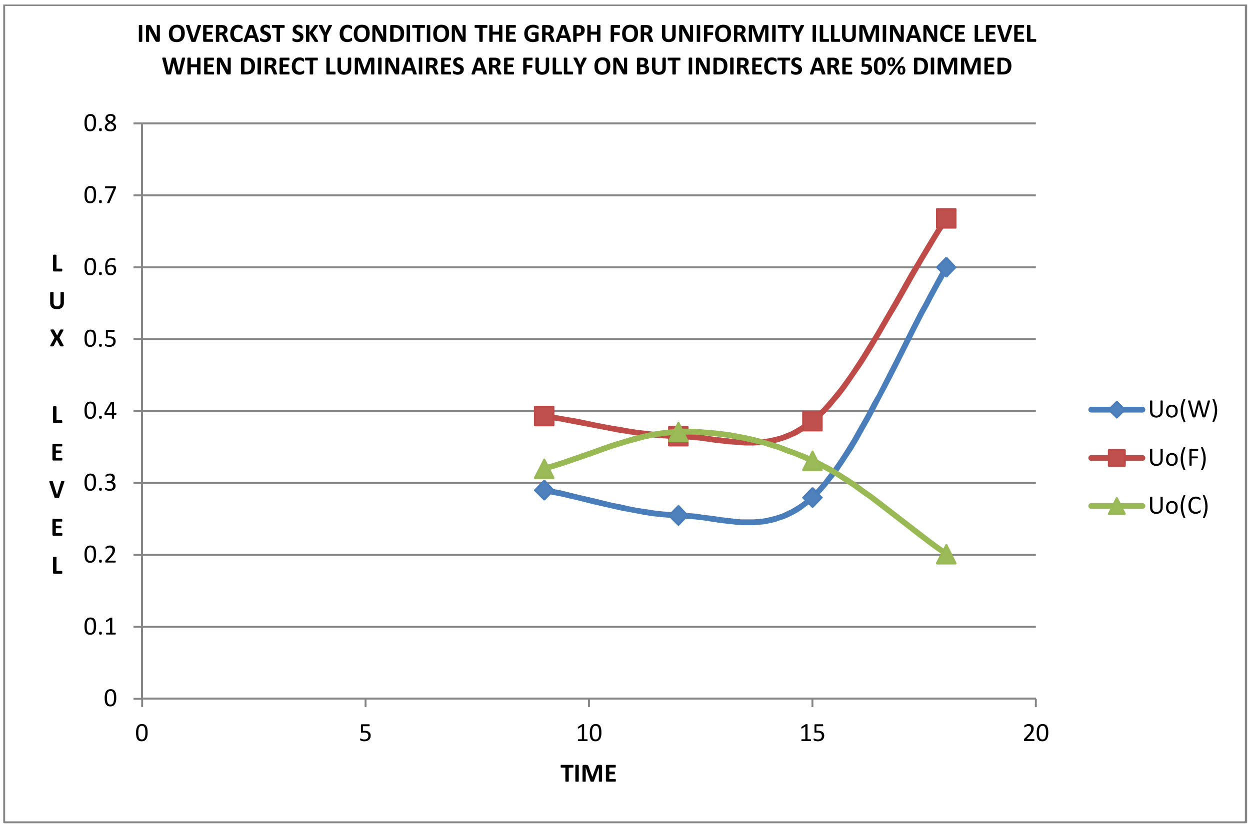
40.3. THE GRAPH FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING



40.3. THE CHART FOR ALL Emax VALUES FOR WORKPLANE, FLOOR AND CEILING

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	2449	1480	942
12	3460	2062	960
15	2647	1594	945
18	504	300	889

40.4. THE GRAPH FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING



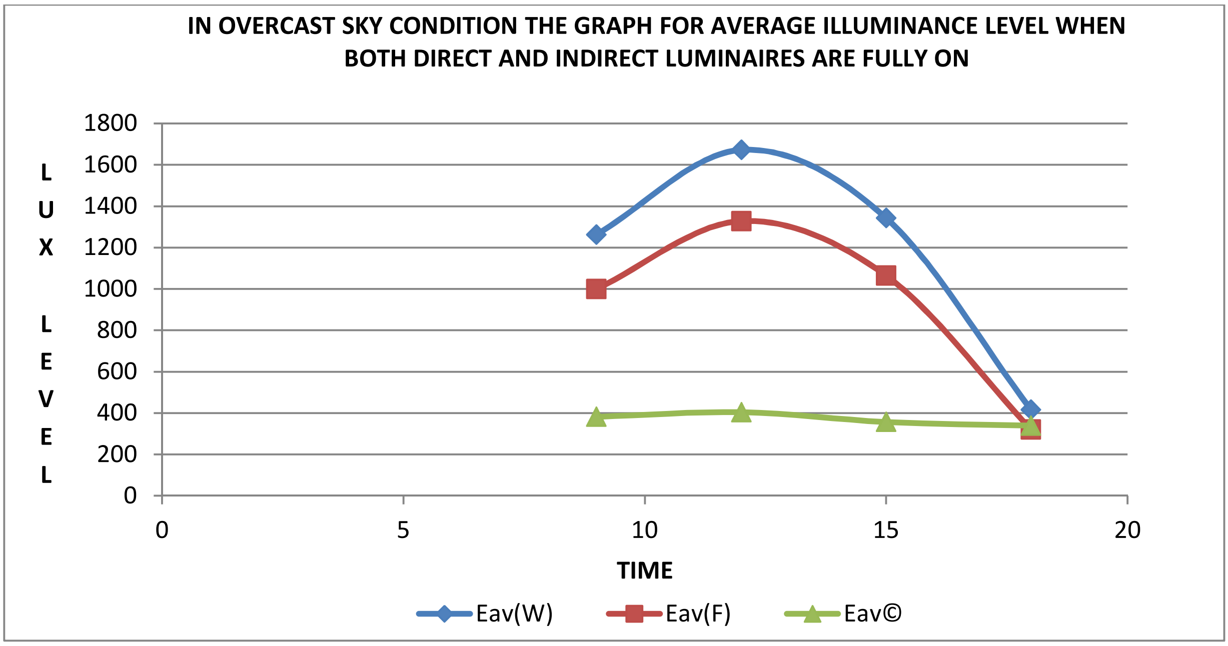
40.4. THE CHART FOR ALL UNIFORMITY VALUES FOR WORKPLANE, FLOOR AND CEILING

	UNIFORMITY		
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.29	0.393	0.32
12	0.255	0.365	0.371
15	0.28	0.386	0.331
18	0.5999	0.668	0.201

CASE : 41

IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE FULLY ON

41.1.1.GRAPH FOR AVERAGE ILLUMINANCE

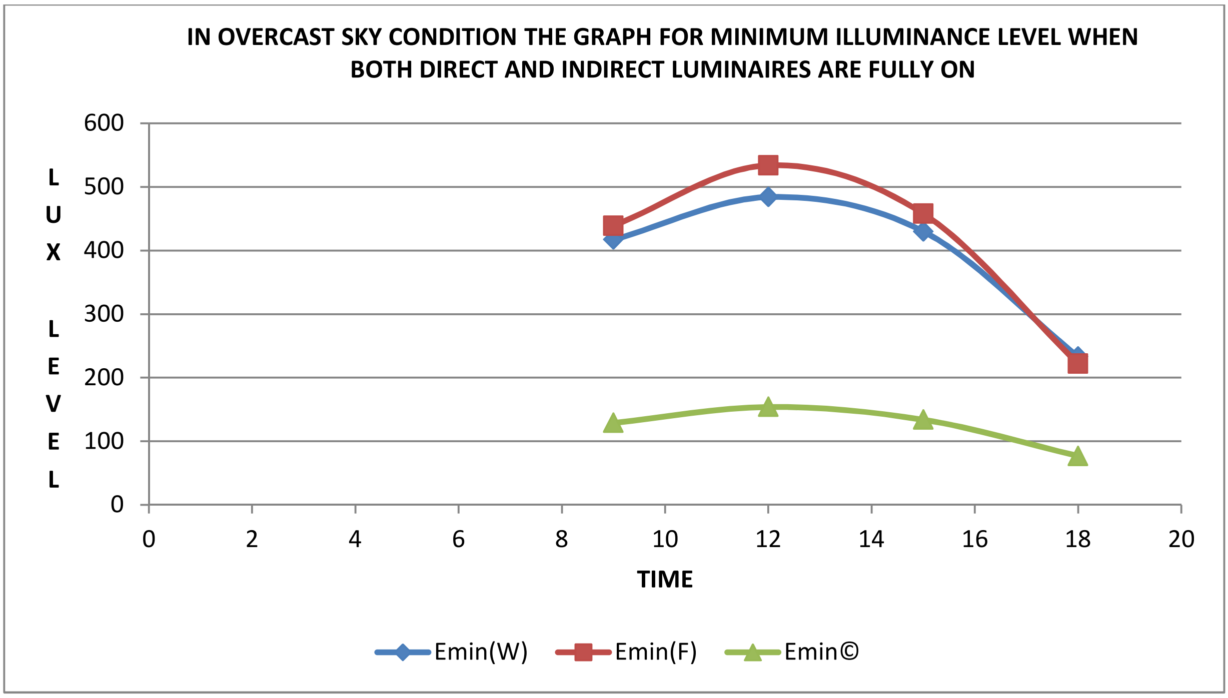


41.1.1.VALUE CHART FOR AVERAGE ILLUMINANCE

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav(C)
9	1263	1000	382
12	1672	1328	404
15	1343	1064	357
18	416	320	339

In overcast sky condition when luminaries are at the height of 0.7m then the workplane and floor shows the same nature of graphs which are intersect with each other in artificial light. Throughout the day the ceiling maintained an average value range so the graph is linear and the last point means the lumen value which produced in artificial light coincide with the rest two parameters and meet at a point.

41.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

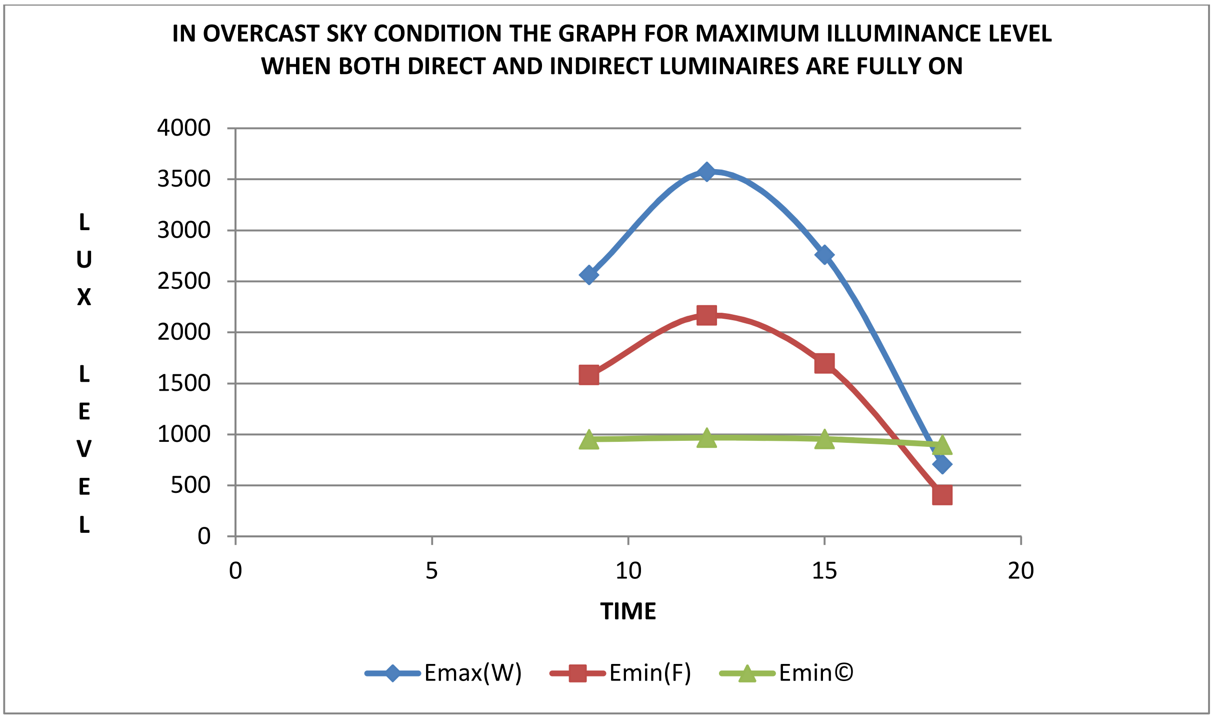


41.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	417	439	129
12	484	534	154
15	430	458	134
18	233	222	77

Here graphs of workplane and floor are just next to each other's, due to the near value of them, at 12PM all of three values goes at its maximum value but at 9AM these values are minimum at their range, for this reason those two graphs are slowly up warded in nature but at 3PM these lux levels are reduces and the graphs became downward. All three graphs shows the same nature.

41.1.3.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

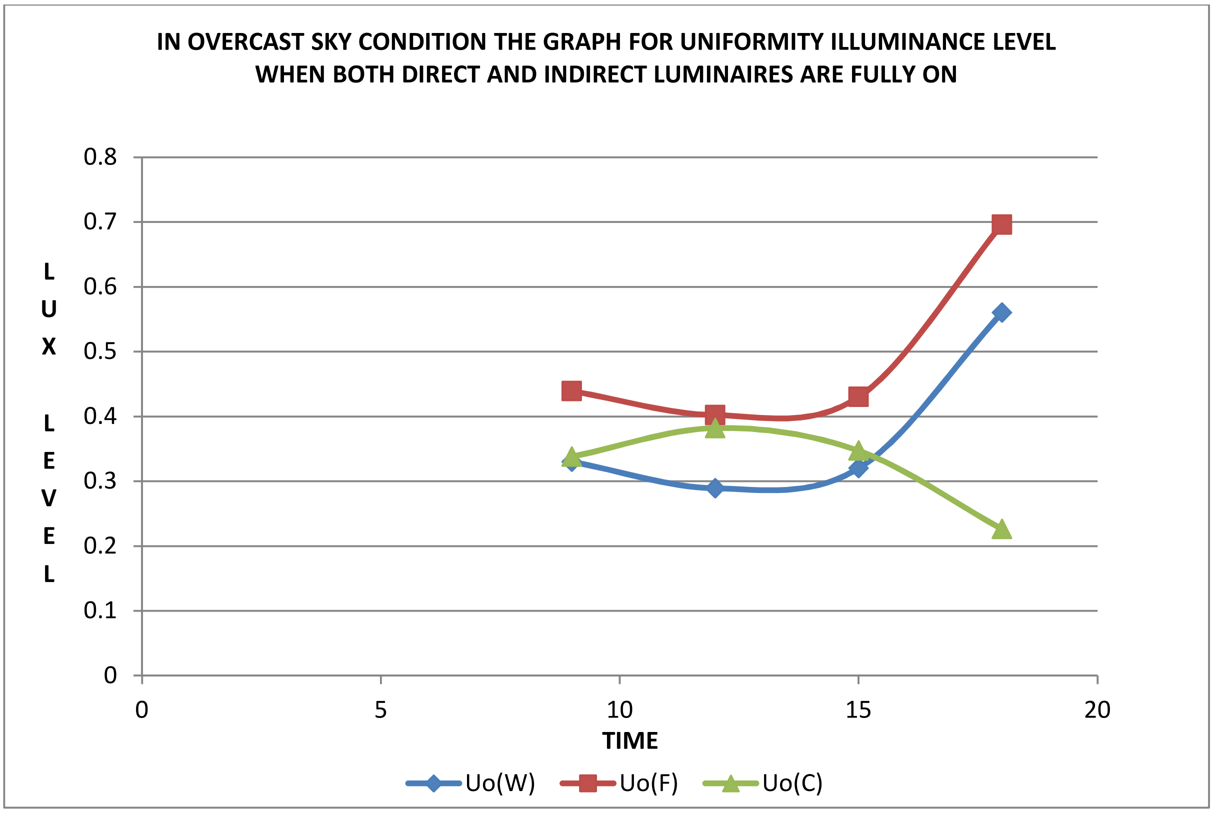


41.1.3.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emax(F)**	**Emax©**
9	2561	1581	951
12	3572	2165	968
15	2757	1694	954
18	706	406	899

With the daylight integration maximum lux values goes highest at 12PM and lowest at 9AM in the morning, so the graph increases slowly and reached at a pick point and then slowly decreased upto 3PM,but with the dimming control method in artificial lighting all the values are in a nearby range, but all of these values are not in the standard ranges due to the reflectivity.

41.1.4.GRAPH FOR MINIMUM ILLUMINANCE LEVEL



41.1.4.CHART FOR MINIMUM ILLUMINANCE LEVEL

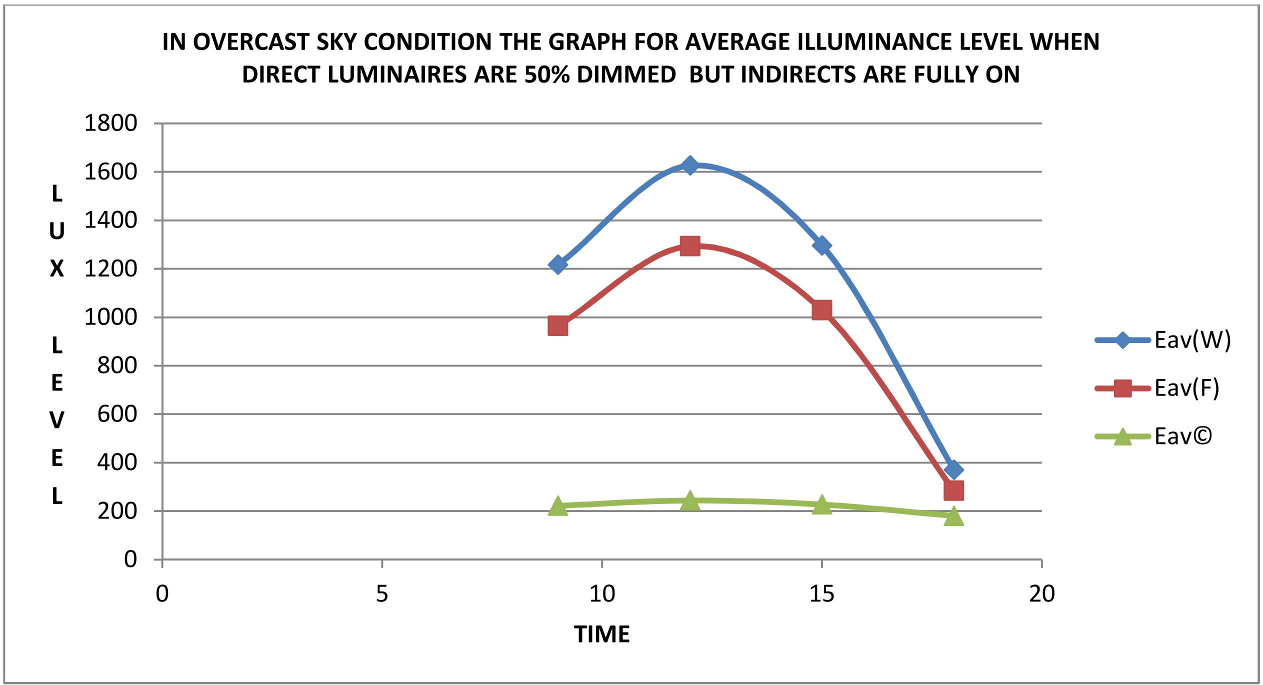
UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.33	0.439	0.338
12	0.289	0.402	0.382
15	0.32	0.43	0.347
18	0.56	0.696	0.226

Here two graphs not only overlapped with each others but also they make an eye curved graph, and this structure occurred by workplane graph and ceiling graph but the floor graph maintained the same nature of workplane so that graph doesn't interfere with any of those others graphs and slowly increased it values. In overcast sky condition the daylight gives an uneven uniformity through out the day and it produce lower uniformity, but with the artificial lighting slowly it upgraded its values.

CASE : 42

IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE 50% DIMMED BUT INDIRECTS ARE FULLY ON

42.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

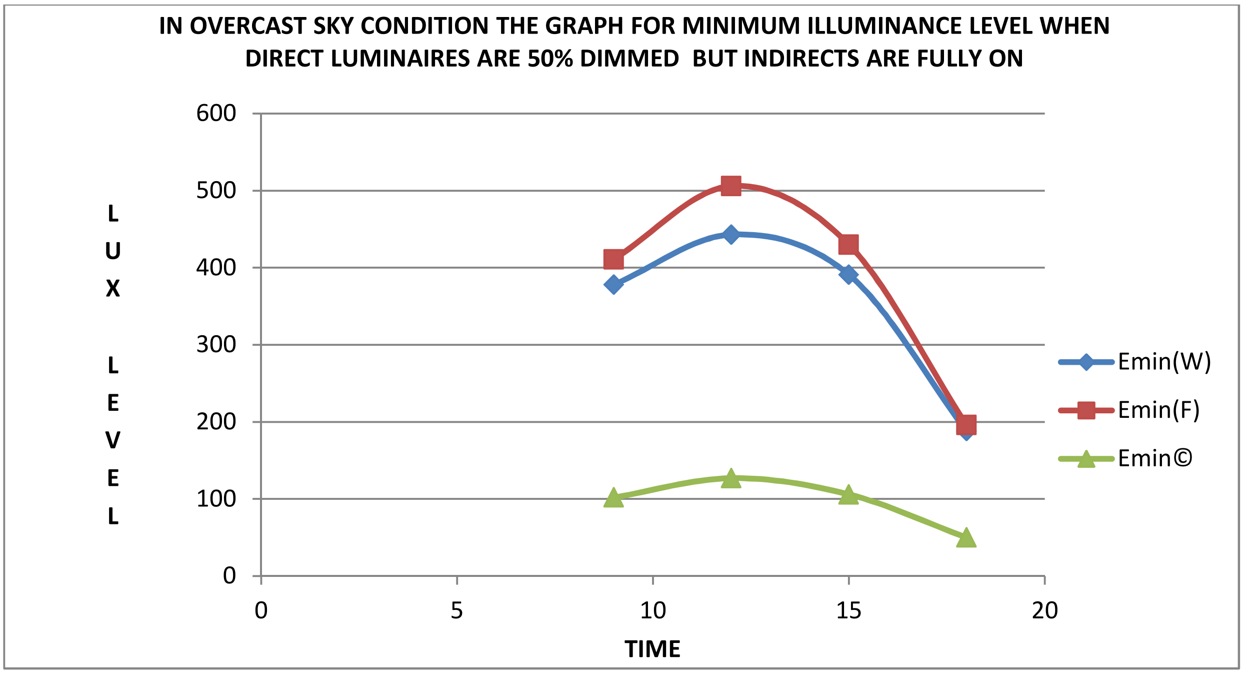


42.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1217	965	222
12	1626	1293	244
15	1296	1029	227
18	370	284	180

In overcast sky condition when luminaries are at the height of 0.7m then the workplane and floor shows the same nature of graphs which are intersect with each other in artificial light. Throughout the day the ceiling maintained an average value range so the graph is linear. When direct luminaires are 50% dimmed but indirects are fully on then there are no coincide points occurred.

<u>42.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL</u>

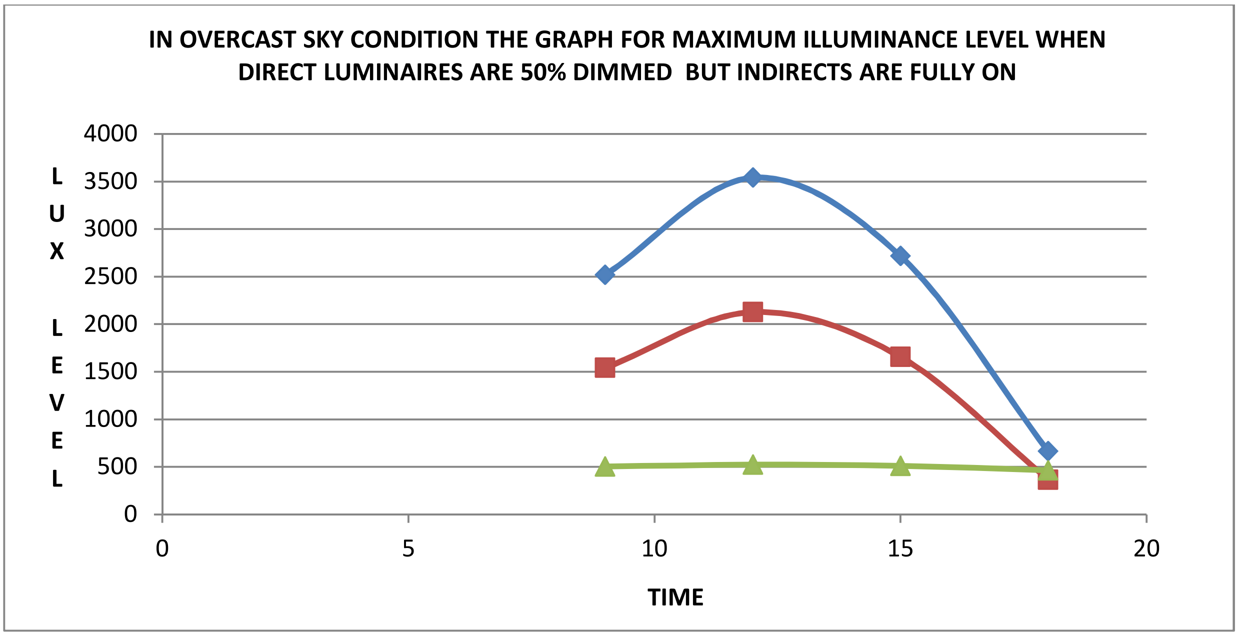


<u>42.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL</u>

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	378	411	102
12	443	506	127
15	391	430	106
18	188	196	50

Here graphs of workplane and floor are just next to each other's, due to the near value of them, at 12PM all of three values goes at its maximum value but at 9AM these values are minimum at their range, for this reason those two graphs are slowly up warded in nature but at 3PM these lux levels are reduces and the graphs became downward and lastly they meet up in a common point. As because he direct luminaires are dimmed into half of its lumen value for that reason minimum value of ceiling is so poor.

42.1.3.GRAPH FOR MAXIIMUM ILLUMINANCE LEVEL

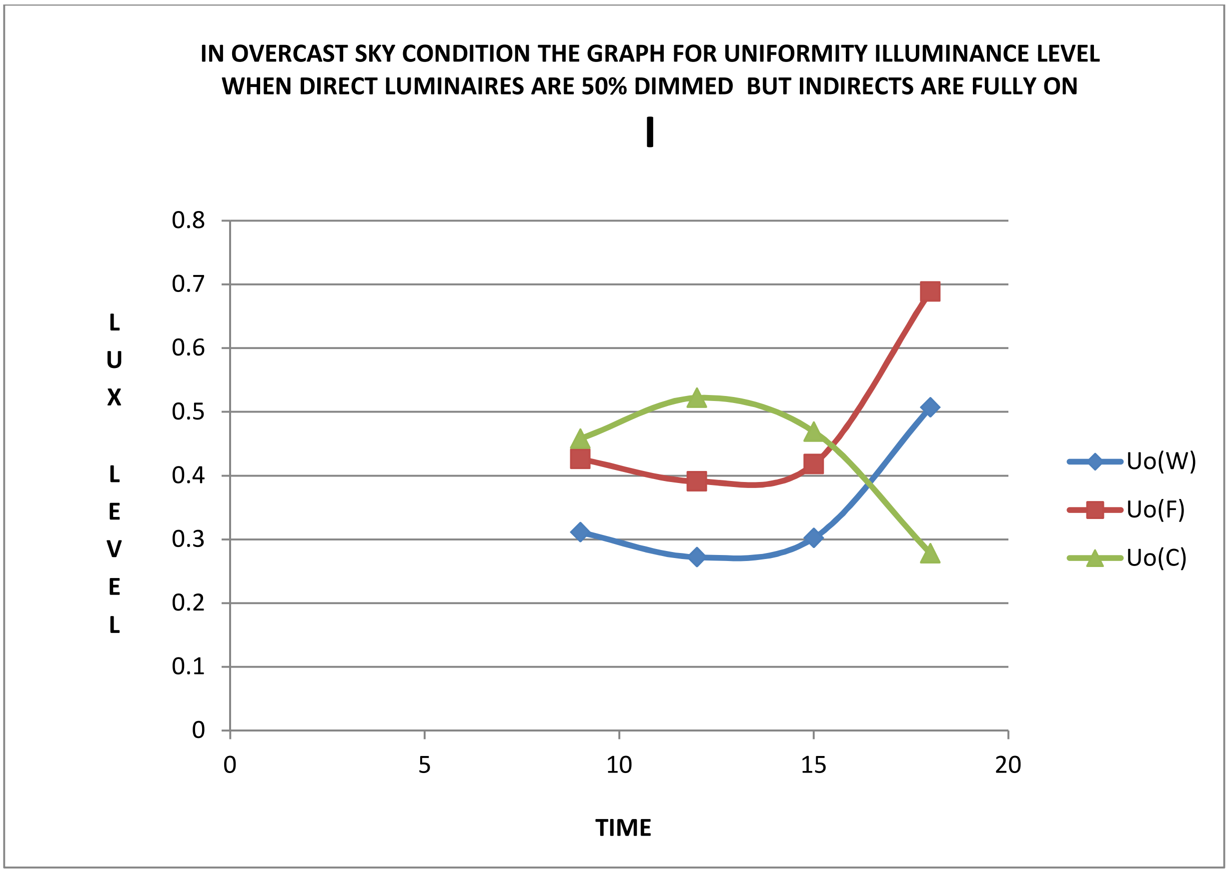


42.1.3.CHART FOR MAXIIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emax(F)**	**Emax©**
9	2518	1542	504
12	3540	2127	524
15	2715	1656	511
18	664	366	464

Here the blue line indicated the maximum illuminance values for workplane, red curve denoted the variation in floor area and the green linear graph shows the ceiling datas in the graphical presentation. With the daylight integration maximum lux values goes highest at 12PM and lowest at 9AM in the morning, so the graph increases slowly and reached at a pick point and then slowly decreased upto 3PM,but with the dimming control method in artificial lighting all the values are in a nearby range, but all of these values are lies in the standard ranges,which was missing in the previous case.

42.1.4.GRAPH FOR UNIFORMITY LEVEL



42.1.4.CHART FOR UNIFORMITY LEVEL

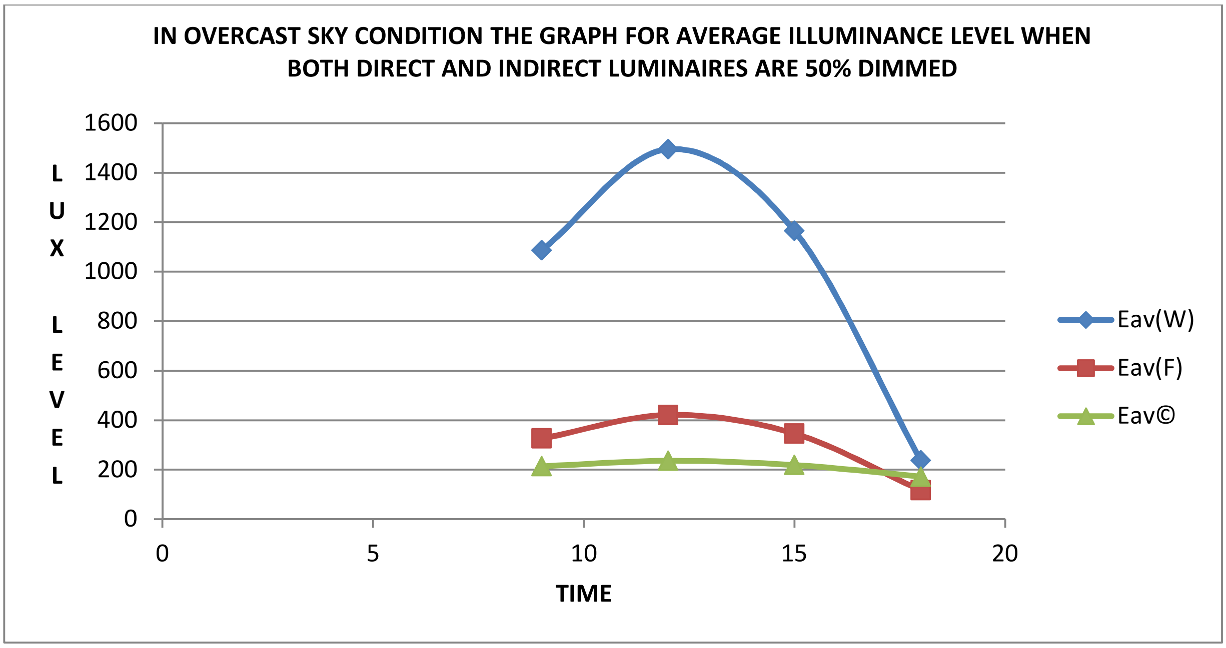
UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.311	0.426	0.458
12	0.272	0.391	0.522
15	0.302	0.418	0.469
18	0.507	0.689	0.278

Here two graphs not only overlapped with each others but also they make an eye curved graph, and this structure occurred by floor graph and ceiling graph but the workplane graph maintained the same nature of floor so that graph doesn't interfere with the eye structure, but it intersect the ceiling graph and slowly increased it values. In overcast sky condition the daylight gives an uneven uniformity through out the day and it produce lower uniformity, but with the artificial lighting slowly it upgraded its values. This type of graph nature occurred in the previous case but there the eye format happened between different two parameters.

CASE : 43

IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE 50% DIMMED

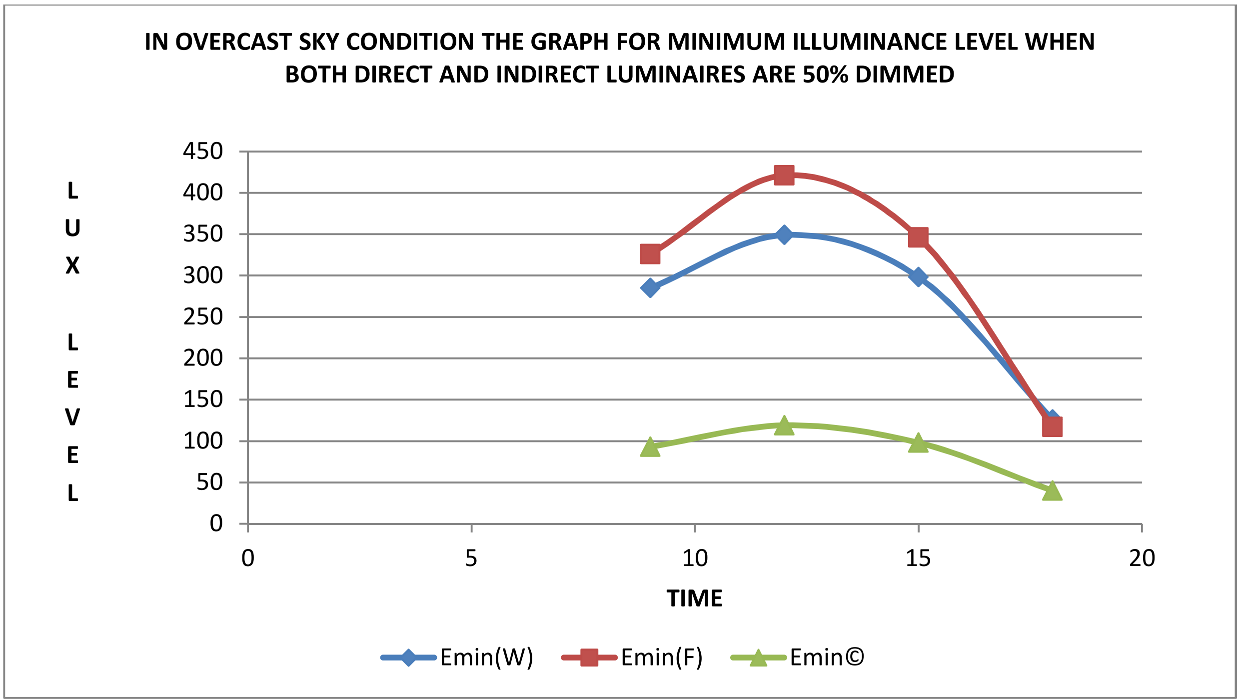
43.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL



43.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1086	865	214
12	1495	1193	236
15	1165	929	219
18	237	183	172

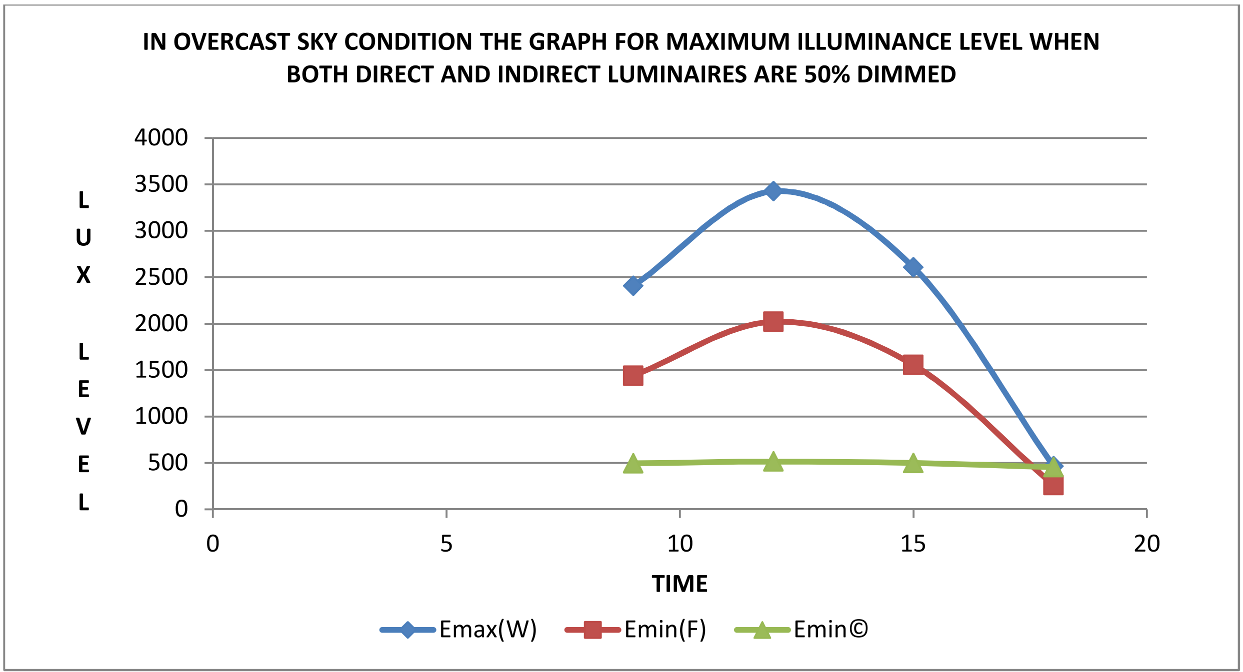
43.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL



43.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	285	326	93
12	349	421	119
15	298	346	98
18	126	117	40

43.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

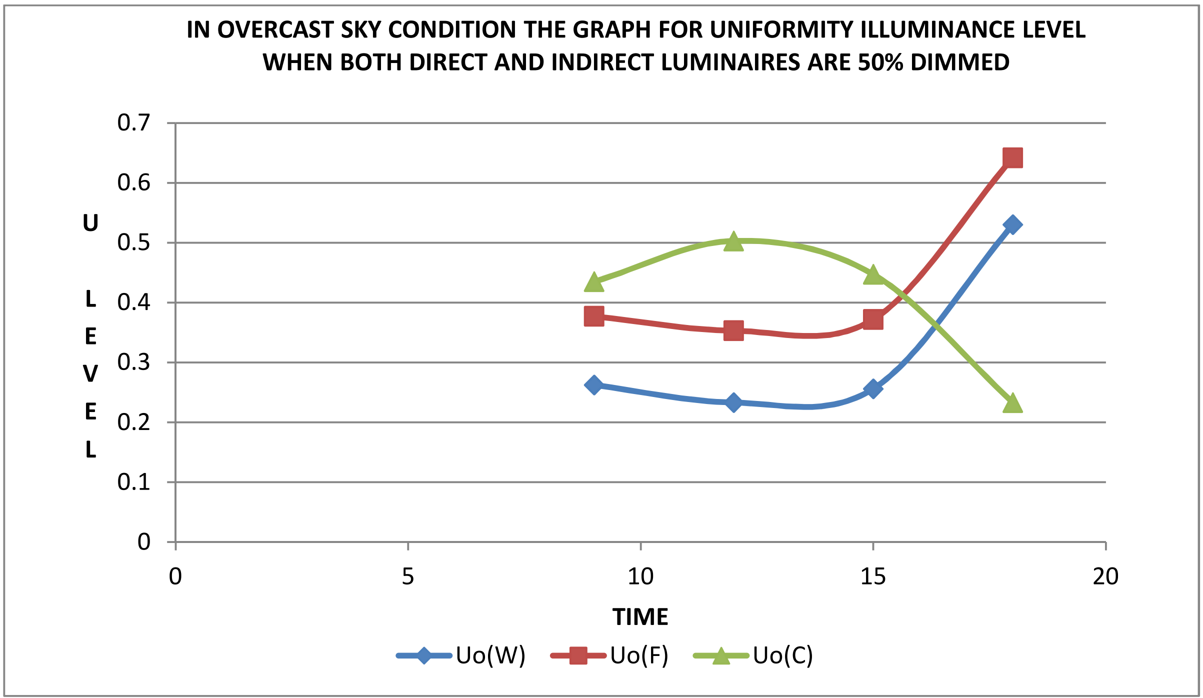


43.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	2407	1440	496
12	3425	2021	515
15	2605	1555	499
18	464	260	455

The same nature of the graph is obtained here when the boundary conditions are: overcast sky,and both direct and indirect luminaires are 50% dimmed then at 9AM daylight integration is moderate,at 12PM daylight is maximum and then it fall down but at 3PM it doesn't lower than 9AM,so a heapped form of graph obtained in the case of workplane and floor,but for ceiling through out the day the values are almost same,so a linear graph formed.

43.1.4.GRAPH FOR UNIFORMITY LEVEL



43.1.4.CHART FOR UNIFORMITY LEVEL

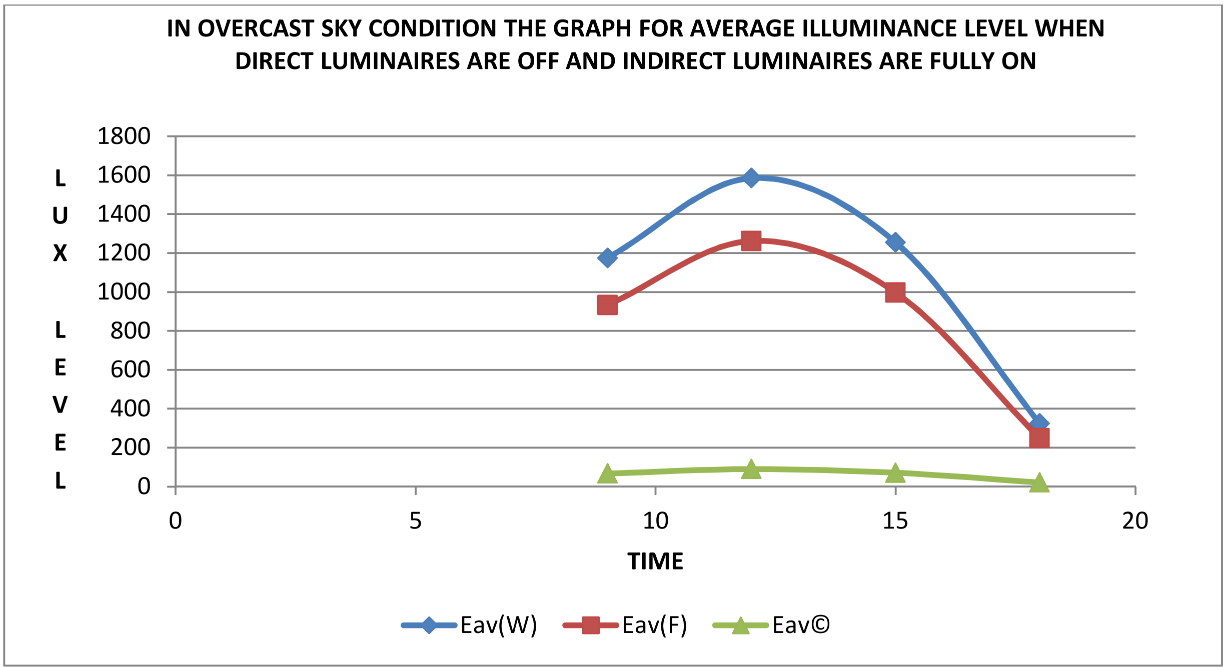
UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.262	0.377	0.435
12	0.233	0.353	0.503
15	0.256	0.372	0.447
18	0.53	0.642	0.233

In overcast sky condition, the above graph create with the help of tabulated datas for uniformity level in overcast sky condition the graph for uniformity illuminance level when both direct and indirect luminaires are 50% dimmed and the reflectivity's are in the range of 65-35-05,mainly in daylight condition the uniformity of ceiling remain in a level which is just half of the standard range but at that time due to uneven daylight distribution workplane and floor haven't that much higher values, but when sun goes off and the room totally illuminated by the artificial luminaires then the vice versa phenomenon happened. For that reason the above graphs intersect with each other, but the graph of workplane and floor maintain the same nature and they are lower in daylight and higher in artificial lights but ceiling shows the opposite nature hence that intersection occurred.

CASE : 44

IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

44.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

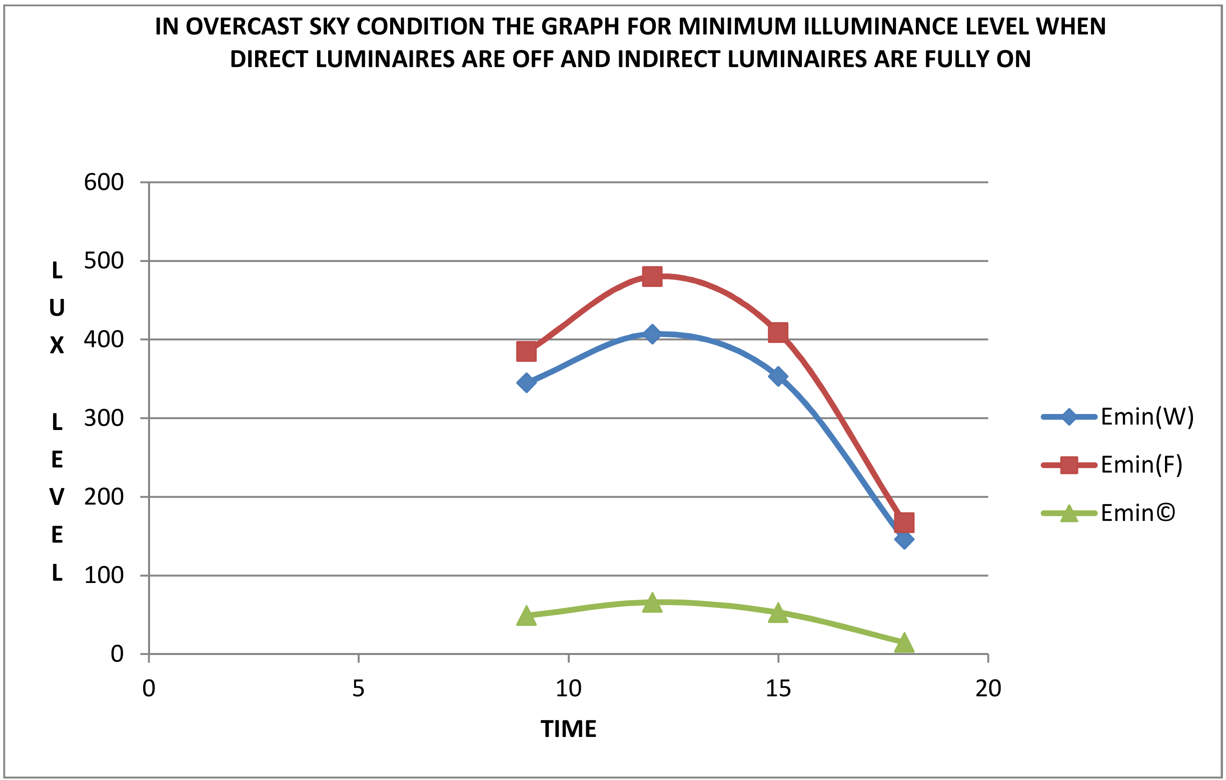


44.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1175	933	67
12	1585	1262	90
15	1255	997	71
18	325	249	21

Average illuminance level is just the average values or middle value of the maximum and minimum illuminace value,so the nature of this above graph is not extraordinary different than the next two graphs.

44.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

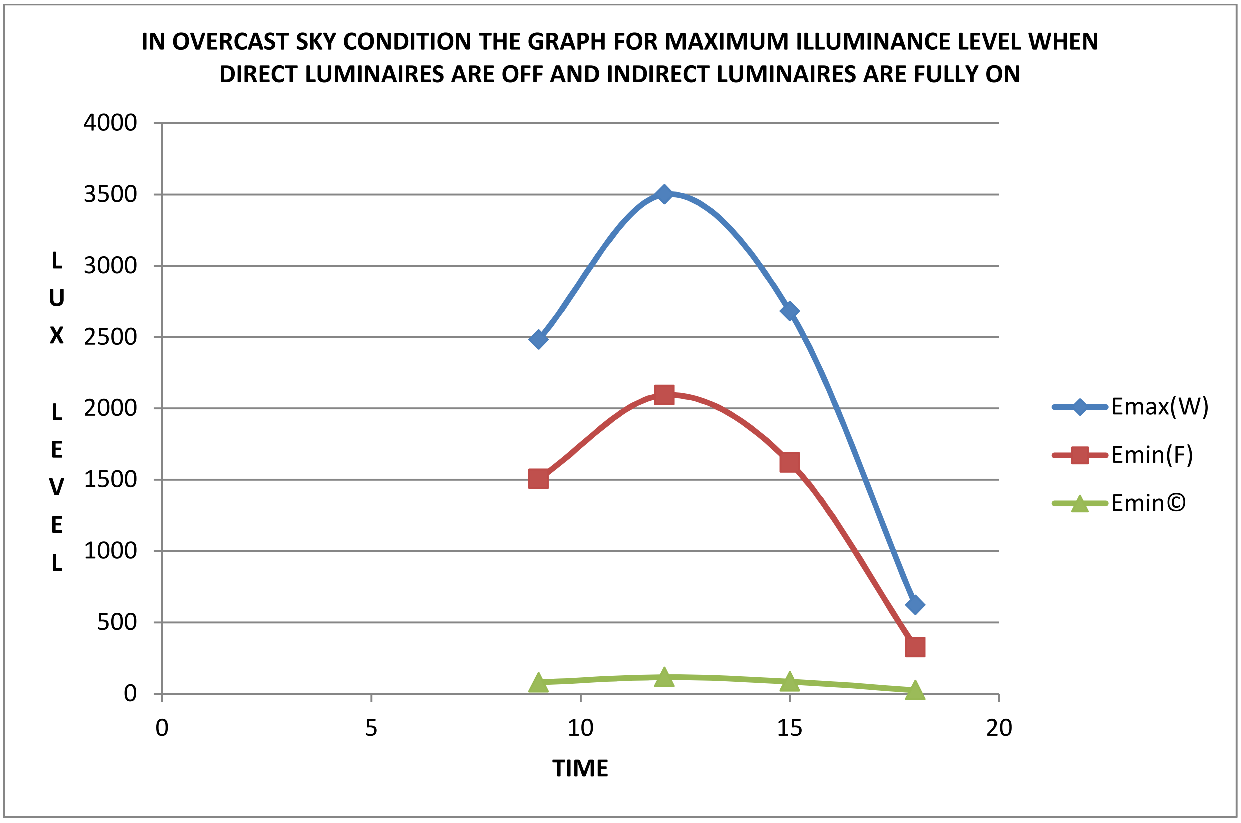


44.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	345	385	49
12	407	480	66
15	353	409	53
18	146	167	15

In overcast sky condition in minimum illuminance level when direct luminaires are off and indirect luminaires are fully on then it observed that the daylight goes at utmost values in the range of minimum lux level at 12PM and then with the sun sets it reduces it values but not less than the value which obtained at 9AM.As because the reflective factor the artificial lighting doesn't support the standard values.This nature is the common findings in these part.

44.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

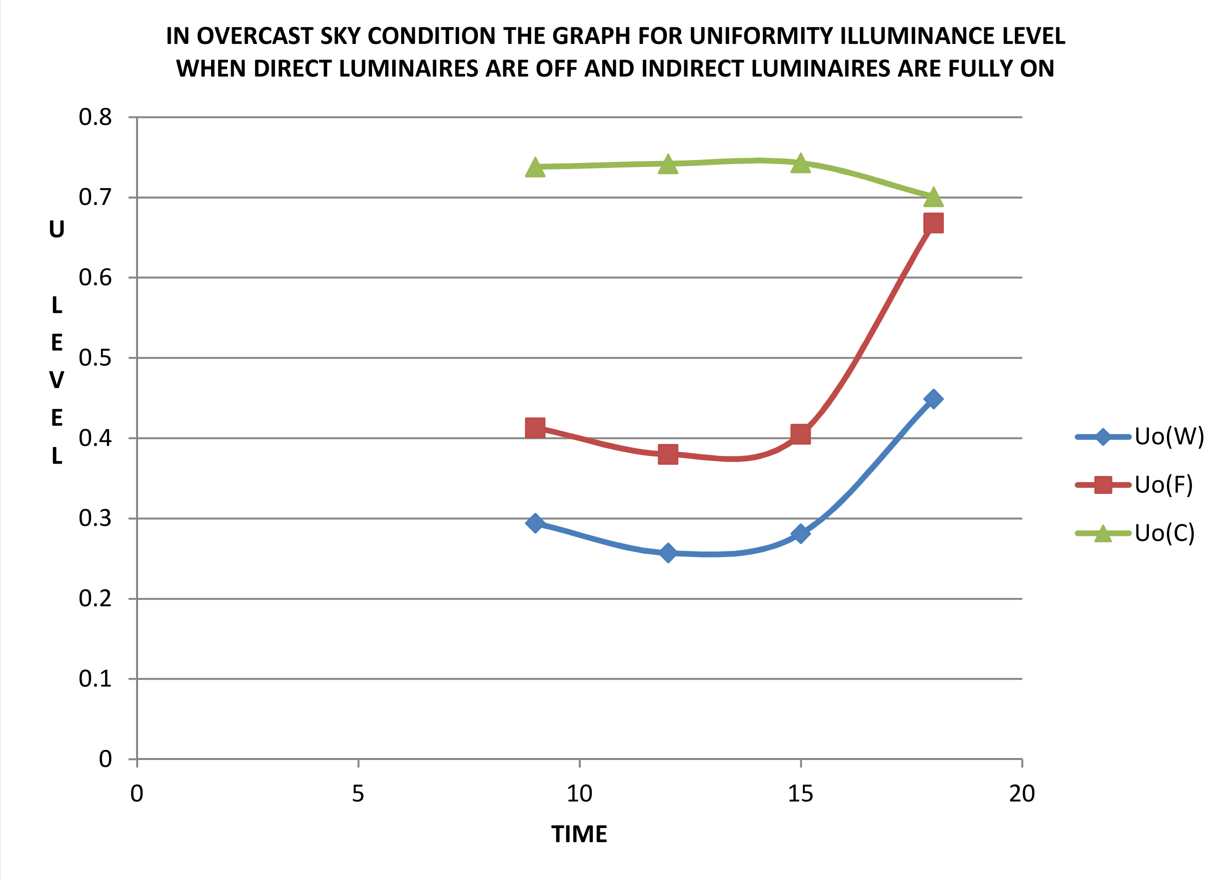


44.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	2483	1507	79
12	3500	2093	116
15	2681	1621	85
18	622	326	25

In overcast sky condition in maximum illuminance level when direct luminaires are off and indirect luminaires are fully on then it observed that the daylight goes at utmost values at 12PM and then with the sun sets it reduces it values but not less than the value which obtained at 9AM.As because the reflective factor the artificial lighting doesn't support the standard values.

44.1.4.GRAPH FOR UNIFORMITY LEVEL



44.1.4.CHART FOR UNIFORMITY LEVEL

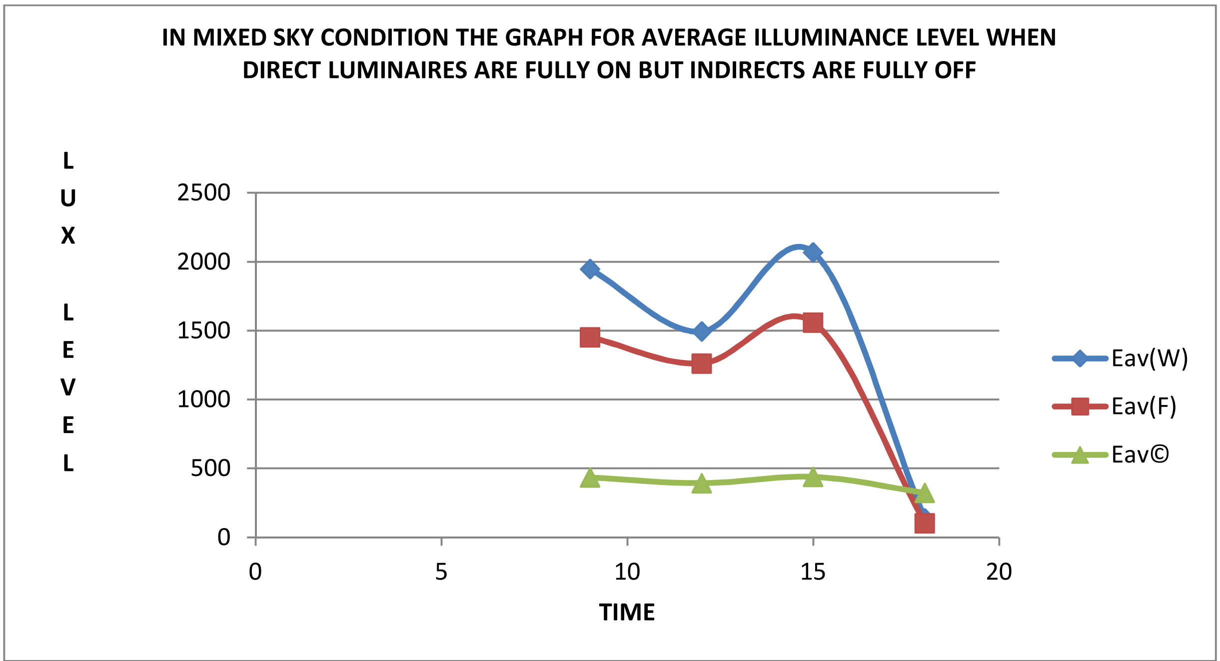
UNIFORMITY			
TIME	Uo(W)	Uo(F)	Uo(C)
9	0.294	0.413	0.738
12	0.257	0.38	0.742
15	0.281	0.405	0.743
18	0.449	0.668	0.701

From the tabulated data and graph here all the values are in the range of very low uniformity, except the ceiling, but in artificial lighting it doesn't follow or maintain the standard values.

CASE : 45

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05,AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE FULLY OFF

45.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

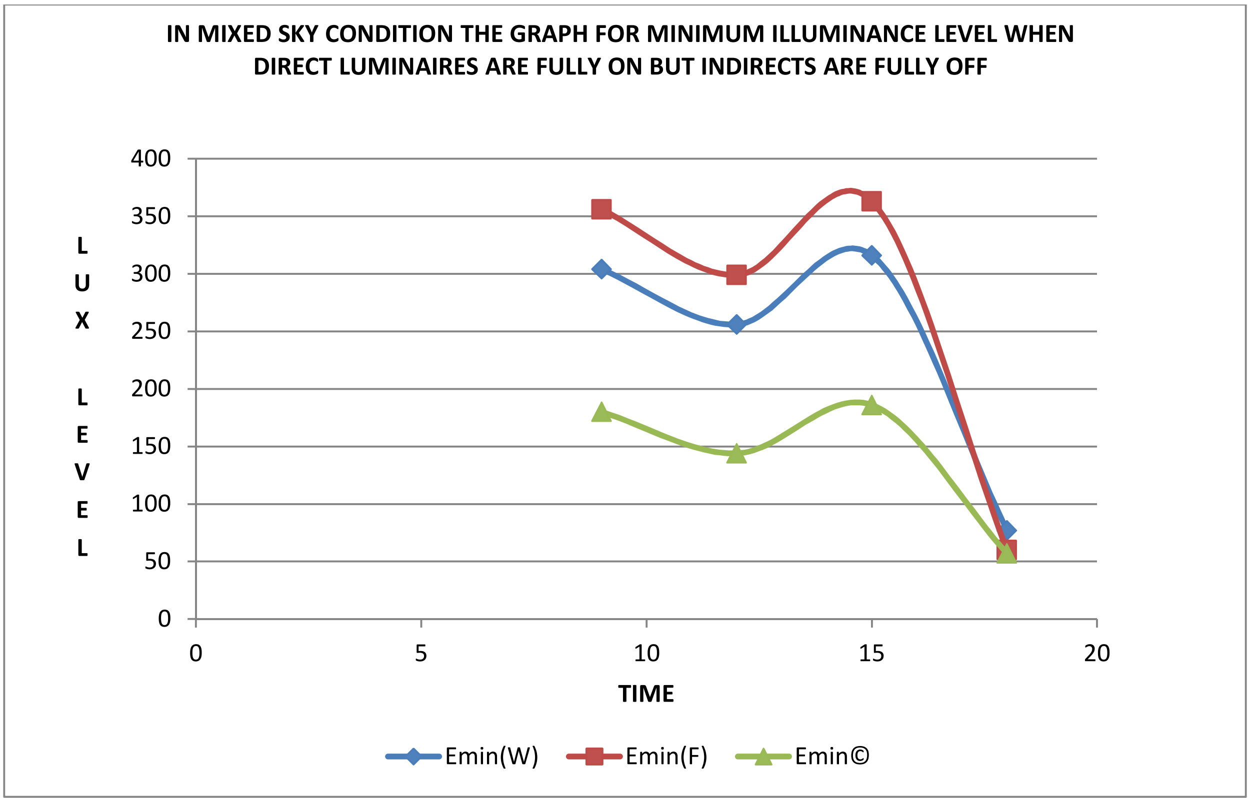


45.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	1946	1452	434
12	1493	1262	393
15	2067	1558	439
18	137	103	323

In mixed sky condition with daylight integration in the reflectivity ranges are in 65-35-05 for average illuminance level when direct luminaires are on and indirect luminaires are off,then at 9AM the average illuminance levels in three parameters are modarate but at 12 PM those datas are slightly less than the previous one for the angle of sun and the positions of windows but at 3PM all the values reached maximum range in average illuminance levels and put the graphs up.So,here we got a curvature nature for all three parameters but in artificial lights all three parameters are in the same regions.

45.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

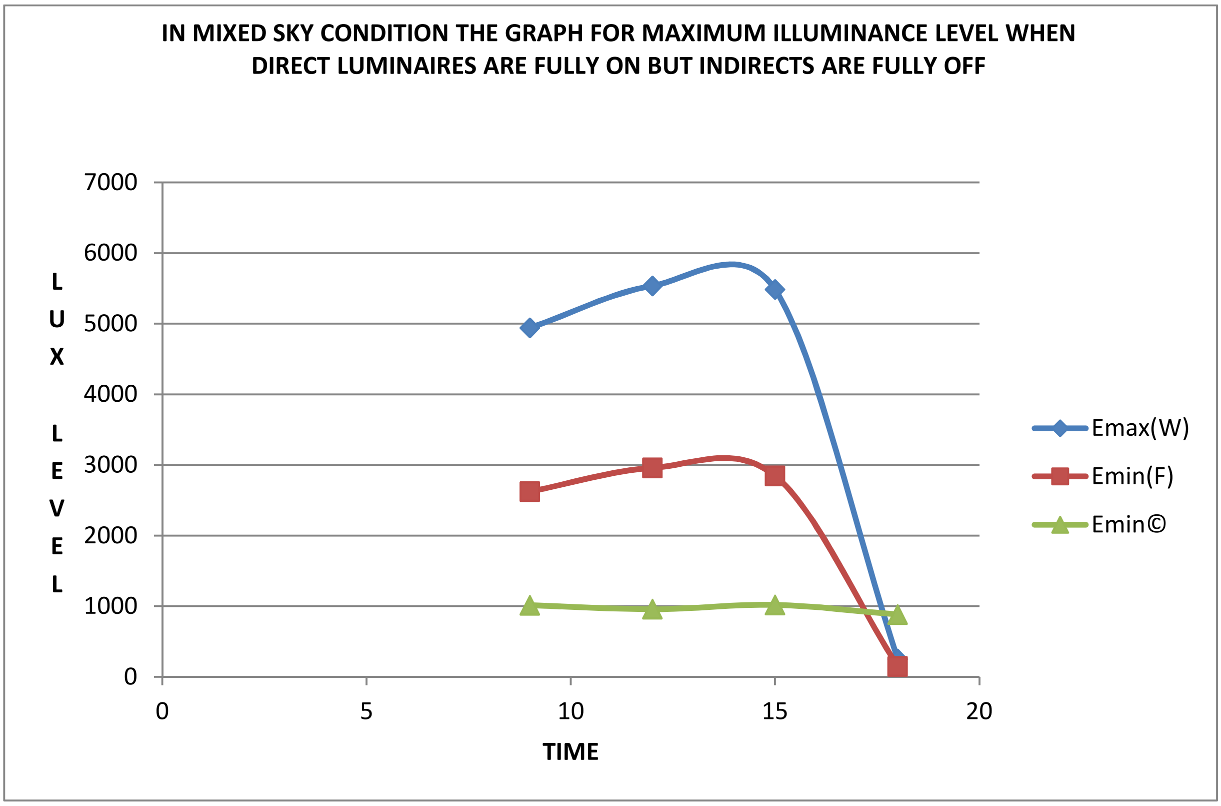


45.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	304	356	180
12	256	299	144
15	316	363	186
18	77	60	57

Here all of three parameters follow the same nature of minimum lux level, although the nature are same but the values are so much different ,mainly in artificial light it doesn't follow the standard values and the reason behind this is dimming and reflection factor. All the values are intersect in a same point on the graph.

45.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

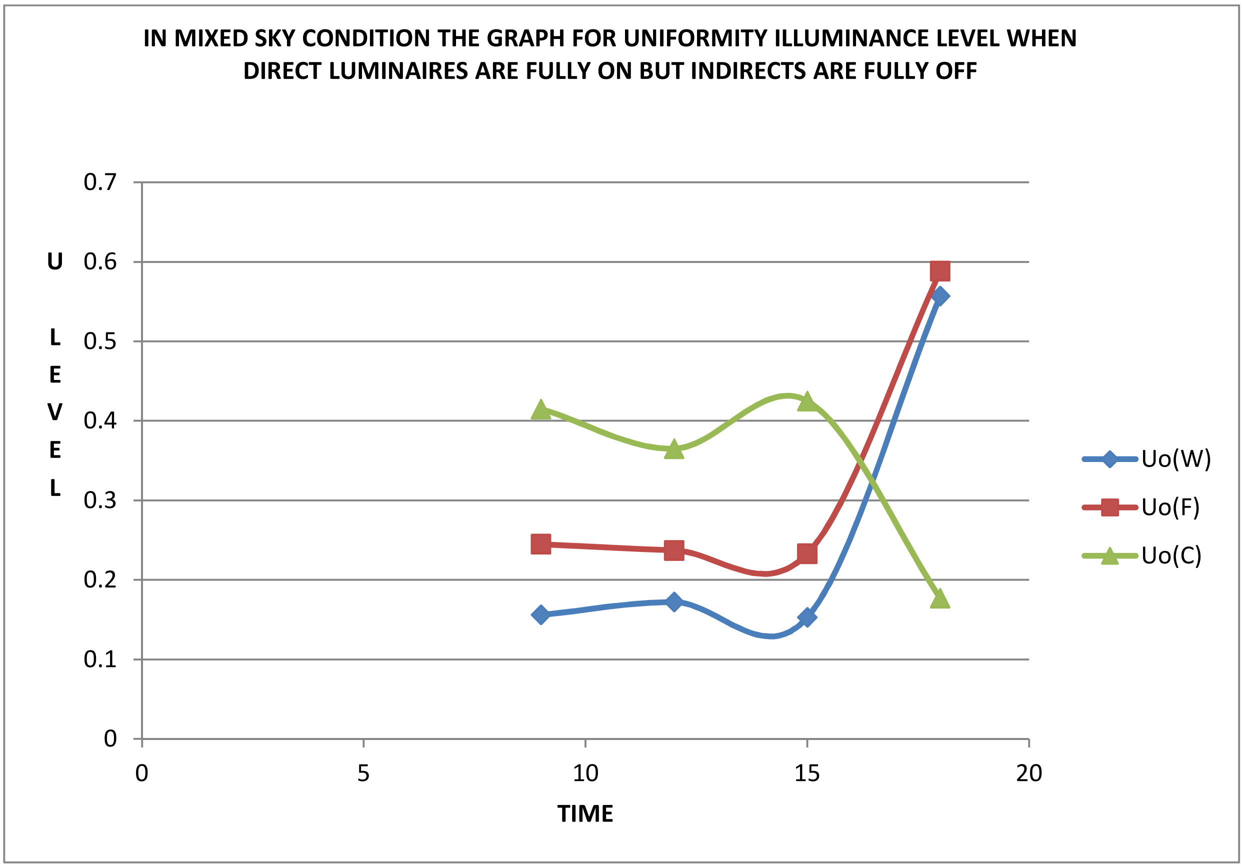


45.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	4940	2623	1015
12	5535	2959	957
15	5485	2845	1018
18	253	149	882

When direct luminaires are fully on but indirect luminaires are off, then in this condition where reflectivities are 65-35-05 takes place and the maximum level of illuminance lies slightly above and a small less than the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low comparatively,so the graph looks like the above one .

<u>45.1.4.GRAPH FOR UNIFORMITY LEVEL</u>



<u>45.1.4.GRAPH FOR UNIFORMITY LEVEL</u>

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.156	0.245	0.415
12	0.172	0.237	0.365
15	0.153	0.233	0.425
18	0.557	0.5883	0.177

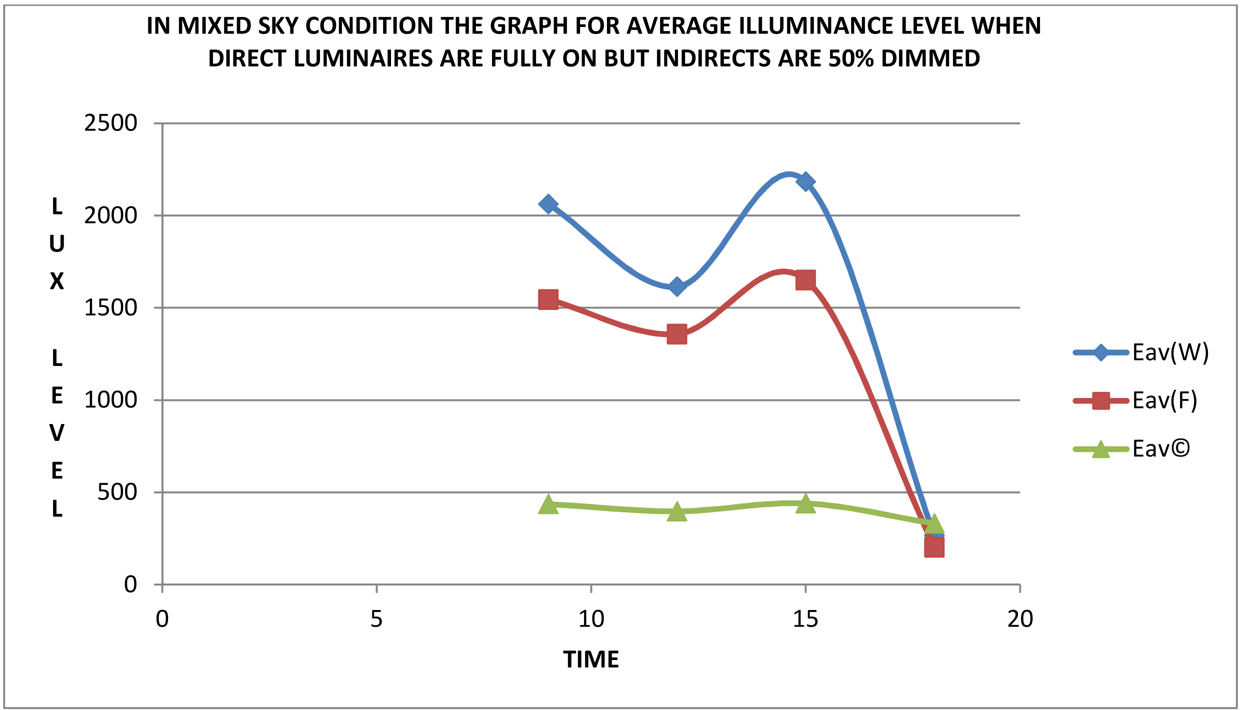
As we all know,in daylight there are less amount of uniformity takes place because of the uneven daylight distribution and this theory reflects on the tabulated datas as well as on the graphs, for this in daylight conditions the uniformity of workplane and floor are very poor .

We also know that the standard reflection factor is 80-50-20 and here we take 65-35-05 so when the total scenario is in artificial lighting then the uniformity is not in the standard defined range.

CASE : 46

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE 50% DIMMED

46.1.1.GRAPH AVERAGE ILLUMINANCE FOR LEVEL

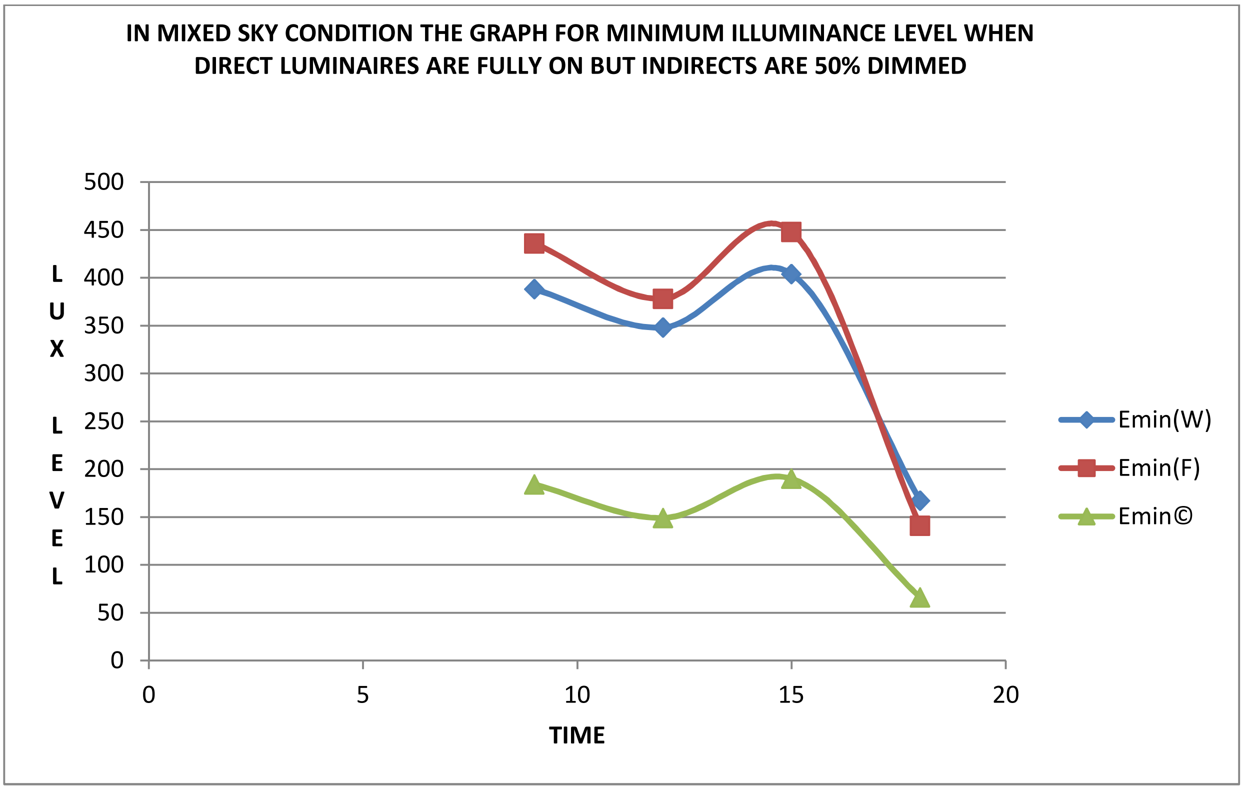


46.1.1.CHART AVERAGE ILLUMINANCE FOR LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2062	1545	436
12	1614	1358	397
15	2183	1650	440
18	267	203	331

In the above case, with daylight integration the average illuminance level utmost at 3PM because of the window position and reflectivity factor.In this graph there is a huge and sharp fall down occurs because when daylight goes off due to the reflection factor and dimming of luminaires all the average lux level came down in the near of standard values.

46.1.2.GRAPH MINIMUM ILLUMINANCE FOR LEVEL

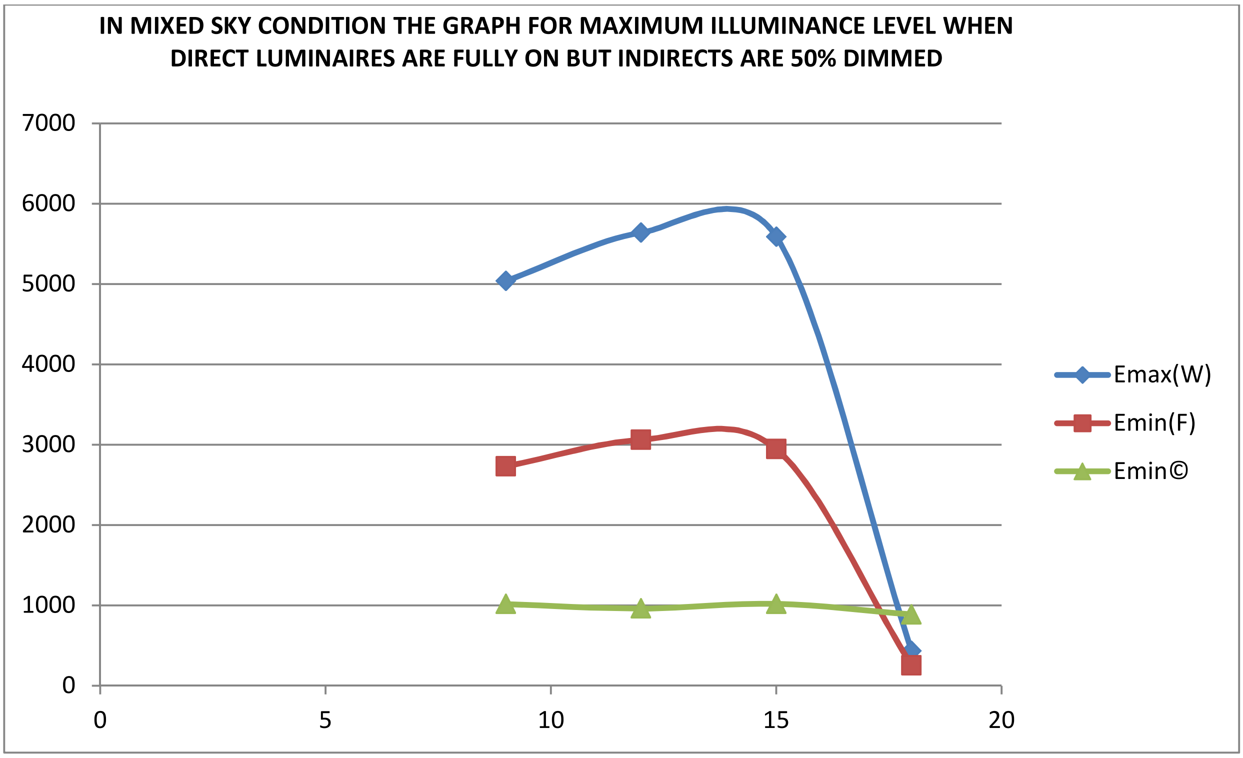


46.1.2.CHART MINIMUM ILLUMINANCE FOR LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	388	436	184
12	348	378	149
15	404	448	190
18	167	141	66

Here all of three parameters follow the same nature of maximum lux level, although the nature are same but the values are so much different ,mainly in artificial light it doesn't follow the standard values and the reason behind this is dimming and reflection factor.

46.1.3.GRAPH MAXIMUM ILLUMINANCE FOR LEVEL

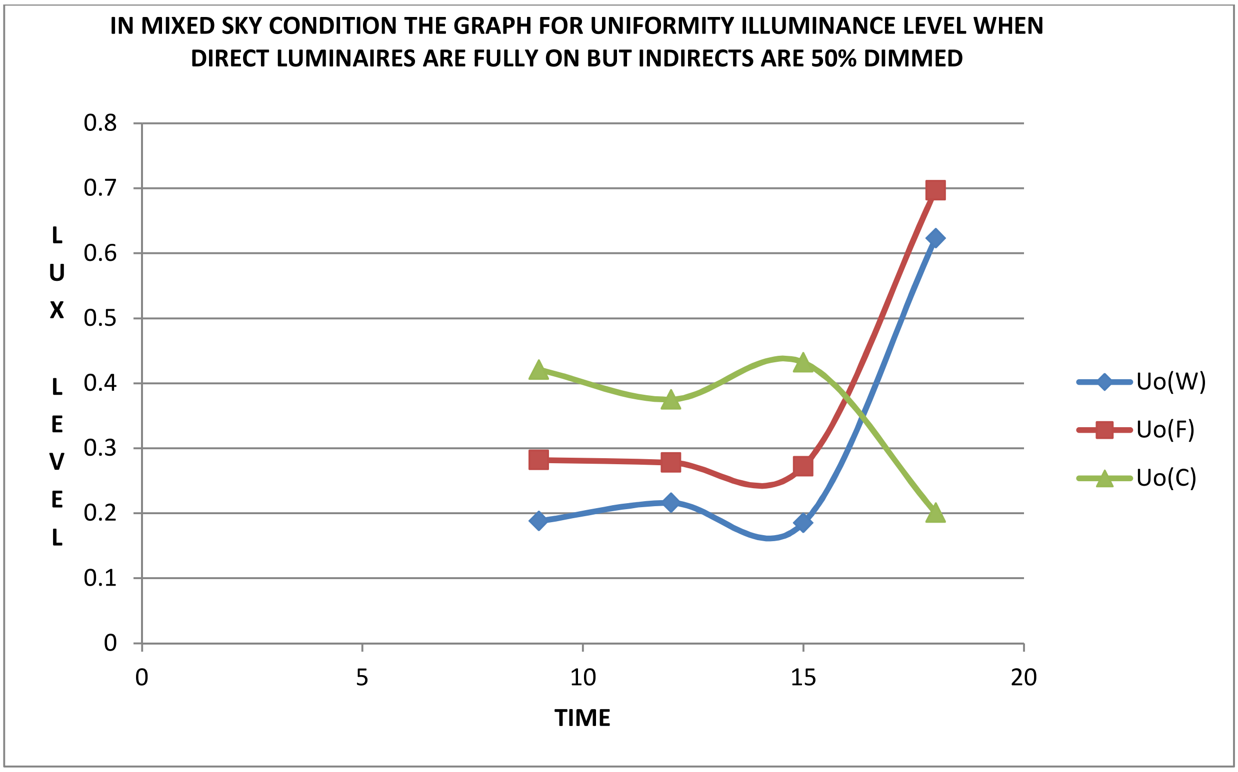


46.1.3.CHART MAXIMUM ILLUMINANCE FOR LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	5040	2731	1017
12	5639	3062	962
15	5589	2946	1020
18	435	255	889

When direct luminaires are fully on but indirect luminaires are 50% dimmed,then this condition where reflectivities are 65-35-05 takes place and the maximum level of illuminance lies slightly above and a small less than the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low so the graph looks like the above one but these theory is only accepted for workplane and floor region and in other part the values of ceilings are much more lower than the previous two parameters but they are beyond there standard values.

46.1.4.GRAPH FOR UNIFORMITY LEVEL



46.1.4.CHART FOR UNIFORMITY LEVEL

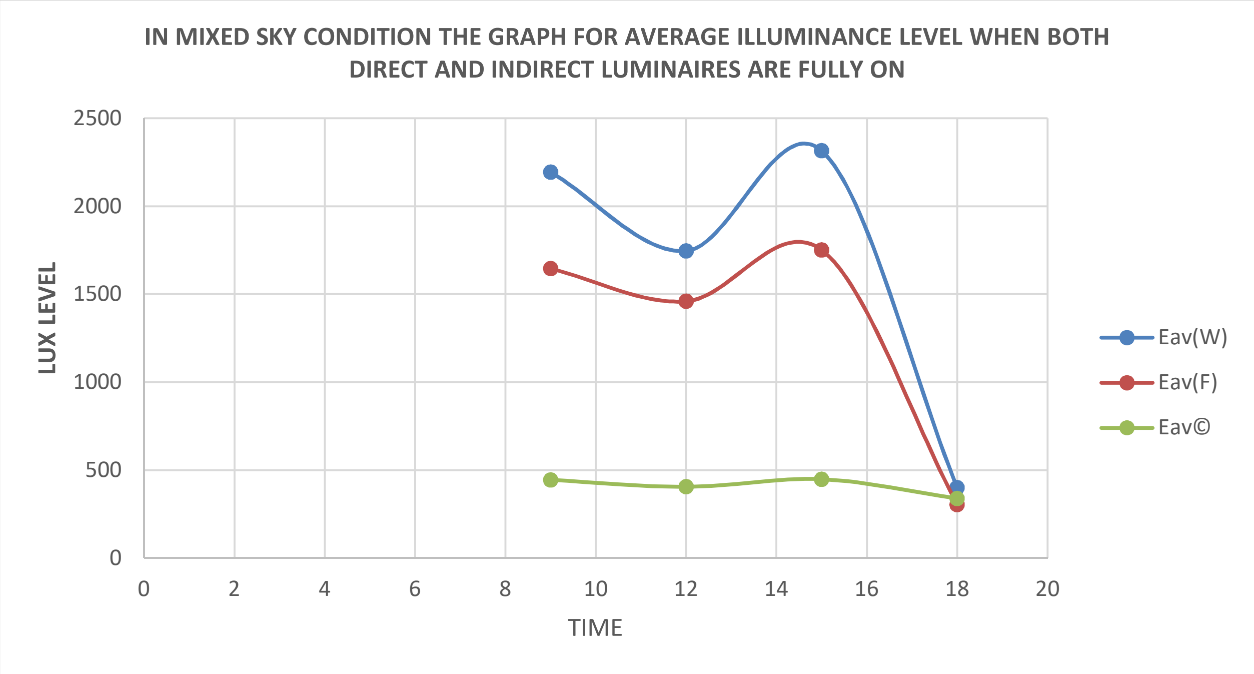
UNIFORMITY			
TIME	$U_{o(W)}$	$U_{o(F)}$	$U_{o(C)}$
9	0.188	0.282	0.421
12	0.216	0.278	0.375
15	0.185	0.272	0.432
18	0.623	0.697	0.201

When direct luminaires are fully on it means total lumen output is downward and as because the indirect luminaires are 50% dimmed so half of the lumen output goes upward from the luminaires, with daylight integration uniformity is poor for all three parameters but in artificial lighting it enhanced. In this case in artificial lighting the uniformity is not upto the standard because of the luminaries setting and reflectivity.

CASE : 47

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE FULLY ON

47.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

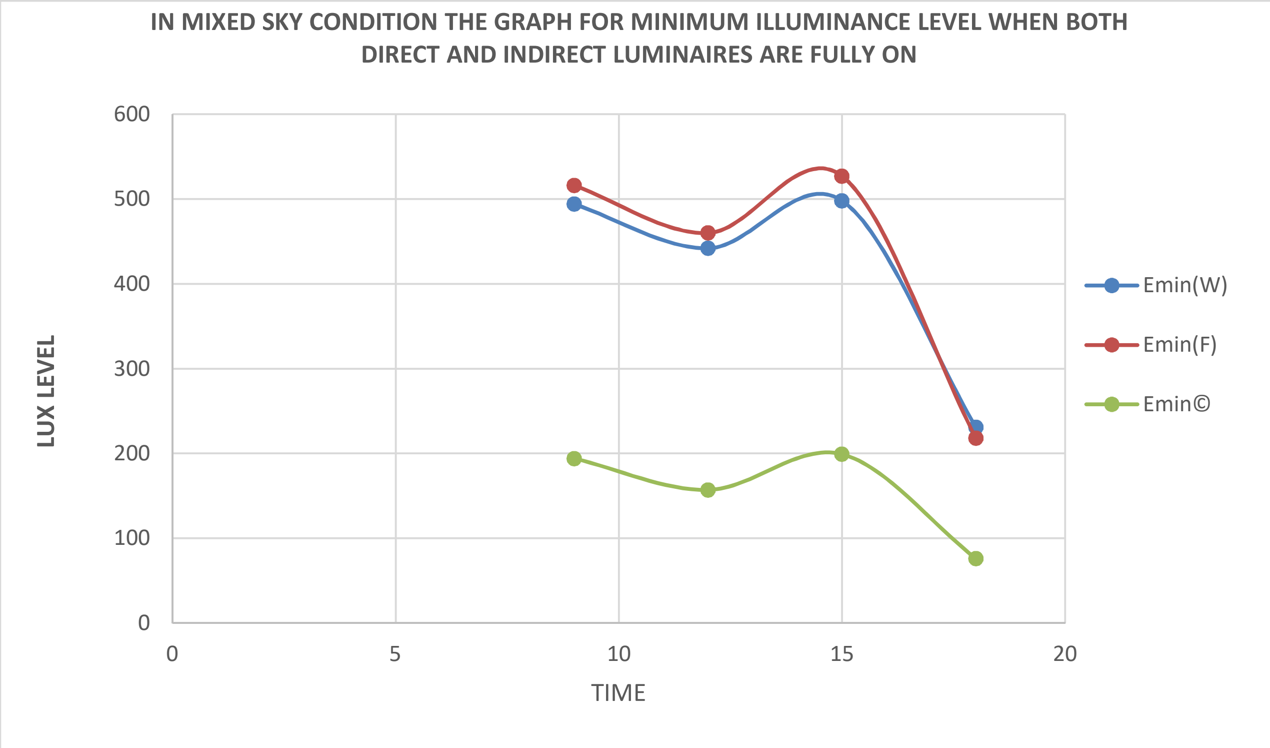


47.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2194	1645	444
12	1746	1459	405
15	2315	1751	448
18	400	304	339

When both the luminaires are on and the sky condition is mixed then the average iluminance level high due to daylight integration but it goes at it upmost values when 3PM,for this reason the nature of graphs are so different here.

47.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

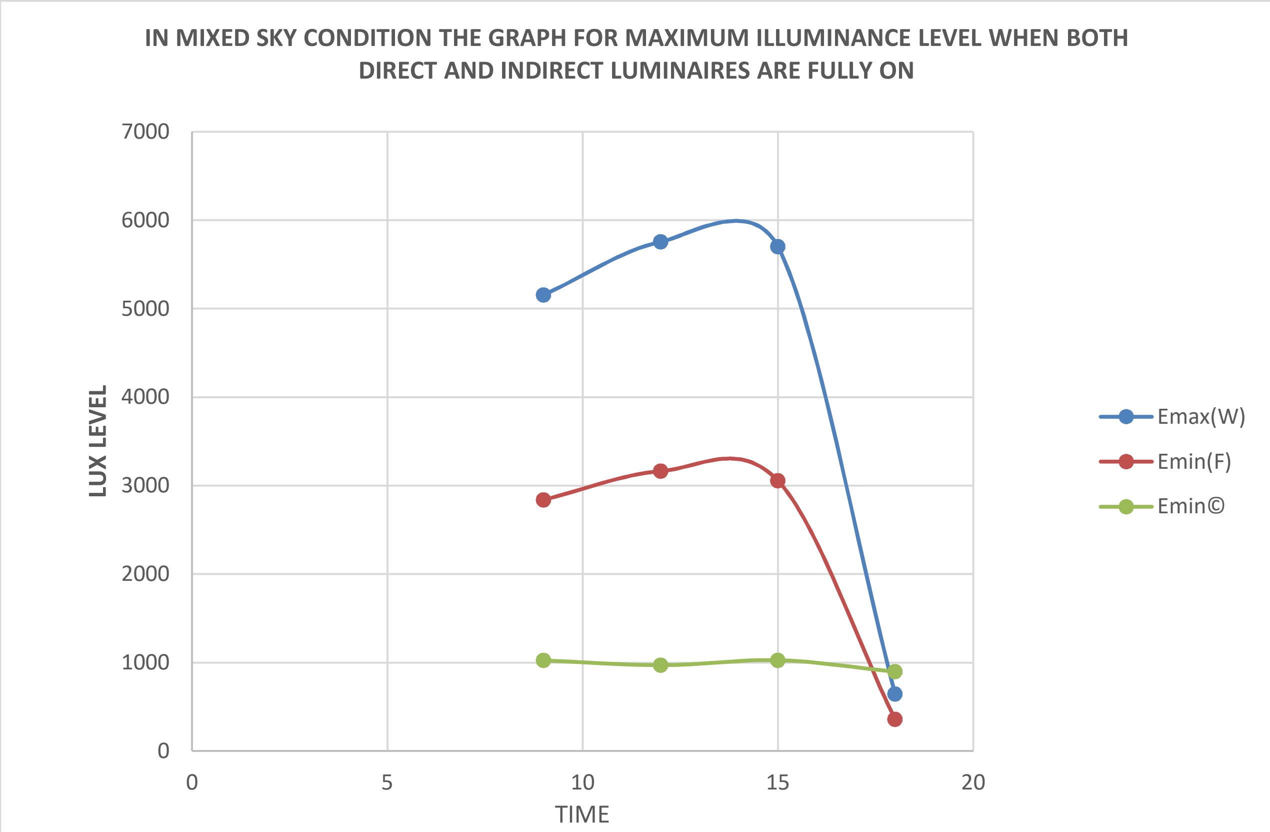


47.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	494	516	194
12	442	460	157
15	498	527	199
18	231	218	76

In mixed sky condition when the reflectivities lies in the range of 65-35-05,then for minimum illuminance level when both the luminaires are fully on,we obtained these three parameters and they all maintained there same nature,and there are slightly overlapping also occurred for workplane and floor,but ceiling curve is totally different from above two parameters.

47.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

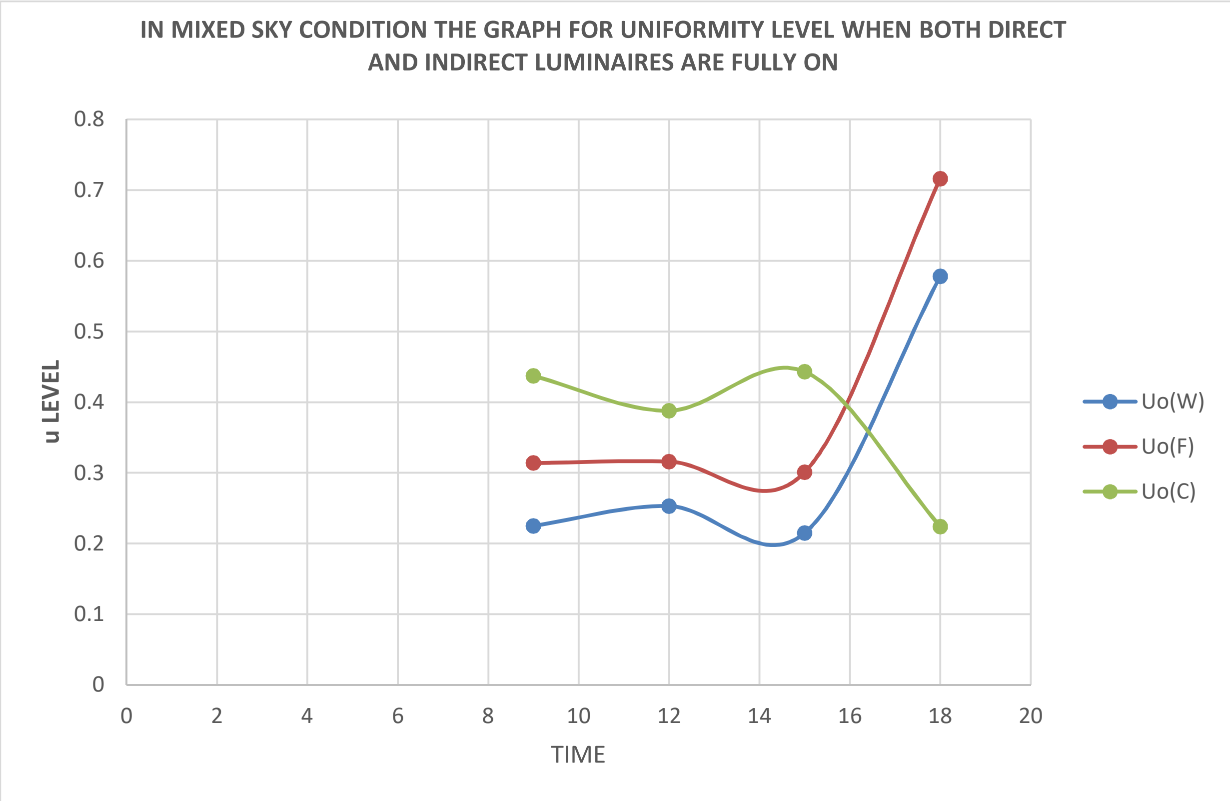


47.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	5155	2840	1026
12	5754	3165	972
15	5700	3056	1028
18	648	362	899

When both direct and indirect luminaires are fully on,then this condition where reflectivities are 65-35-05 takes place and the maximum level of illuminance lies in the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low so the graph looks like the above one but these theory is only accepted for workplane and floor region and in other part the values of ceilings are much more lower than the previous two parameters but they are beyond there standard values.

47.1.4.GRAPH FOR UNIFORMITY LEVEL



47.1.4.CHART FOR UNIFORMITY LEVEL

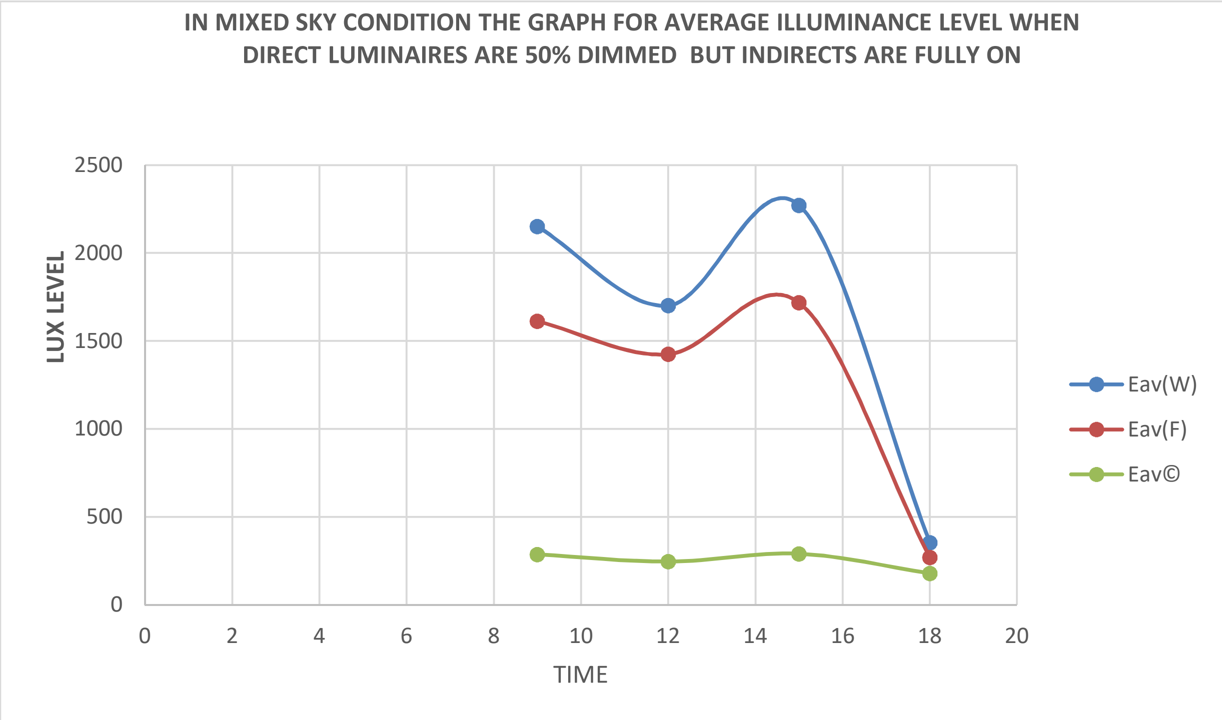
UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.225	0.314	0.437
12	0.253	0.316	0.388
15	0.215	0.301	0.443
18	0.578	0.716	0.224

As we all know,in daylight there are less amount of uniformity takes place because of the uneven daylight distribution and this theory reflects on the tabulated datas as well as on the graphs, for this in daylight conditions the uniformity of workplane and floor are very poor but in artificial light those values enriched and goes upto the standard values. But in the ceiling uniformity was good in daylight because of the position of it but in artificial lights this parameter reduces so the above graph will produced. When both direct and indirect luminaires are fully on but the sky condition is mixed then the above phenomenon occurred.

CASE : 48

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m LEVEL WHEN DIRECT LUMINAIRES ARE 50% DIMMED BUT INDIRECTS ARE FULLY ON

48.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

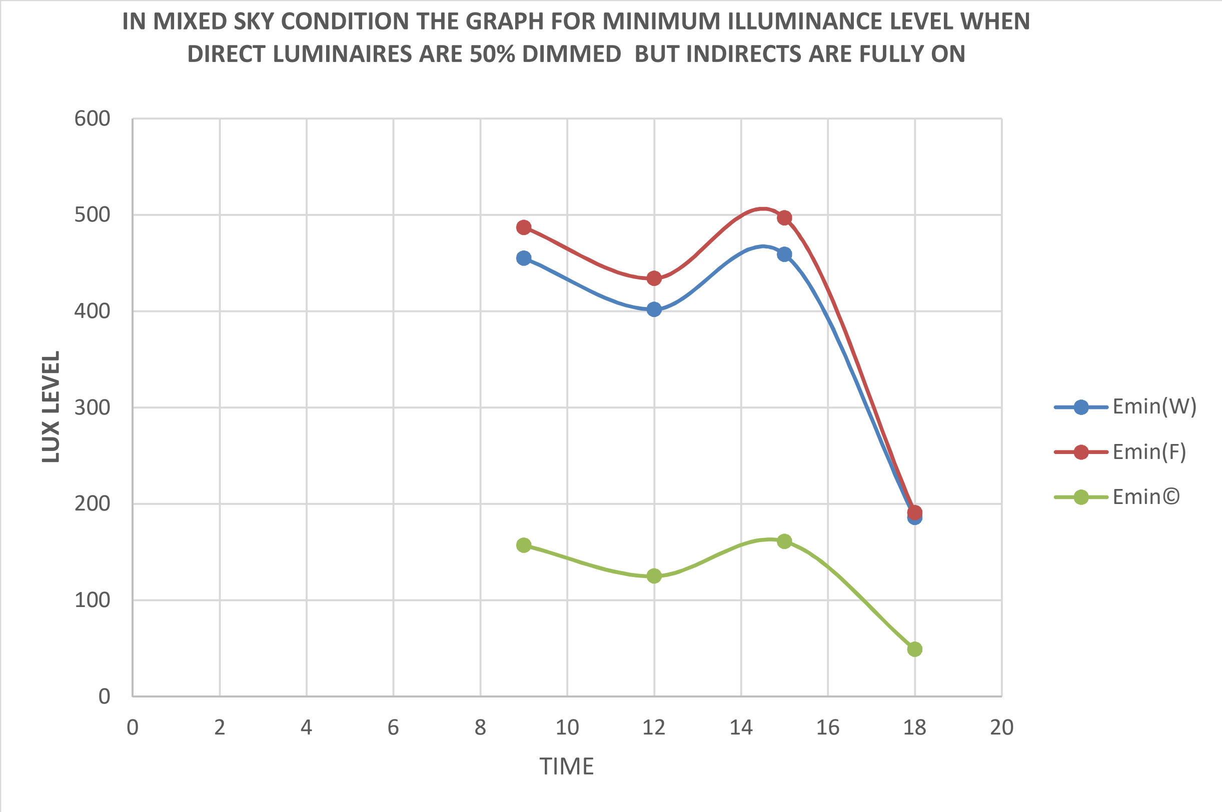


48.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2150	1612	286
12	1701	1424	246
15	2271	1717	290
18	354	269	179

When direct luminaires are 50% dimmed but indirects are fully on means,they are not delivered the full lumen output ,mainly the direct lumainres delivered half of it lumen output but indirect luminaires are delivered 100% lumen output,then the average illuminance level also reduced for the reason and in no daylight condition average illuminance level on workplane,floor and ceiling are shows near values.But with daylight integration all the values are highly increased so the above graph generated.

48.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

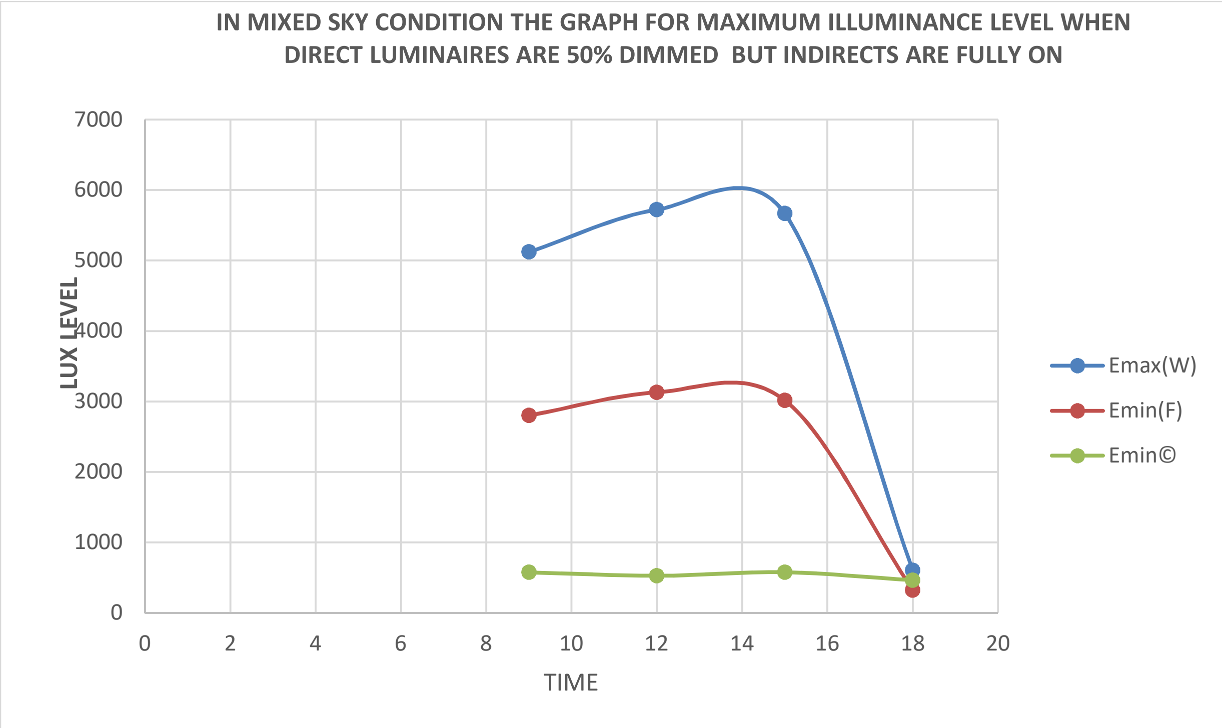


48.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	455	487	157
12	402	434	125
15	459	497	161
18	186	191	49

In mixed sky condition when the reflectivities lies in the range of 65-35-05,then for minimum illuminance level when direct luminaires are 50% dimmed but indirects are fully on we obtained these three parameters and they all maintained there same nature,and there are slightly overlapping also occurred for workplane and floor,but ceiling curve is totally different from above two parameters.

48.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

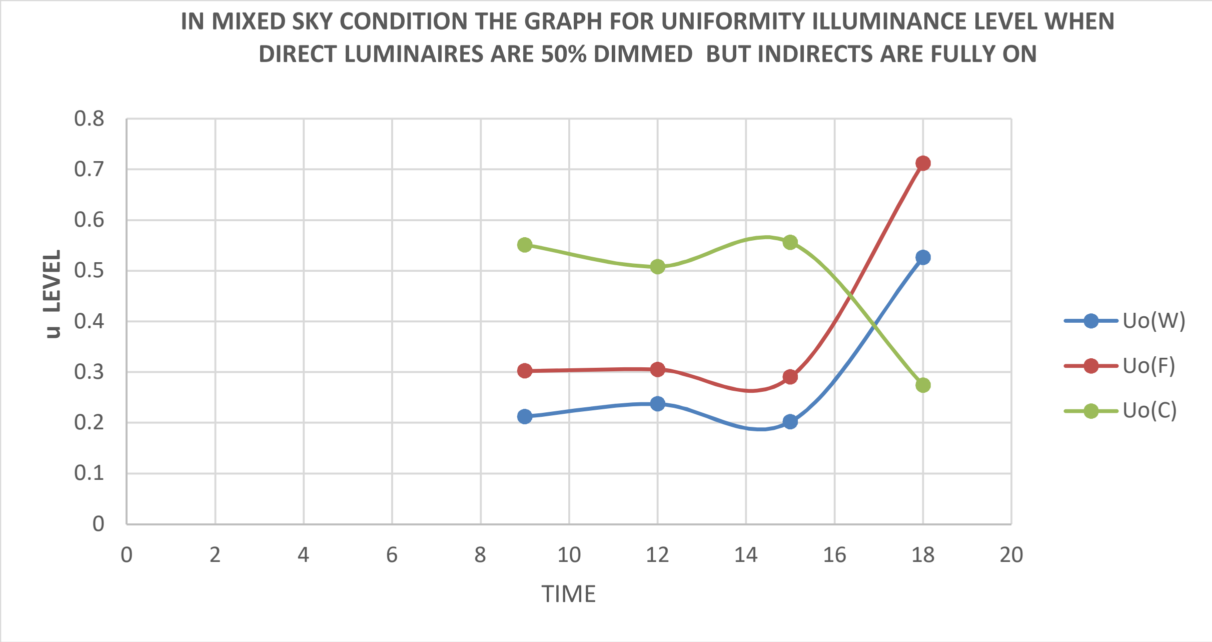


48.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	5121	2800	574
12	5720	3129	527
15	5667	3016	576
18	604	323	463

When direct luminaires are 50% dimmed but indirects are fully on in this condition where reflectivities are 65-35-05 then the maximum level of illuminance lies in the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low so the graph looks like the above one but these theory is only accepted for workplane and floor region but the illuminance range in ceiling remains in a even condition means,it doesn’t varies much neither in daylight nor in artificial light.And for all these above phenomenon three parameters are intersect with each other at the end.

48.1.4.GRAPH FOR UNIFORMITY LEVEL



48.1.4.CHART FOR UNIFORMITY LEVEL

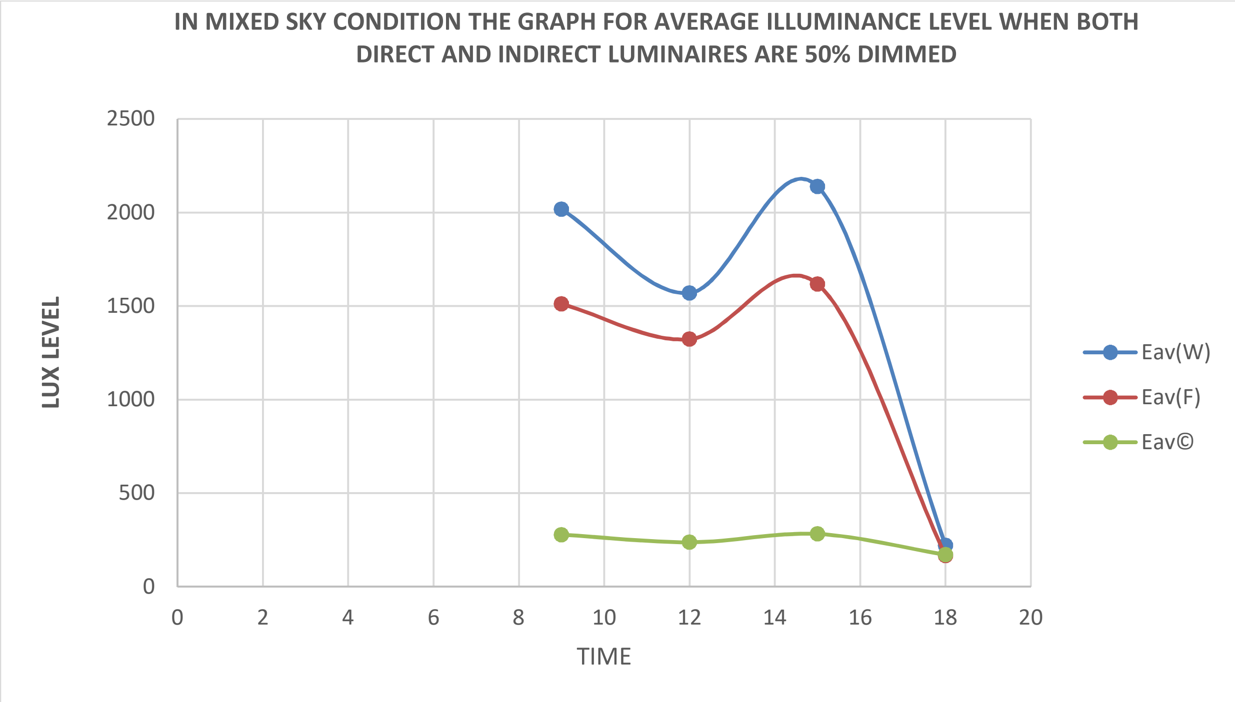
UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.212	0.302	0.551
12	0.237	0.305	0.508
15	0.202	0.29	0.556
18	0.526	0.712	0.274

As we all know,in daylight there are less amount of uniformity takes place because of the uneven daylight distribution and this theory reflects on the tabulated datas as well as on the graphs, for this in daylight conditions the uniformity of workplane and floor are very poor but in artificial light those values enriched and goes upto the standard values. But in the ceiling uniformity was good in daylight because of the position of it but in artificial lights this parameter reduces so the above graph will produced.

CASE : 49

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE 50% DIMMED

49.1.1.GRAPH FOR AVERAGE ILLUMINANCE LEVEL

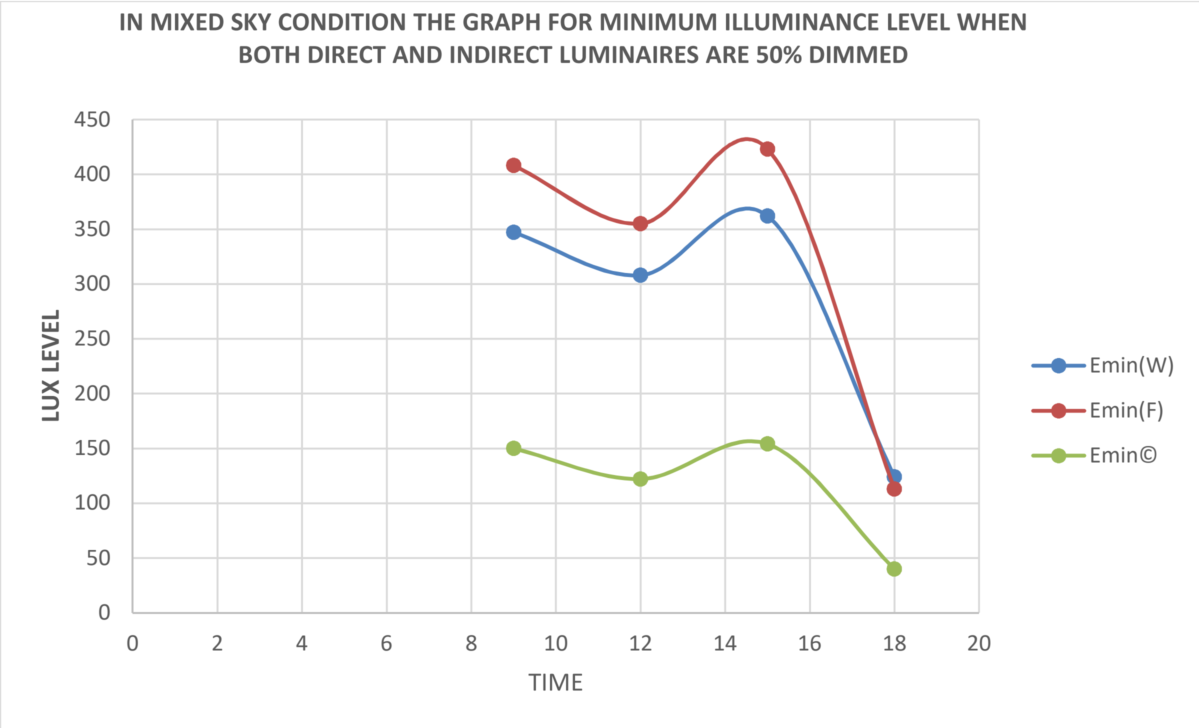


49.1.1.CHART FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2018	1511	278
12	1570	1323	238
15	2139	1617	282
18	221	167	171

When both direct and indirect luminaires are 50% dimmed means they are not delivered the full lumen output then the average illuminance level also reduced for the reason and in no daylight condition average illuminance level on workplane,floor and ceiling are shows near values.But with daylight integration all the values are highly increased so the above graph generated.

49.1.2..CHART FOR MINIMUM ILLUMINANCE LEVEL

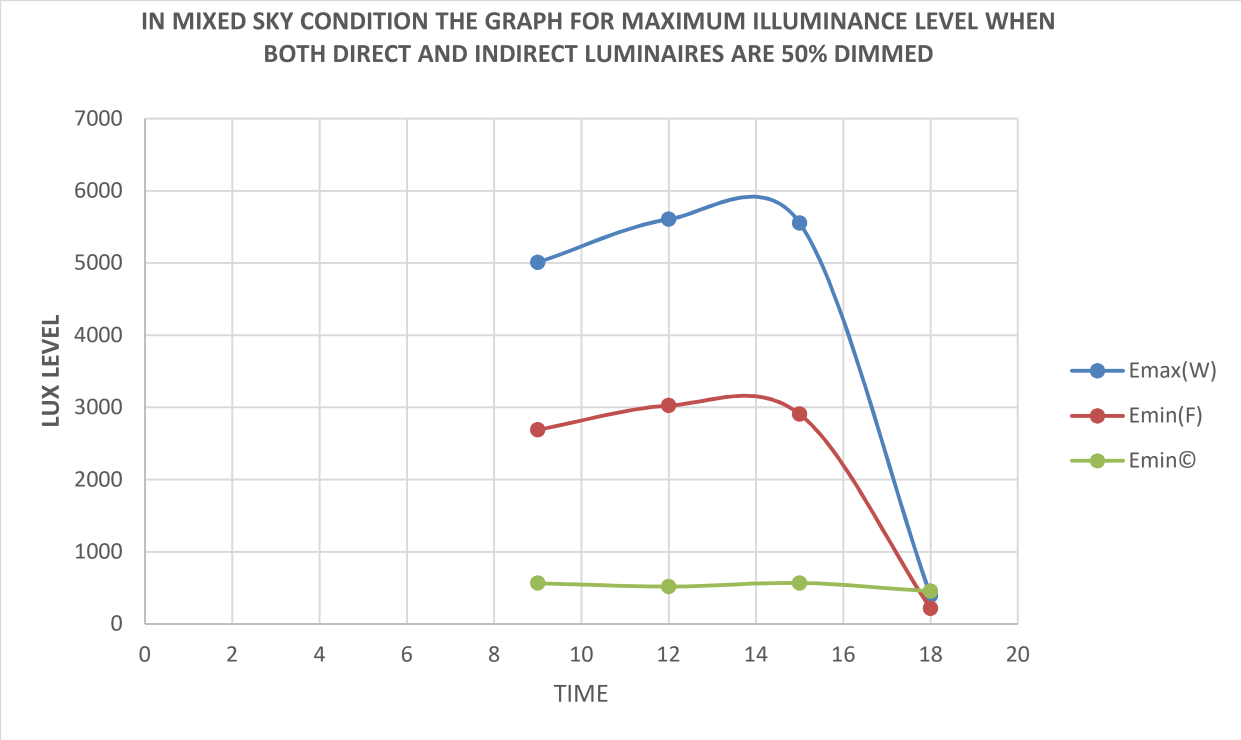


49.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	347	408	150
12	308	355	122
15	362	423	154
18	124	113	40

In mixed sky condition when the reflectivities lies in the range of 65-35-05,then for minimum illuminance level when both direct and indirect luminaires are 50% dimmed we obtained these three parameters and they all maintained there same nature,and there are slightly overlapping also occurred for workplane and floor.

49.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

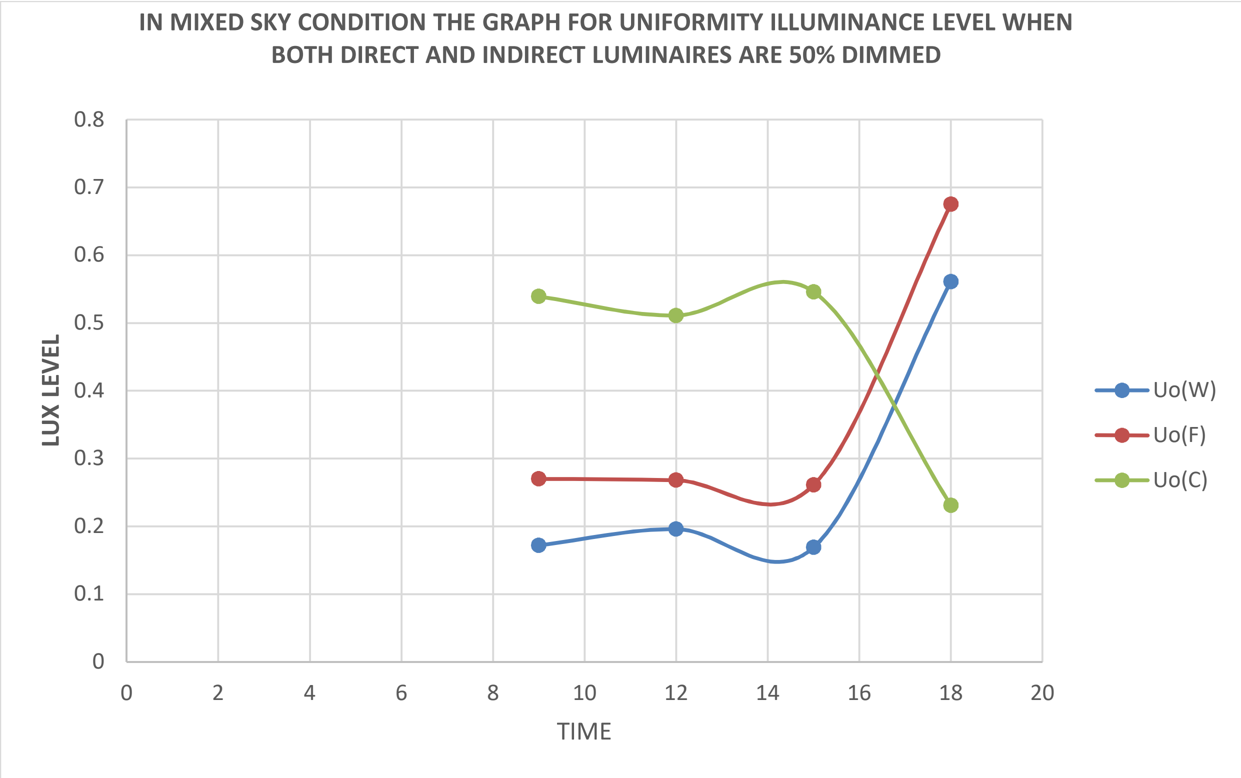


49.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	5009	2689	565
12	5604	3025	518
15	5555	2906	568
18	391	215	453

When both direct and indirect luminaires are 50% dimmed in a condition where reflectivities are 65-35-05 then the maximum level of illuminance lies in the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low so the graph looks like the above one but these theory is only accepted for workplane and floor region but the illuminance range in ceiling remains in a even condition means,it doesn’t varies much neither in daylight nor in artificial light.And for all these above phenomenon three parameters are intersect with each other at the end.

49.1.4.GRAPH FOR UNIFORMITY LEVEL



49.1.4.CHART FOR UNIFORMITY LEVEL

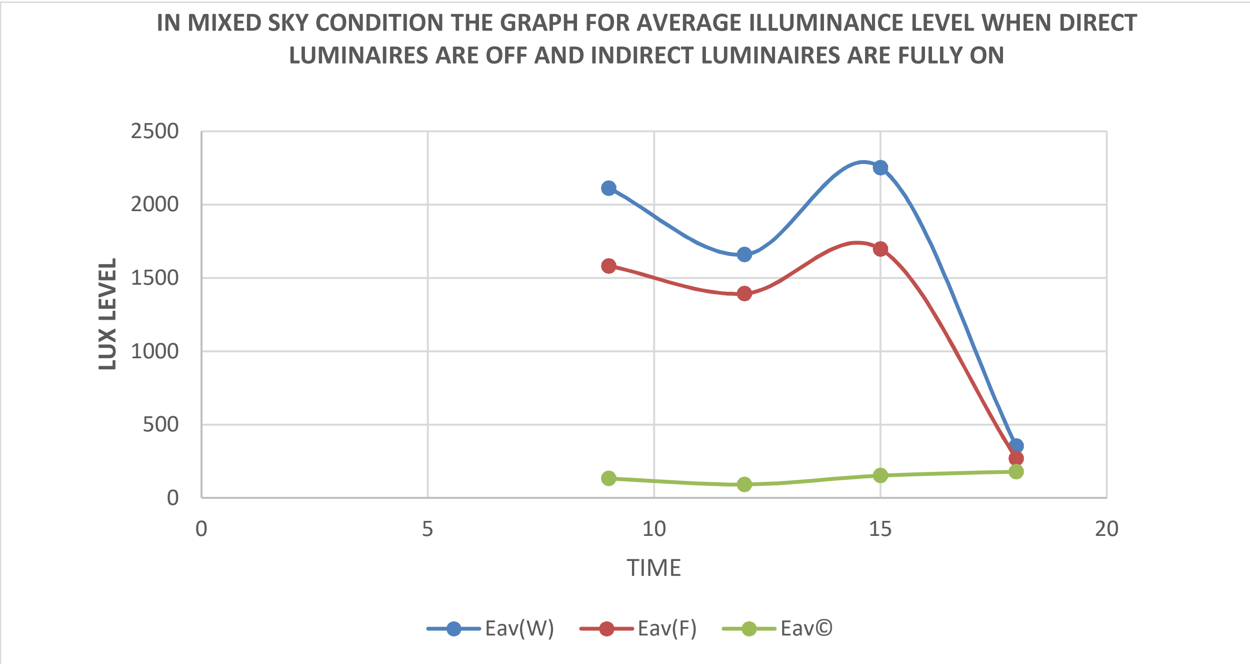
UNIFORMITY			
TIME	**U_0(W)**	**U_0(F)**	**U_0(C)**
9	0.172	0.27	0.539
12	0.196	0.268	0.511
15	0.169	0.261	0.546
18	0.561	0.675	0.231

In daylight there are less amount of uniformity takes place because of the uneven daylight distribution and this theory reflects on the tabulated datas as well as on the graphs, for this in daylight conditions the uniformity of workplane and floor are very poor but in artificial light those values enriched and goes upto the standard values. But in the ceiling uniformity was good in daylight because of the position of it but in artificial lights this parameter reduces so the above graph will produced.

CASE : 50

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 65-35-05, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

50.1.1..GRAPH FOR AVERAGE ILLUMINANCE LEVEL

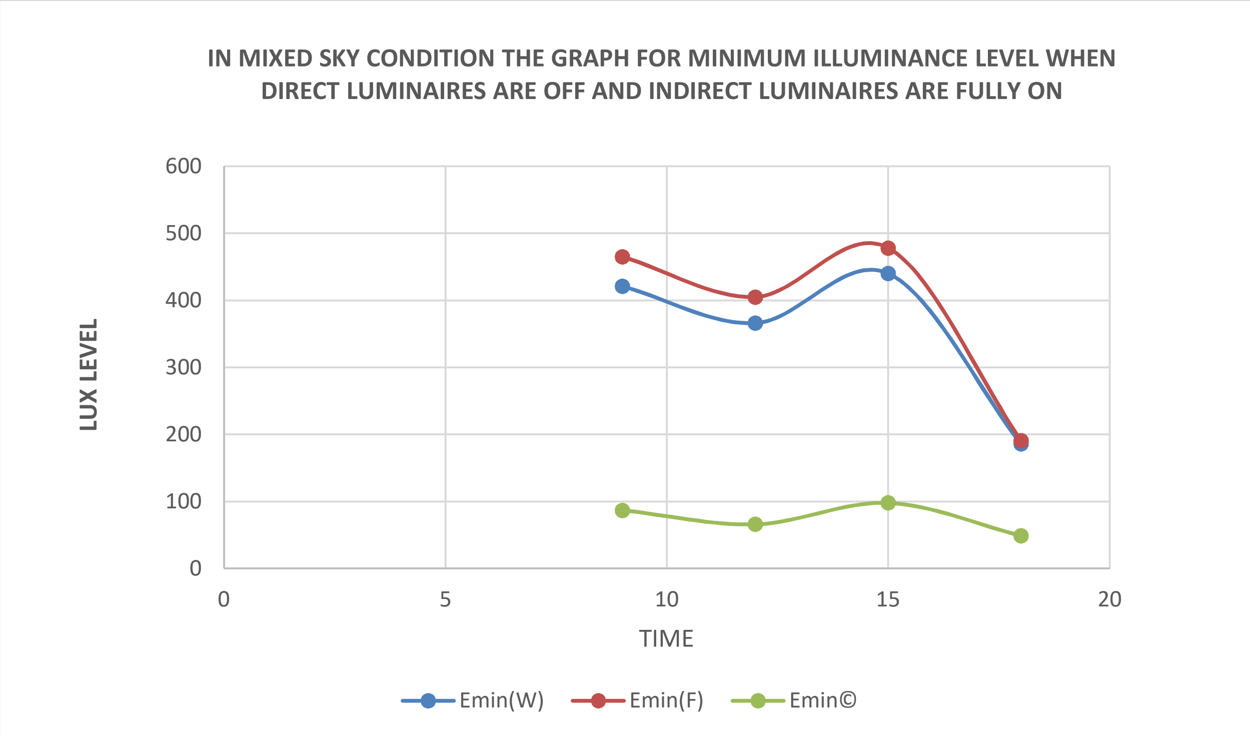


50.1.1..GRAPH FOR AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	Eav(W)	Eav(F)	Eav©
9	2111	1582	133
12	1659	1393	92
15	2252	1697	153
18	354	269	179

In mixed sky condition with daylight integration in the reflectivity ranges are in 65-35-05 for average illuminance level when direct luminaires are off and indirect luminaires are fully on then at 9AM the average illuminance levels in three parameters are optimum but at 12 PM those datas are slightly less than the previous one for the angle of sun and the positions of windows but at 3PM all the values reached maximum range in average illuminance levels and put the graphs up.So,here we got a curvature nature for all three parameters but in artificial lights all three parameters are in the same regions.

50.1.2.GRAPH FOR MINIMUM ILLUMINANCE LEVEL

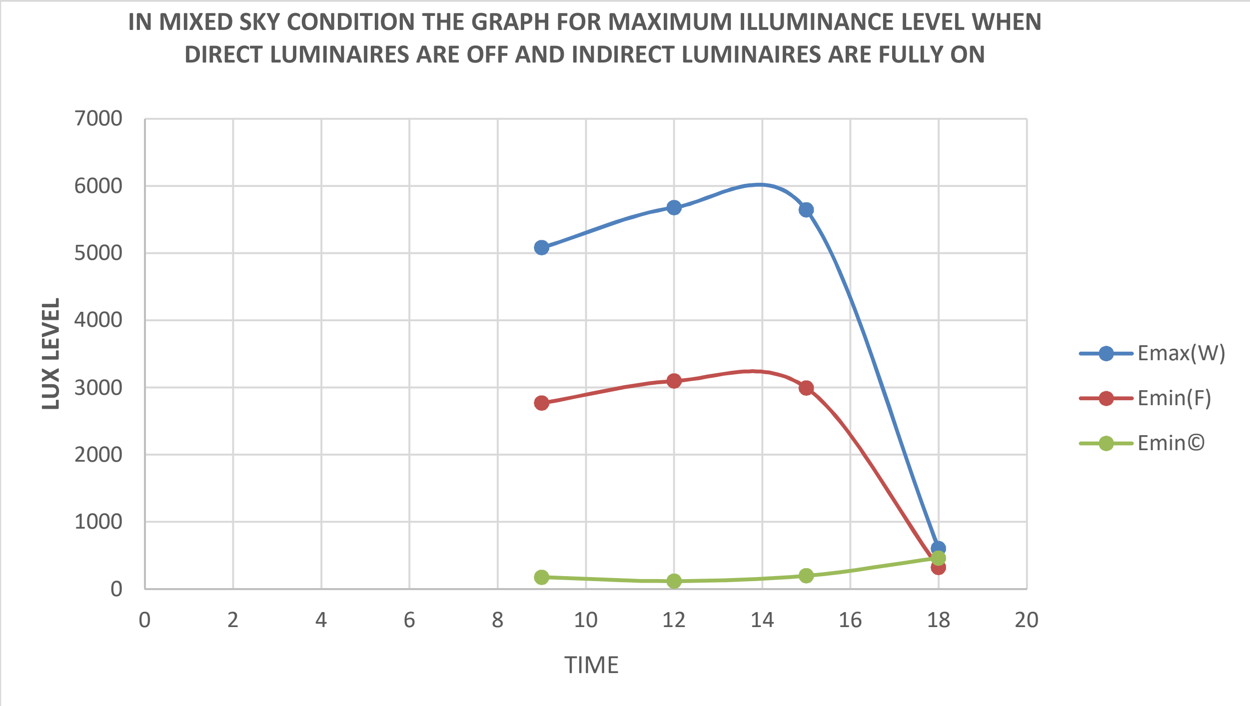


50.1.2.CHART FOR MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	421	465	87
12	366	405	66
15	440	478	98
18	186	191	49

In mixed sky condition with daylight integration in the reflectivity ranges are in 65-35-05 for minimum illuminance level when direct luminaires are off and indirect luminaires are fully on then at 9AM the average illuminance levels in three parameters are optimum but at 12 PM those datas are slightly less than the previous one for the angle of sun and the positions of windows but at 3PM all the values reached minimum range in average illuminance levels and put the graphs up.So,here we got a curvature nature for all three parameters but in artificial lights all three parameters are in the same regions but they don’t intersect with each others.

50.1.3.GRAPH FOR MAXIMUM ILLUMINANCE LEVEL

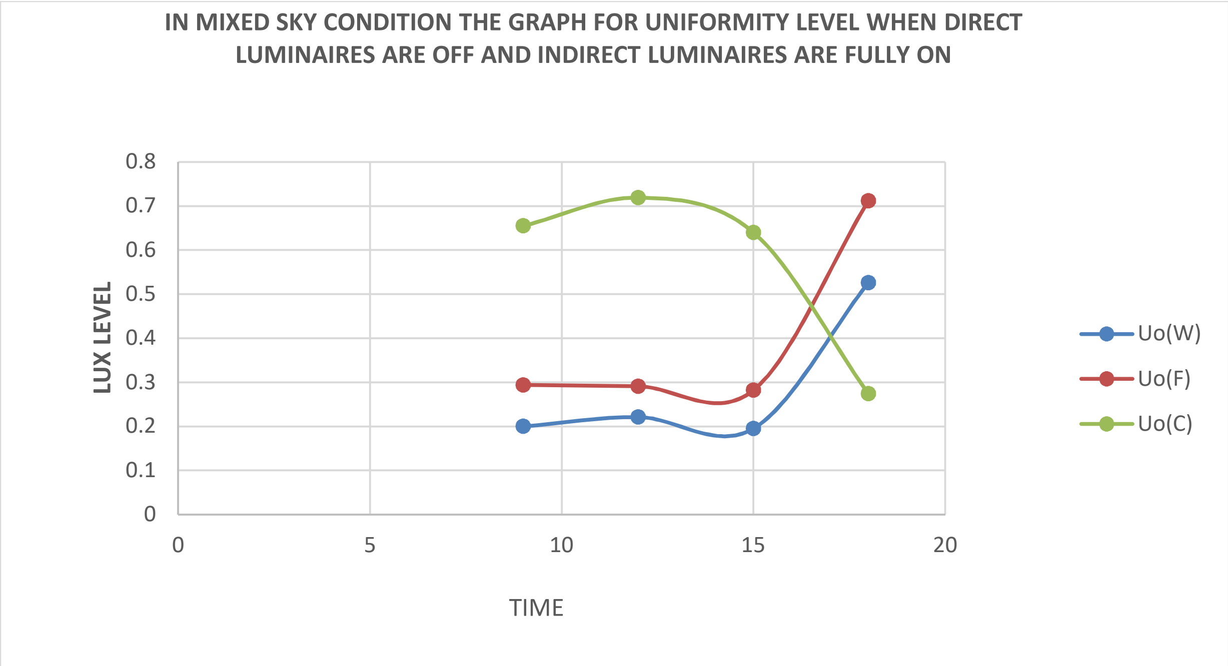


50.1.3.CHART FOR MAXIMUM ILLUMINANCE LEVEL

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin(C)**
9	5082	2768	177
12	5680	3097	118
15	5644	2996	198
18	604	323	463

When direct luminaires are off and indirect luminaires are fully on in a condithion where reflectivities are 65-35-05 then the maximum level of illuminance lies in the standard range and this all are happened when there is no daylight takes place.When daylight integration take place then the maximum range of illuminance goes higher for workplane and floor but then also ceiling remains low so the graph looks like the above one.

50.1.4.GRAPH FOR UNIFORMITY LEVEL



50.1.4.CHART FOR UNIFORMITY LEVEL

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.199	0.294	0.655
12	0.221	0.291	0.719
15	0.195	0.282	0.64
18	0.526	0.712	0.274

In mixed sky condition, the above graph create with the help of tabulated datas for uniformity level when direct luminaires are off and indirect luminaires are fully on and the reflectivity's are in the range of 65-35-05,mainly in daylight condition the uniformity of ceiling remain in a level which is near to the standard range but at that time due to uneven daylight distribution workplane and floor haven't that much higher values, but when sun goes off and the room totally illuminated by the artificial luminaires then the vice versa phenomenon happened. For that reason the above graphs intersect with each other, but the graph of workplane and floor maintain the same nature and they are lower in daylight and higher in artificial lights but ceiling shows the opposite nature hence that intersection occurred.

CASE : 51

IN CLEAR SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE FULLY ON AND INDIRECT LUMINAIRES ARE OFF

Table:51.1. COMPARATIVE STUDY OF ALL Eav, Emin AND Emax VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2278	1807	515
12	3636	3294	566
15	2487	2293	523
18	487	342	50

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	364	363	235
12	428	436	262
15	376	380	241
18	252	233	34

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20139	20527	1113
12	44873	43045	1112
15	22883	27674	1115
18	789	419	62

Figure:51.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL

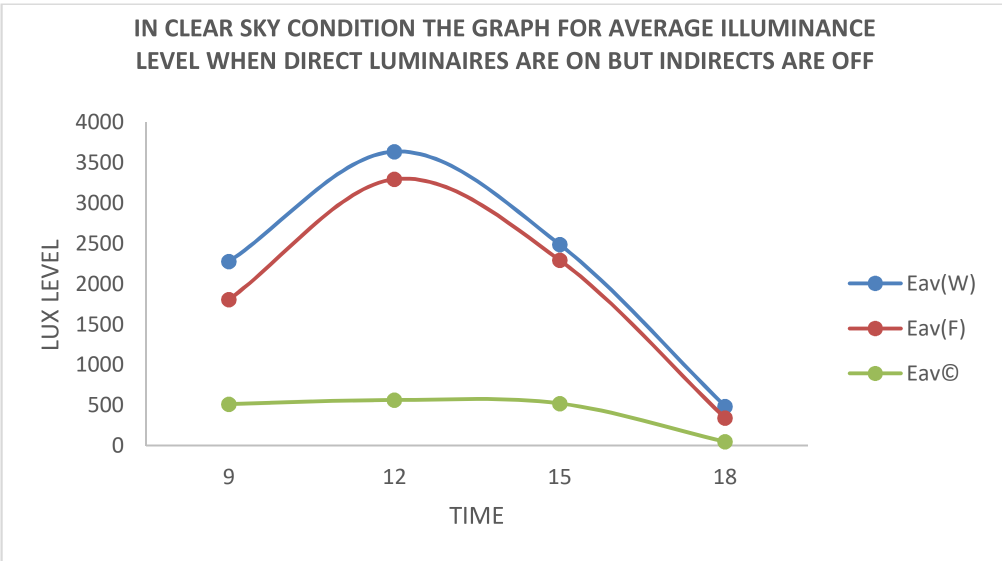


Figure:51.2. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL

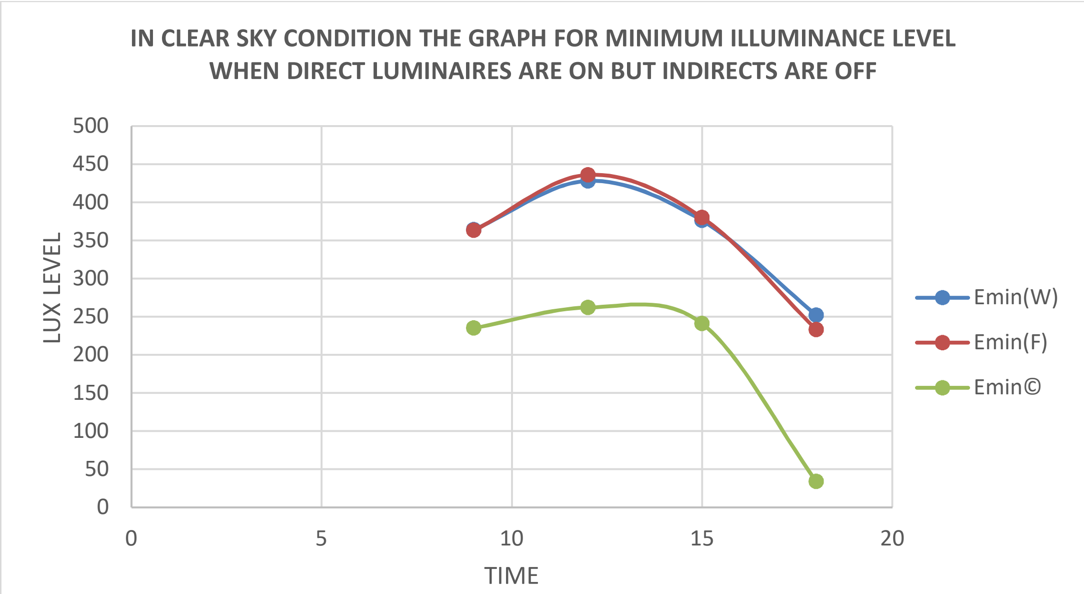


Figure:51.3. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL

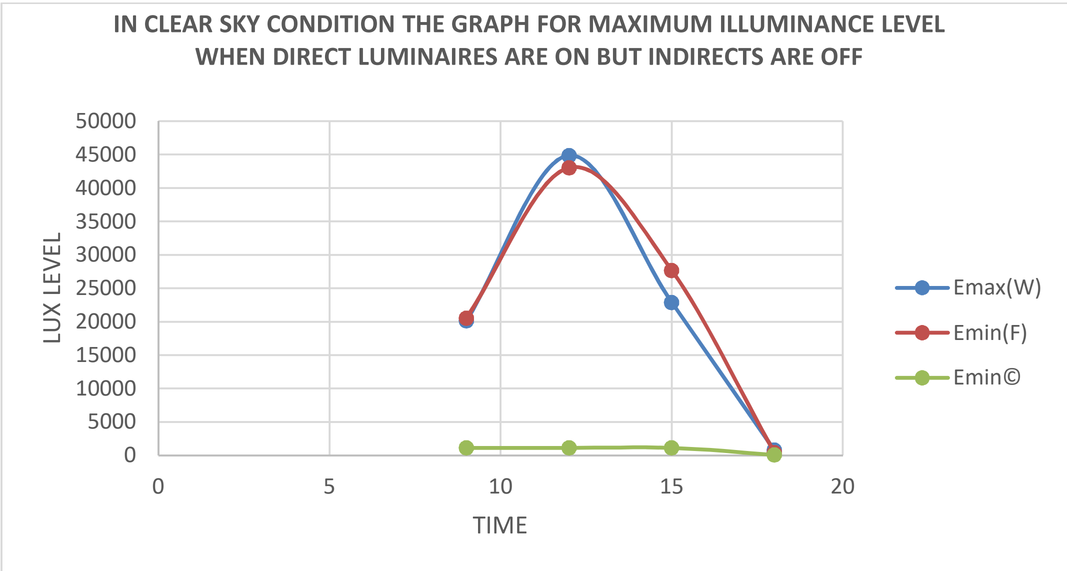
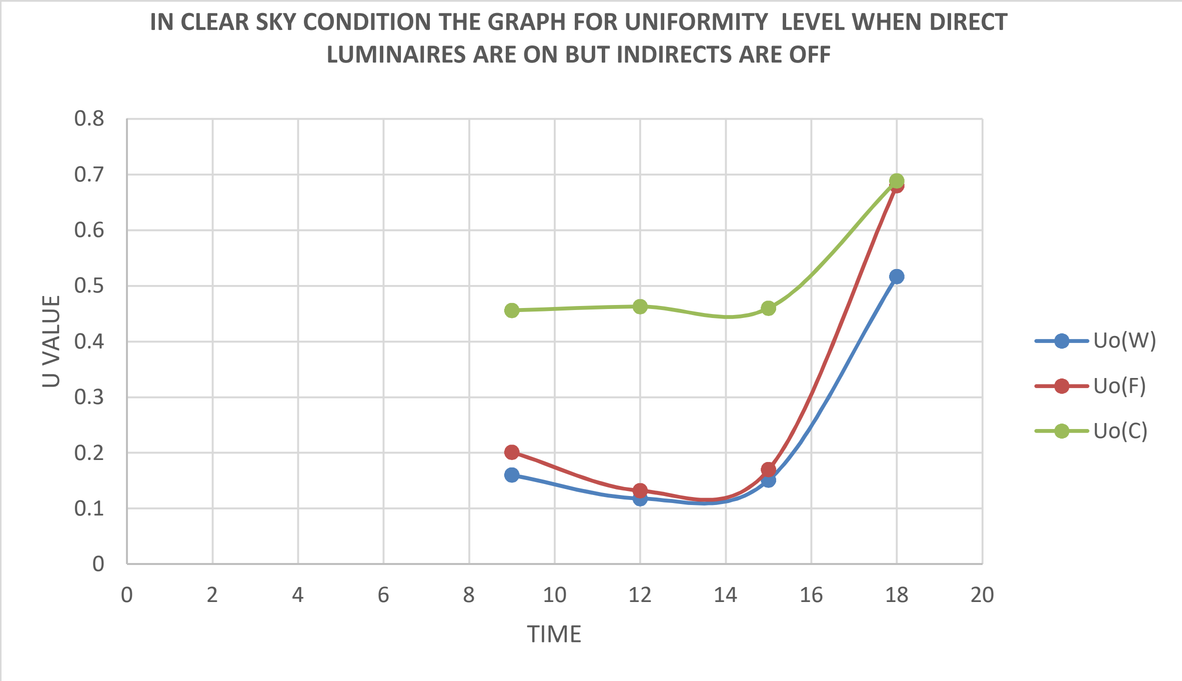


Table:51.2. THE CHART OF UNIFORMITY LEVEL

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.16	0.201	0.456
12	0.118	0.132	0.463
15	0.151	0.17	0.46
18	0.517	0.68	0.689

Figure:51.4. THE GRAPH OF UNIFORMITY LEVEL



In the case of minimum and maximum illuminance level, workplane and floor are very close to each other's and they follow their nature, but ceiling is different than these two factors. In the case of uniformity, this phenomenon remains unchanged. There is a coincide point takes place under artificial lighting, and in that point at 6PM interference occurred.

CASE : 52

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE FULLY ON AND INDIRECT LUMINAIRES ARE 50% DIMMED

52.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

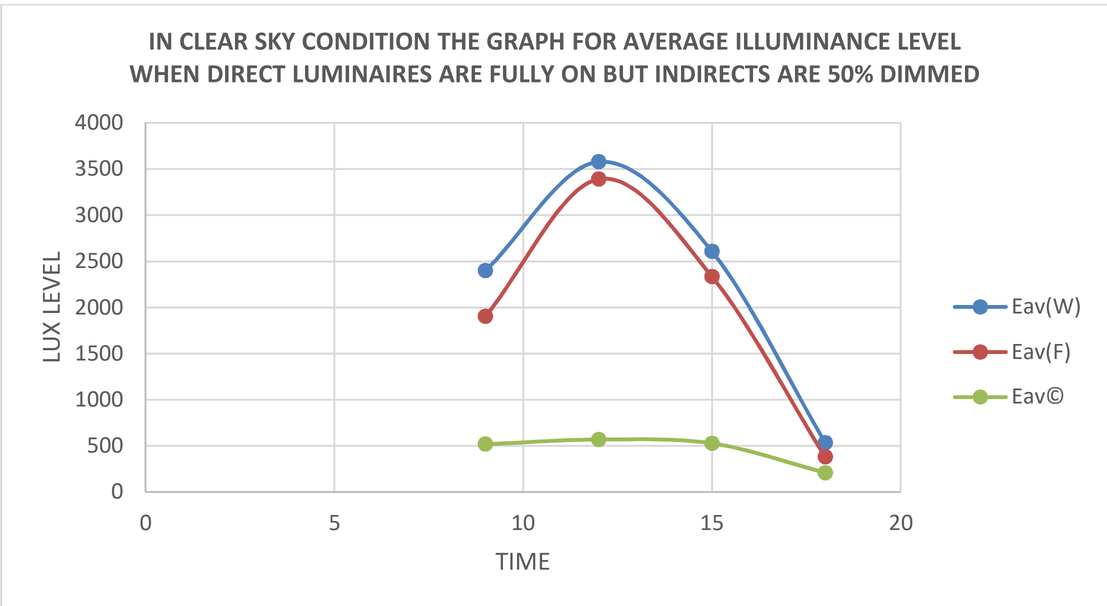
AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2398	1902	518
12	3578	3391	569
15	2607	2334	527
18	535	380	209

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	465	452	238
12	527	529	267
15	473	470	246
18	305	264	79

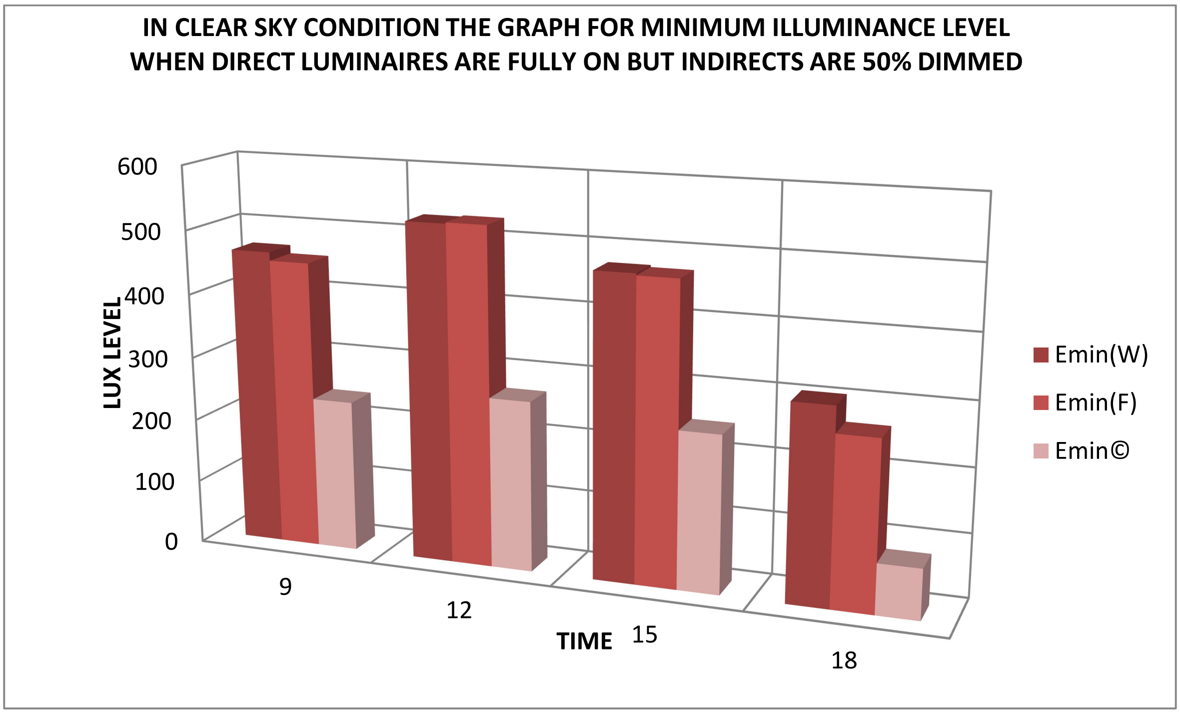
MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20279	20630	1114
12	44970	43144	1113
15	22975	27778	1114
18	837	461	497

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.194	0.238	0.46
12	0.14	0.156	0.47
15	0.181	0.201	0.466
18	0.57	0.695	0.398

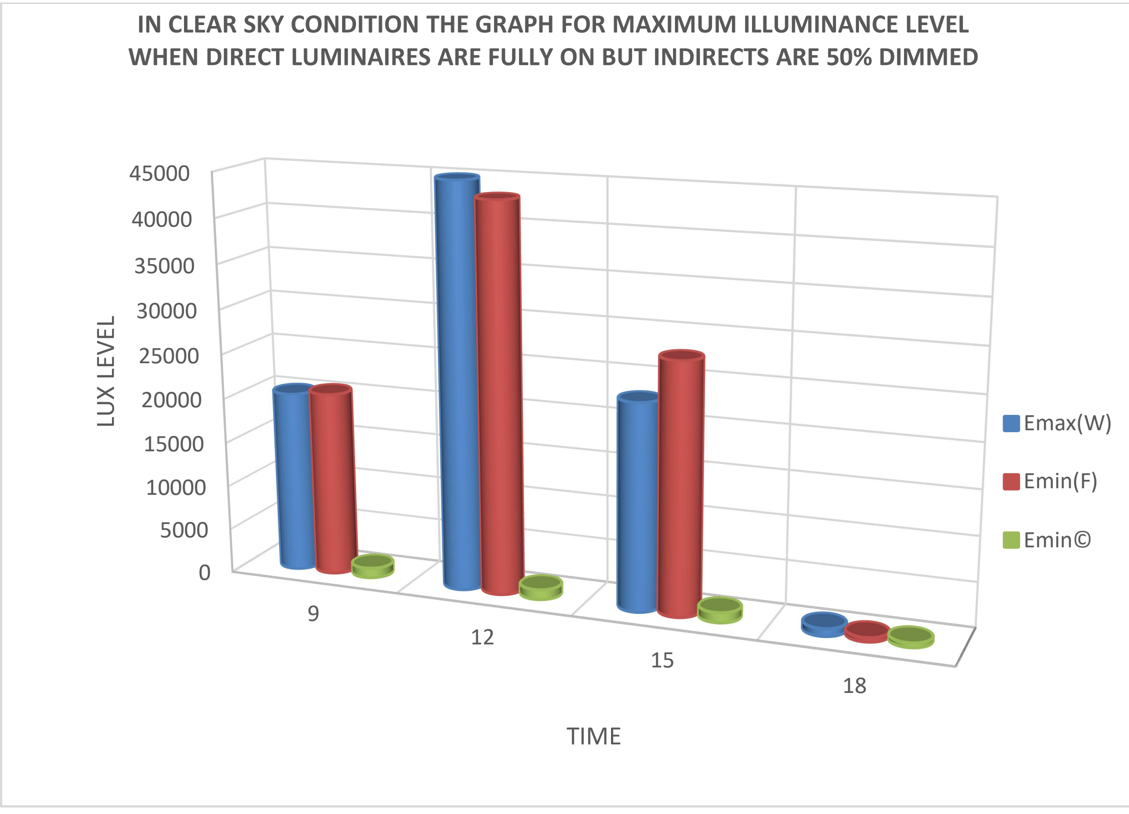
52.2. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



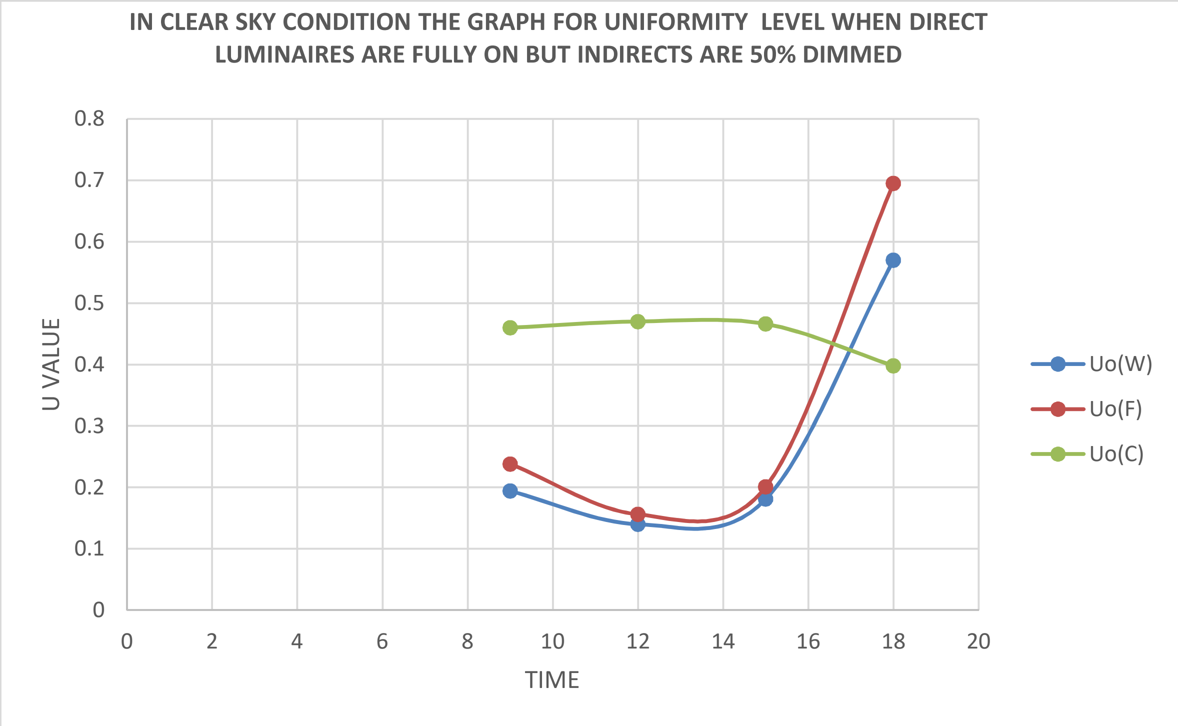
52.3. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



52.4. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL



52.5. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL



Average and minimum these two parameters shows the similarities between none other than workplane and floor area, but the ceiling is always make a distance from these two parameters. But in the case of maximum illuminance, primarily its obtain the same nature but at 3PM floor area illuminance is getting higher and it crosses the value of workplane, for this reason in uniformity graphs, there doesn't occurred any kind of intersection between workplane and floor area, but a cross over occurred due to ceiling uniformity, which stay very much steady and linear throughout the day, but with the presence of artificial lighting it decreases slightly.

CASE : 53

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES AND INDIRECT LUMINAIRES ARE FULLY ON

53.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

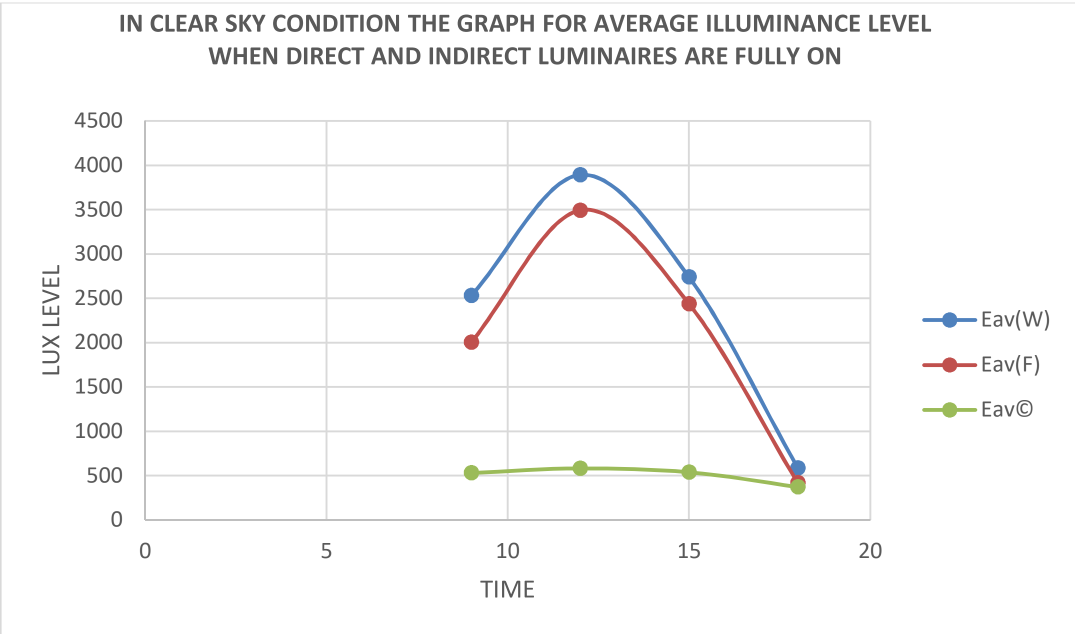
AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2532	2005	530
12	3892	3493	581
15	2740	2437	538
18	587	420	372

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	561	550	249
12	623	618	297
15	560	572	253
18	361	292	107

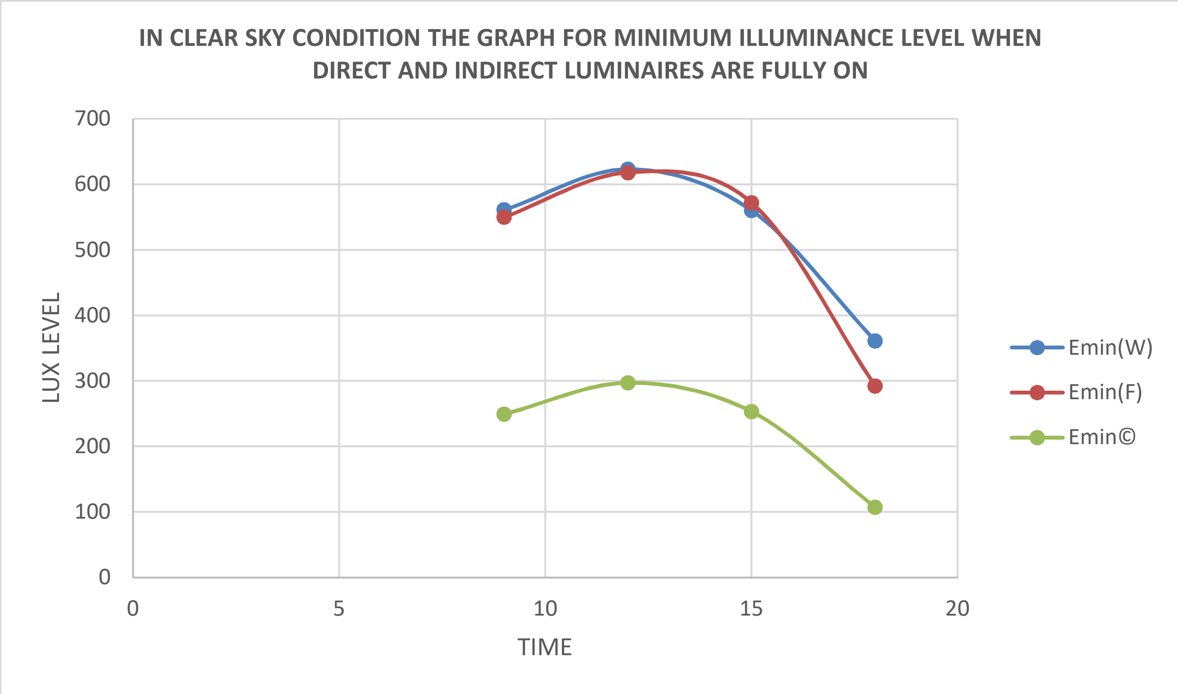
MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20425	20725	1124
12	45081	43249	1124
15	23097	27888	1125
18	887	506	941

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.222	0.274	0.47
12	0.16	0.177	0.511
15	0.205	0.235	0.47
18	0.615	0.695	0.288

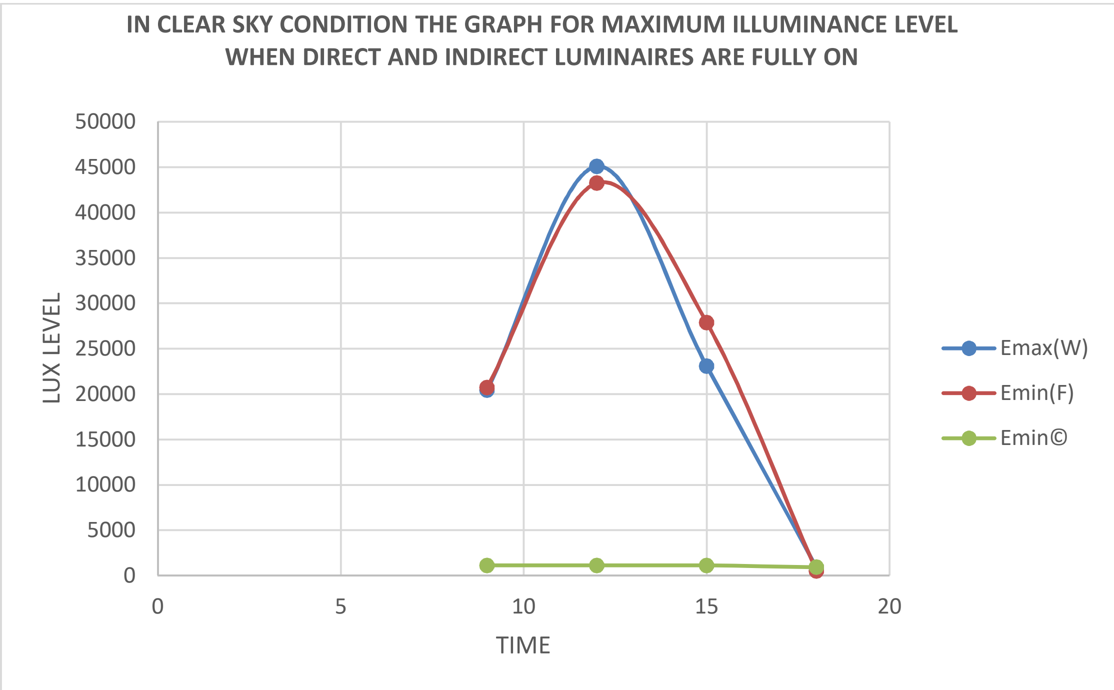
53.2. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



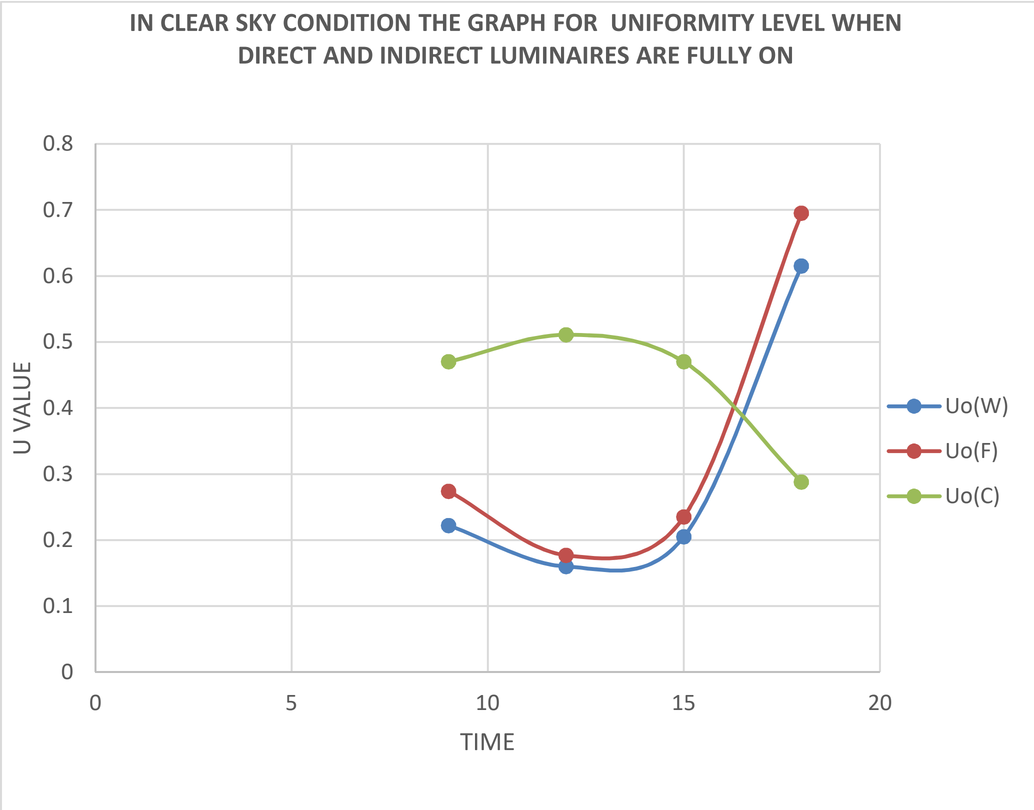
<u>53.3. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL</u>



<u>53.4. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL</u>



<u>53.5. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL</u>



In this case an exception occurs due to all of this boundary conditions, which are as follows: the clear sky condition, the reflectance values are 70-40-10, and the suspension height of the luminaires are 0.7m when direct luminaires and indirect luminaires are fully on, then in all the cases floor and workplane changes their values in a order which doesn't break their graphs nature. But here also the same cross over occurred due to ceiling uniformity, which stay very much steady, stable and linear through out the day, but with the presence of artificial lighting it decreases sharply.

CASE : 54

IN CLEAR SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE 50% DIMMED BUT INDIRECTS ARE FULLY ON

54.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

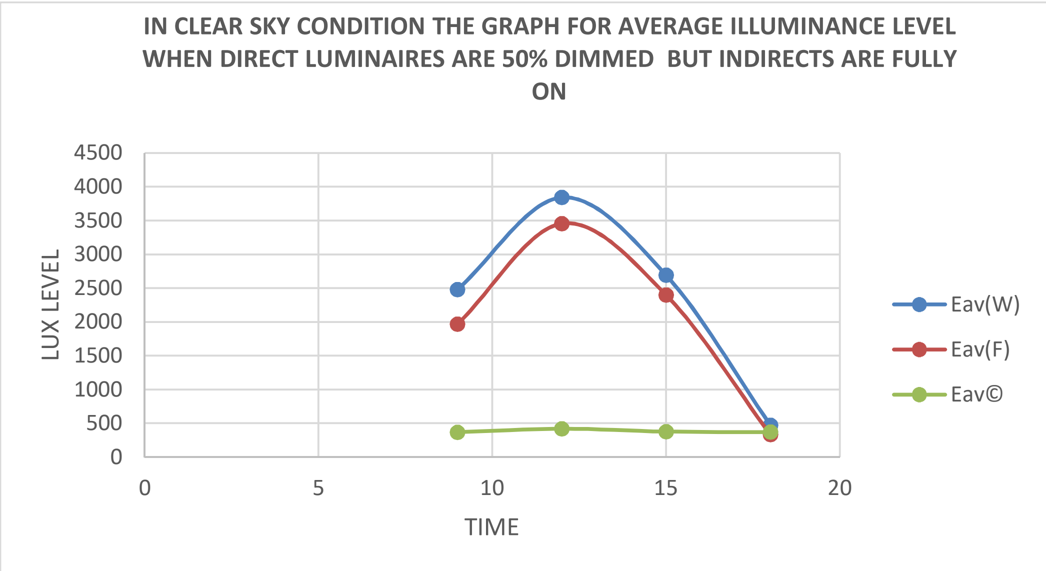
AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2481	1966	368
12	3841	3454	420
15	2691	2398	377
18	473	332	371

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	507	522	205
12	580	588	232
15	515	544	208
18	277	218	100

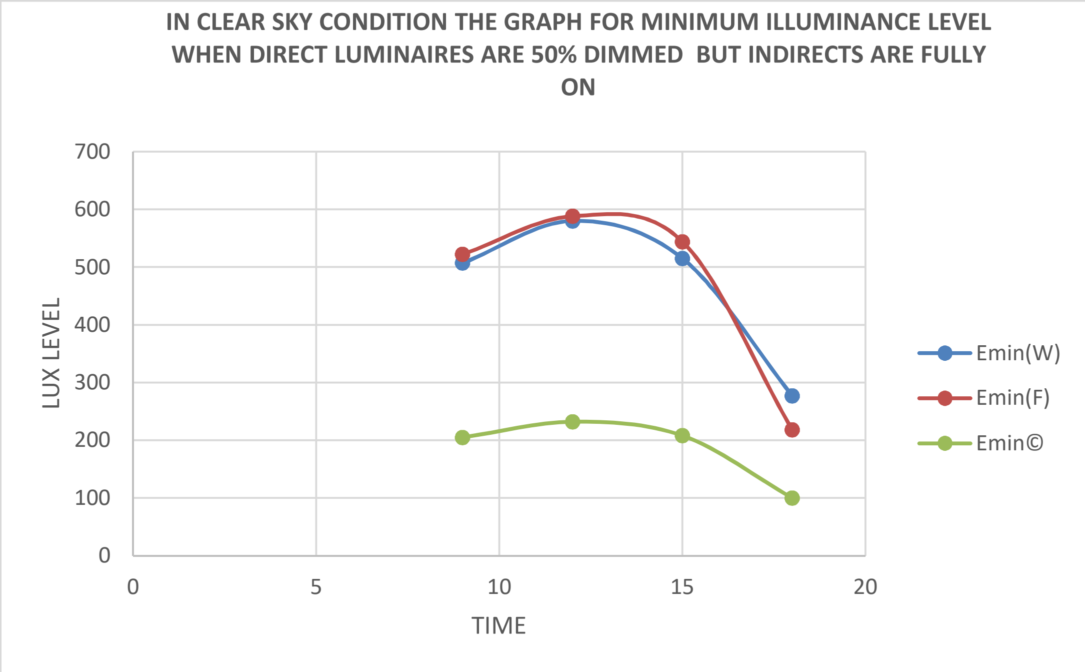
MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20373	20690	706
12	45035	43214	702
15	23054	27847	706
18	696	407	945

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.204	0.266	0.558
12	0.151	0.17	0.553
15	0.191	0.227	0.551
18	0.584	0.656	0.27

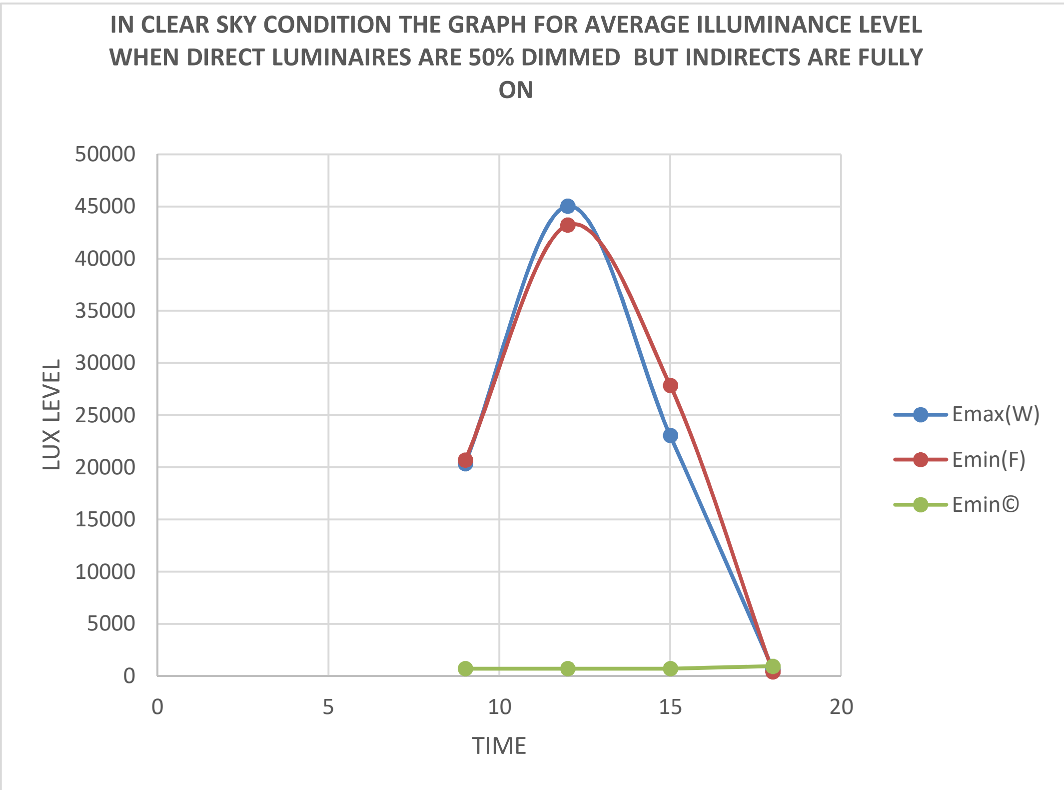
54.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



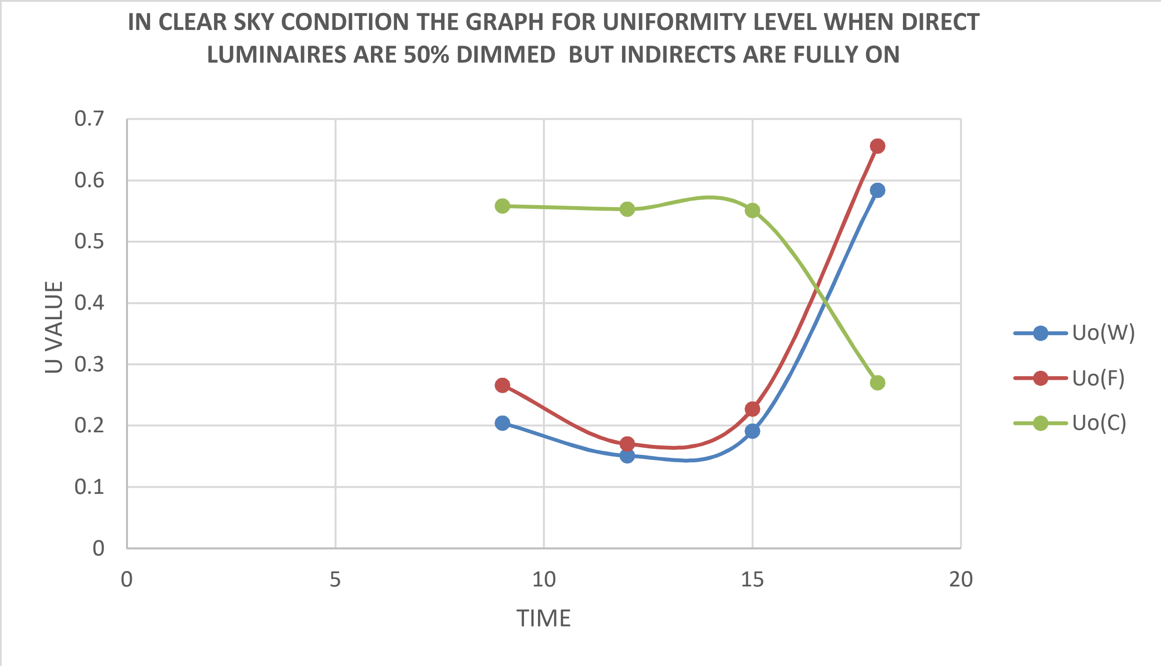
54.2. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



54.3. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL



54.4. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



Although all the boundary conditions are changed here, but the nature of the all four graphs named as 54.1 to 54.4 are same, excluding the graph of maximum illuminance level. In that case an overlapping occurred after 12PM and then these two are separated from each other's.

CASE : 55

IN CLEAR SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7mWHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE 50% DIMMED

Table:55.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2348	1862	357
12	3706	3350	407
15	2557	2294	365
18	415	287	206

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	420	427	198
12	485	498	222
15	427	443	197
18	227	183	72

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20231	20593	696
12	44923	43107	686
15	22930	27737	695
18	635	356	497

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.179	0.229	0.555
12	0.131	0.149	0.546
15	0.167	0.193	0.54
18	0.547	0.639	0.35

Figure:55.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL

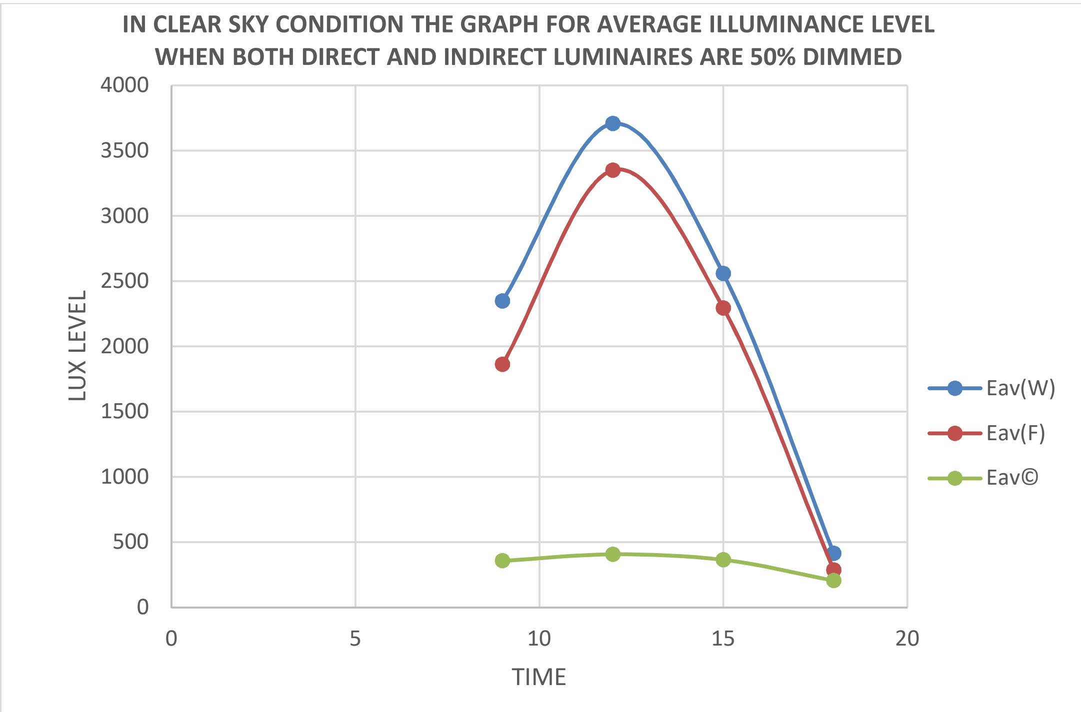


Figure:55.2. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL

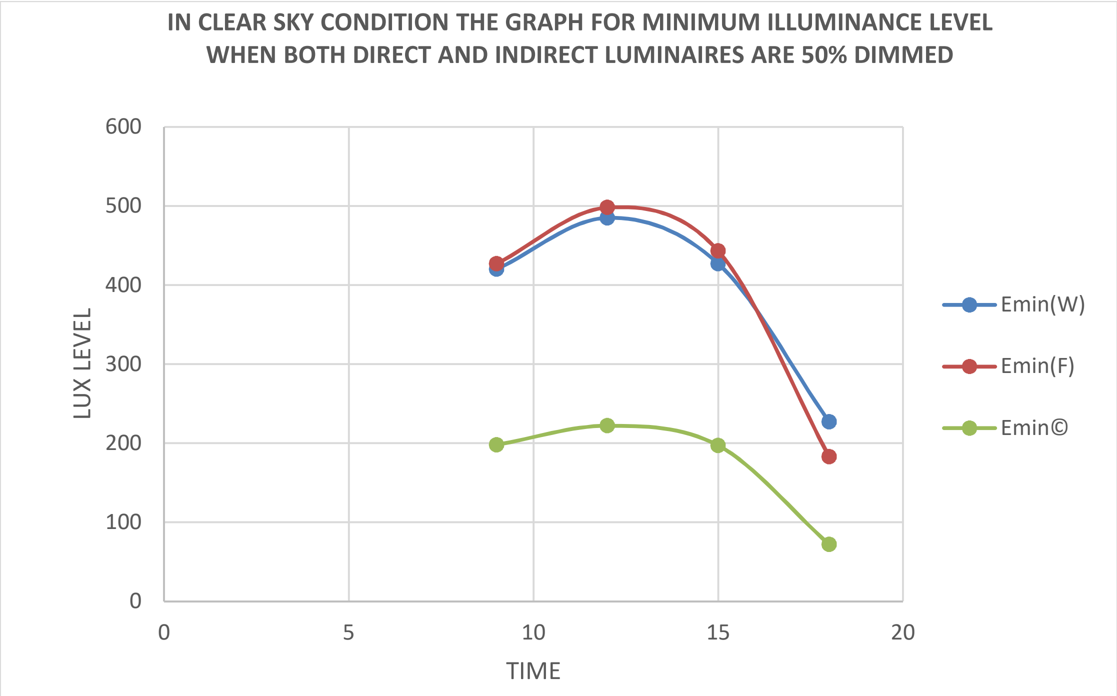


Figure:55.3. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL

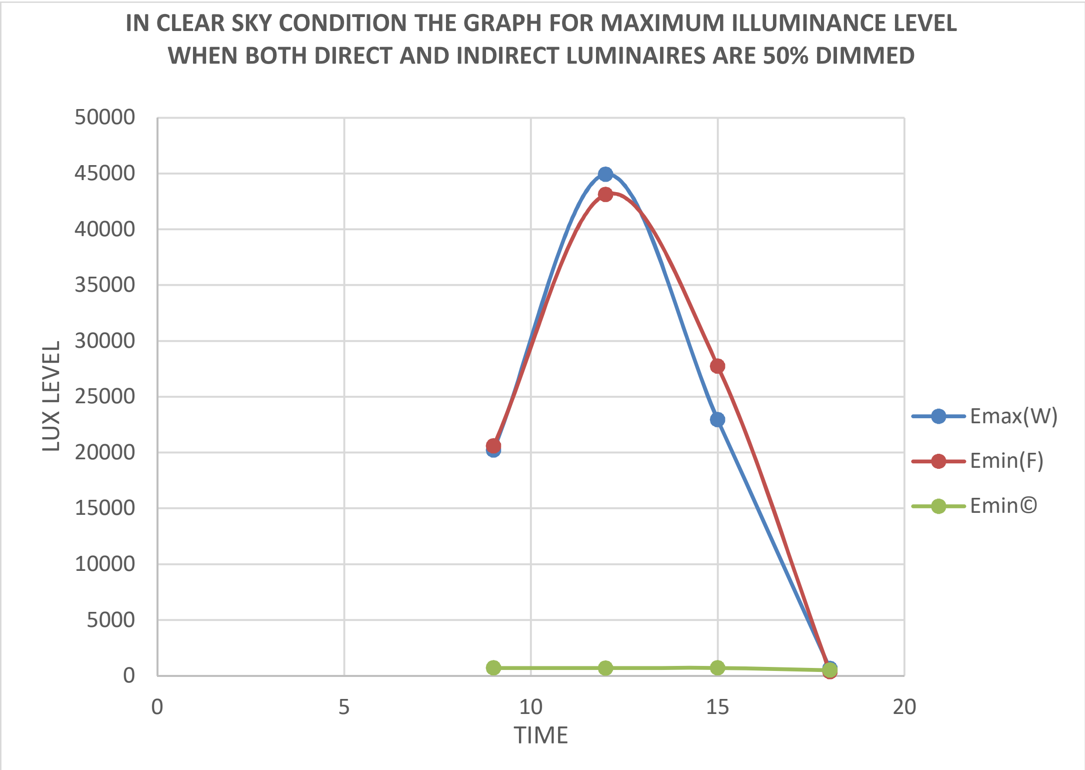
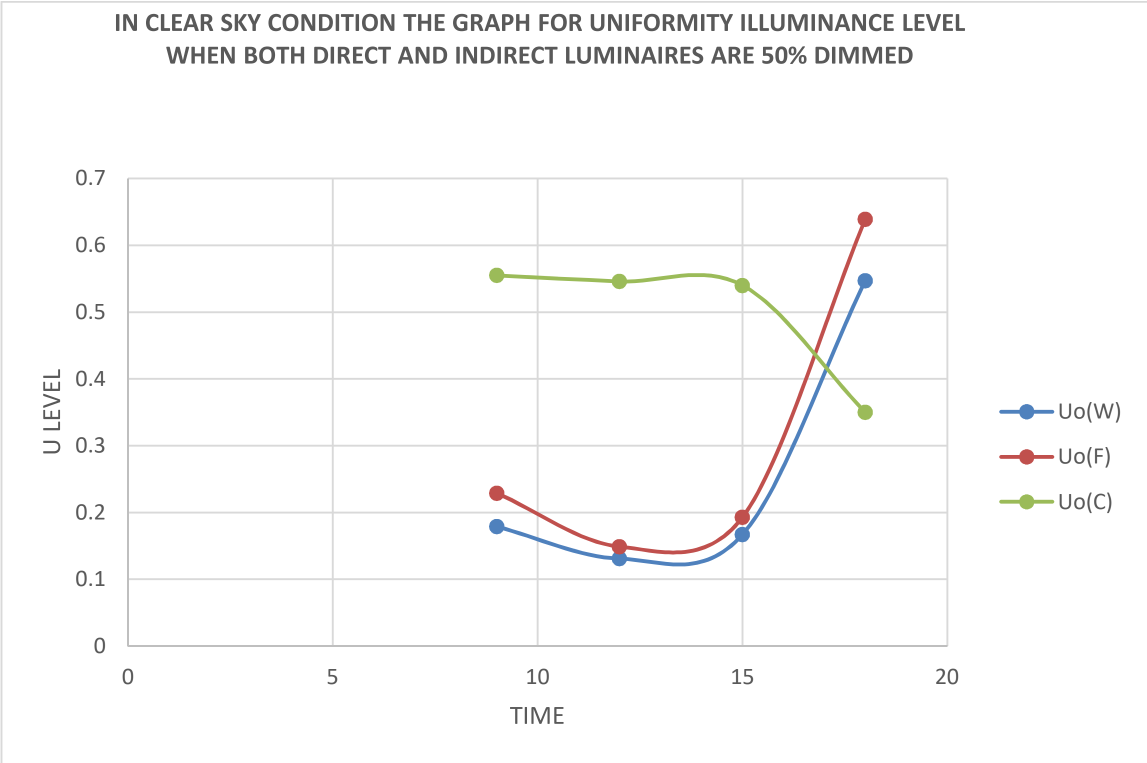


Figure:55.4. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL



No significant change occurred in the nature of the graphs numbered as figure no.54.1 to 54.4 for the sky conditions.

CASE : 56

IN CLEAR SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

Table:56.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	2397	1879	158
12	3791	3419	263
15	2644	2364	221`
18	323	216	352

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	424	449	101
12	536	557	168
15	472	506	140
18	137	222	84

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	20295	20297	282
12	44997	43182	486
15	23009	27812	370
18	505	284	922

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.177	0.239	0.641
12	0.141	0.163	0.637
15	0.179	0.214	0.633
18	0.424	0.564	0.238

Figure:56.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL

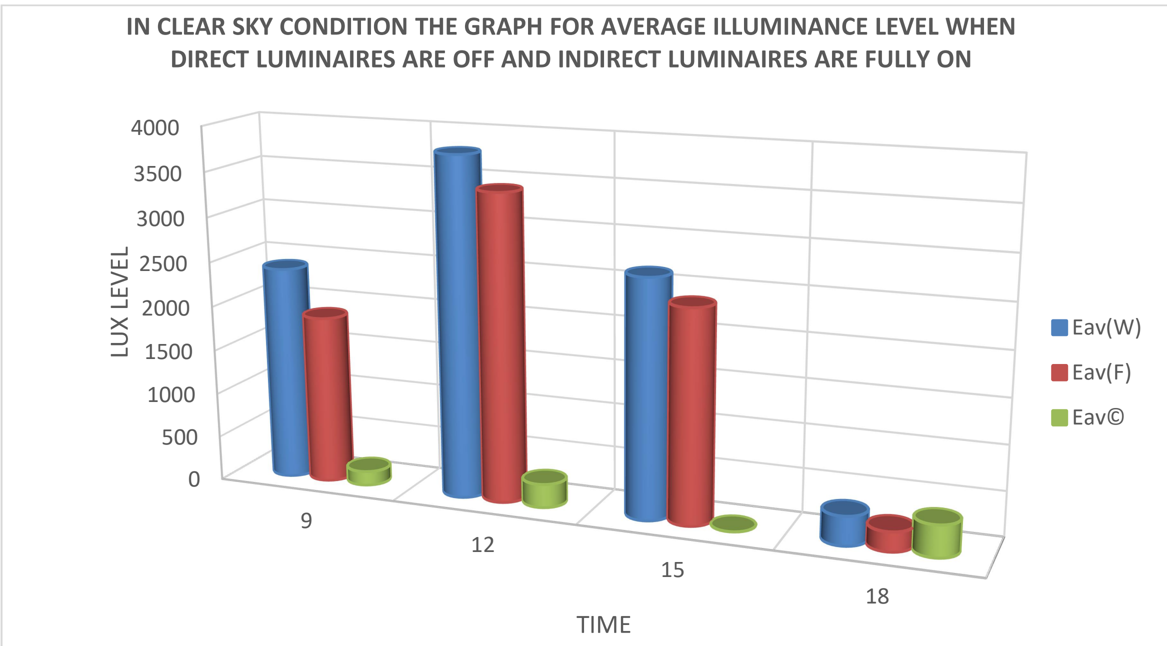


Figure:56.2. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL

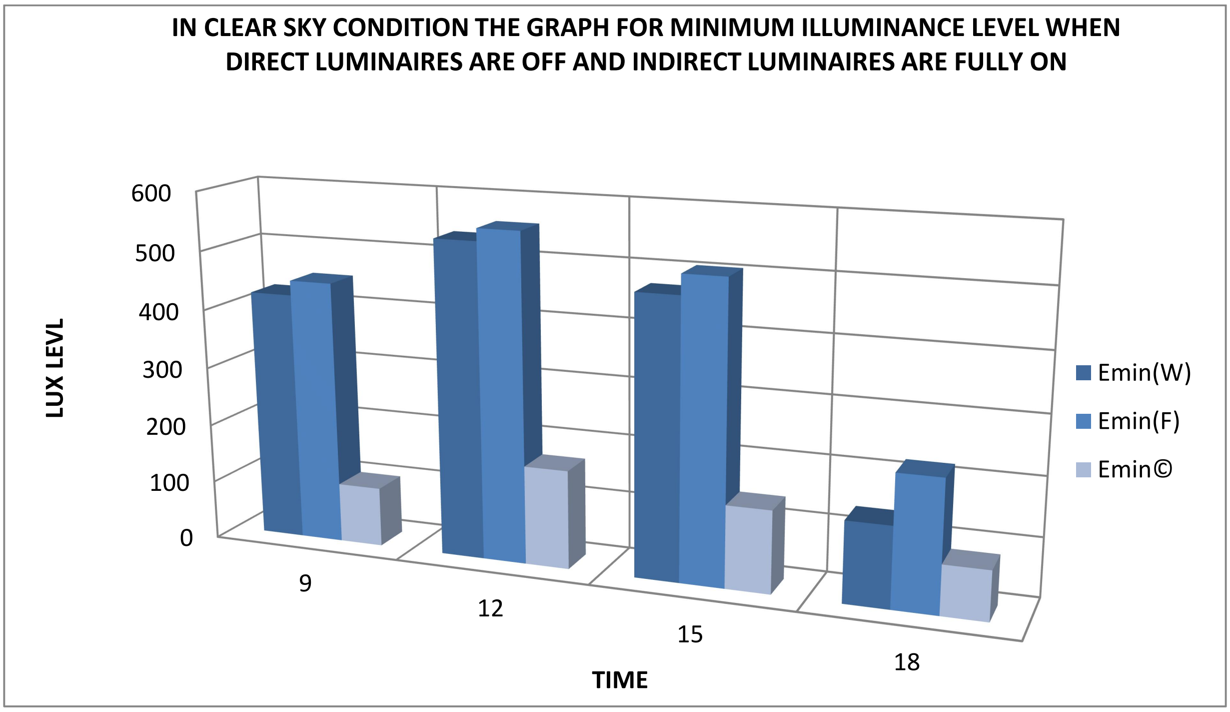


Figure:56.3. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL

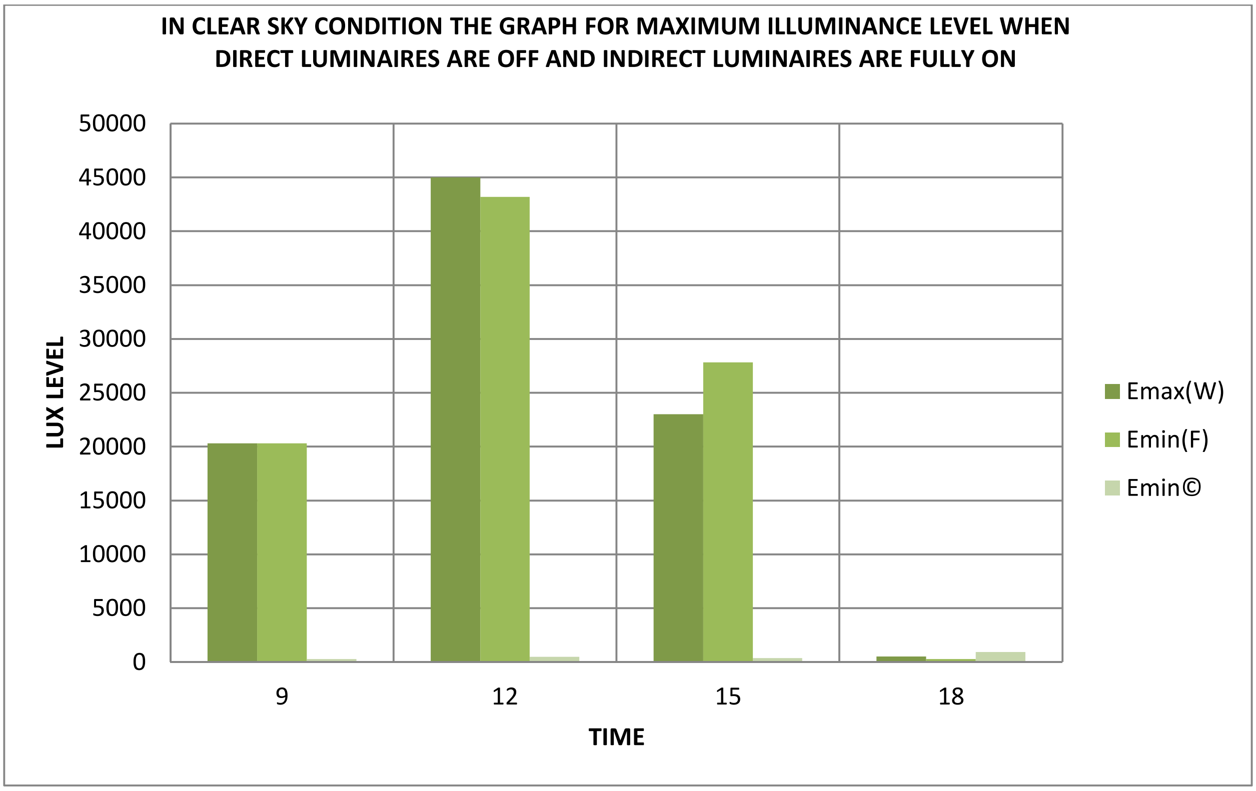
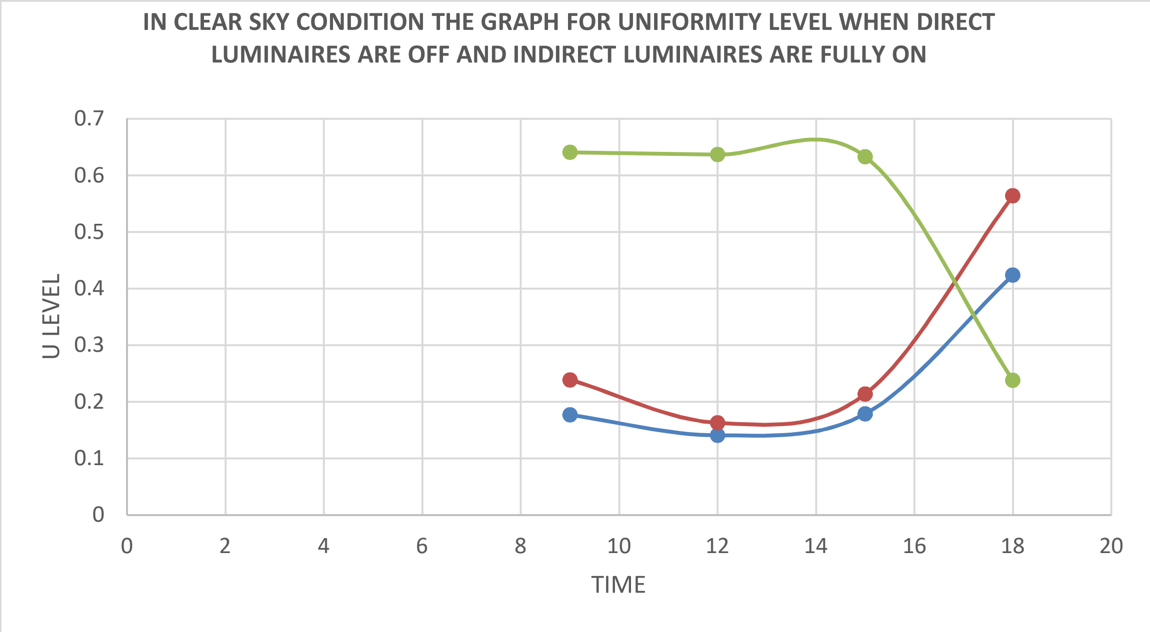


Figure:56.4. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL



Average and minimum these two parameters shows the similarities between none other than workplane and floor area, but the ceiling is always make a distance from these two parameters. But in the case of maximum illuminance which shown in Figure:56.3, primarily its obtain the same nature but at 3PM floor area illuminance is getting higher and it crosses the value of workplane, for this reason in uniformity graphs,as depicted in Figure:56.4 ,there doesn’t occurred any kind of intersection between workplane and floor area, but a cross over occurred due to ceiling uniformity, which stay very much steady and linear through out the day, but with the presence of artificial lighting it decreases rapidly.

CASE : 57

IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE ON BUT INDIRECTS ARE OFF

Table:57.1. COMPARATIVE STUDY OF ALL Eav, Emin, Emax and UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	1035	831	397
12	1451	1168	430
15	1116	897	404
18	387	302	32

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	258	296	146
12	335	401	184
15	273	317	153
18	193	194	24

MAXIMUM LUX LEVEL			
TIME	**Emax(W)**	**Emin(F)**	**Emin©**
9	2356	1404	961
12	3376	1993	989
15	2555	1519	967
18	645	384	37

UNIFORMITY			
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.249	0.356	0.366
12	0.231	0.343	0.429
15	0.245	0.354	0.378
18	0.498	0.642	0.744

Figure:57.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL

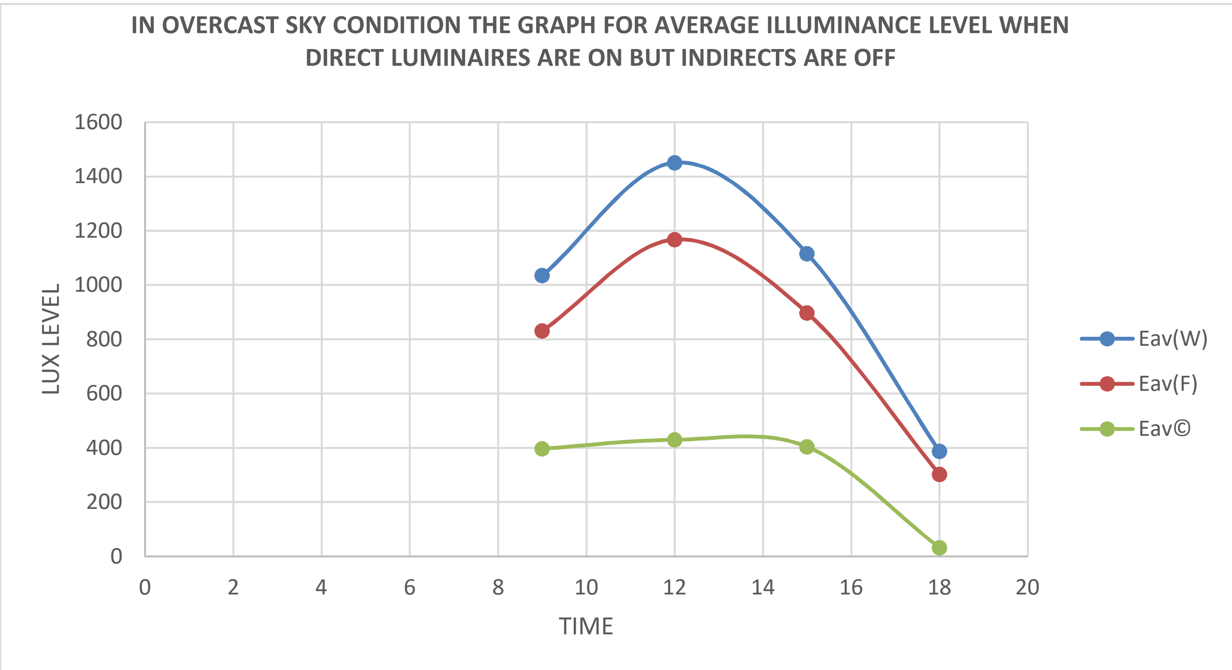


Figure:57.2. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL

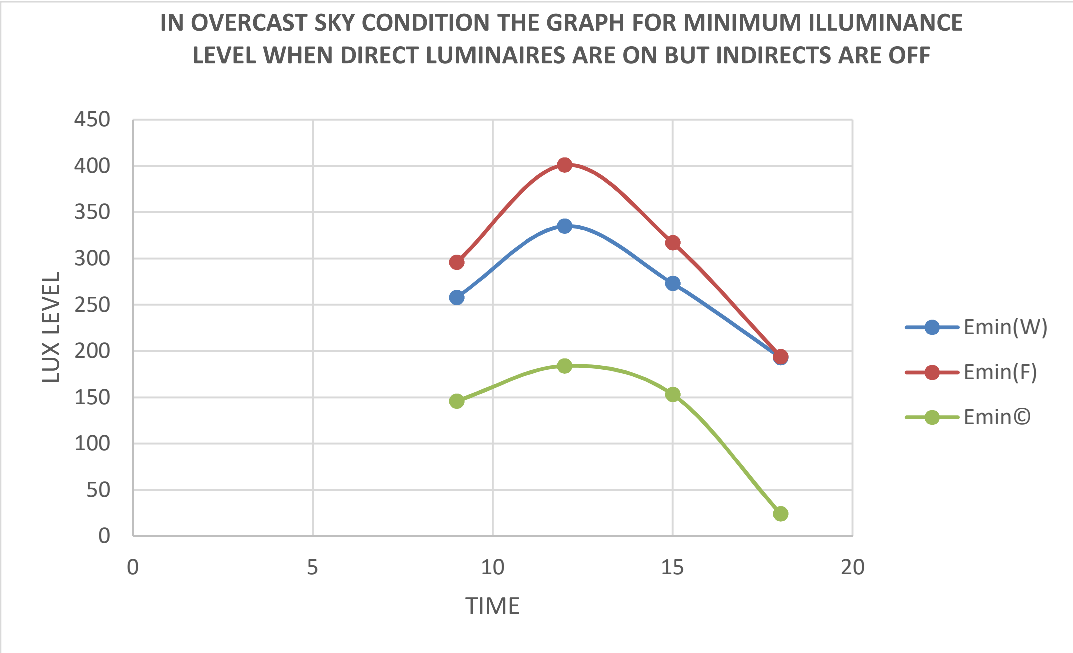


Figure:57.3. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL

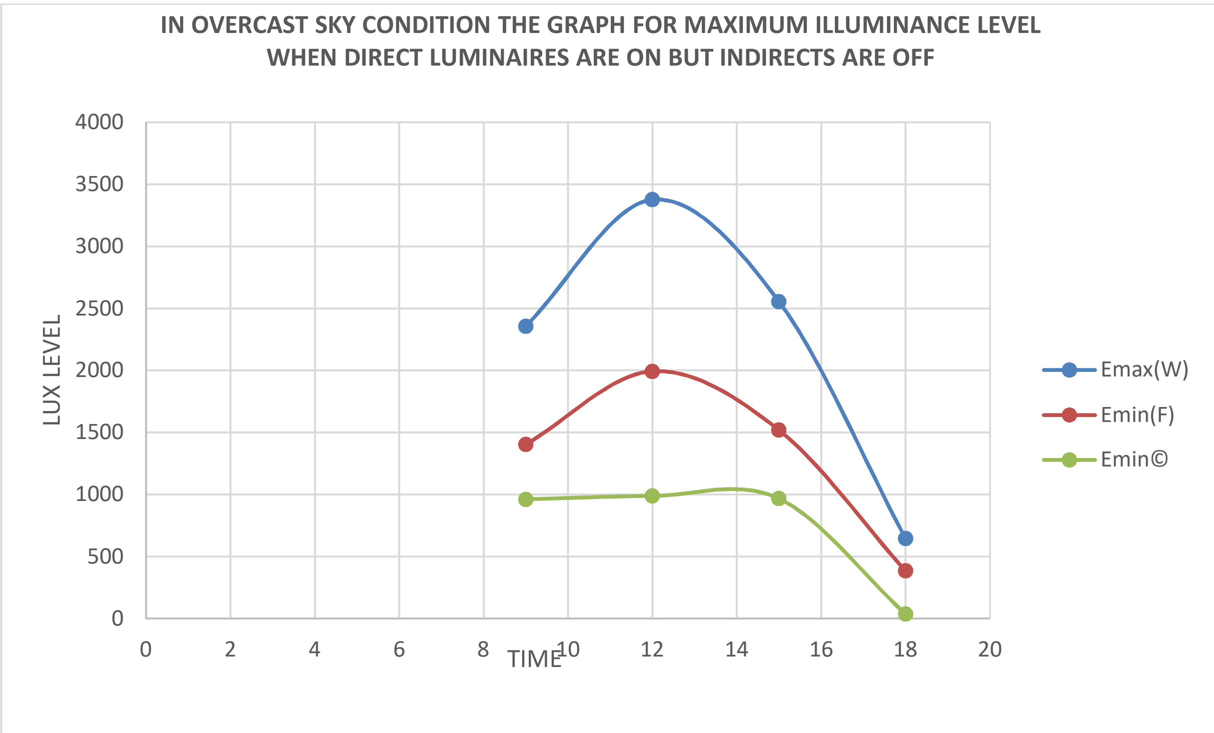
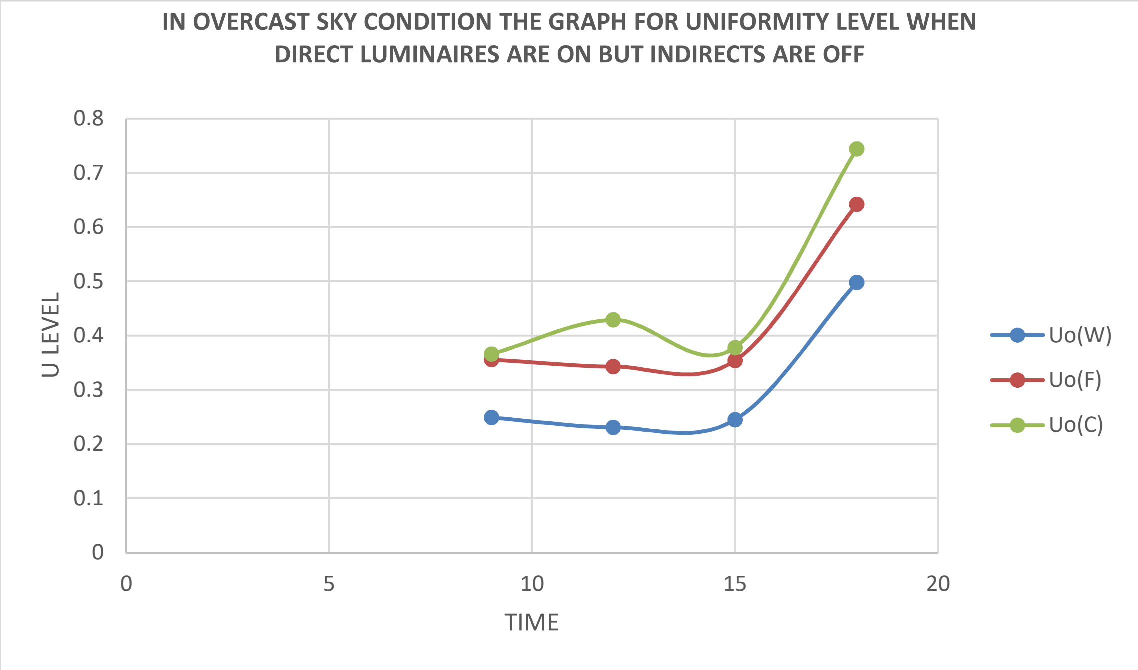


Figure:57.4. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL



There is no overlapping or intersection takes place,as shown in figure 57.1 to 57.3, through out the day even under the artificial lighting also all three graphs for maximum, minimum, average illuminance are maintaining their nature, and this nature is followed by workplane, floor and ceiling area also. In the case of uniformity,which is depicted in figure 57.4 there also no intersection happened, but a rapid fall down occurred at 3PM but it rises fastly.

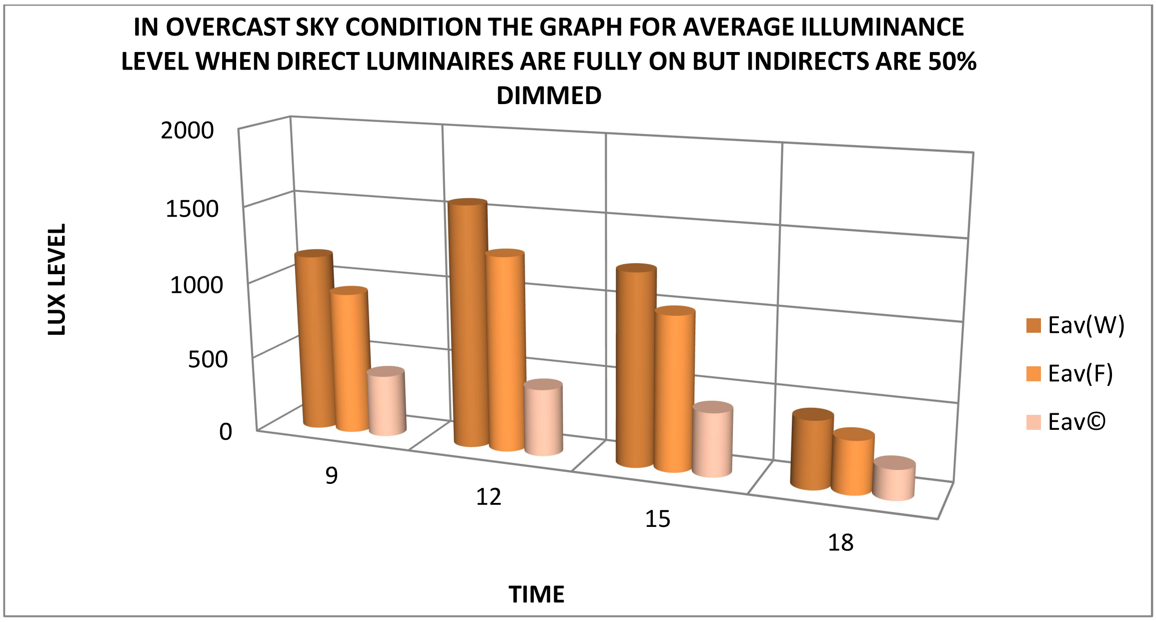
CASE : 58

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE FULLY ON BUT INDIRECTS ARE 50% DIMMED

Table:58.1. THE CHART OF AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	1159	930	405
12	1573	1266	436
15	1240	995	411
18	436	341	193

Figure:58.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



In overcast sky condition, when the reflectance values are 70-40-10, and the suspension height of the luminaires are 0.7m when direct luminaires are fully on but indirects are 50% dimmed, then it obeys all the nature which are obtaining from the prior cases . Always workplane is much higher than the floor and ceiling, and its maintain through out the day even if without daylight also,as per the figure of 58.1.

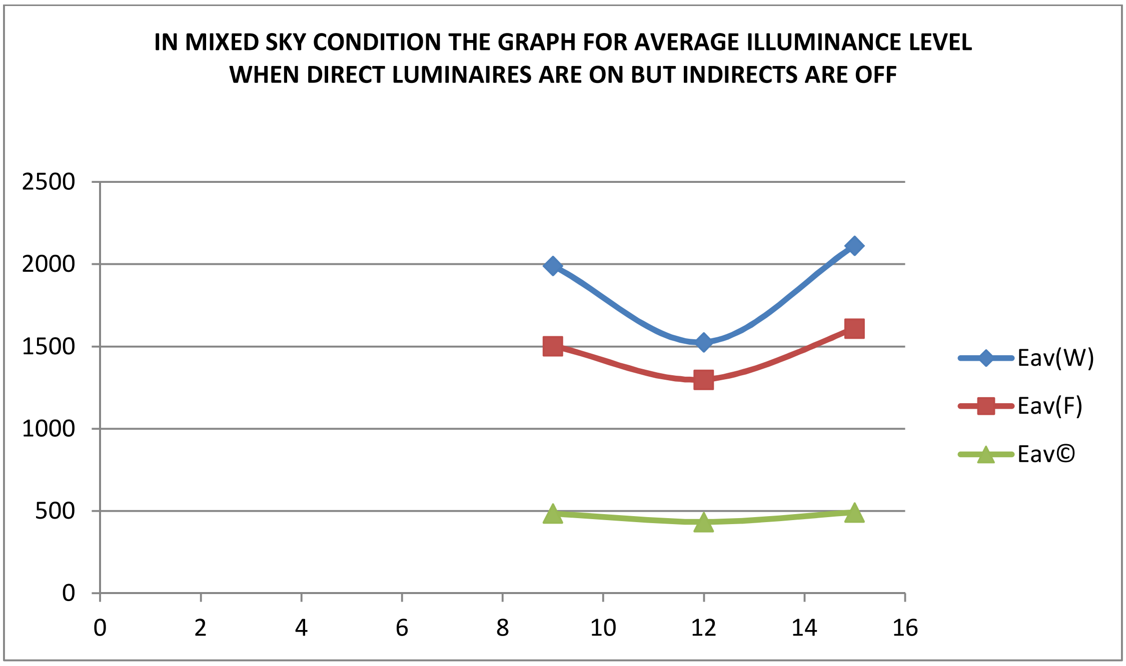
CASE : 59

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m DIRECT LUMINAIRES ARE ON BUT INDIRECTS ARE OFF

Table:59.1. THE CHART OF AVERAGE ILLUMINANCE LEVEL

AVERAGE LUX LEVEL			
TIME	**Eav(W)**	**Eav(F)**	**Eav©**
9	1990	1503	485
12	1526	1299	434
15	2113	1610	492

Figure:59.1. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



In this case all three are in the same manner ,floor area and workplane area shows the same nature,as shown in figure 59.1, although the values which are obtained from simulation at 12PM is lesser than all the other values so a curvy nature of graph is obtaining here, but at 3PM the values are much higher than all the previous values.

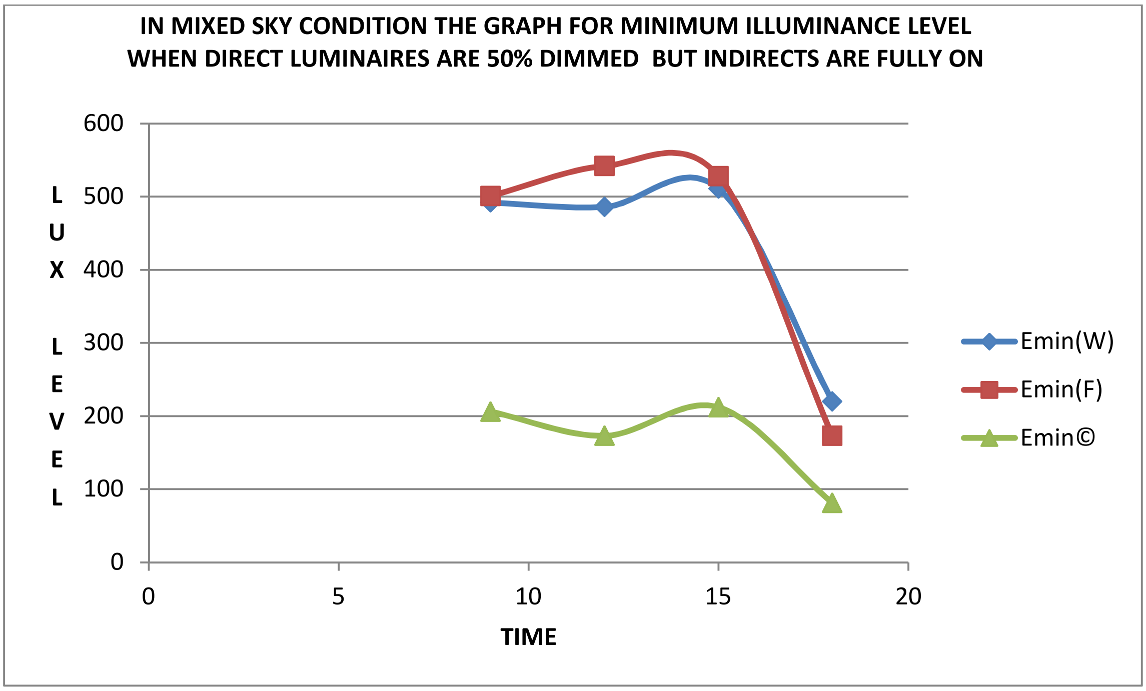
CASE : 60

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN DIRECT LUMINAIRES ARE 50% DIMMED BUT INDIRECTS ARE FULLY ON

Table:60.1. THE CHART OF MINIMUM ILLUMINANCE LEVEL

MINIMUM LUX LEVEL			
TIME	**Emin(W)**	**Emin(F)**	**Emin©**
9	492	501	206
12	486	542	173
15	511	528	212
18	220	173	81

Figure:60.1. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



Here the overlapping and intersection occurred due to all the boundary conditions which occurred at 3PM,as per the figure 60.1, and then the decreasing values are continuously decreased and the overlapped format remain maintained even under the artificial lighting.

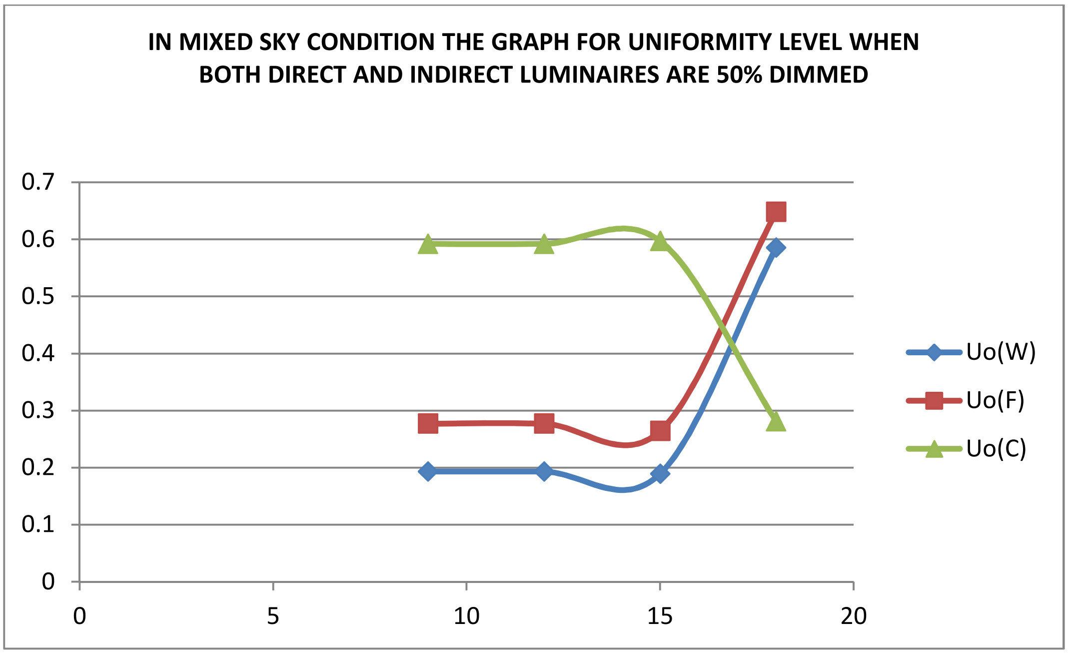
CASE : 61

IN MIXED SKY CONDITION,THE REFLECTANCE VALUES ARE 70-40-10, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.7m WHEN BOTH DIRECT AND INDIRECT LUMINAIRES ARE 50% DIMMED

Table:61.1. THE CHART OF UNIFORMITY LEVEL

	UNIFORMITY		
TIME	**Uo(W)**	**Uo(F)**	**Uo(C)**
9	0.193	0.277	0.592
12	0.193	0.277	0.592
15	0.189	0.264	0.597
18	0.585	0.648	0.281

Figure:61.1. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL

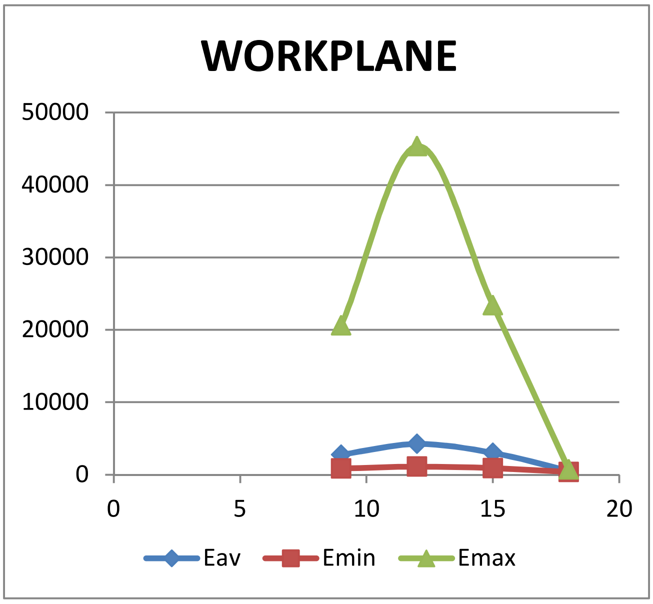


In this case also ,the same cross over occurred due to ceiling uniformity, which stay very much steady, stable and linear through out the day,as depicted in the figure of 61.1, but with the presence of artificial lighting it decreases sharply and interfacing with rest two parameters.

CASE :62

IN CLEAR SKY CONDITION,THE REFLECTANCE VALUES ARE 95-65-35,AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23m WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

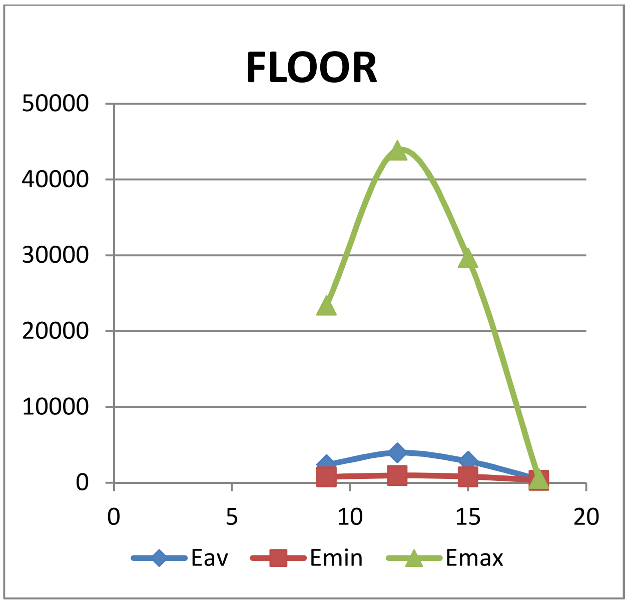
62.1. WORKPLANE VALUE CHART AND GRAPH OF IT



CLEAR SKY CONDITION				
WORKPLANE				
TIME	Eav (lx)	Emin (lx)	Emax (lx)	Uo
9	2772	855	20584	0.308
12	4238	1109	45365	0.262
15	3007	905	23398	0.301
18	543	368	708	0.679

62.2 FLOOR VALUE CHART AND GRAPH OF IT

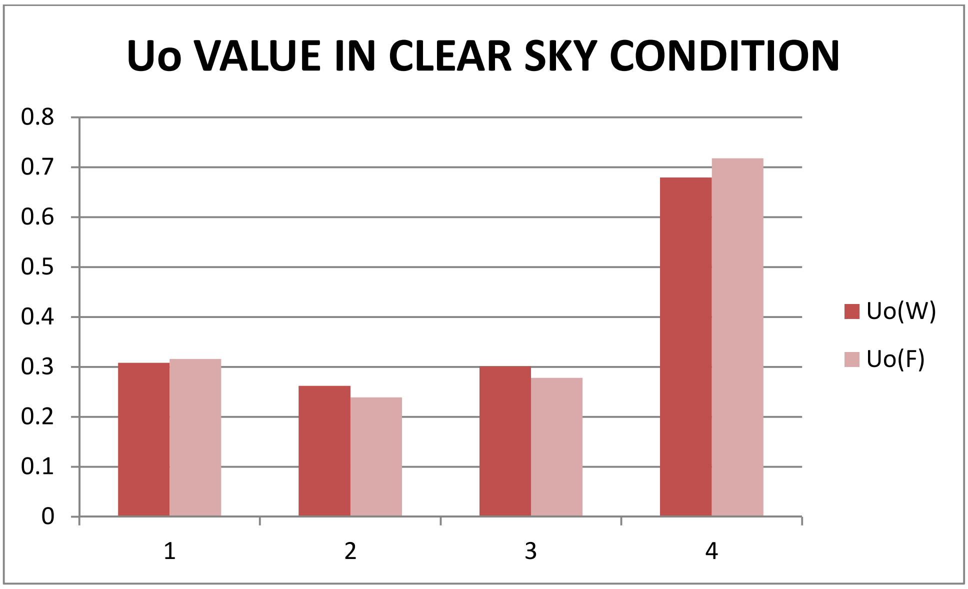
CLEAR SKY CONDITION				
FLOOR				
TIME	Eav	Emin	Emax	Uo



	(lx)	(lx)	(lx)	
9	2368	749	23369	0.316
12	3943	944	43836	0.239
15	2813	782	29610	0.278
18	423	304	497	0.718

Here from the charts and graphs one thing is observed that, the workplane and floor shows the same manner and this unique nature always observed in all of those cases where we obtained all the parameters in one graph. Mainly a heaped structure is created due to maximum illuminance level and minimum and average level are close to each others.

62.3. GRAPHS OF UNIFORMITY FOR WORKPLANE AND FLOOR



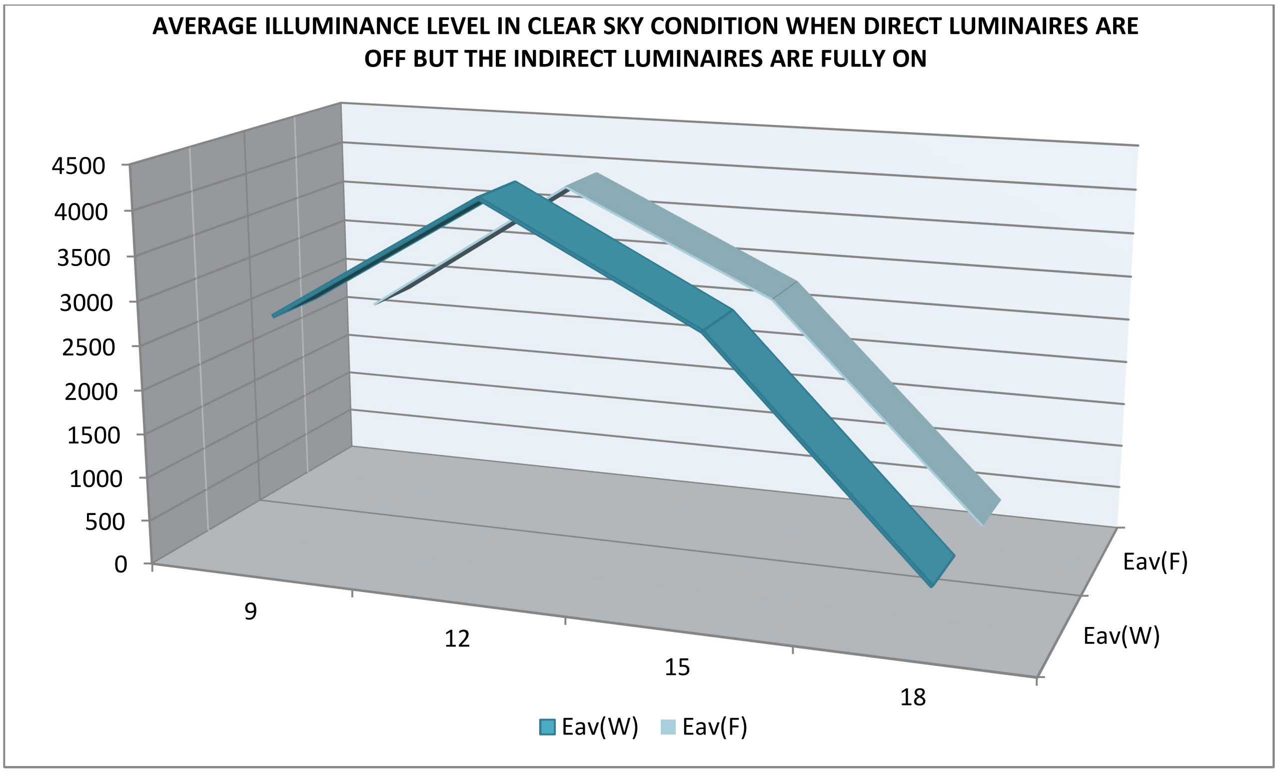
From the above bar graph its is easily obtained that, workplane value is always more than the floors uniformity but in artificial lighting this observation changed slightly and it improves its value.

62.4. COMPARETIVE STUDY OF ALL Eav ,Emin and Emax VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS :

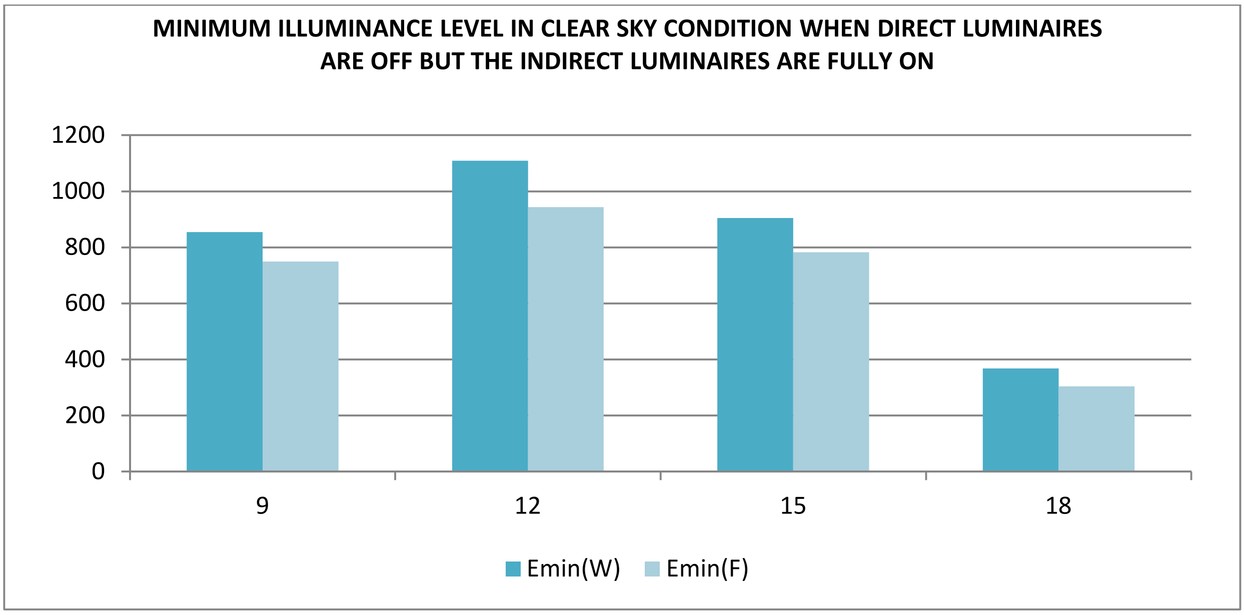
CLEAR SKY CONDITION		
TIME	Eav(W)	Eav(F)
9	2772	2368
12	4238	3943
15	3007	2813
18	543	423

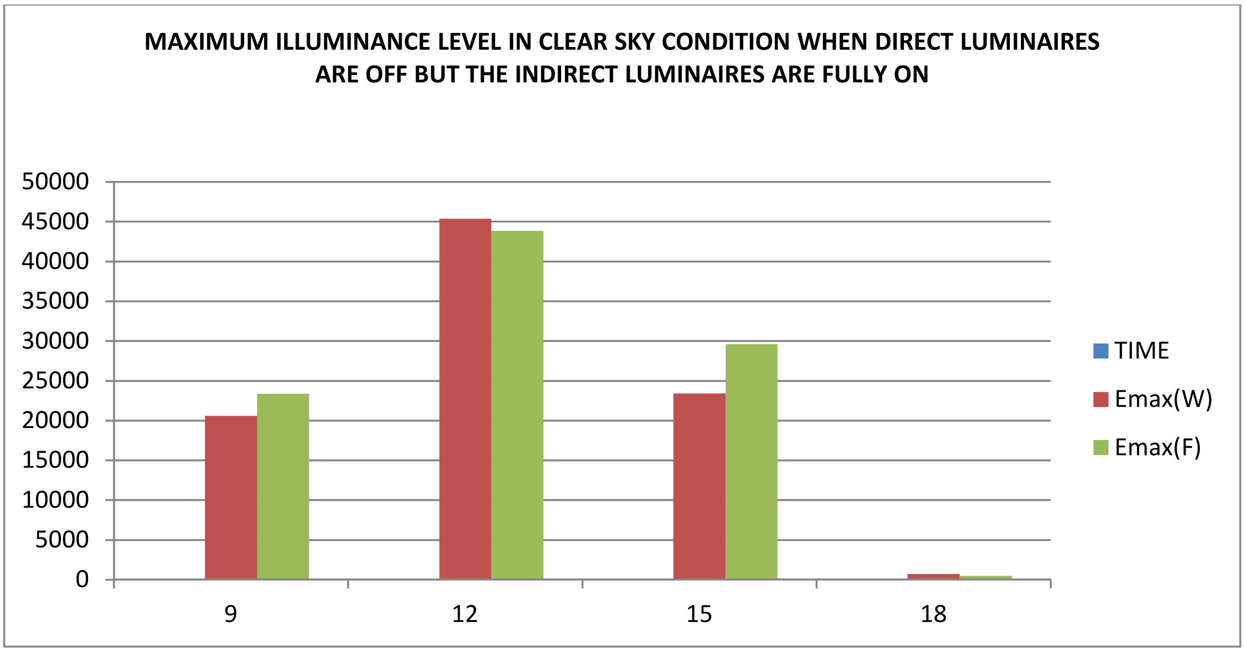
CLEAR SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	855	749
12	1109	944
15	905	782
18	368	304

CLEAR SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	20584	23369
12	45365	43836
15	23398	29610
18	708	497



Here these two slops described the average illuminance values of workplane and floor , from the chart also it is obtained that the average value of workplane is more than floor.





With the help of the comparative bar graphs of minimum and maximum illuminance level always workplane value is more than the value of floor area.And for the clear sky condition it is obtained and the results is appropriate.

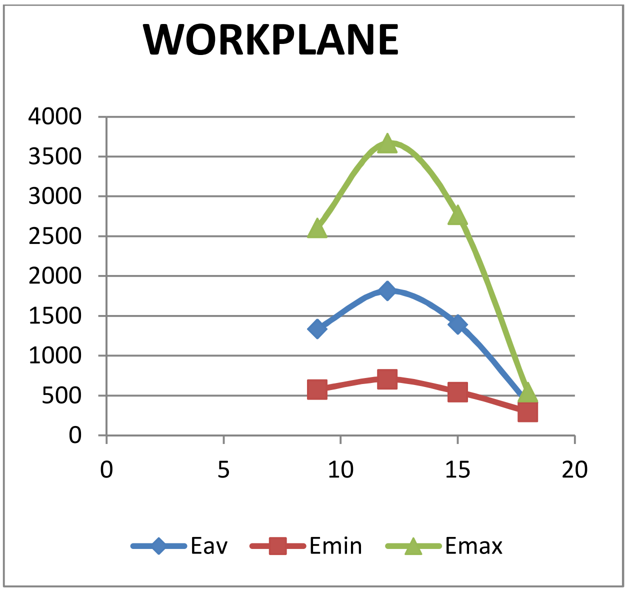
CASE :63

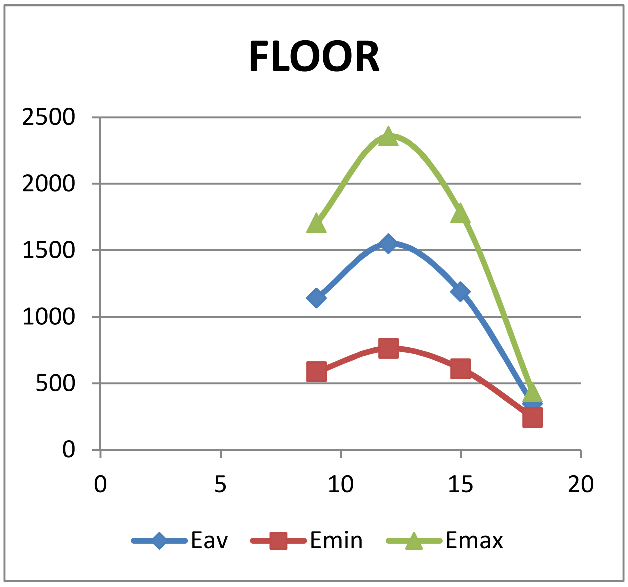
IN OVERCAST SKY CONDITION,THE REFLECTANCE VALUES ARE 95-65-35,AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23m WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

63.1. WORKPLANE AND FLOOR VALUE CHART AND GRAPH OF IT

OVERCAST SKY CONDITION				
WORKPLANE				
TIME	**Eav (lx)**	**Emin (lx)**	**Emax (lx)**	**Uo**
9	1337	576	2608	0.431
12	1814	705	3670	0.389
15	1395	547	2769	0.392
18	411	298	547	0.724

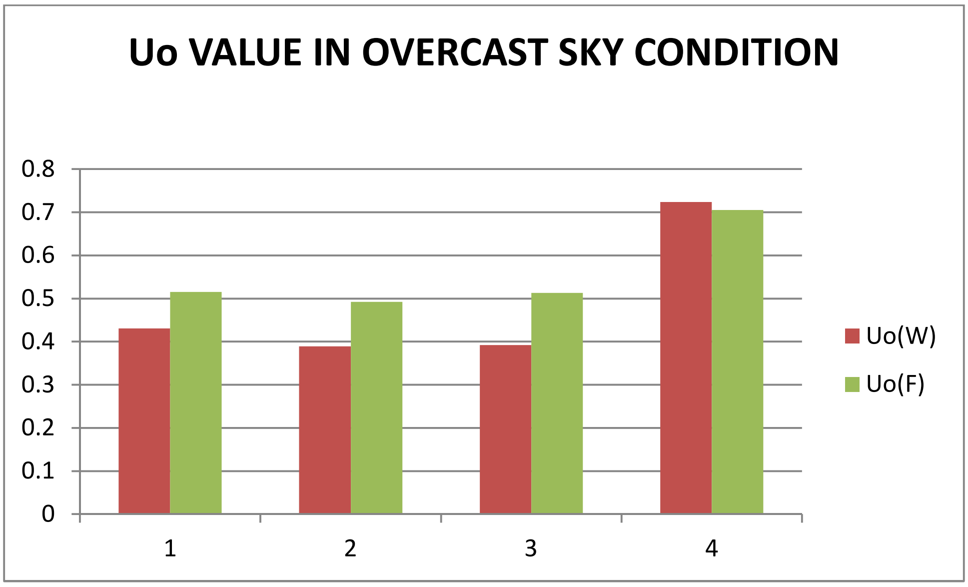
OVERCAST SKY CONDITION				
FLOOR				
TIME	**Eav (lx)**	**Emin (lx)**	**Emax (lx)**	**Uo**
9	1142	588	1706	0.515
12	1551	763	2358	0.492
15	1189	610	1782	0.513
18	346	244	433	0.705





From the above charts and with the help of these above graphs an easy conclusion can be obtained which shows that workplane and floor share the same nature.

63.2. GRAPHS OF UNIFORMITY FOR WORKPLANE AND FLOOR



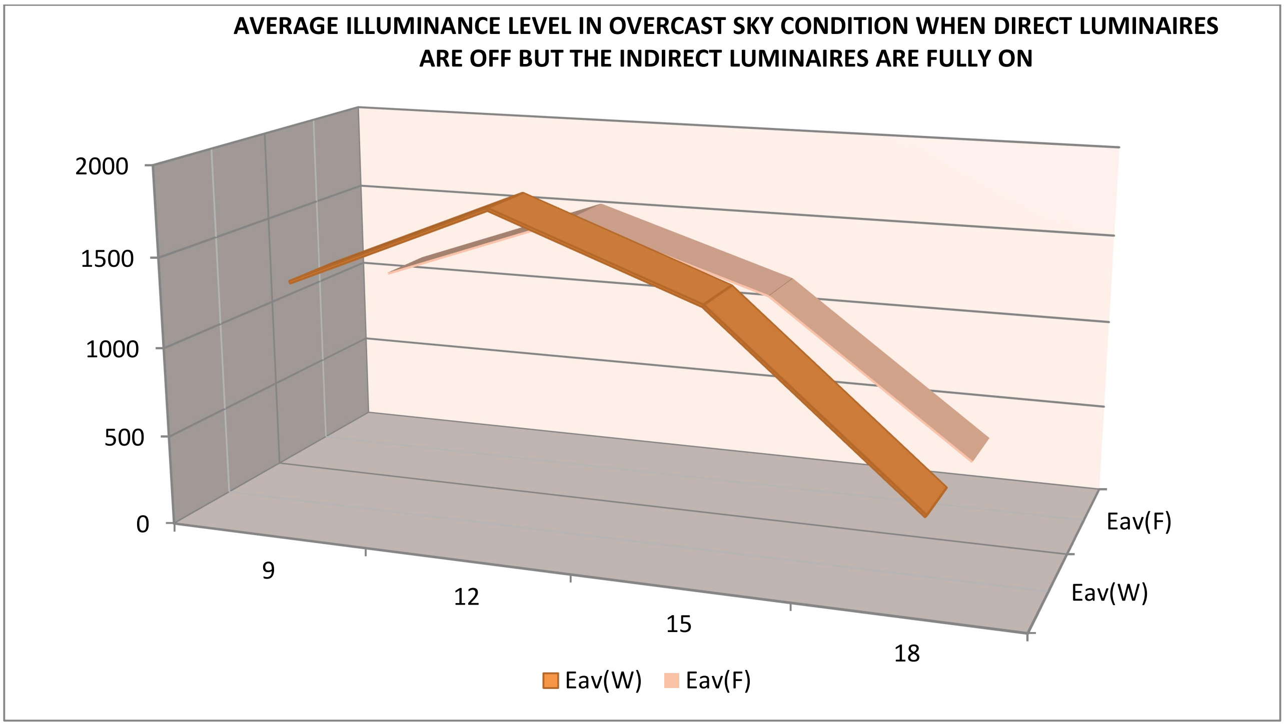
Here an exception occurred, during artificial lighting the uniformity value of workplane is higher than floor area. But during the full day uniformity of workplane remains low than the other parameter.

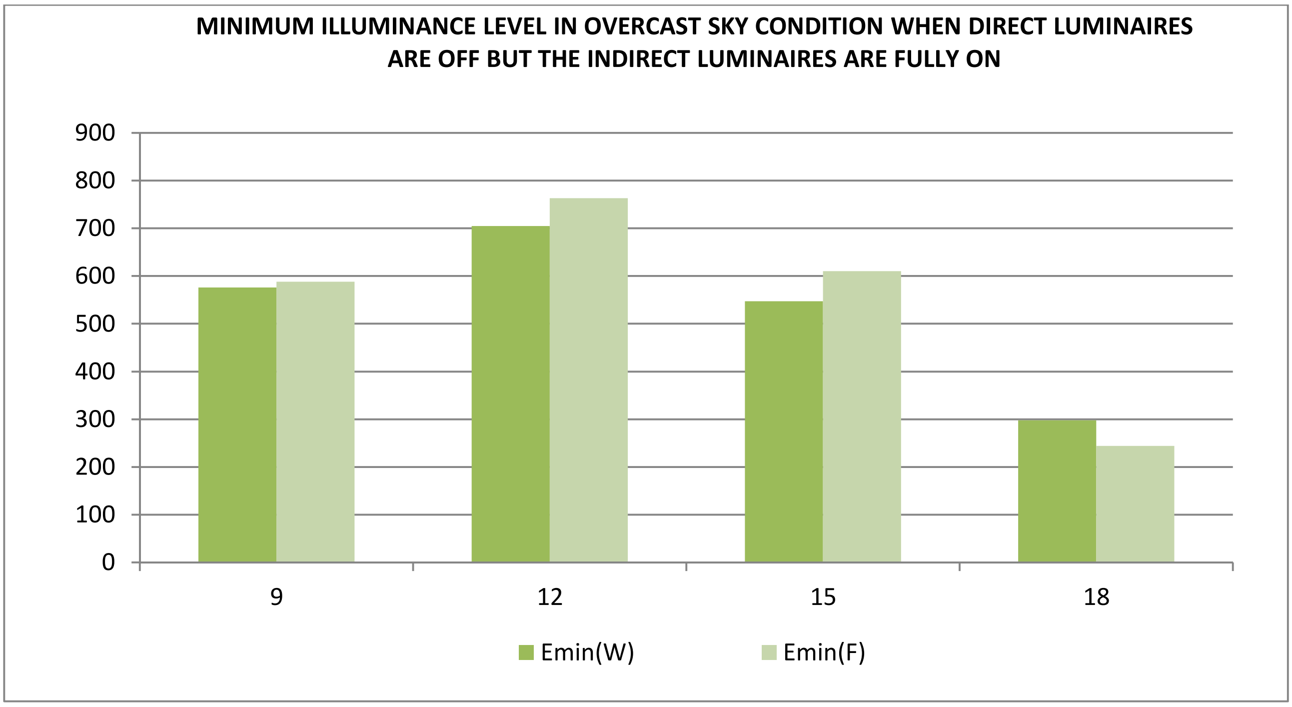
63.3. COMPARETIVE STUDY OF ALL Eav, Emin and Emax VALUES FOR WORKPLANE

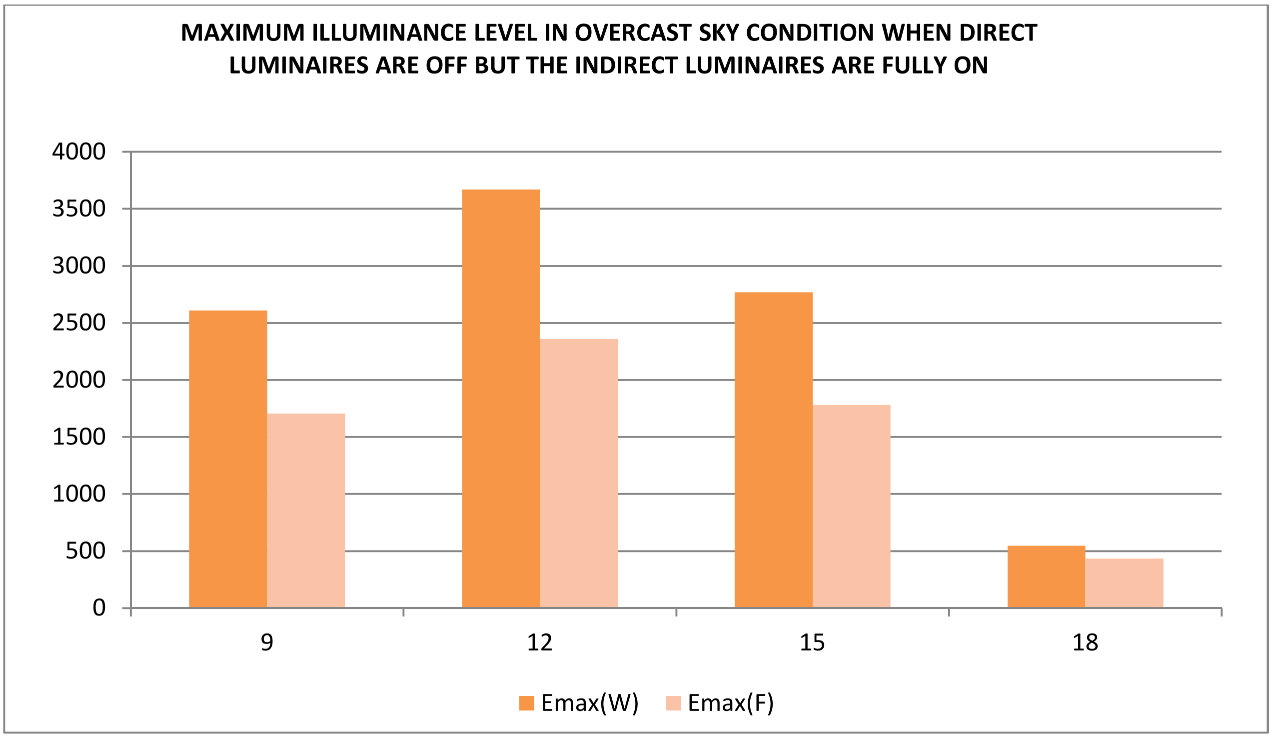
OVERCAST SKY CONDITION		
TIME	Eav(W)	Eav(F)
9	1337	1142
12	1814	1551
15	1395	1189
18	411	346

OVERCAST SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	576	588
12	705	763
15	547	610
18	298	244

OVERCAST SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	2608	1706
12	3670	2358
15	2769	1782
18	547	433


AVERAGE ILLUMINANCE LEVEL IN OVERCAST SKY CONDITION WHEN DIRECT LUMINAIRES ARE OFF BUT THE INDIRECT LUMINAIRES ARE FULLY ON
2000
1500
1000
500
0
9
12
15
18
Eav(F)
Eav(W)
Eav(W) Eav(F)


MINIMUM ILLUMINANCE LEVEL IN OVERCAST SKY CONDITION WHEN DIRECT LUMINAIRES ARE OFF BUT THE INDIRECT LUMINAIRES ARE FULLY ON
900
800
700
600
500
400
300
200
100
0
9
12
15
18
Emin(W) Emin(F)



Comparative study shows various things which are obtained from plotting of average illuminance level in overcast sky condition when direct luminaires are off but the indirect luminaires are fully on and also from minimum and maximum level of illuminance one common thing is obtained that is the value of workplane is always greater than the value of floor area. But in the case of minimum illuminance through out the day the level of workplane is lower than the floor area but under the artificial light the value of workplane is higher than the rest parameter.

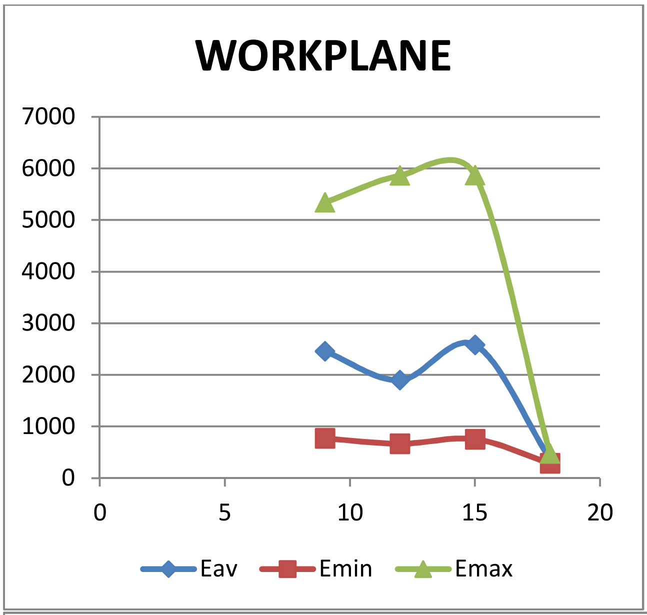
CASE: 64

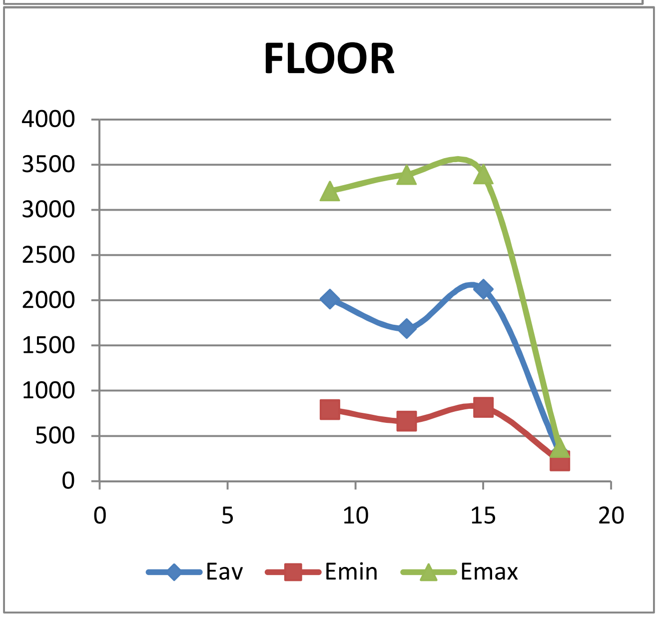
IN MIXED SKY CONDITION, THE REFLECTANCE VALUES ARE 95-65-35, AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23m WHEN DIRECT LUMINAIRES ARE OFF AND INDIRECT LUMINAIRES ARE FULLY ON

64.1. WORKPLANE AND FLOOR VALUE CHART AND GRAPH OF IT

MIXED SKY CONDITION				
WORKPLANE				
TIME	**E_{av} (lx)**	**E_{min} (lx)**	**E_{max} (lx)**	**U_o**
9	2456	770	5342	0.313
12	1898	665	5858	0.35
15	2580	754	5866	0.292
18	374	288	471	0.771

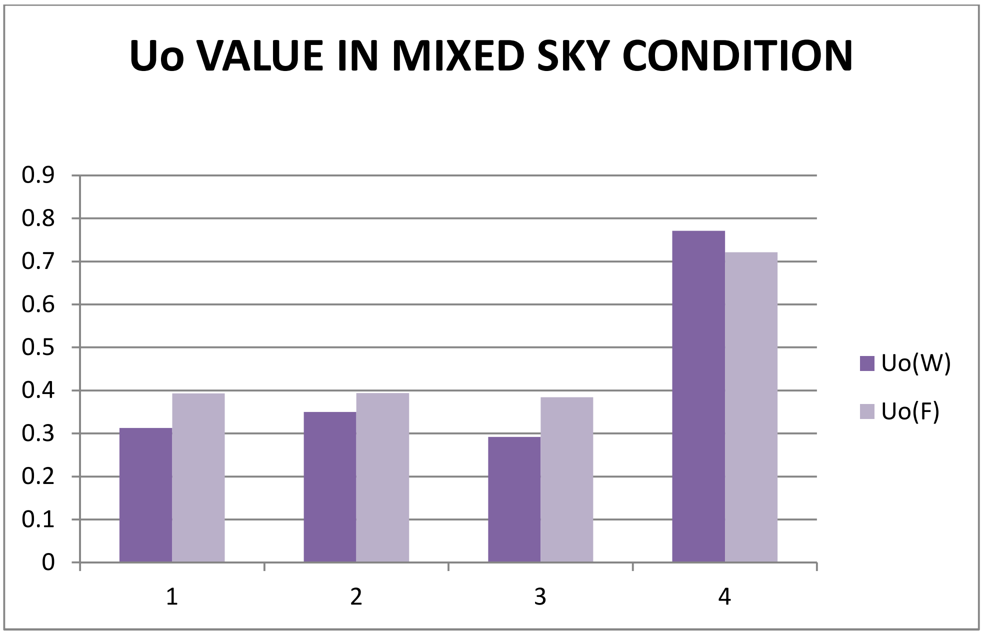
MIXED SKY CONDITION				
FLOOR				
TIME	**E_{av} (lx)**	**E_{min} (lx)**	**E_{max} (lx)**	**U_o**
9	2012	791	3208	0.393
12	1687	664	3389	0.394
15	2123	816	3393	0.384
18	309	223	368	0.721





Above two charts and graphs are obtained for mixed sky condition, where the reflectance values are 95-65-35, and the suspension height of the luminaires are 0.23m when direct luminaires are off and indirect luminaires are fully on. These two shows the same similarities.

64.2. GRAPHS OF UNIFORMITY FOR WORKPLANE AND FLOOR



Here also the same exception occurred, during artificial lighting the uniformity value of workplane is higher than floor area. But during the full day uniformity of workplane remains low than the other parameter.

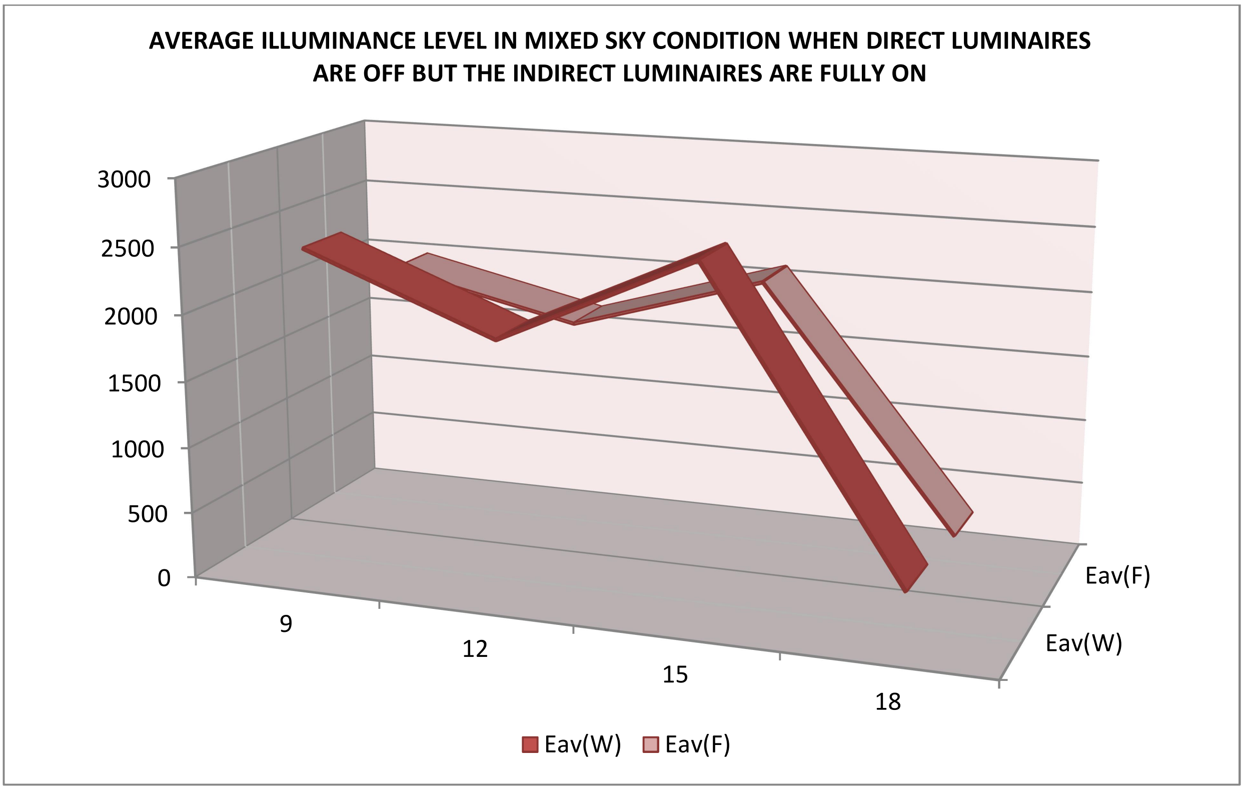
64.3. COMPARETIVE STUDY OF ALL Eav, Emin and Emax VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

MIXED SKY CONDITION		
TIME	Eav(W)	Eav(F)
9	2456	2012
12	1898	1687
15	2580	2123
18	374	309

MIXED SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	770	791
12	665	664
15	754	816
18	288	223

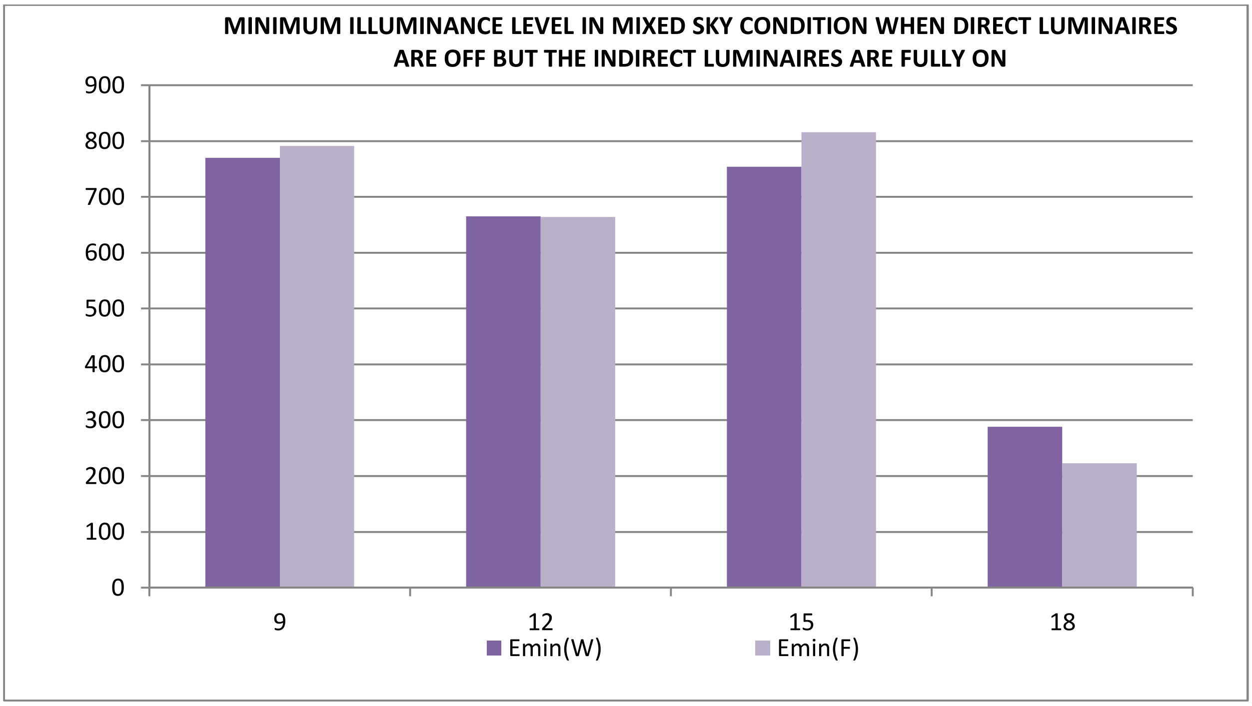
MIXED SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	5342	3208
12	5858	3389
15	5866	3393
18	471	368

64.4. GRAPH FOR AVERAGE ILLUMINANCE LEVEL IN MIXED SKY CONDITION

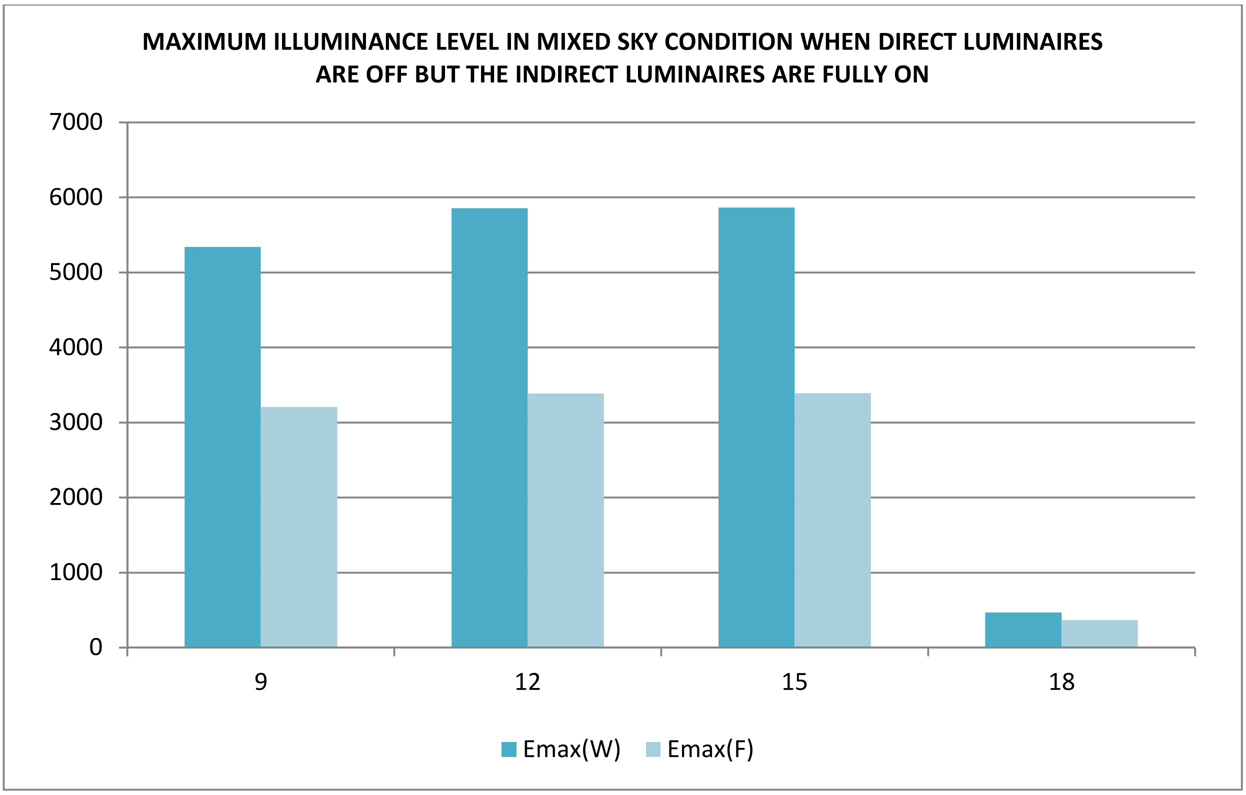


At 9AM the average illuminance level was tends to decreased over time but then it picked up its highest values at 12PM and after that it decrease rapidly for both of them.

64.5. GRAPH FOR MINIMUM ILLUMINANCE LEVEL IN MIXED SKY CONDITION



64.6. GRAPH FOR MAXIMUM ILLUMINANCE LEVEL IN MIXED SKY CONDITION



Minimum illuminance for floor is higher at 9AM but the value is same for both of them at 12PM and then the floor value increases over workplane value due to daylight integration. But with artificial lighting this just changed its nature and the average illuminance value reached its best values which is more than the floor value. Maximum illuminance is always higher in workplane due to daylight integrations which is also maintained in artificial lighting also.

CASE :65

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 90-60-30 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23m WHEN DIRECT AND INDIRECT LUMINAIRES BOTH ARE 50% DIMMED

65.1. WORKPLANE AND FLOOR VALUE CHART

CLEAR SKY CONDITION				
WORKPLANE				
TIME	E_{av} (lx)	E_{min} (lx)	E_{max} (lx)	U_o
9	2697	791	20540	0.293
12	4147	1034	45304	0.249
15	2926	829	23314	0.283
18	335	250	416	0.746

CLEAR SKY CONDITION				
FLOOR				
TIME	E_{av} (lx)	E_{min} (lx)	E_{max} (lx)	U_o
9	2263	697	2284	0.308
12	3821	886	43661	0.232
15	2704	728	28709	0.269
18	272	197	327	0.25

65.2. COMPARETIVE STUDY OF ALL Eav, Emin and Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

CLEAR SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	2263	2697
12	3821	4147
15	2704	2926
18	272	335

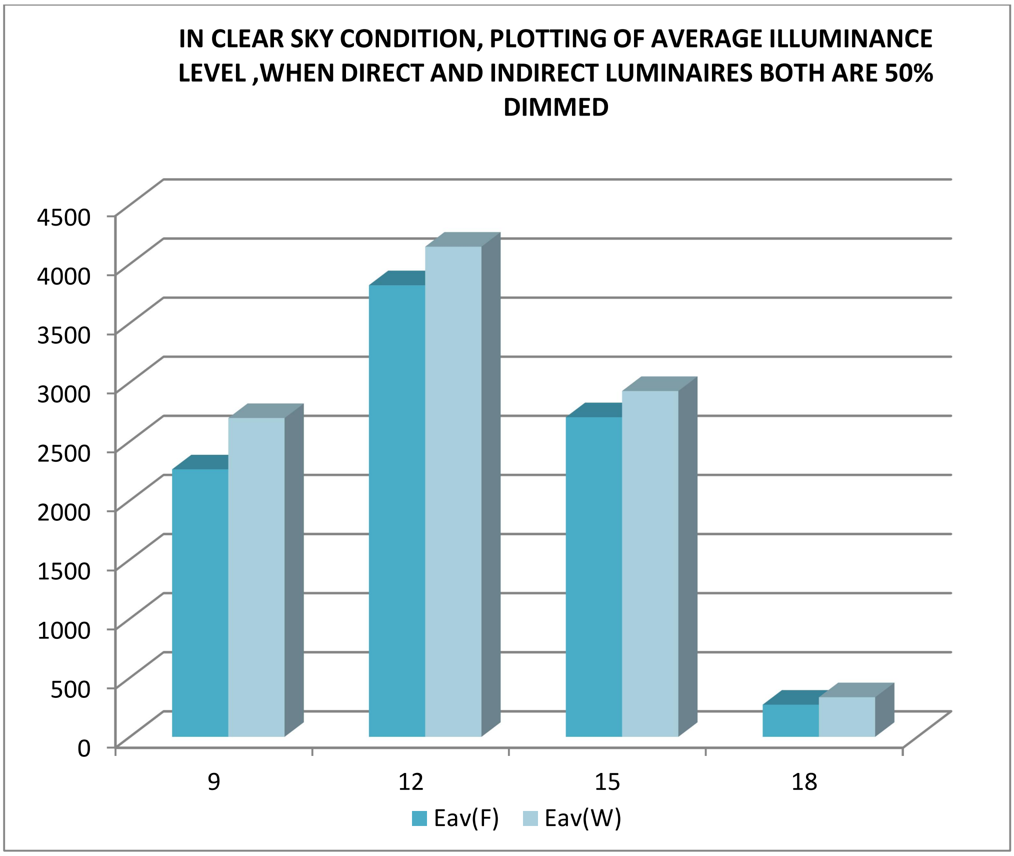
CLEAR SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	791	697
12	1034	886
15	829	728
18	250	197

CLEAR SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	20540	2284
12	45304	43661
15	23314	28709
18	416	327

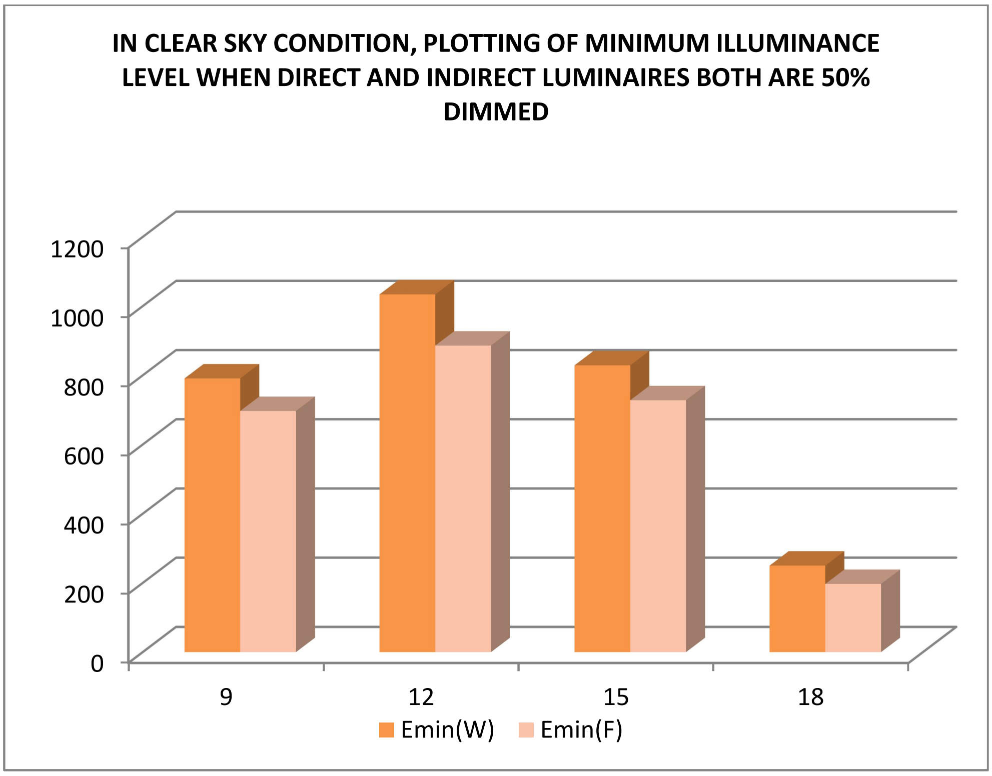
CLEAR SKY CONDITION		
TIME	$U_{o(W)}$	$U_{o(F)}$
9	0.293	0.308
12	0.249	0.232
15	0.283	0.269
18	0.746	0.25

All the values of average, maximum, minimum illuminance which are obtained from the simulation is tabulated here with the uniformity data's, all of the values are appropriate for clear sky condition, where the reflectance values are 90-60-30 and the suspension height of the luminaires are 0.23m when direct and indirect luminaires both are 50% dimmed .

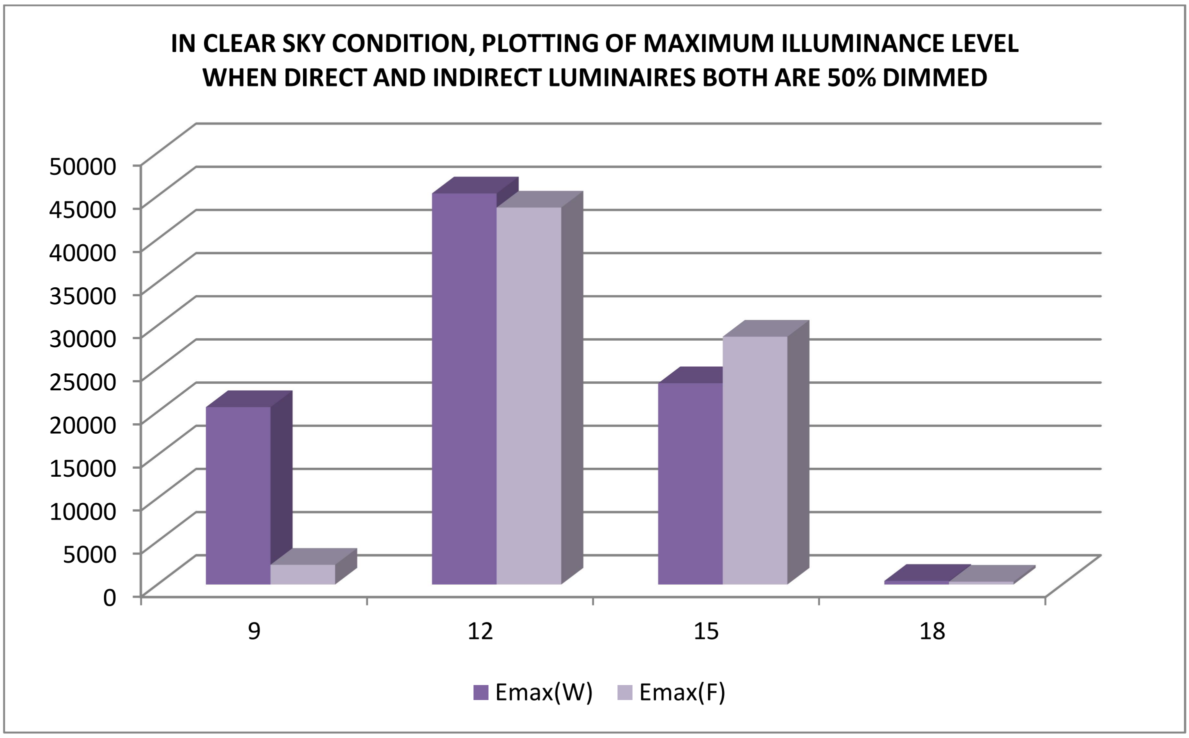
65.3. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



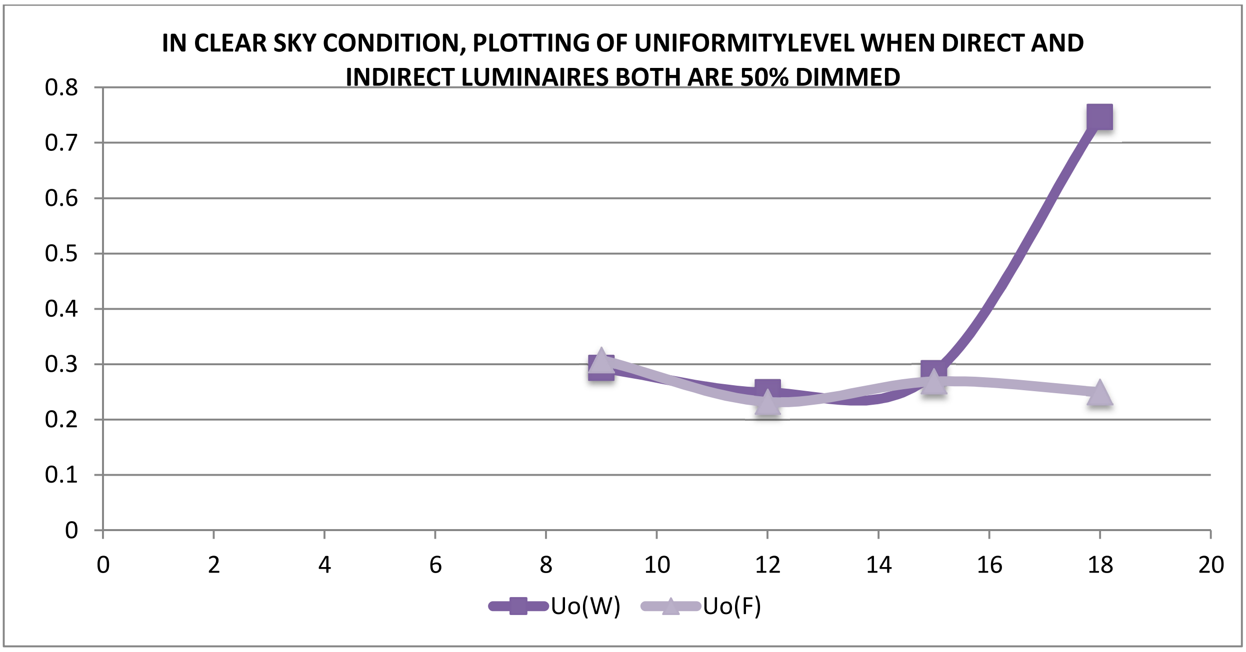
65.4. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



65.5. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL



65.6. THE GRAPH OF UNIFORMITY LEVEL



When the control group is set as the above mentioned conditions then the average illuminance values of floor area remains high through out the day, and only in the artificial lighting conditions this phenomenon remain unchanged, but for minimum values of illuminance always the opposite thing happened so the larger value obtained by workplane here. Because of the daylight integration, at 9AM,12PM always the workplane values are in the top position, but when sun sets down then for the control group dimming value the maximum level of illuminance goes lower than floor values.

The main changed happened in the region of uniformity,where the initial values are same at 9AM and there is a overlapping occurred upto 3PM,which means with daylight there is no significant change occurred, but under the artificial light uniformity for workplane rises sharply but floor are uniformity doesn't change more.

CASE: 66

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 90-60-30 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23m WHEN DIRECT AND INDIRECT LUMINAIRES BOTH ARE 50% DIMMED

66.1. COMPARETIVE STUDY OF ALL Eav, Emin and Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS

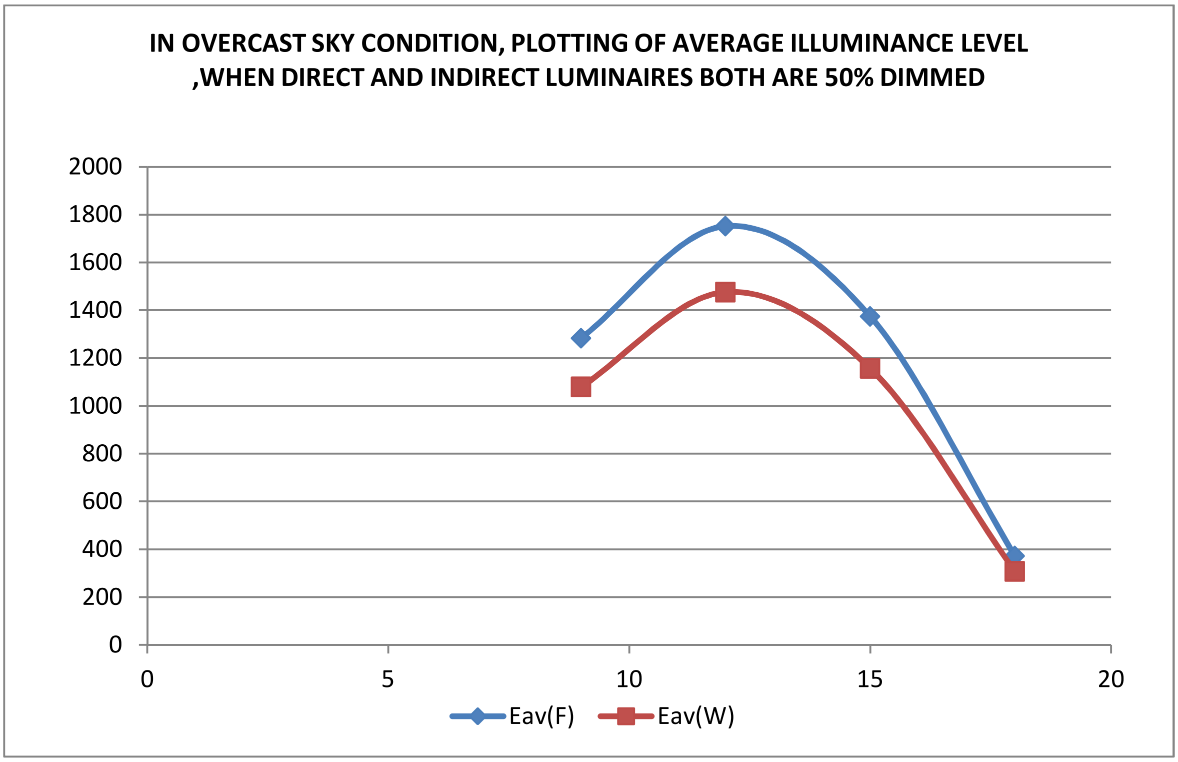
OVERCAST SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	1283	1079
12	1752	1476
15	1374	1157
18	372	308

OVERCAST SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	515	538
12	635	705
15	533	571
18	269	214

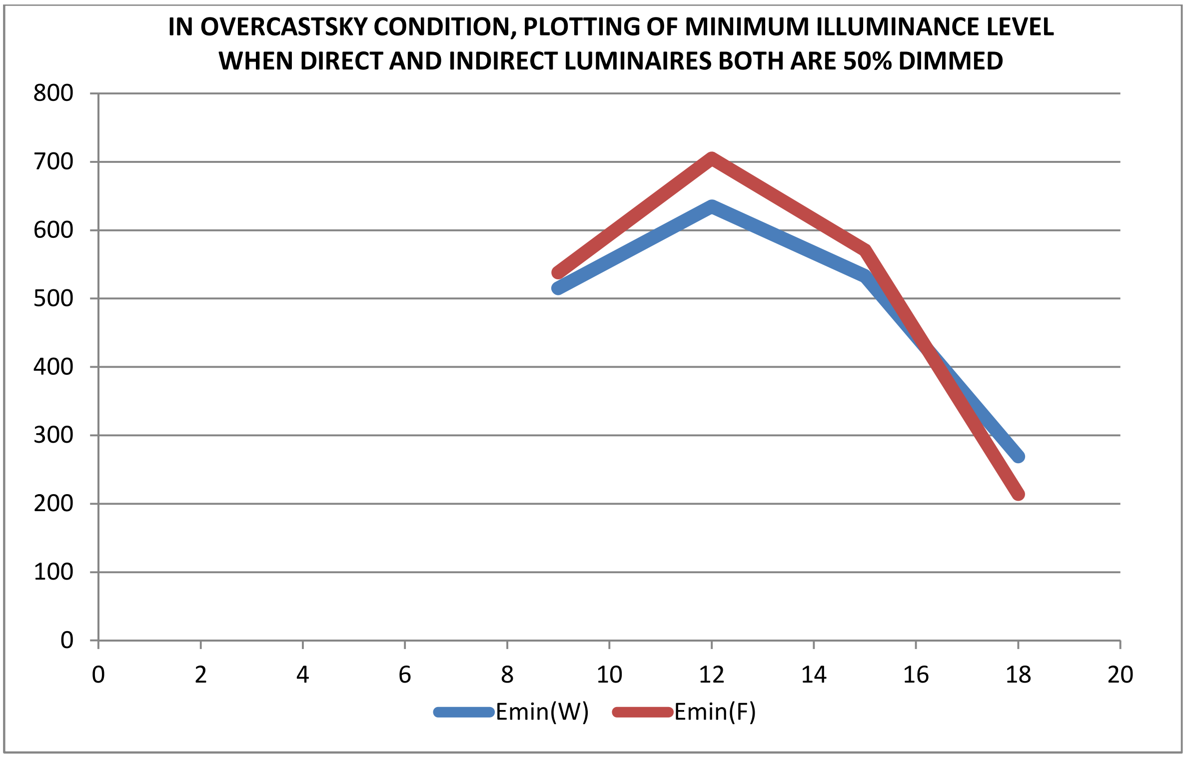
OVERCAST SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	2561	1646
12	3608	2287
15	2766	1772
18	506	391

OVERCAST SKY CONDITION		
TIME	**$U_{o(W)}$**	**$U_{o(F)}$**
9	0.401	0.498
12	0.363	0.478
15	0.388	0.494
18	0.723	0.695

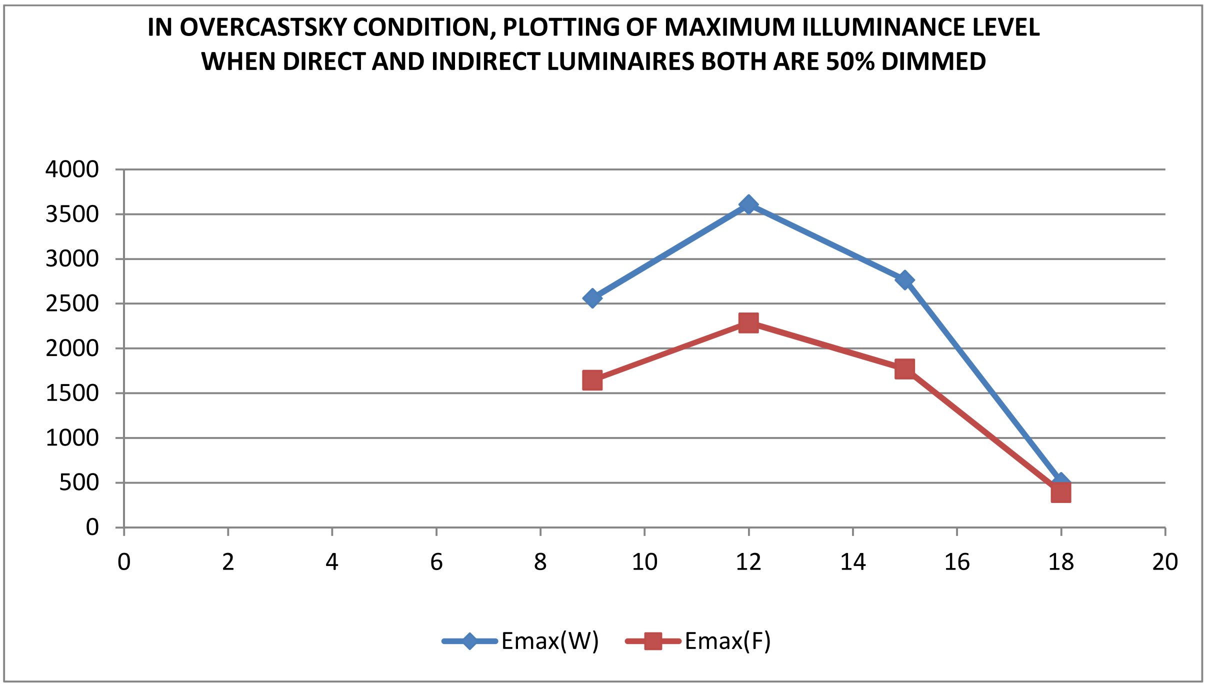
66.2. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



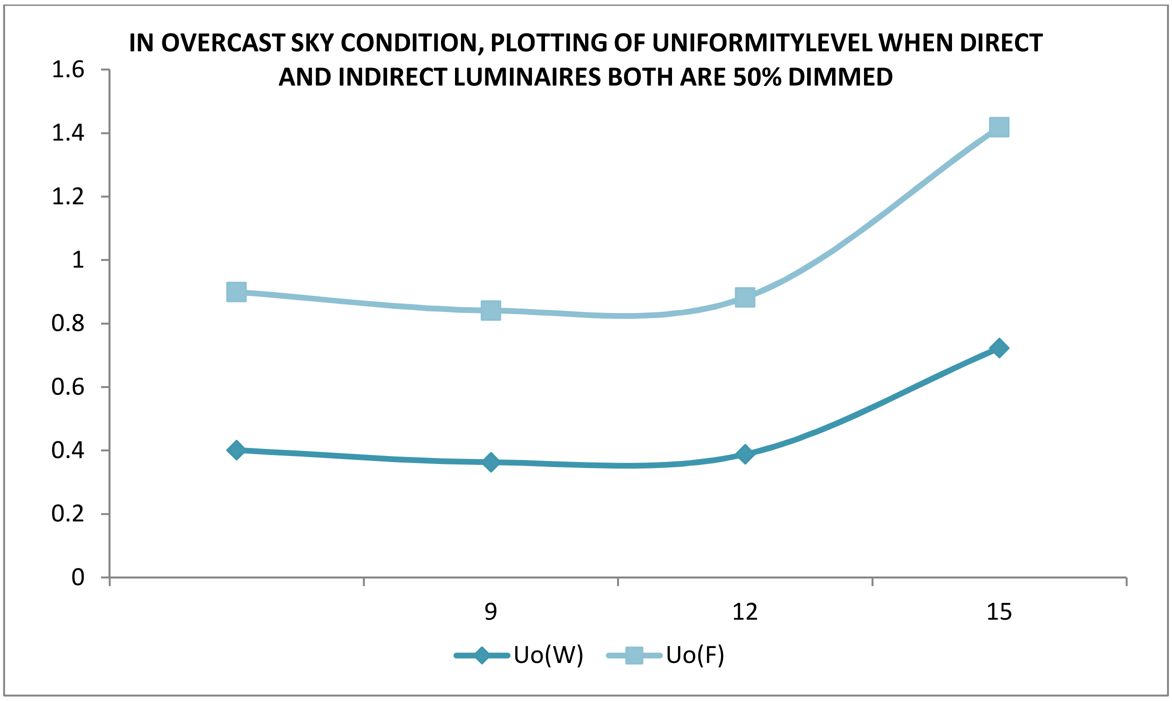
66.3. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



66.4. THE GRAPH OF MAXIMUM ILLUMINANCE LEVEL



66.5. THE GRAPH OF UNIFORMITY ILLUMINANCE LEVEL



In the overcast sky condition, where the reflectance values are 90-60-30 and the suspension height of the luminaires are 0.23m when direct and indirect luminaires both are 50% dimmed then for maximum, minimum, average illuminance values and for uniformity values also the same observation happened, which is workplane value is always better than the value of floor area, this is not just concluded from the above graphs but validated from the simulating data's also which are tabulated above.

CASE : 67

IN MIXED SKY CONDITION, THE REFLECTANCE VALUES ARE 90-60-30 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT AND INDIRECT LUMINAIRES BOTH ARE 50% DIMMED

67.1. COMPARATIVE STUDY OF ALL Eav, Emin and Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS AND GRAPHS

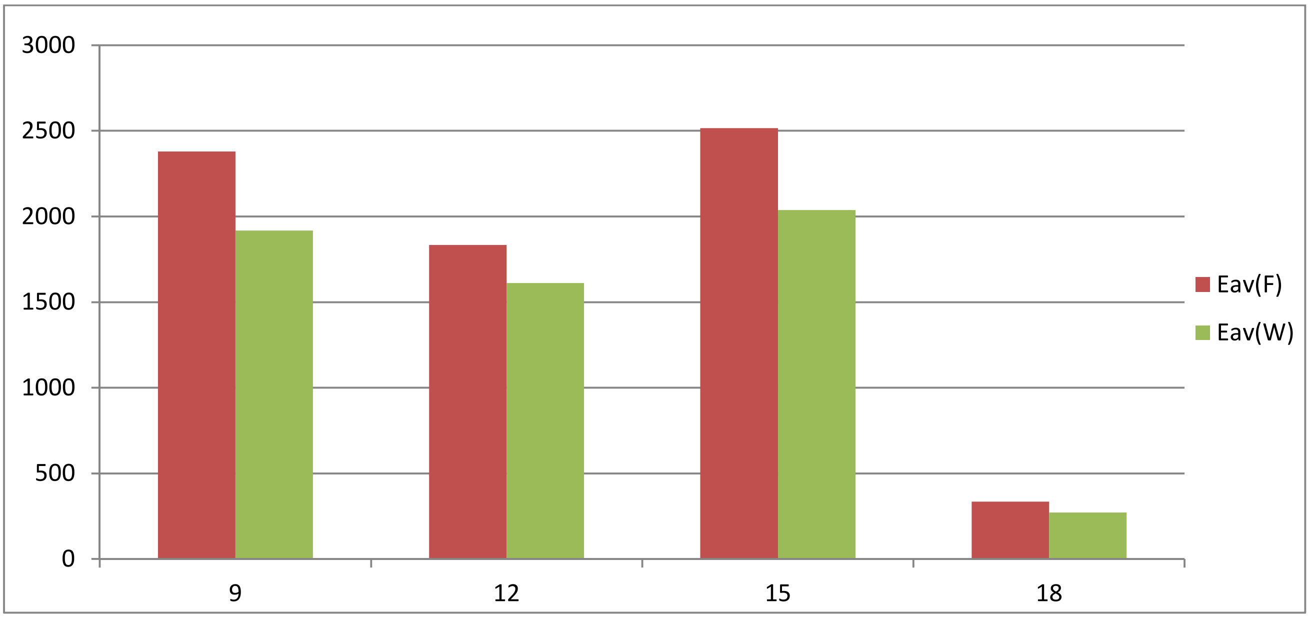
MIXED SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	2380	1917
12	1834	1612
15	2515	2037
18	335	272

MIXED SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	690	731
12	609	603
15	715	738
18	250	197

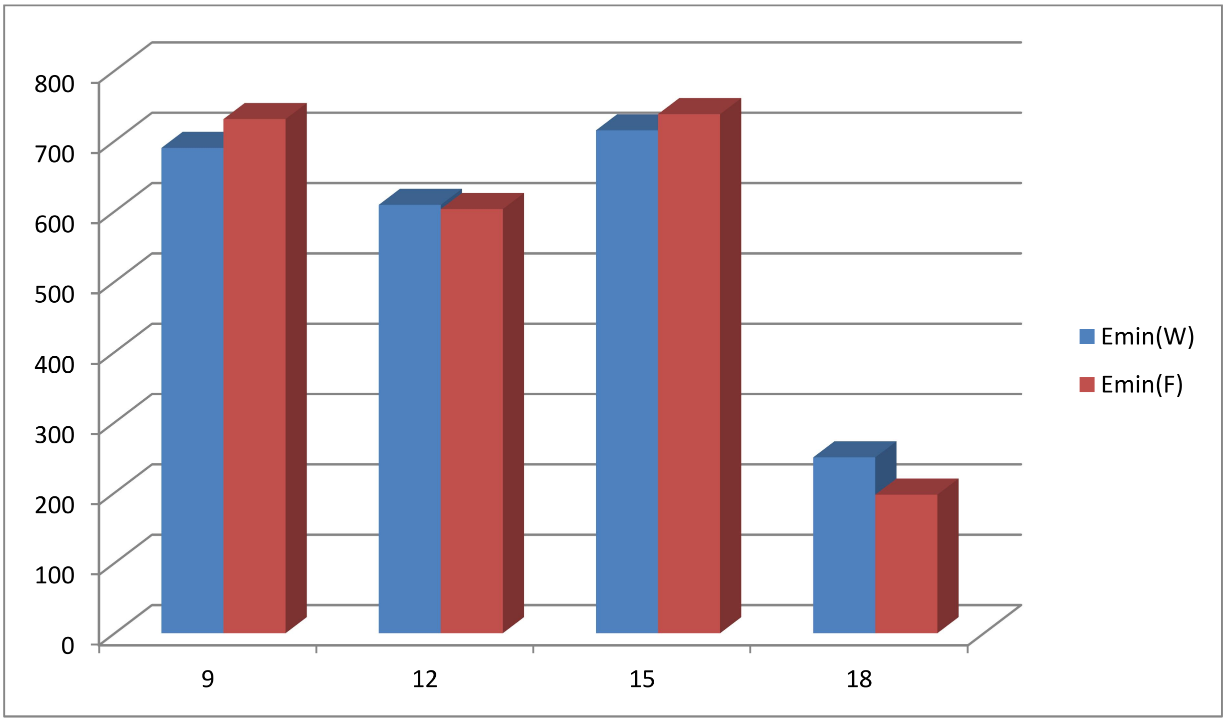
MIXED SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	5267	3112
12	5799	3298
15	5824	3307
18	416	327

OVERCAST SKY CONDITION		
TIME	**$U_{o(W)}$**	**$U_{o(F)}$**
9	0.29	0.381
12	0.332	0.374
15	0.284	0.362
18	0.746	0.25

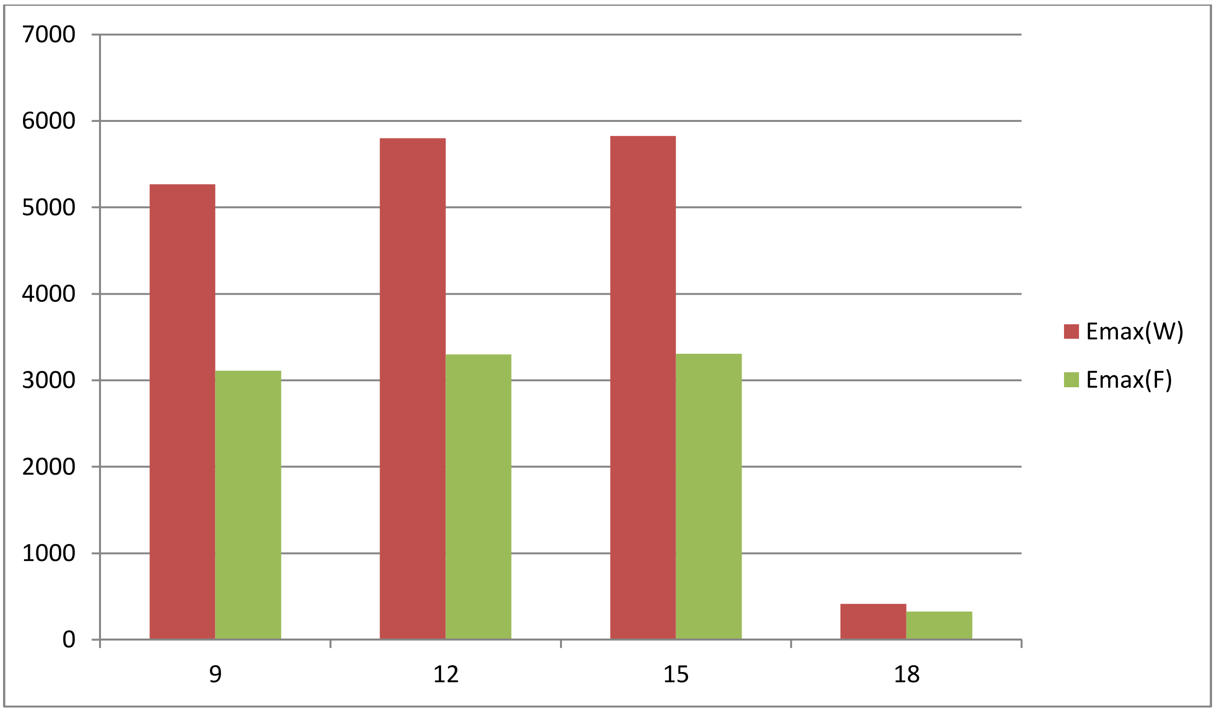
67.2. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



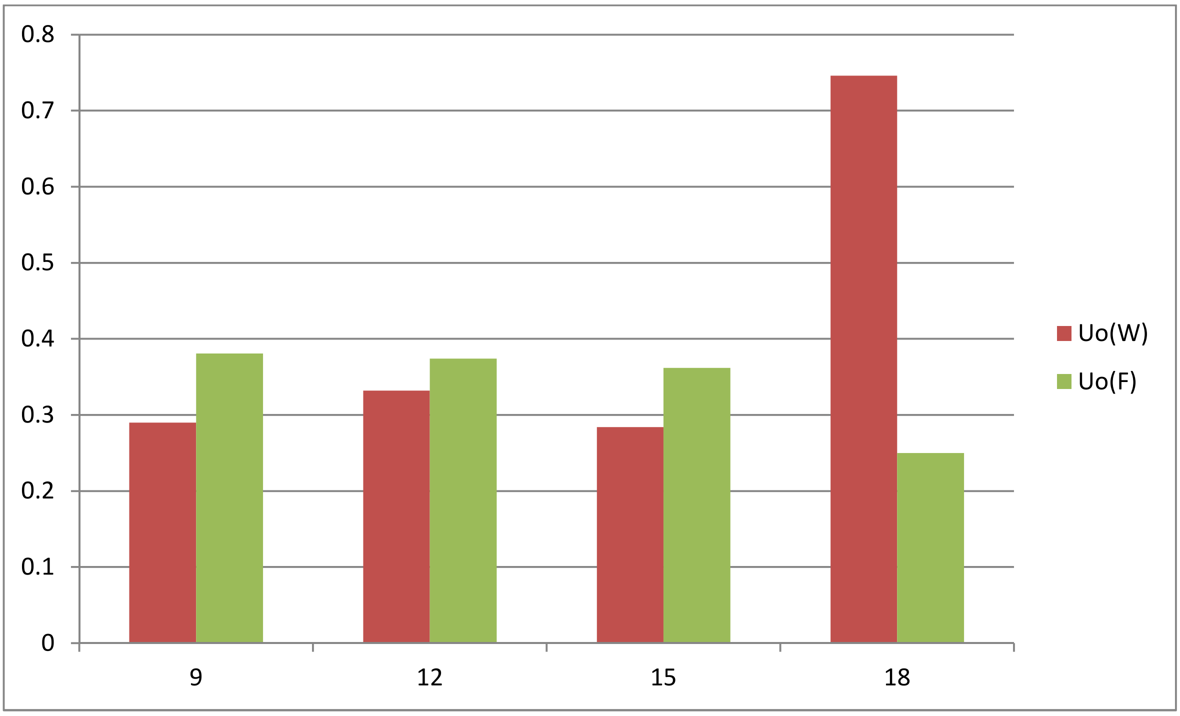
67.3. THE GRAPH OF MINIMUM ILLUMINANCE LEVEL



67.4. THE GRAPH OF AVERAGE ILLUMINANCE LEVEL



64.5. THE GRAPH OF UNIFORMITY LEVEL



Minimum illuminance level of floor is always higher in position than the workpalne values, but this observation occurred due to the daylight integration ,but when daylight elimination occurred then the opposite observation takes place.

For average and maximum illuminance level throughout the day unless it is with daylight or without daylight workplane values are higher than the floor area.

Here also the same exception occurred which is obtained in a condition, where, all the conditions are : the sky should be in mixed sky condition,the reflectance values are 95-65-35, and the suspension height of the luminaires are 0.23m when direct luminaires are off and indirect luminaires are fully on, during artificial lighting the uniformity value of workplane is higher than floor area.But during the full day uniformity of workplane remains low than the other parameter.

CASE: 68

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 80-50-20 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT LUMINAIRES ARE 50% DIMMED AND INDIRECTLUMINAIRES ARE FULLY ON

68.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

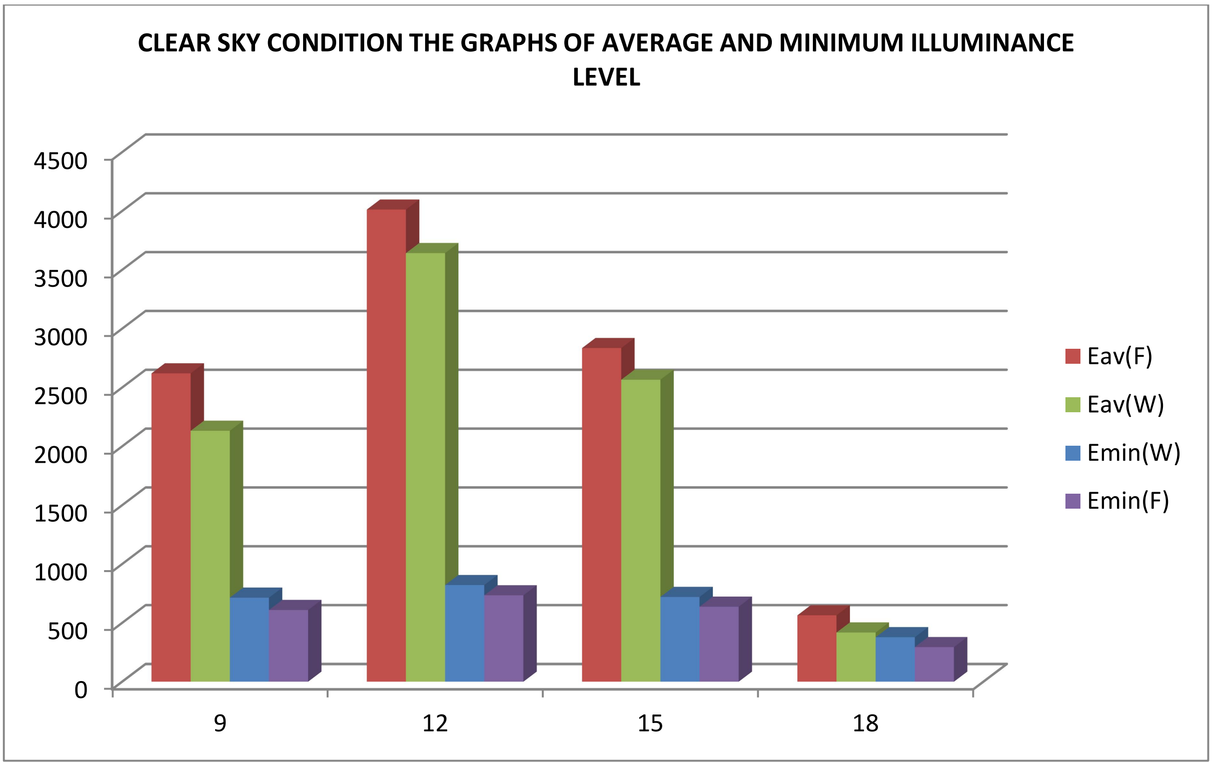
CLEAR SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	2620	2132
12	4012	3642
15	2835	2566
18	564	418

CLEAR SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	714	609
12	821	734
15	720	637
18	378	294

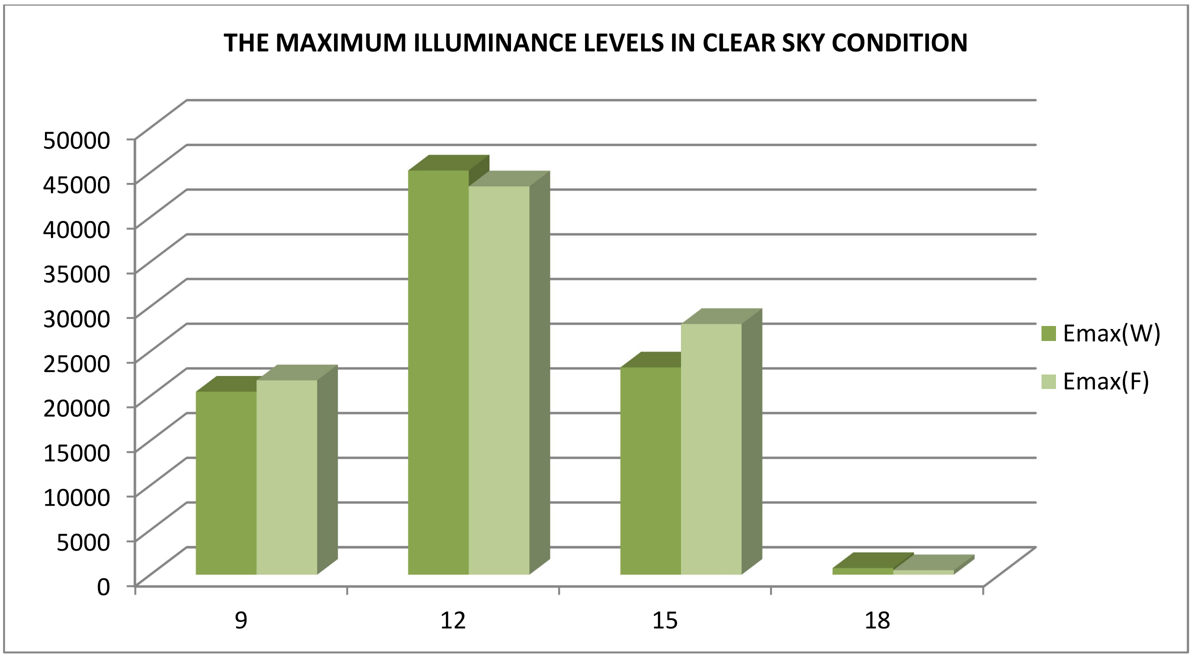
CLEAR SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	20467	21741
12	45208	43433
15	23180	28037
18	737	498

CLEAR SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.272	0.286
12	0.205	0.202
15	0.254	0.248
18	0.671	0.703

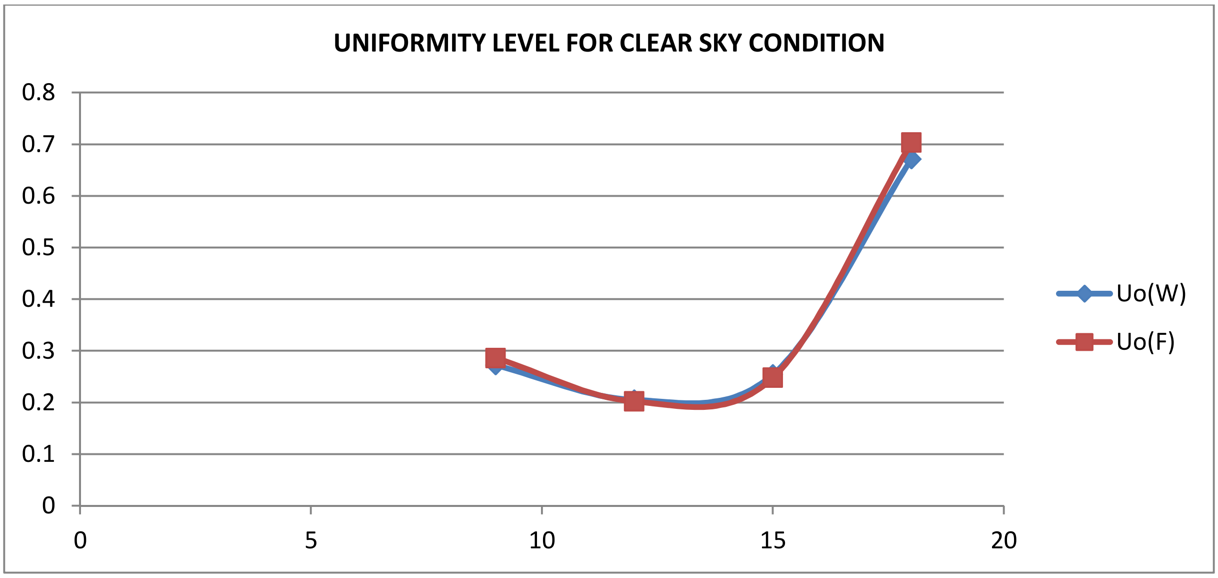
68.2.GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



68.3. GRAPH FOR MAXIMUMILLUMINANCE LEVELS OF WORKPLANE AND FLOOR:



68.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



When the consideration of all boundary conditions are like:for clear sky condition,where the reflectance values are 80-50-20 and the suspension height of the luminaires are 0.23m when direct luminaires are 50% dimmed and indirect luminaires are fully on, then the average floor area illuminance level is higher than the workplane value, but this is not valid for minimum illuminance level, where workplane is higher than floor area. Maximium illuminance level of workplane is lower at first then it rises up and then it decrease its value after that pick up.

Uniformity level of these two parameters are continuously overlapping to each other and it increase rapidly in artificial lighting.

CASE: 69

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 80-50-20 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT LUMINAIRES ARE 50% DIMMED AND INDIRECTLUMINAIRES ARE FULLY ON

69.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

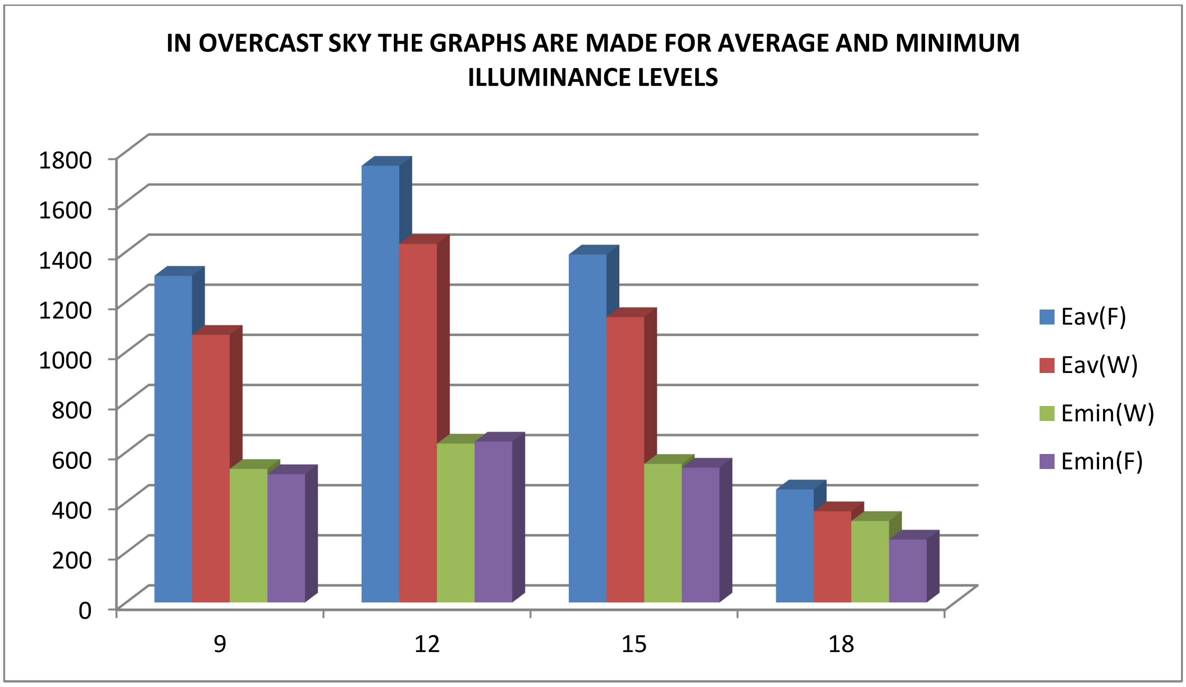
OVERCAST SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	1304	1068
12	1743	1431
15	1389	1139
18	451	364

OVERCAST SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	533	512
12	634	642
15	553	538
18	325	251

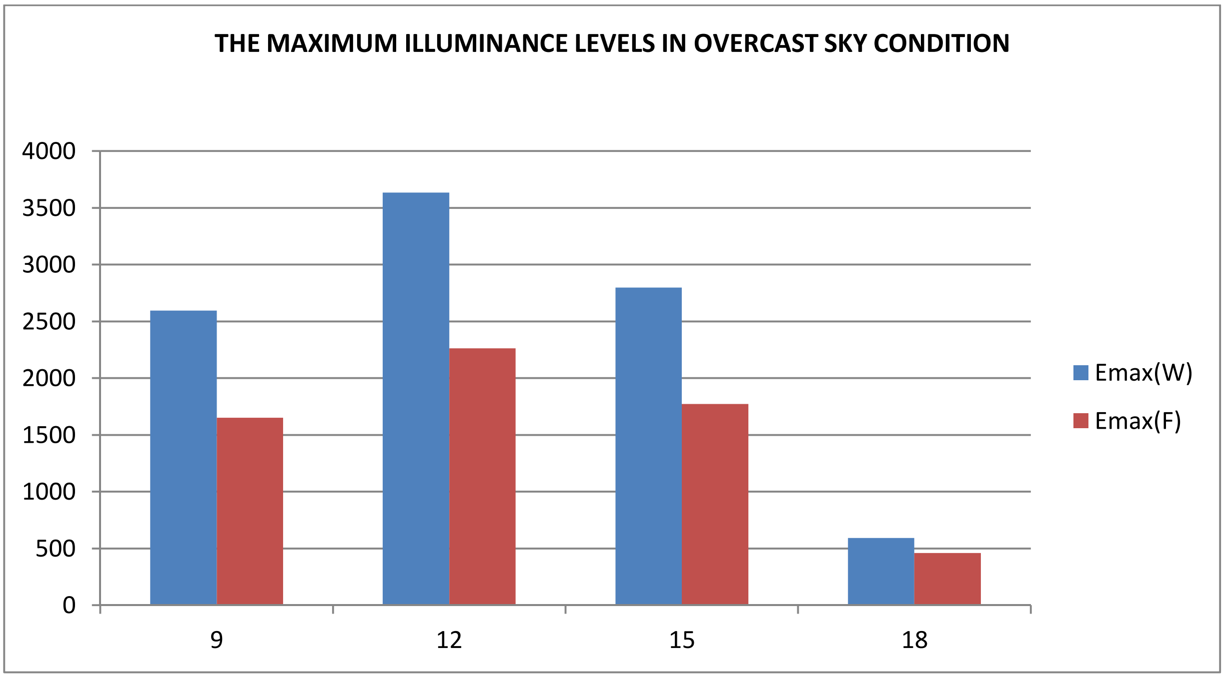
OVERCAST SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	2597	1652
12	3636	2263
15	2799	1772
18	594	460

OVERCAST SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.409	0.479
12	0.364	0.449
15	0.398	0.472
18	0.721	0.69

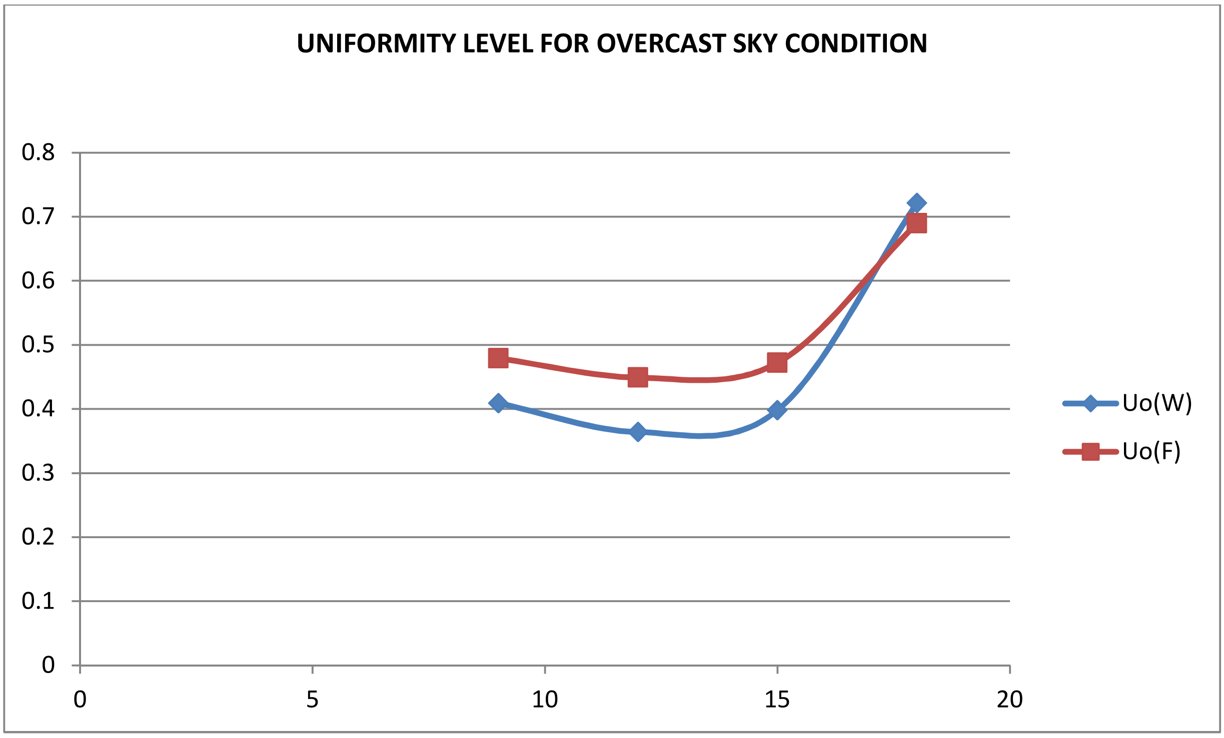
69.2.GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



69.3. GRAPH FOR MAXIMUMILLUMINANCE LEVELS OF WORKPLANE AND FLOOR:



69.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



Here the same things happened which shows that the value of workplane is higher than the value of floor area, there is a similarities takes place in uniformity also which depicted that there is a small coincide point occurred at 6PM,which means under the artificial lighting.

CASE: 70

IN MIXED SKY CONDITION, THE REFLECTANCE VALUES ARE 80-50-20 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT LUMINAIRES ARE 50% DIMMED AND INDIRECTLUMINAIRES ARE FULLY ON

70.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

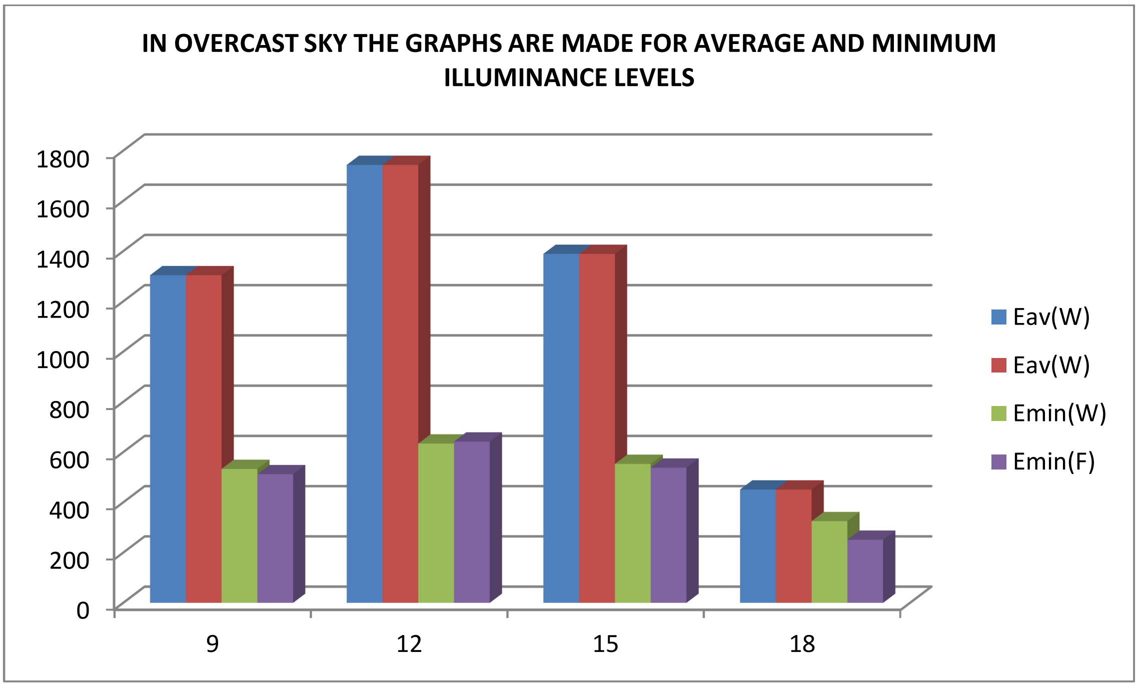
MIXED SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	2321	1812
12	1821	153
15	2448	1924
18	417	330

MIXED SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	663	632
12	580	548
15	681	648
18	310	235

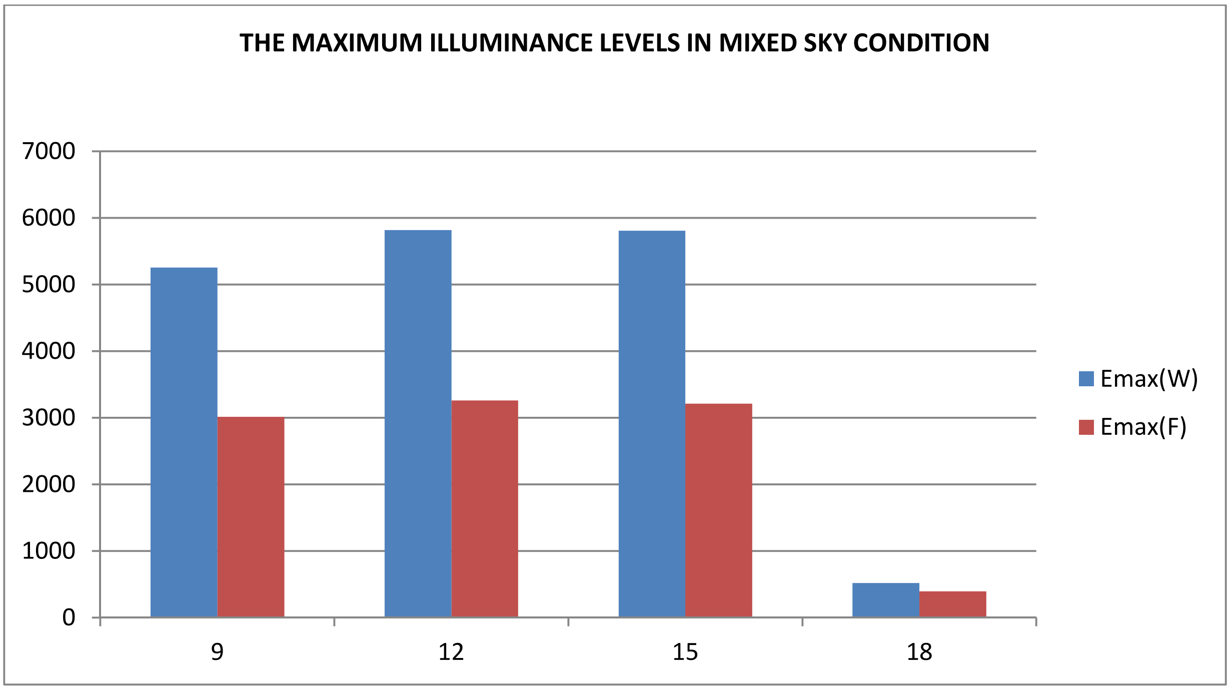
MIXED SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	5258	3014
12	5820	3262
15	5810	3215
18	520	397

MIXED SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.285	0.349
12	0.318	0.351
15	0.278	0.337
18	0.744	0.711

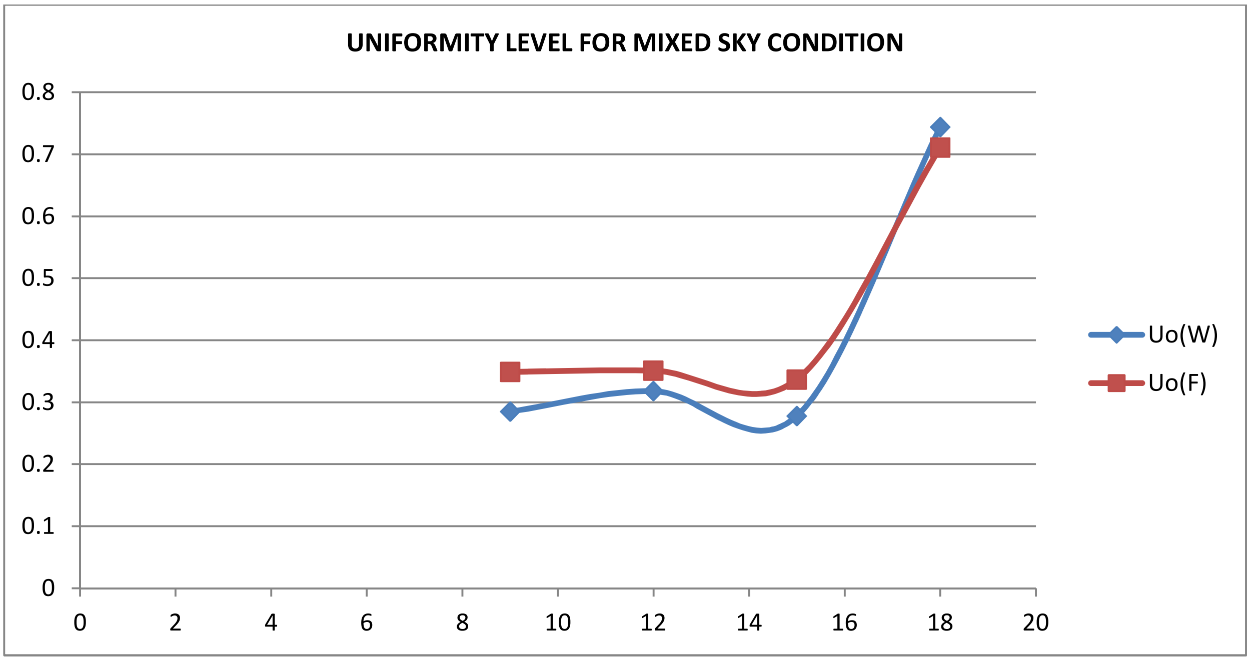
70.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



70.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR :



70.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



Here the average illuminance value totally played the same role of floor area average illuminance level which means they are very much similar to each other and the same thing happened in the case of minimum and maximum illuminance level also. The nature of the uniformity curves maintain the same nature and it varies with time so at 3PM when daylight integration is lesser than the dimmed control groups then the value is decreases then it increases rapidly under only artificial lighting, and reaches the standard values.

CASE: 71

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT AND INDIRECTLUMINAIRES BOTH ARE FULLY ON

71.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

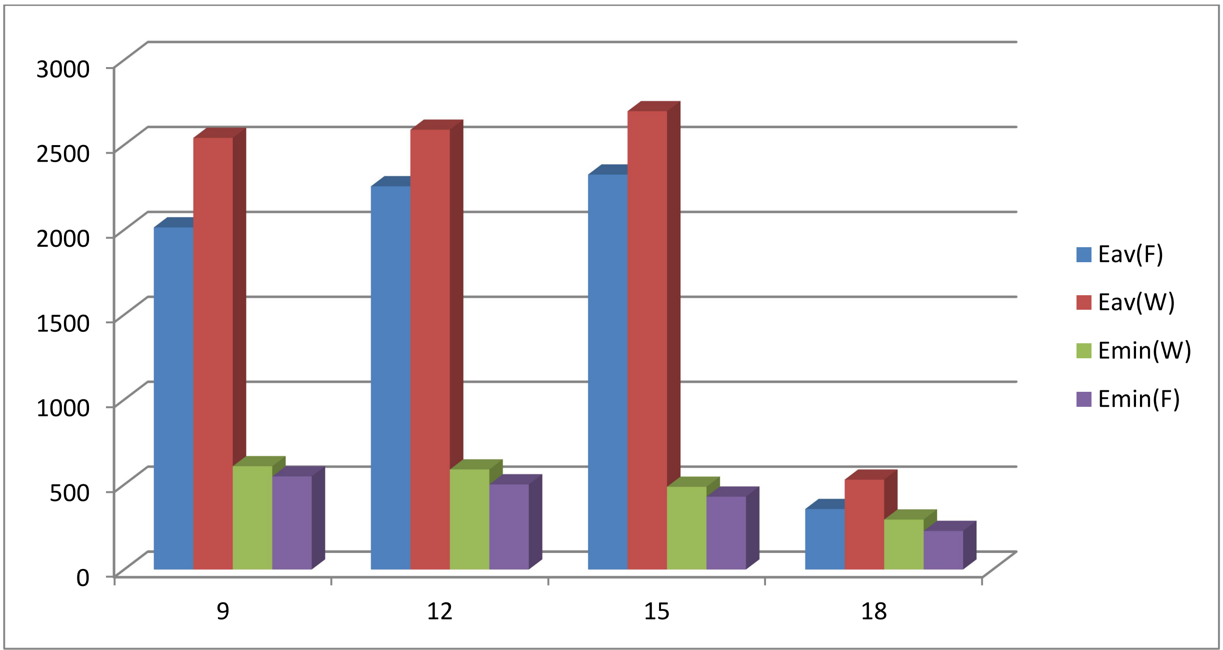
CLEAR SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	2014	2541
12	2256	2589
15	2325	2698
18	356	529

CLEAR SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	608	548
12	589	501
15	487	429
18	294	227

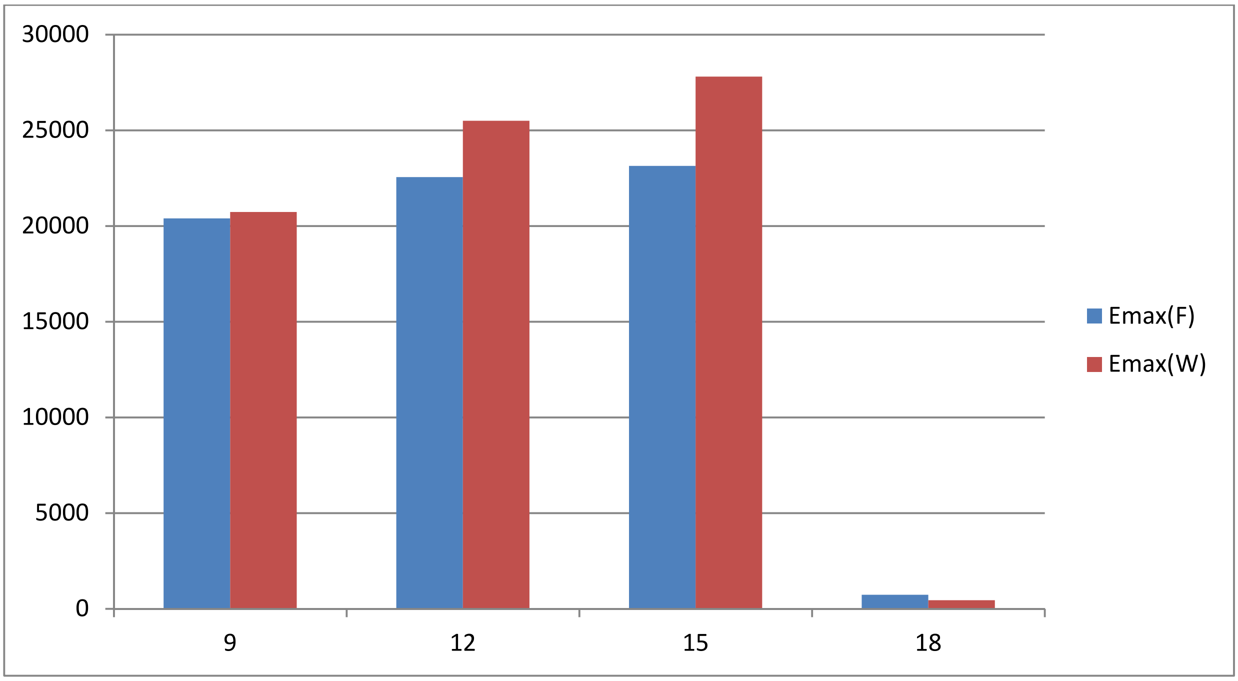
CLEAR SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	20388	20736
12	22545	25498
15	23129	27798
18	725	454

CLEAR SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.239	0.272
12	0.215	0.248
15	0.18	0.185
18	0.556	0.638

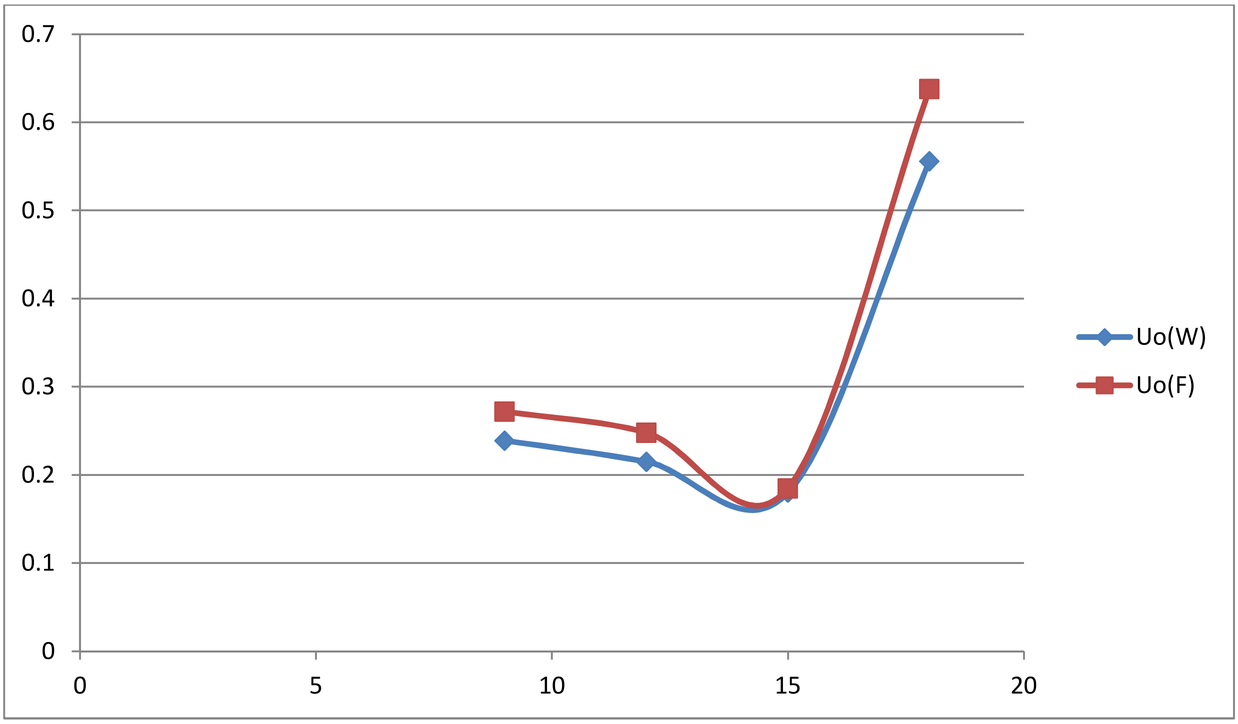
71.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



71.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR:



71.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



From the above charts and graphs, it shows that the value of workplane is higher than the value of floor area, there is a similarities takes place in uniformity also which depicted that there is a small coincide point occurred at 6PM and the value is also decreasing after mid of the day, which means under the artificial lighting.

CASE: 72

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT AND INDIRECTLUMINAIRES BOTH ARE FULLY ON

72.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

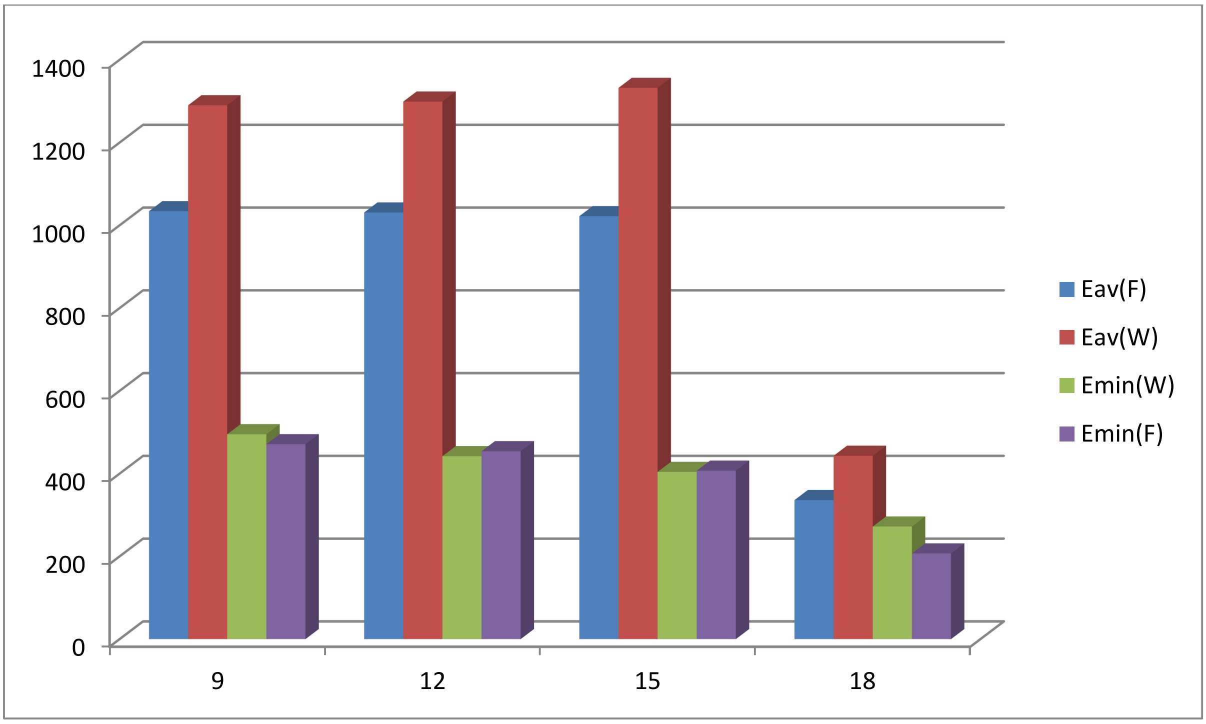
OVERCAST SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	1034	1290
12	1031	1299
15	1022	1332
18	336	443

OVERCAST SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	495	471
12	442	454
15	404	407
18	272	207

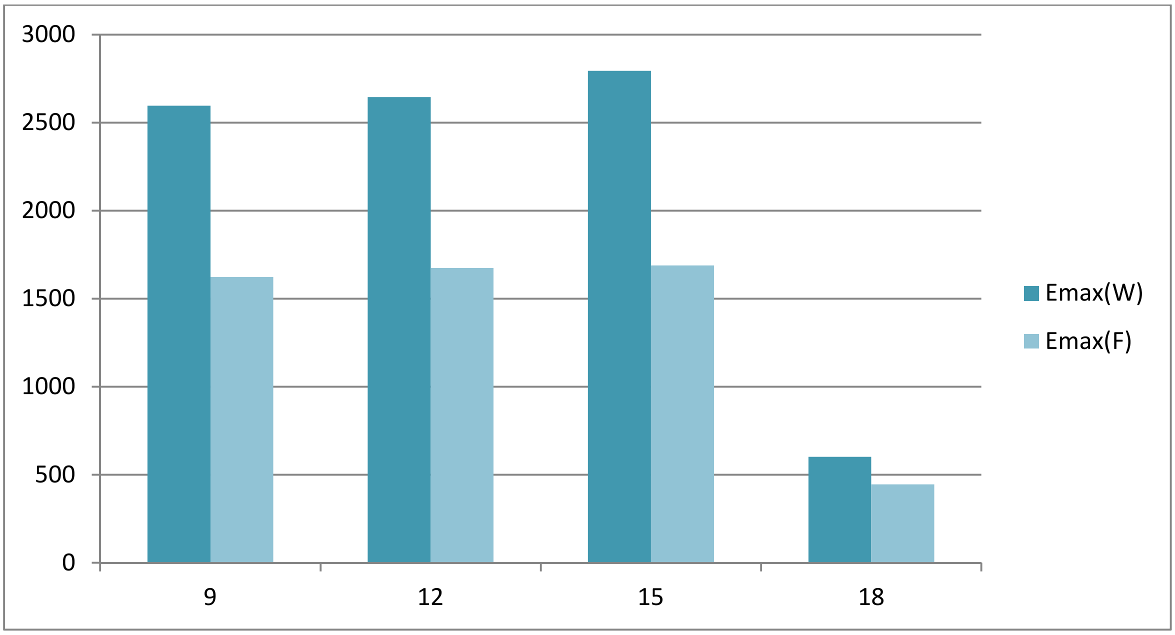
OVERCAST SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	2596	1623
12	2645	1675
15	2794	1689
18	602	446

OVERCAST SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.384	0.456
12	0.378	0.426
15	0.303	0.398
18	0.615	0.618

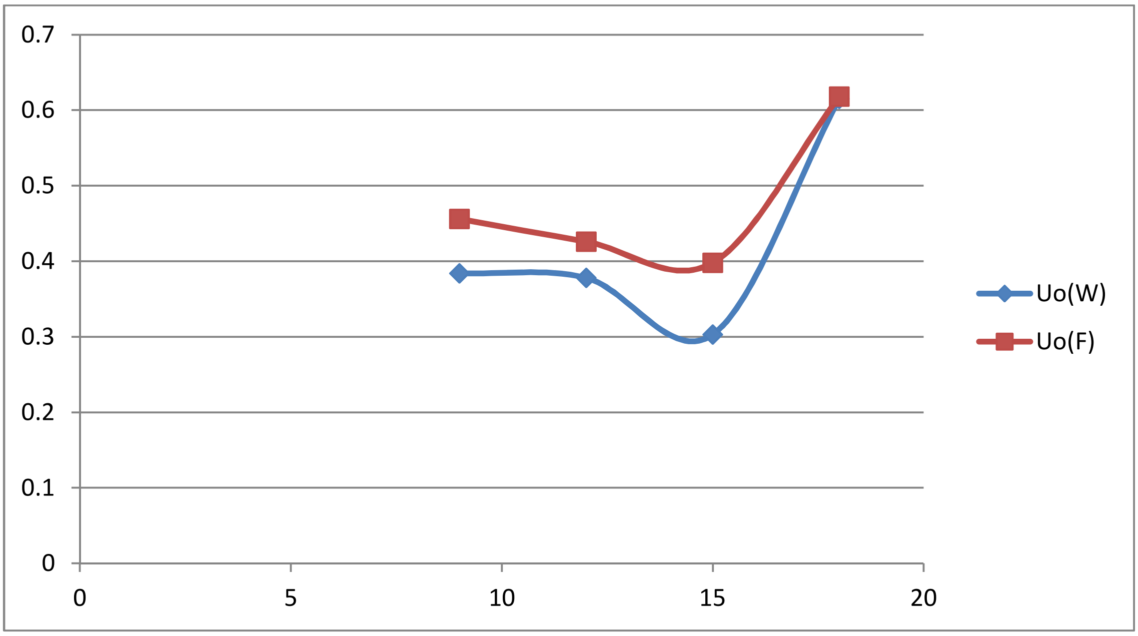
72.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



72.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR :



72.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



Here also the same observation takes place which indicated that average, minimum and maximum illuminance levels of workplane is higher than the same parameters of floor area due to the height of the calculation area, But one significant change is occurred here which shows the value of uniformity decreases slowly at first and then the rapid fall down occurred but under artificial lighting it restores the pick value of it.

CASE: 73

IN MIXED SKY CONDITION, THE REFLECTANCE VALUES ARE 70-40-10 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT AND INDIRECTLUMINAIRES BOTH ARE FULLY ON

73.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

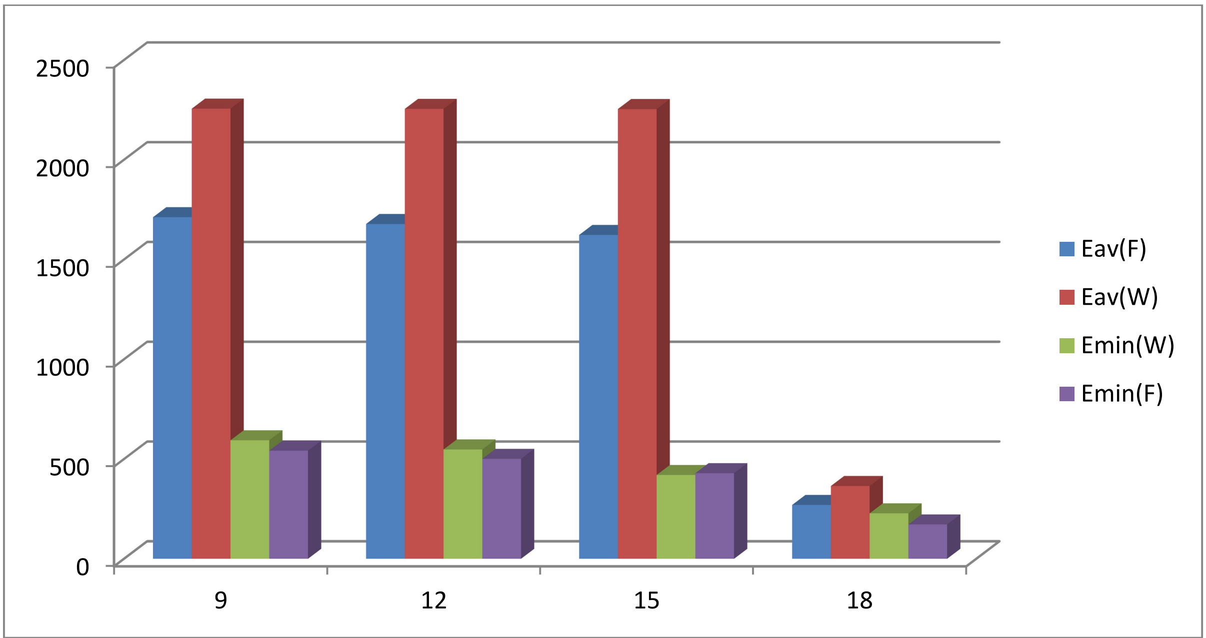
MIXED SKY CONDITION		
TIME	Eav(F)	Eav(W)
9	1712	2256
12	1678	2255
15	1623	2254
18	270	365

MIXED SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	594	542
12	548	501
15	420	429
18	228	172

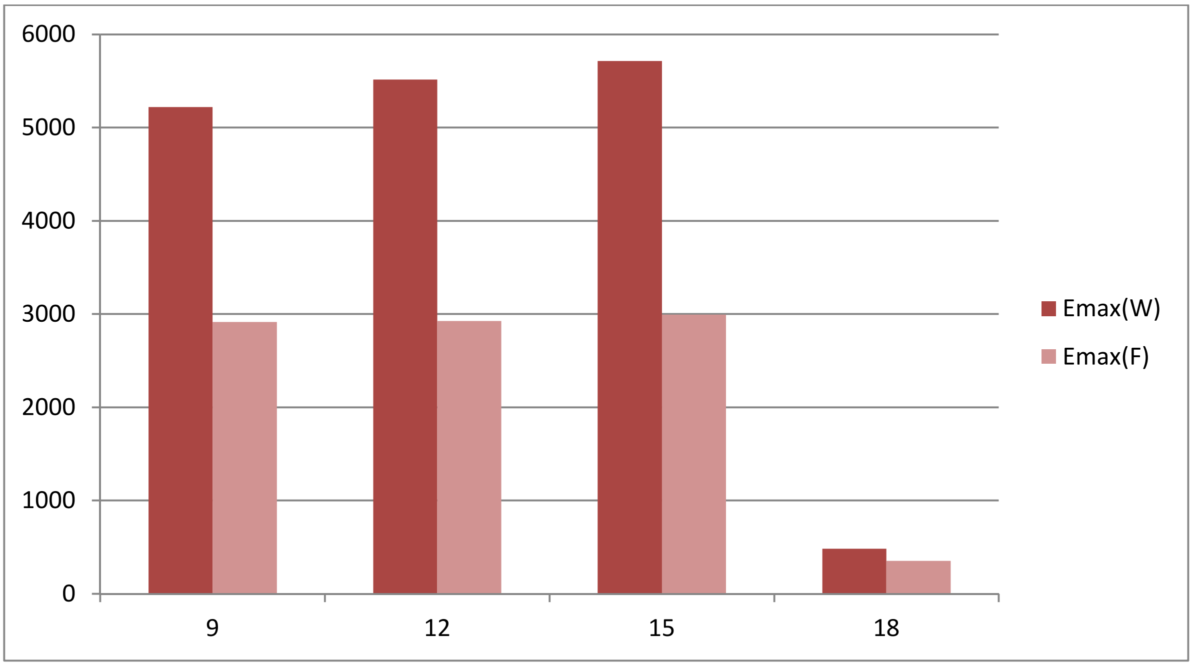
MIXED SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	5218	2913
12	5515	2925
15	5713	2994
18	482	351

MIXED SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.263	0.317
12	0.253	0.299
15	0.186	0.263
18	0.626	0.638

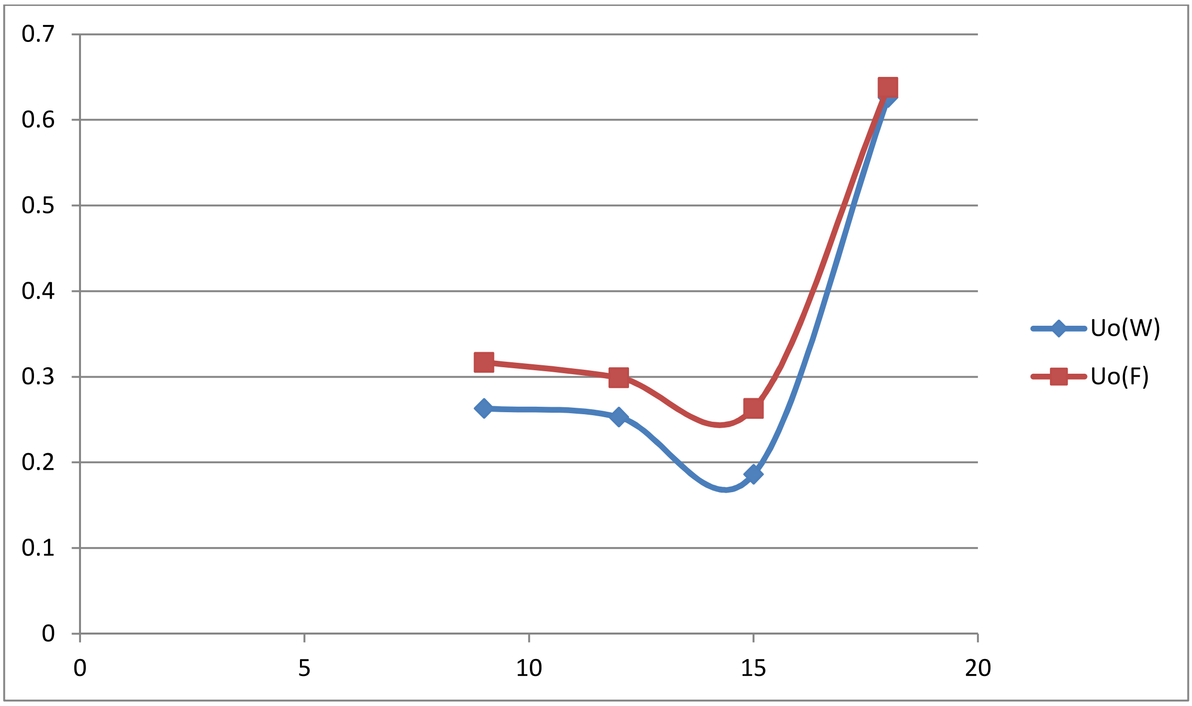
73.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



73.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR :



73.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



The same observation occurred in this case also, so easily a conclusion can be drawn from here that sky condition just creates a significant change into illuminance value, but its not affected on the nature of graphs. Although rest boundary conditions are remain unchanged here.

CASE: 74

IN CLEAR SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT LUMINAIRES ARE OFF BUT INDIRECTLUMINAIRES ARE FULLY ON

74.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

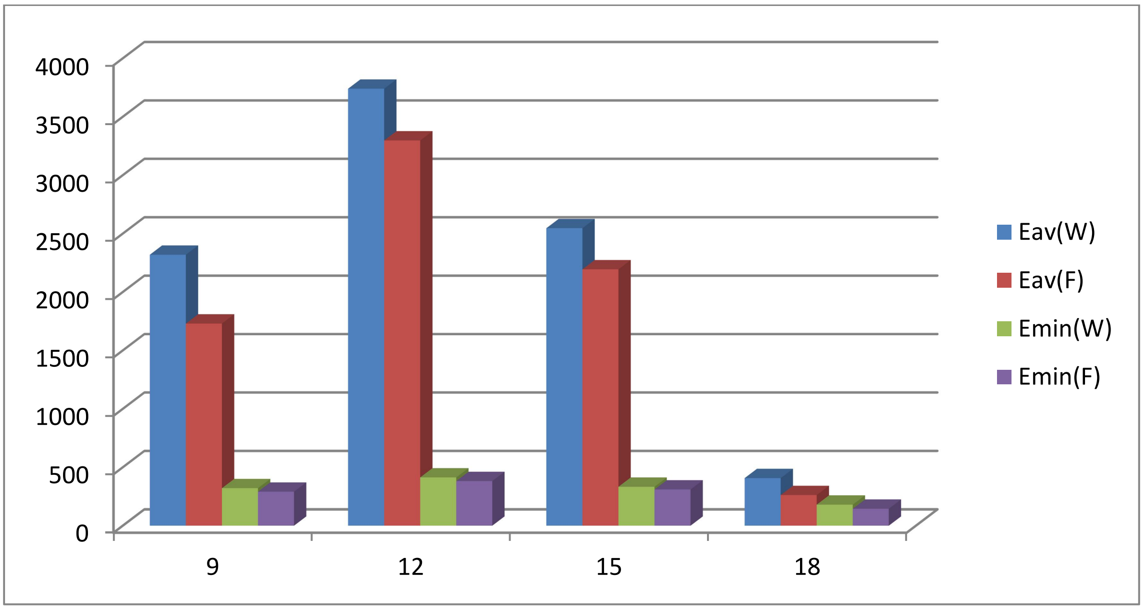
CLEAR SKY CONDITION		
TIME	Eav(W)	Eav(F)
9	2319	1730
12	3740	3297
15	2546	2194
18	407	262

CLEAR SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	321	291
12	413	382
15	333	310
18	180	145

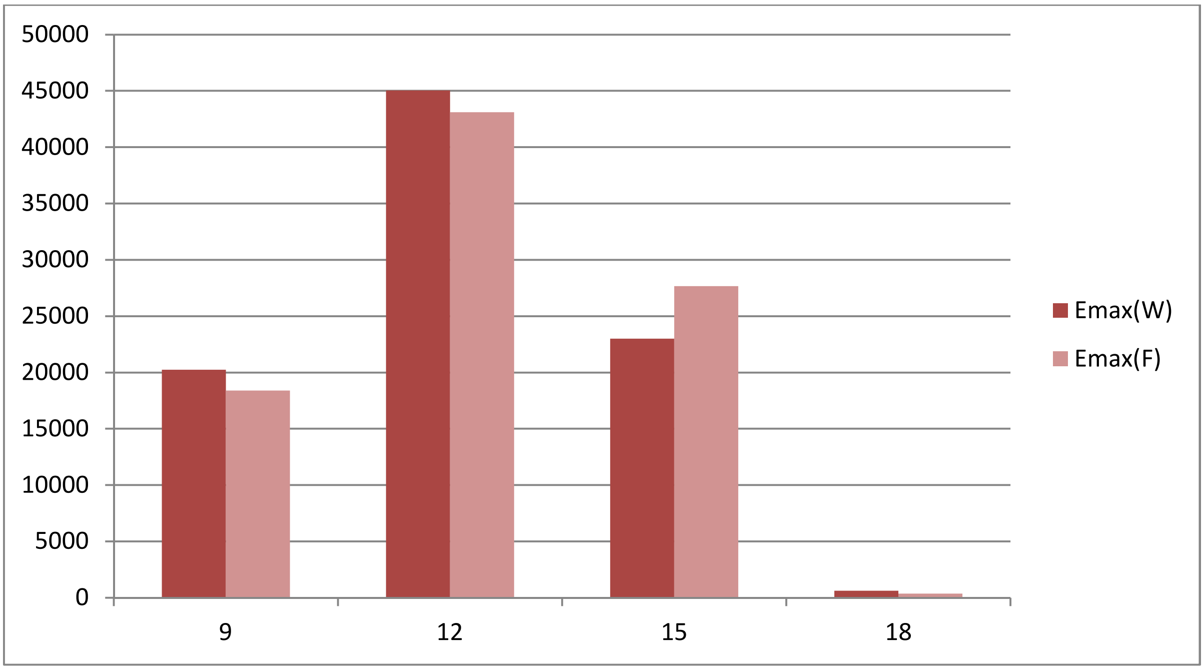
CLEAR SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	20241	18396
12	45034	43101
15	22996	27659
18	613	355

CLEAR SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.139	0.168
12	0.11	0.116
15	0.131	0.141
18	0.443	0.556

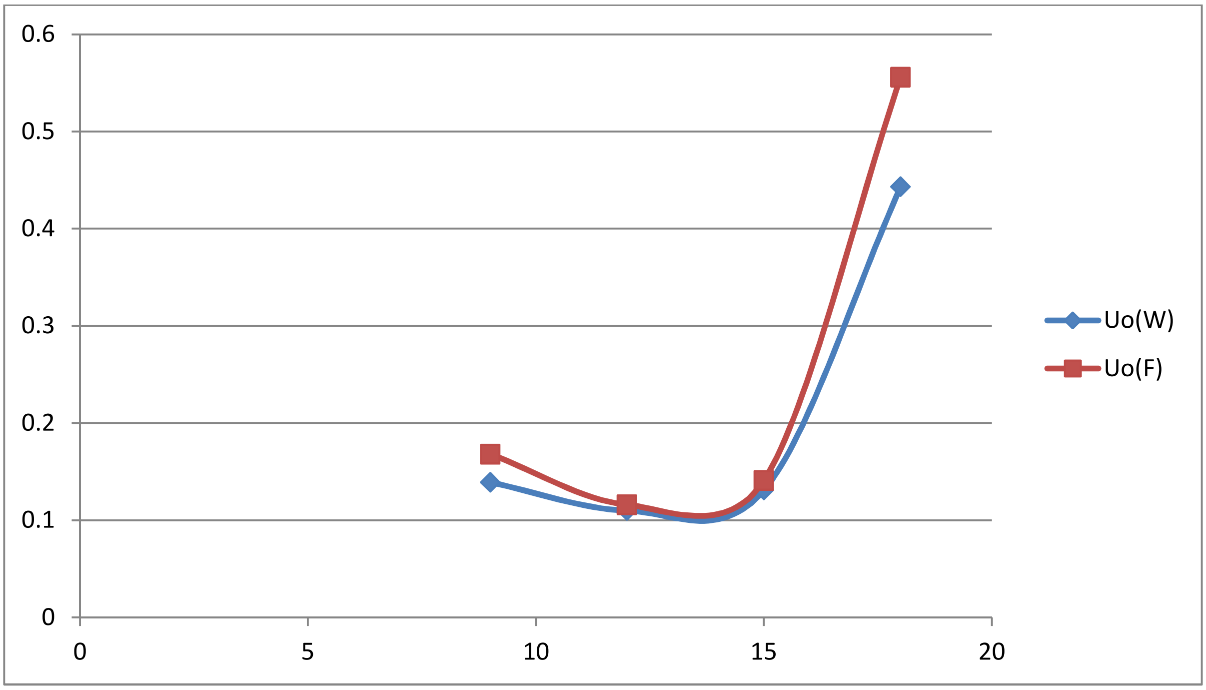
74.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



74.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR :



74.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



Here the average illuminance value totally played the same role of floor area average illuminance level which means they are very much similar to each otherand the same thing happened in the case of minimum and maximum illuminance level also. But for the uniformity, the change of reflectance values change the graph characteristics, so an overlapping part created from 12PM to 3PM but after that the graphs rises sharply and reaches its standard values.

CASE : 75

IN OVERCAST SKY CONDITION, THE REFLECTANCE VALUES ARE 65-35-05 AND THE SUSPENSION HEIGHT OF THE LUMINAIRES ARE 0.23mWHEN DIRECT LUMINAIRES ARE OFF BUT INDIRECTLUMINAIRES ARE FULLY ON

75.1. COMPARETIVE STUDY OF ALL Eav, Emin, Emax AND UNIFORMITY VALUES FOR WORKPLANE AND FLOOR BY CHARTS:

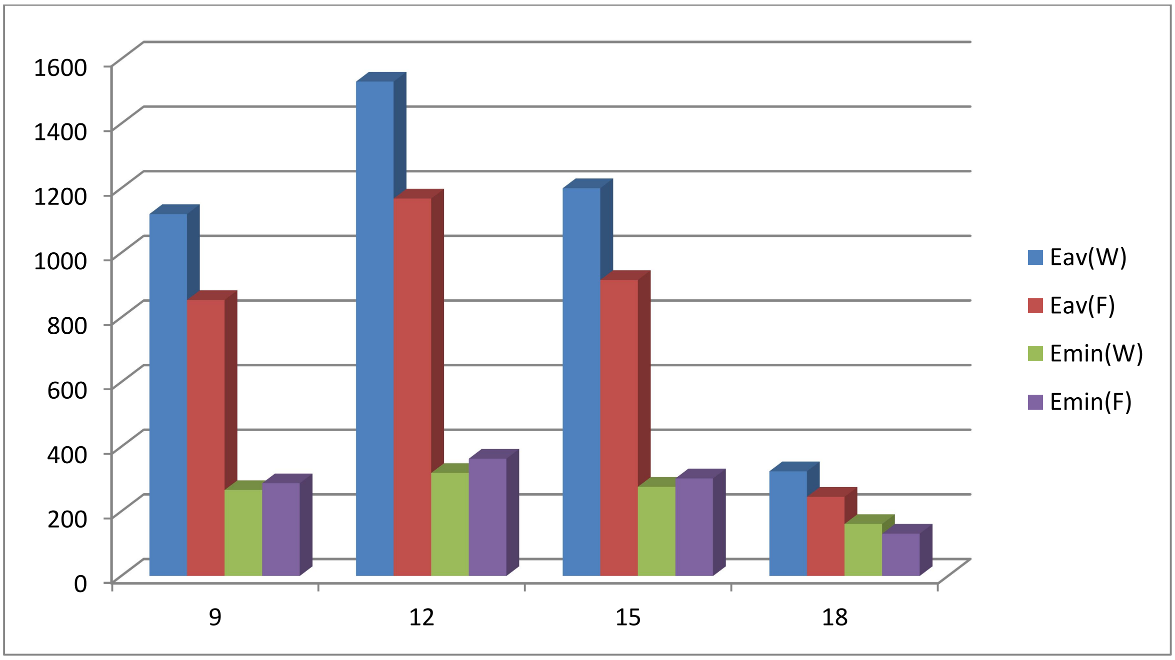
OVERCAST SKY CONDITION		
TIME	Eav(W)	Eav(F)
9	1120	854
12	1530	1168
15	1200	916
18	324	245

OVERCAST SKY CONDITION		
TIME	Emin(W)	Emin(F)
9	266	287
12	319	363
15	276	302
18	161	131

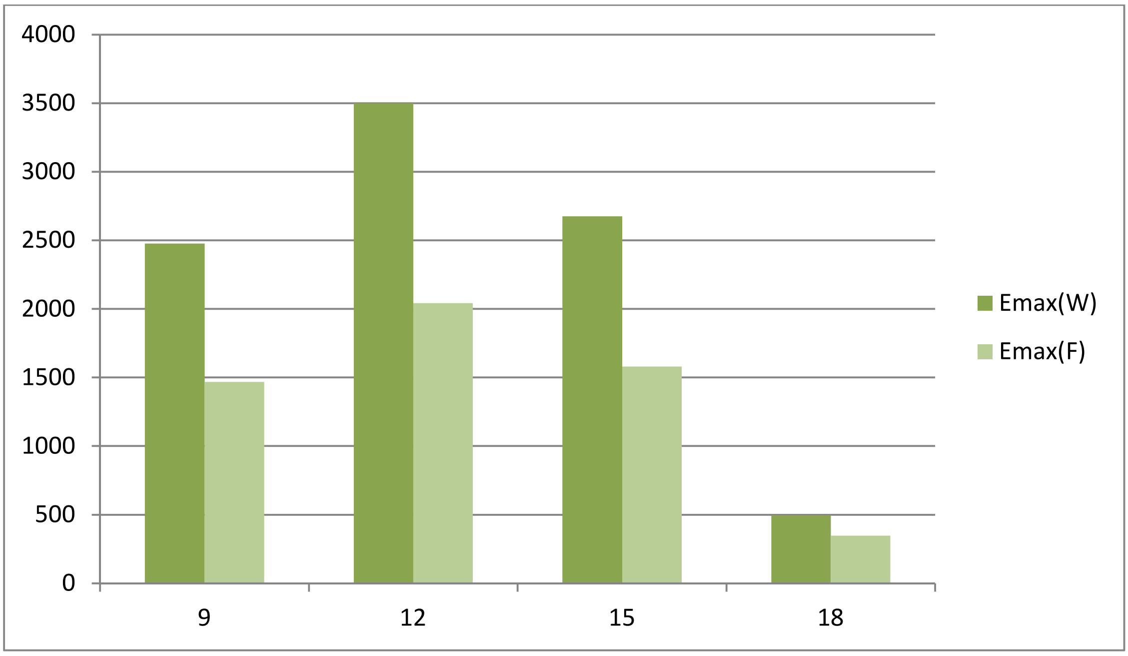
OVERCAST SKY CONDITION		
TIME	Emax(W)	Emax(F)
9	2477	1468
12	3499	2043
15	2676	1581
18	494	347

OVERCAST SKY CONDITION		
TIME	Uo(W)	Uo(F)
9	0.237	0.335
12	0.208	0.311
15	0.23	0.329
18	0.498	0.533

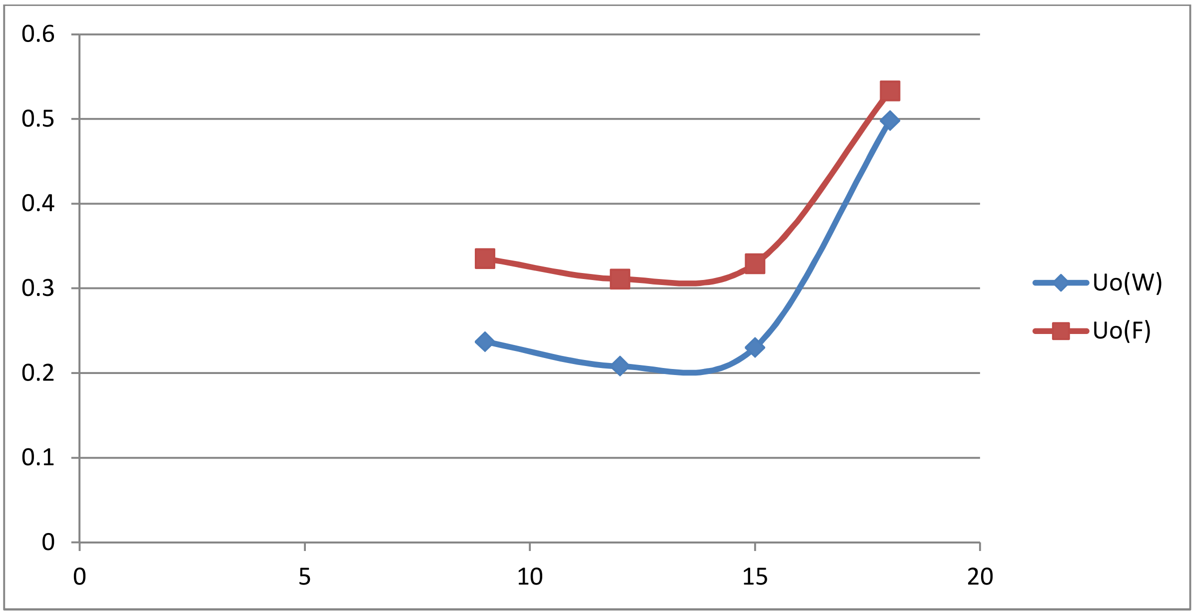
75.2. GRAPHS FOR AVERAGE AND MINIMUM ILLUMINANCE LEVEL OF WORKPLANE AND FLOOR:



75.3. GRAPH FOR MAXIMUM ILLUMINANCE LEVELS OF WORKPLANE AND FLOOR :



75.4. GRAPH FOR UNIFORMITYLEVELS OF WORKPLANE AND FLOOR:



There is no significant change observe in average, minimum and maximum illuminace levels. All the changes occurred due to change of reflectivity's and dimming control groups, although the nature of the uniformity graphs doesn't changed much, but these two parameters didn't intersect with each others, and the slop of change is not sharp as prior cases.

CHAPTER – 20

CONCLUSIONS

The objective of this simulation based study is focused on figuring out the relationship among average illuminance level, minimum and maximum illuminance level with reflectance of interior surfaces such as: wall, ceiling, floor under daylight as well as artificial lighting conditions. To fulfil the aforementioned target, myriads simulations were performed based on several scenarios to calculate illuminance and glare on calculation surfaces with various mounting heights. Illuminance calculation was used to calculate its average value Eav , Emax Emin and the uniformity of light Uo. Considering the variations in surface reflectance values across scenarios it can be safely averred that the wall, floor and ceiling reflection considerably impact average illuminance and uniformity and UGR, however the effect of floor reflectance value on all of the selected indies was negligible. In the hindsight, elevating the value of refection coefficient of indoor surfaces and using light colour materials can be considered as the suitable passive energy efficiency solution for indoor environments, though discomfort glare limits for different visual task should be carefully taken into design considerations.

This study looked at different lighting design strategies including type, number and mounting height of luminaires as well as the reflectance properties of the surface finishing which mentioned earlier. The room simulated in this study was the digital model of a real room.The analysis was conducted from both an electric energy consumption and daylight integration point of view. The findings of the study present new insights to improve energy efficiency and reduce electric energy demand while helping to create lighting conditions acceptable for daylight integration. According to numerous simulations, it is evident that the evaluation of the performance of different lighting proposals during the early design stage can ensure low energy consumption and high visual comfort level in indoor environments.

The outcomes and contributions of this study are elaborated as follows:

- The type of luminaire is a principal factor in energy saving via daylight integration. Accordingly, an optimal lighting in terms of energy saving needs to balance both direct and indirect light.
- There is no single solution to give the best results in terms of electric energy consumption and a comfortable lighting environment. For instance, a direct luminaire gives the lowest average energy consumption, but it is characterized by the worst values of UGR and Uo.
- Characteristics of the surfaces, are important factors for ameliorating the optimal lighting conditions.
- The highest reflection properties of the surfaces result in the moderate performance in terms of renewable energy use.
- The number of luminaires is not an influential parameter in electric energy consumption. On the contrary, increasing the numbers of luminaire causes a relevant decrease in uniformity.
- Concerning Uo the best scenario was under the clear sky scenario while the worst one was the mixed sky .
- The lower mounting height helped reduce energy consumption. On the contrary, the scenarios with luminaire mounting height are characterized by the highest Uo and the lowest UGR values on average. This phenomenon is due to the fact that the higher

distance of the lighting feature from the working place resulted in the better diffusion of the luminous flux on it.

To conclude, this study articulated that all the assessed parameters play decisive roles in lighting quality and quantity in an indoor space, and there are no one stop solution to all cases and environments. It should imperative to remember, though these simulations were performed in a relatively small room, the influence of different lighting strategies and surface properties on energy consumption and visual comfort was substantial due to moderate glare rating and as a result, these results might be significantly at a higher end in large size rooms/spaces. Although this methodology, results and associated findings described in this research were based on a case study, the characteristics of the room and the selected lighting systems are common in scores of buildings. So, the findings of this study could be extended and applied in lighting design of other interior spaces such as offices, galleries and indoor exhibitions. To achieve optimum energy efficiency and the desired extent of visual comfort, a detailed study based on the visual exercise and related lighting requirement analysis & associated design is highly recommended

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CHAPTER – 21

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CHAPTER-22

ANNEXTURE