Studies and Analysis of Façade Lighting Design through some practical projects, their Challenges and Opportunities

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CERTIFICATE OF RECOMMENDATION

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his MTech. (Illumination Technology and Design) studies during academic session 2023-24

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

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

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Chapter 1

1. Introduction

Floodlights play a pivotal role in providing illumination across a wide area, from sports stadiums to architectural landmarks. Their versatility and functionality make them indispensable in various outdoor lighting applications. Understanding the photometric properties of floodlight luminaires is essential for optimizing their performance and ensuring effective lighting solutions. Additionally, exploring their external applications, particularly in facade lighting, offers insights into leveraging floodlight technology for architectural enhancement and visual impact.

In the year of 1880 Thomas Edison's invention of the incandescent bulb paved the way for early floodlighting. These bulbs were widely used for general illumination but were not very efficient for large-scale outdoor lighting due to their high energy consumption and low light output.

Early 20th Century Carbon Arc Lamps were among the first types of lamps used for floodlighting, particularly in theatres and film production due to their intense light output.

Then 1930s Mercury Vapour Lamps introduced as a more efficient option than incandescent bulbs, mercury vapour lamps were used in street lighting and industrial applications. They provided a bluish light and were more energy-efficient.

In 1960s Metal halide lamps offered better colour rendering and higher efficiency than mercury vapour lamps. They became popular for sports stadiums, parking lots, and other large outdoor areas and in 1970s High-Pressure Sodium (HPS) Lamps Known for their distinctive yellow-orange light, HPS lamps were extremely efficient and had a long lifespan. They were widely used for street lighting and industrial applications.

Then In the year 2000 the development of LED technology revolutionized floodlighting. LEDs offer significant advantages, including higher energy efficiency, longer lifespan, improved durability, and better light quality. They also allow for more precise control of light direction and intensity [16].

1.1. Motivation

The motivation for conducting a study on floodlight luminaire photometry and its external applications in facade lighting arises from several key factors:

Optimizing Performance: Floodlights are widely used for illuminating large outdoor areas, including sports fields, parking lots, and architectural facades. Understanding the photometric properties of floodlight luminaires is essential for optimizing their performance in terms of illuminance distribution, energy efficiency, and visual comfort.

Enhancing Aesthetics: Facade lighting plays a crucial role in enhancing the visual appeal and architectural identity of buildings and structures. By exploring the external applications of floodlight luminaires in facade lighting, we aim to uncover innovative ways to accentuate architectural features, create dynamic lighting effects, and improve the overall night-time aesthetics of urban environments.

Meeting Functional Requirements: Floodlighting serves various functional purposes, such as providing safety, security, and visibility in outdoor spaces. By studying floodlight luminaire photometry, we can ensure that lighting solutions meet the specific requirements of different applications, from sports lighting standards to pedestrian-friendly illumination in public spaces.

Addressing Light Pollution: As outdoor lighting continues to proliferate, concerns about light pollution and its adverse effects on the environment, wildlife, and human health are becoming increasingly important. By understanding the photometric characteristics of floodlight luminaires and their external applications, we can develop strategies to mitigate light pollution while still achieving effective illumination and aesthetic objectives.

Advancing Lighting Technology: The field of lighting technology is constantly evolving, with advancements such as LED lighting, smart controls, and adaptive lighting systems offering new opportunities for outdoor lighting design. By studying floodlight luminaire photometry and exploring its external applications in facade lighting, we can assess the potential of emerging technologies to improve performance, energy efficiency, and flexibility in outdoor lighting solutions.

Overall, the motivation for this study stems from the desire to contribute to the development of sustainable, visually appealing, and technologically advanced lighting solutions for outdoor environments. By integrating photometric analysis with practical applications in facade lighting, we aim to provide valuable insights that benefit lighting designers, architects, urban planners, and other stakeholders involved in outdoor lighting projects.

1.2. Objectives

The objective of this paper is to comprehensively investigate floodlight luminaire photometry and explore its external applications in facade lighting.

This study aims to investigate floodlight luminaire photometry and explore its external applications, focusing on facade lighting. By comprehensively analysing the photometric characteristics of floodlights, including illuminance distribution, luminous intensity, and colour rendering, we aim to gain deeper insights into their performance and potential applications in architectural lighting.

The study will involve:

Photometric Analysis: Conducting photometric measurements and analyses of floodlight luminaires to characterise their light distribution, intensity, and colour properties. This includes assessing parameters such as beam angle, uniformity, glare, and colour rendering index (CRI).

Performance Evaluation: Evaluating the performance of floodlight luminaires in various outdoor environments, such as sports fields, public spaces, and architectural facades. This involves assessing factors like energy efficiency, maintenance requirements, and compliance with lighting standards and regulations.

Facade Lighting Applications: Exploring the external applications of floodlight luminaires in facade lighting design. This includes case studies, simulations, and design guidelines for using floodlights to enhance the aesthetic appeal, visibility, and security of architectural facades.

Technological Advancements: Investigating recent advancements in floodlight luminaire technology, such as LED lighting, smart controls, and adaptive lighting systems. Assessing how these innovations improve performance, energy efficiency, and flexibility in outdoor lighting applications.

Environmental Considerations: Addressing the environmental impact of floodlighting, including light pollution, wildlife disturbance, and energy consumption. Identifying strategies and best practices for minimizing environmental harm while maximizing lighting effectiveness.

By integrating photometric analysis with practical applications in facade lighting, this study aims to provide valuable insights for lighting designers, architects, urban planners, and other stakeholders involved in outdoor lighting projects. Ultimately, the findings will contribute to the development of sustainable, visually appealing, and technologically advanced lighting solutions for outdoor environments.

Chapter 2

(Definition and Descriptions of Different Terminologies)

2.1.Façade Lighting

2.1.1. About Facade Lighting

Facade lighting is a way to highlight the beauty of a house or building at night. It can be implement it in numerous ways – depending on the structure it will illuminate. It's important to choose the correct lighting technique – not just to bring out the beauty of a structure, but to also add to the overall charm of the urban and rural area [17].

- What is facade lighting?

Facade lighting is the use of light fixtures to illuminate the exterior of a building at night. The primary goal is to bring out the architectural beauty of a structure after the sun sets. But other than that, it can also increase security or appeal to the local community.

It's essential to recognize that facade lighting is more than just providing illumination. When done artistically, it can attract attention and highlight a beautiful landmark for the local population. It can even be an orientation point for travellers.

Some municipalities use facade lighting to increase the value and overall aesthetic of the locality to bring tourism and economic growth to their area. Companies can also use it to promote their corporate image.

Considering this, it'll be realize that facade lighting is more of an artistic statement than a tool to bring illumination. It has the ability to transform a bland facade into an incredible work of art.

This is why it's not surprising that facade lighting comes with many requirements, including sustainability and energy efficiency [6].

- LED facade lights

In the past, halogen lights were the norm. People use it to light up the facade of buildings or homes. Since halogen lights aren't energy efficient, only significant buildings can use them for artistic purposes.

But with the growing popularity and preference for LED lights, more people and structures can now take advantage of the aesthetic benefits of facade lighting. LED lights provide energy efficiency, reliability, and durability. That means it's easier to apply the lights artistically. LED lights come in different colours and emit a more intense beam of light to allow a more explicit focus.

This means it's easier to make a building the main attraction.

2.1.2. Type of Facade Lighting

There are three different ways to illuminate the facade of a building.

- From the floor

This type of facade lighting means the light fixtures are on the floor. It illuminates the facade of the building from the ground up. This results in a stronger light at the bottom, where the beam gets wider as it gets higher. The intensity of the light also gets softer as it reaches the middle of the structure.

If it has been gone for an imposing feel to the structure, this is a great option to use [18].

Figure 01: Picture for Façade lighting

Spotlights, flood lights, or ground spike spotlights can be used for this. The landscape spotlights are ideal because they allow flexibility and don't have to fix the lights on the wall.

- From the ceiling

For this type of facade lighting, the light fixtures come from the top. For residential houses, the fixtures use the roof gutters as the base for the facade lights.

In this application, the lights at the top are given more attention. If the structure has a great ceiling, this is the option that can highlight it. The downward direction of the lights can create shadows and accentuate the silhouettes of the architecture.

Among the lights it can be use here includes spotlights, flood lights, recessed downlights, track lights, linear lights, and panel lights.

- From the wall

Finally, this type of facade lighting refers to the light fixtures that are on the wall. This is great for creating a shadow effect on the facade of the building.

Figure 02: Picture for Façade lighting

When using this technique, there's more freedom to choose where to position the light fixture. This includes windows, columns, or other vital structures that can help create the right shadow and mood. With the correct positioning of the lights, it's easier to create the right accents and elements in the building [18].

The ideal fixtures for this facade lighting include wall washer lights, outdoor downlights, facade linear lights, and other exterior wall lights [17].

- Mix different facade lighting types

When it comes to lighting up the facade of a structure, there's no one formula on how to do it. So feel free to mix and match the three different types of facade lighting.

If the structure is big enough, it can be even use all three. Just make sure, take into consideration the beam angles, colour, intensity, and other factors that could affect the overall look that it will be aiming for [3].

2.1.3. Importance of Facade lighting

Installing facade lighting is essential because of 3 reasons.

- First, it defines the structure of the building. It can bring life to what should have been a dark building at night. It can complement the architectural beauty of the building so it brightens even the surrounding areas.
- Second, it can also increase the commercial value of a building. Anything that makes it aesthetically appealing will boost its value and make it attractive to people.
- Third, it can uplift the overall value of the local community. Beautiful structures attract attention. That includes the local population and tourists as well. When a building is well-lit, it can be an art form by itself [3].

2.1.4. Application of Facade lighting.

Different facade lighting applications

Now that the type of facade lighting can be use let's talk about how it can be apply it.

The type of facade lighting that it'll use be significantly depend on the design of the architecture. When choosing the right light, it's essential to consider how the facade of the building looks and the overall aesthetic and mood it will aim for.

Here are the most usual facade lighting applications that lighting experts use today.

- Solid Facade

This refers to facades with a smooth surface. While wash lighting is the go-to application here, it's possible to be more artistic. It can play with different lights and layering. Since the facade is flat, it's easy to see the shadows, patterns, shapes, and lines that the lights make.

Be careful of the patterns it'll create. It might overshadow the beauty of the building's architecture. Ensure it will only highlight the facade, not drown it in light.

- Perforated Facade

This structure uses perforated wells to allow natural light into the building. But at the same time, it can also project light from the building [17] [6].

How to do light up this facade?

There are different techniques to do this most of them will focus on the windows.

During the day, the windows will appear dark as the natural light hits the majority of the building facade. But at night, it can put lights on the windows to make it brighter and the rest of the building darker. Or it can put floodlights at the bottom of the building to illuminate only a portion of the windows as the light hits it from below. This will bring attention to the window frames. it can be also forgot the leading lights and put individual recessed lights on every window [3] [18].

- Banded Facade

This refers to structures that use alternating bands of different materials to make up the facade of a building. For instance, alternating glass windows and concrete.

These strips are the main focus on the facade so that's what the lights should accentuate. It can do this by positioning the lights on balustrades to amplify the horizontal bands. It can also focus on defining the light and dark areas of the band – like the glass windows would be lighter while the concrete between the windows is darker.

- Transparent Facade

Glass buildings are trickier to light up because it naturally reflects light. So it will be needed to position the lights properly to achieve the lighting effect looking for.

In this case, ceiling wash lights indoors can provide a beautiful reflection of brightness outside. It can be also take advantage of the darkness by putting minimal lights at the bottom of the building and letting the glass facade reflect the lights around it. Or it can simply put lines of light on every floor to create a line of division.

- With Vertical Divisions

When the facade of a structure has vertical divisions, it's best to highlight these by using narrow beams from the ground. It have been achieve this by using spotlights or floodlights. It can be also use a mix of up lights and downlights to achieve a more dramatic effect – especially if the structure has a fantastic ceiling or rooftop as well.

It can be also use different techniques to highlight the vertical divisions of a building. It can use up lights on either side of the columns if there are columns. Or, if it simply want to accentuate the vertical lines, spotlights from either the top or bottom (or both) would do.

- With Horizontal Divisions

If it has been a structure with defined horizontal divisions, the best way to accentuate it is by using shadows. Position the lights at the bottom of the structure and let the heavy shadows it'll define the aesthetic appeal.

The alternative brightness and shadows will bring life to the facade. It can also bring attention to the texture of the building. It can be position the lights closer to the structure to achieve longer shadows. It have been positioned it further from the building to make the whole effect brighter.

- With Recessed or Protruding Sections

Building structures with recessed or protruding sections will need heavy shadows to highlight the different areas of the facade. It can be use a mix of different facade lights here.

For the recessed sections, it have been use up lights to highlight the corners. It can be also choose to use different colours of lights to magnify the contrasting sections. Just ensure that every beam of light will align with every section [18].

2.2.Important Terms

2.2.1. Beam Angle:

- The beam angle is the angle at which light is emitted from a light source, measured between the points on either side of the beam where the light intensity drops to 50% of the maximum intensity (full width at half maximum, or FWHM).
- It defines the spread of light, indicating how wide or narrow the light distribution is.

Types of Beam Angles

I. Narrow Beam Angles (≤20°):

Spotlight: Creates a focused, intense beam of light.
Applications: Used for highlighting specific objects or areas, such as artwork, displays, and architectural details. Narrow beam angles (≤20°) are utilized in various lighting applications for their ability to provide focused, intense illumination. This makes them ideal for spotlighting, accent lighting, task lighting, theatrical and stage lighting, and highlighting architectural and landscape features. Their precise light distribution also contributes to energy efficiency by minimizing light spill and waste. Understanding these benefits helps in selecting the right lighting fixtures to achieve the desired effect in both functional and decorative lighting projects.

II. Medium Beam Angles (21°-40°):

Floodlight: Provides a broader spread of light than spotlights.
Applications: Ideal for general lighting in areas like living rooms, retail spaces, and hallways. Medium beam angles (21°-40°) are preferred in many lighting applications due to their ability to provide a balanced distribution of light. They are ideal for general and ambient lighting, task lighting, retail and commercial spaces, offices, residential areas, and hospitality settings. Their versatility and ability to evenly illuminate spaces while maintaining comfort and functionality make them a popular choice in lighting design.

III. Wide Beam Angles (≥41°):

Wide Beam Angle Floodlight: Distributes light over a large area.
Applications: Suitable for area lighting, such as large rooms, outdoor areas, and landscapes. Wide beam angles (≥41°) are employed in a variety of lighting applications to provide broad, diffuse illumination. They are ideal for general area lighting, ambient lighting, outdoor and landscape lighting, commercial and retail spaces, warehouses, event and stage lighting, residential applications, and architectural lighting. Their ability to evenly distribute light over large areas makes them essential for creating comfortable, functional, and visually appealing environments [9].

2.2.2. Why Photometry?

Photometry is crucial for both area lighting and facade lighting because it helps ensure optimal performance, efficiency, and visual comfort in these applications.

Uniform Illumination: Photometric measurements provide information about the distribution of light in a given area. For area lighting, uniform illumination is essential to ensure that spaces are evenly lit without any dark spots or glare, providing better visibility and safety for pedestrians and vehicles.

Lighting Quality: Photometric data helps lighting designers evaluate the quality of light produced by fixtures. This includes metrics such as colour rendering index (CRI), which indicates how accurately colours are rendered under the light, and correlated colour temperature (CCT), which describes the colour appearance of the light (e.g., warm white, cool white). Achieving the desired lighting quality is essential for creating visually appealing and comfortable environments.

Glare Control: Excessive glare from outdoor lighting fixtures can be uncomfortable for pedestrians, drivers, and nearby residents. Photometric measurements allow designers to assess glare potential and implement measures to control it, such as proper fixture placement, shielding, and light cut-off angles.

Energy Efficiency: By analysing photometric data, designers can optimize the layout and configuration of lighting fixtures to minimize energy consumption while still meeting illumination requirements. This may involve selecting fixtures with the right light distribution characteristics and using lighting controls such as dimmers or sensors to adjust light levels based on occupancy or ambient light conditions.

Compliance and Standards: Photometric data is often used to ensure compliance with lighting standards and regulations set by authorities or industry organizations. These standards may specify requirements for illuminance levels, uniformity ratios, glare limits, and other photometric parameters to ensure adequate lighting quality and safety.

Façade Aesthetics: For facade lighting, photometry helps designers achieve desired aesthetic effects by accurately controlling the distribution and intensity of light on building surfaces. This includes highlighting architectural features, creating visual focal points, and enhancing the overall appearance of the building facade.

Light Pollution Reduction: Photometric analysis enables designers to minimize light pollution by directing light only where it is needed and avoiding unnecessary upward or stray light that contributes to sky glow, glare, and energy wastage [1].

In summary, photometry plays a vital role in optimizing the performance, efficiency, and visual comfort of both area lighting and facade lighting systems, ensuring that they meet functional, aesthetic, and regulatory requirements.

2.2.3. Type of photometry.

In facade lighting, several types of photometry are commonly used to assess and design lighting systems effectively:

- Illuminance: Illuminance measurements are crucial for determining the amount of light reaching a surface in an area lighting application. For area lighting, designers often use illuminance measurements (in lux or foot-candles) to ensure uniform light distribution and adequate brightness levels across the illuminated space. Similarly, for facade lighting, illuminance measurements help designers achieve desired lighting levels on building surfaces to enhance visibility and aesthetics.

- Luminance: Luminance measurements are important for evaluating the brightness of surfaces and assessing glare in both area lighting and facade lighting. In area lighting, luminance measurements (in candelas per square meter, cd/m^2) help designers manage glare by controlling the brightness of light sources and surfaces to ensure visual comfort for pedestrians and drivers. In facade lighting, luminance measurements aid in achieving desired lighting effects while minimizing glare and maintaining architectural integrity.

- Luminous Intensity: Luminous intensity measurements are used to quantify the brightness of light sources and assess their directional characteristics. In area lighting, designers may analyse luminous intensity distributions to select fixtures with appropriate beam angles and light distribution patterns for optimal coverage and efficiency. In facade lighting, luminous intensity measurements help designers control the directionality of light beams to highlight architectural features and create desired visual effects.

- Colour Rendering Index (CRI): CRI measurements are relevant for both area lighting and facade lighting to ensure accurate colour representation. In area lighting, high CRI sources are preferred to enhance visibility and colour recognition, especially in outdoor environments with diverse objects and surfaces. In facade lighting, CRI measurements help maintain the integrity of architectural colours and materials, ensuring that illuminated surfaces appear as intended.

- Correlated Colour Temperature (CCT): CCT measurements help designers select light sources with appropriate colour appearances for area lighting and facade lighting applications. In area lighting, designers may choose warmer or cooler colour temperatures (measured in Kelvin, K) based on the desired ambiance and functionality of the illuminated space. In facade lighting, CCT measurements assist designers in achieving specific lighting effects and complementing architectural aesthetics with suitable colour temperatures [1].

These photometric measurements and metrics provide essential data for designing, evaluating, and optimizing area lighting and facade lighting systems to meet functional, aesthetic, and regulatory requirements.

2.2.4. Reflector and lens impact on Photometry

Reflector and lens designs have significant impacts on the photometry of lighting systems. Here's how each component influences photometric characteristics:

- Reflector:
  Light Distribution: Reflectors shape the distribution of light emitted by a light source. They can concentrate light into a narrow beam, spread it evenly in a flood pattern, or redirect it in a specific direction. The geometry and surface properties of the reflector determine the resulting light distribution pattern.

- Beam Control: Reflectors control the directionality and divergence of light beams. They help shape the beam angle, which determines the spread of light and the coverage area. Reflectors can be designed to produce narrow, medium, or wide beam angles to suit different applications.

- Intensity Enhancement: Reflectors increase the intensity of light by redirecting and focusing it towards the desired area. They help maximize the luminous flux reaching the target surface, increasing brightness and visibility. Reflectors are particularly useful for directing light in outdoor applications, such as street lighting or floodlighting.

- Glare Reduction: Well-designed reflectors minimize glare by controlling the distribution of light and reducing direct glare from the light source. They help produce uniform illumination with smooth transitions between light and dark areas, enhancing visual comfort for occupants [2].

Lens:

- Beam Control: Lenses modify the directionality and spread of light emitted by a light source. They can focus light into a narrow beam, diffuse it evenly over a wide area, or shape it into a specific pattern. The optical properties of the lens determine the resulting beam angle and distribution pattern.

- Light Transmission: Lenses influence the transmission and diffusion of light. They can enhance the transmission efficiency by minimizing optical losses and maximizing the amount of light emitted from the luminaire. High-quality lenses ensure that a greater proportion of light reaches the target surface, improving luminous efficacy.

- Colour Mixing: Some lenses are designed to mix and blend different colours of light, especially in fixtures with multiple light sources or colour-changing capabilities. Lenses help ensure uniform colour distribution and smooth transitions between hues, enhancing the quality of coloured light output.

- Glare Control: Lenses help reduce glare by diffusing light and minimizing harsh shadows and reflections. They scatter light more evenly, producing soft, diffused illumination with reduced glare and hotspots. Anti-glare lenses are particularly beneficial for indoor applications where visual comfort is essential [2].

In summary, reflectors and lenses play critical roles in shaping the photometric characteristics of lighting systems. They control the distribution, intensity, directionality, and quality of light, influencing factors such as visibility, glare, and energy efficiency. Designers must carefully select and optimize reflector and lens designs to achieve the desired lighting effects and meet the requirements of specific applications.

2.12. Lighting Pollution related with façade lighting and Area lighting.

- Wasted Light: Inefficient or misdirected facade lighting fixtures waste light by illuminating areas beyond the intended target, such as neighbouring buildings, the sky, or nearby natural habitats. This contributes to light pollution without providing any useful illumination.

- Disruption of Wildlife: Excessive and improperly directed light from facade lighting can disrupt the behaviour and habitats of nocturnal wildlife, including birds, insects, and mammals. Light pollution can interfere with migration patterns, foraging behaviours, and reproductive cycles, leading to ecological imbalances.

- Glare and Visual Discomfort: Area lighting installations that produce glare can cause visual discomfort for pedestrians, cyclists, and drivers. Glare reduces visibility, impairs depth perception, and increases the risk of accidents, particularly in roadways, parking lots, and pedestrian pathways.

- Sky glow: Area lighting fixtures that emit light upward contribute to sky glow, similar to facade lighting. This diminishes the visibility of stars and celestial objects, affects astronomical observations, and disrupts the natural day-night cycle for nocturnal animals.

- Ecological Impact: Light pollution from area lighting can disrupt the behaviour, migration patterns, and habitats of wildlife. Bright artificial lighting at night can confuse and disorient nocturnal animals, interfere with their feeding and breeding habits, and contribute to population declines.

- Energy Waste: Inefficient area lighting fixtures waste energy by emitting light in unnecessary directions, such as upward or sideways. This energy waste not only contributes to light pollution but also increases operating costs and carbon emissions associated with electricity generation.

Addressing light pollution in facade requires careful consideration of fixture design, installation practices, and lighting controls. Strategies such as using shielded fixtures, directing light only where needed, implementing motion sensors or timers, and selecting warm-coloured, low-intensity lighting can help mitigate the adverse effects of light pollution while still meeting illumination requirements [7] [8] [9] [10].

Chapter 3

(Computer added lighting design)

3.1. Lighting Design Methodology: Input Data

Lighting design methodology refers to the systematic approach and process followed by lighting designers to create effective and visually appealing lighting schemes for various spaces and applications. While different designers may have their own variations, here is a general outline of the steps involved in lighting design methodology:

3.1.1. Drawing of the Area giving Plan and Elevation

To initiate any lighting design for an area, it is essential to build/design the virtual structure on software, and that structure should be built/designed with exact dimensions as the original space. For this we need AutoCAD layouts/façade picture. This detail helps in deciding the length, width and height of the area. It also gives information about the type and any constraints in locating the luminaires. If AutoCAD layout is not available in that case direct site survey can/should be conducted to get these details.

3.1.2. Required Illumination Level

Another important criterion before designing is to know what the client wants for this space. Tender documents contain the requirements of the client, i.e., Airports Authority of India (AAI) here. Some of the requirements are certain maintained lux level values, uniformity ratio, design parameters, plan and profile of the project etc.

3.1.3. Layout and Heights of building

This will help in location of luminaires such that light is not obstructed by them and design becomes much more practical optimized. From AutoCAD layout we have idea of elevation. It also helps determining the work plane height considerations for any particular area.

3.2. Method of Lighting

The method of lighting design involves a systematic approach to create effective and visually appealing lighting schemes. During the actual lighting design phase of a lighting project, a lighting engineer has to perform lighting calculations in order to arrive at solutions that will satisfy the relevant lighting requirements. Lighting simulation software are being used to simulate and visualize any design virtually. At this stage, consideration is given to how the light is to be delivered. The fixtures may be roof mounted, in-ground, wall mounted direct or indirect, type and distribution of floodlight to be chosen, necessary mast and pole height to illuminate the required area optimizing at the same time, making it more economic.

3.3. Selecting the Lighting Equipment

Once the method of lighting has been selected, the most appropriate light source can then be chosen followed by the luminaire. The following attributes should be studied when choosing the light source:

- Light output (lumens)
- Total input wattage
- Efficacy (lumen per watt)
- Surface brightness / glare

• Narrow Beam angle lens

• Colour characteristics

• Electrical characteristics

• Photometric attributes

• Requirement for control gear

Apart from these there are also some other factors which affect the luminaire choice.

These are:

• Characteristics of light source and control gear

• Luminaire efficacy

• Light distribution

• Glare control

• Finish and appearance

• Size

• Accessibility of components for maintenance

• Ability to handle adverse operating conditions

• Aesthetics

• Thermal management

3.4. Choice of Luminaire

The performance of a luminaire should be considered just as carefully as its cost. In the long term a well-designed, well-constructed luminaire will be cheaper than a poor-quality unit; and the salient features of a good quality luminaire are:

• Sound electrical and mechanical construction with durable finish.

• Adequate screening of high luminance lamps to minimize discomfort and glare.

• Adequate heat dissipation to prevent over-heating of the lamp, wiring and ancillary equipment.

• High light output ratio with the appropriate light distribution.

• Ease of installation, cleaning and maintenance.

3.5. Design Tools

3.5.1. AutoCAD

AutoCAD is an architectural tool which provides complete information on the dimensions of the room like length, width and height of the room. And after the completion of the design, the same can be used to provide the lighting layout as well. AutoCAD drawings are saved using the DWG extension, and over the years this has become a standard format for exchanging technical drawings, to the extent that even programs such as Adobe Illustrator will recognize DWG files. AutoCAD also supports an even more widely recognized format called DXF which was specifically designed as an interchange format.

3.5.2. DIALux

DIALux is a user-friendly lighting simulation software which is used to calculate the luminaire quantity required to achieve the illumination level on the area as per the standard. 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. DIALux enables us to enjoy complete freedom for designing, whether it is an Indoor Area, or an Industrial Shed or an Exterior area.

3.6. Design Methodology

3.6.1. Client Meet and Discussion

For any lighting designer, the first and foremost step is to have a formal discussion with the client or end user and other members of the design team, so as to get the essence of what function the area or space would serve for, and hence to have an idea about what design needs to be done.

3.6.2. Obtaining the AutoCAD Layout

After client meeting, we need AutoCAD file of the project. AutoCAD layout provides us the exact length, width and height of particular area which helps in proper selection and arrangement of the luminaire. The more accurate/detailed the AutoCAD layout the more accurate will be the lighting design output.

3.6.3. Study of Guidelines

Now being a lighting designer, it is a responsibility to study the relevant standard codes, guidelines in detail. For this particular project work relevant standards and guidelines which needs to be followed in the previous chapter.

3.6.4. Design Simulation with the Site layout

After studying the guidelines, we have to import the AutoCAD layout in the lighting design software e.g., DIALux. During this import, one should take care about the dimension unit in the AutoCAD File.

3.6.5. Illumination Design for Façade area

Facade area design is done by DIALux. The following steps are involved in indoor illumination design:

STEP I – Deciding the type of area and type of task to be performed

In the first step after having building pictures, we have to identify the type of work to be done.

STEP II – Deciding the illuminance level required

Once the area type and task to be performed decided then as per relevant code or guideline or tender document recommendation illuminance level required can be found out.

STEP III – Finding out the dimension of the building after importing the JPEG file to AutoCAD, we can find the length, width and height. Once of the dimension of the area is found out, then the type of lighting arrangement can be decided.

STEP IV – Selecting the luminaire

Luminaire is chosen based upon the application, traffic volume, visual guidance, intersection density in the area. Generally, in outdoor area we use flood light [from medium beam to narrow beam]. Depending upon illuminance required we have to select suitable wattage of the lamps

STEP V – Selecting Maintenance Factor

In any lighting design calculation, an appropriate maintenance factor has to be included to allow for depreciation. Maintenance factor is chosen as discussed earlier otherwise mentioned by the client. Generally, for conventional light sources we consider maintenance factor 0.60 and for LED light sources 0.85.

STEP V- Mounting height of luminaire

Depending upon illuminance and uniformity required high mast height should be selected. Because higher the mast height greater will be the uniformity attained but cost the design will also increase simultaneously. Hence to achieve optimization both combination of asymmetric medium beam and narrow beam to be employed such that by installing relatively smaller mast height the design specifications can be maintained.

STEP VI – Aiming of Luminaires

To achieve good uniformity, we have to select suitable tilt and orientation. Too much tilt of luminaires results in improved uniformity (Emin/Eavg) but in compromise of maintained illuminance level and ULR (Upward light ratio). Stringent care has to give such that ULR remains within 7% to 10% so that it will not cause “Skyglow”. Hence possibility of “Light Pollution” is minimized.

STEP VI – Selecting the reflectance factors

Depending upon the area we have to select the reflectance factors of the wall. For office area reflectance factors for ceiling, walls and floor are to be considered 70%, 50% and 20% respectively. For industry shed area reflectance factors for ceiling, walls and floor 50%, 30% and 10%.

STEP VII – Software simulation

To find out luminaire quantity we have to simulate DIALux software after all the above steps done. In DIALux to simulate the software we have to select calculate option.

STEP VIII – Output

After software simulation done, we have to select output option in DIALux. In output we have to choose summary option to find out required illuminance levels and luminaire quantity for a particular task [8] [9] [11].

3.6.6. Summary

In a nutshell, lighting design is, in fact, the planning of our visual environment. Good lighting design aims to create perceptual conditions which allow us to work effectively and orient ourselves safely while promoting a feeling of wellbeing in a particular environment and at the same time enhancing that same environment in an aesthetic sense. The physical qualities of a lighting situation can be calculated and measured. Ultimately it is the actual effect the lighting has on the user of a space, his subjective perception, that decides whether a lighting concept is successful or not.

Chapter 4

(Case Studies)

Case Study 1:

4.1. Facade Design 1

The case study has been done using floodlights with two different beam angles. One is narrow beam angle (15 degree beam angle) (Ref. to Page no 18) and the second one is medium wide beam angle (60 degree beam angle). Here, 2 types of building have been considered. Type 1 building for 15 degree narrow beam angle floodlight and Type 2 building for 60 degree medium wide beam angle floodlight.

4.1.1. Type 1 Building

Design with 15 degree beam angle Flood Light:-

Luminaire Used – Narrow Beam angle Floodlight - 100 watt

Figure 3: Model of the Floodlight Fixture

Figure 3 shows the body of the original floodlight with 15 degree narrow beam angle, made of pressure Die-cast aluminium housing with a clear diffuser. Here, the lens

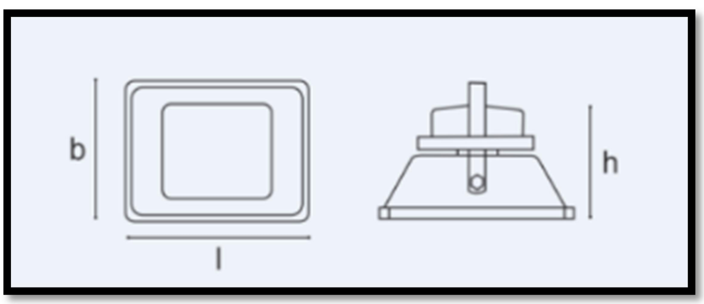


Figure 4: Fixture Dimension

Figure 4 shows the different dimensions of the luminaire that actually used in project.

Fixture Height	128mm
Fixture Length	270mm
Fixture Width	220mm

For fixing/mounting the fixture in a proper way, dimensions are required to be known well.

Table 01 - Technical Data (Electrical Data)

Nominal wattage Tolerance (±5%)	100W
Rated input voltage	240Vac
Operating voltage range	120-300Vac
Power factor	>=0.95
ITHD	<=10%
Input frequency	50Hz
Hi Pot Protection	1.5KVac
Driver Efficiency	>=90%
Surge Protection	10KV
High voltage Cut off	>= 330 ±20
Current foldback at Low Voltage	<=150 +-10 VAC
Phase to phase Protection	Yes
Over Voltage Protection	Yes
Thermal Protection	Yes
Short Circuit Protection	Yes
Operating mode	Constant Current

Table 01 shows the electrical data of this floodlight, where it can be seen that the total power consumption of the fixture is 100 watt & it has an input voltage of 240 volt with an operating range of 120-300 Vac. It has a surge protection over 10KV i.e. the driver is capable of protecting against electrical surges or spikes that reach up to and exceed 10,000 volts (10 kilovolts) with power factor >=0.95 means a very high percentage of the electrical power is being effectively converted into useful work output. In simpler terms, it indicates that the electrical system is very efficient with minimal energy loss.

ITHD ≤ 10% means that the Total Harmonic Distortion of the current is less than or equal to 10%. Total Harmonic Distortion (THD) is a measure of the distortion in a waveform caused by harmonics, which are higher frequency components superimposed on the fundamental frequency.

High voltage cut off >= 330 ±20 VAC means that the device or system has a protective feature that will disconnect or shut down the power supply when the voltage exceeds a certain threshold, specifically in the range of 310 to 350 volts AC (alternating current). Hi Pot Protection 1.5KVac typically refers to high potential (hi-pot) testing, a common safety test for electrical insulation.

Table 02 - Photometric data

Colour temperature(±200K)	5700K
Luminous flux Tolerance (±5%)	11500
Luminous efficacy Tolerance (±5%)	115
Colour rendering index (CRI)	>70
Beam angle	15°

Table 02 shows the photometric data of this fixture. Here , it can be seen that , the CCT for this laminar 5700k (the light source has a colour temperature of 5700 Kelvin with a permissible variation of ±200 Kelvin.) relates to the colour temperature of a light source, indicating its appearance in terms of warmth or coolness of the light it emits and CRI >70 indicates that the light source has good colour rendering capabilities, making it suitable for many general lighting applications where high colour accuracy is not critical but still important. This specification ensures that colour appear natural enough for most practical purposes, striking a balance between quality, efficiency, and cost.

Luminous flux Tolerance (±5%) 11500 lux means that the light output of a lighting device is consistent and reliable, with the actual output allowed to vary between 10925 lux and 12075 lux. This specification is crucial for maintaining the quality and effectiveness of lighting in various applications.

Beam angle 15° specifies that the light emitted from the source is concentrated within a narrow cone of 15 degrees.

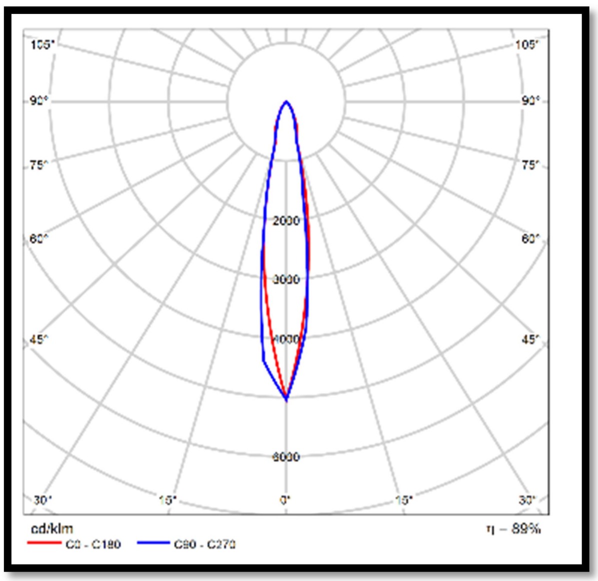


Figure 5: Photometric characteristics of lighting fixture)

Figure 5 shows to represent the photometric characteristics of lighting fixtures. In this graph where the concentric circles represent luminous intensity (candela, cd) and the radial lines represent angles (in degrees) from 0° to 360°.

Red Line shown in Figure 5 (C0 - C180): Represents the luminous intensity distribution in one plane (usually the vertical plane).

Blue Line shown in Figure 5 (C90 - C270): Represents the luminous intensity distribution in a perpendicular plane to the red line's plane (usually the horizontal plane).

Such lighting diagrams are essential for lighting designers to understand how a fixture will perform in a real-world setting.

4.1.2. Working Steps

Step 1

First I visited the site and spoke to the site engineers. After getting their inputs on the front lighting I suggested this floodlight and assured that "I will submit a suitable lighting design for this space".

After that some pictures were clicked for my reference. Here I have attached some of them.

Figure 6: Front view of actual Building

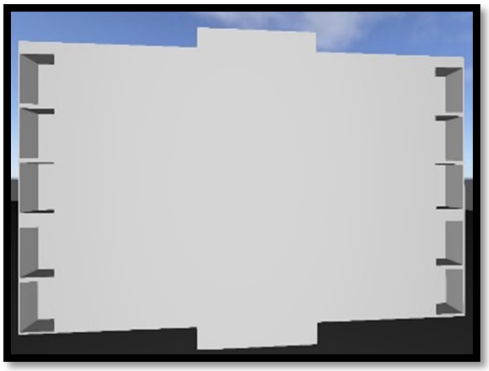
Figure 7: Side view of actual Building

Step 2

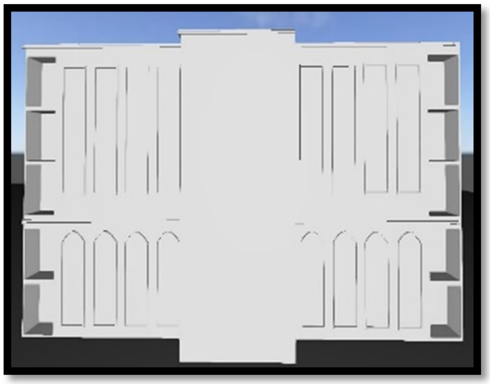
After that I formatted this image in AutoCAD software. And scaled as per their suggestion.

Step 3

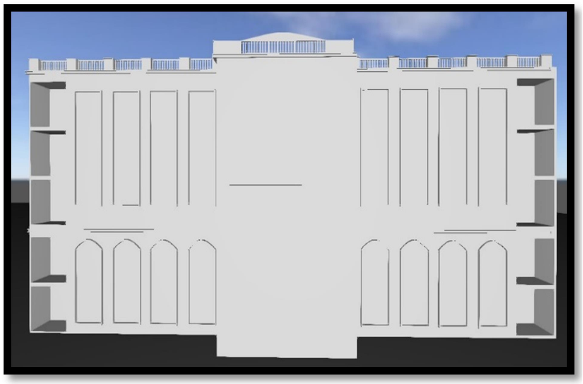
Then I drew every block of the building in dialux evo software and decorated the building as shown in picture.

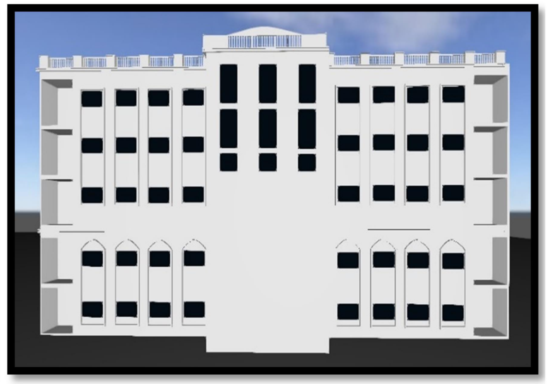


8(a)

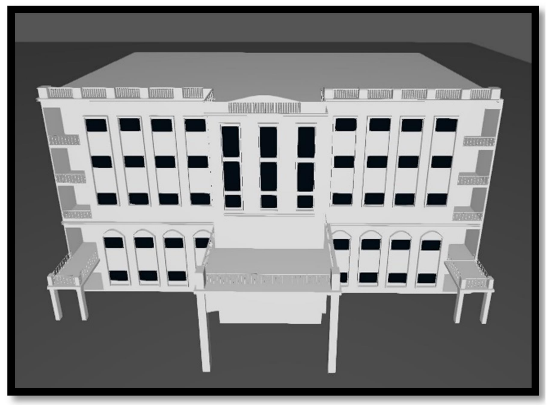


8(b)





8(c) **8(d)**



8(e) **8(f)**

Figure 8: Simulation work

Figure 8 shows, how the Simulation work has been done from the actual building photocopy.

Figure 9: Picture of the building after completion of the Simulation work

Step 4

After completing the building construction work, I had drawn a linear arrangement of the floodlight. Here I took 15 degree narrow beam angle floodlight for better outcome. I kept some of them far away from the building to focus on the middle area of the building and kept some luminaries in front of the building to highlight the lower part and kept some linear wall washer luminaries upward Beam for highlighting the upper part of the building.

Step 5

After completing this action, the simulation was performed by Dialox Evo. Here I have attached some result images of the building. In between I had to draw a calculation surface to understand light pollution.

Figure 10: Front View - Picture after simulation 01

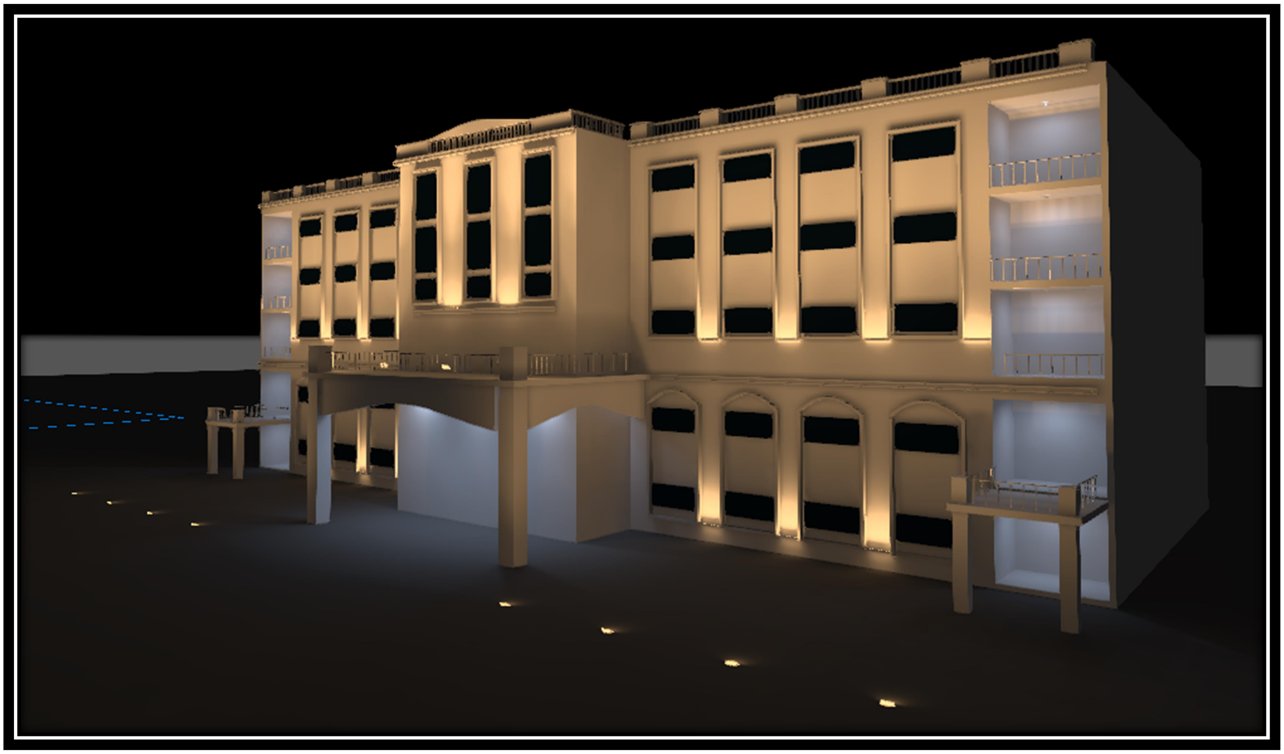


Figure 11: Side view - Picture after simulation 02

Figure 10 and 11 shows the simulated work output, getting from DiaLUX EVO. Here the major work has been done by floodlights and some wall washer used to highlight the beam of the building. Distance between the floodlight position and building is 15 meter.

4.1.2. Type 2 Building

Design with 60 degree beam angle Flood Light:-

Luminaire Used – Medium Wide Beam angle Floodlight - 100 watt

Figure 12: Model of the Floodlight Fixture

Figure 12 shows the body of the original floodlight with 60 degree narrow beam angle, made of pressure Die-cast aluminium housing with a clear diffuser.

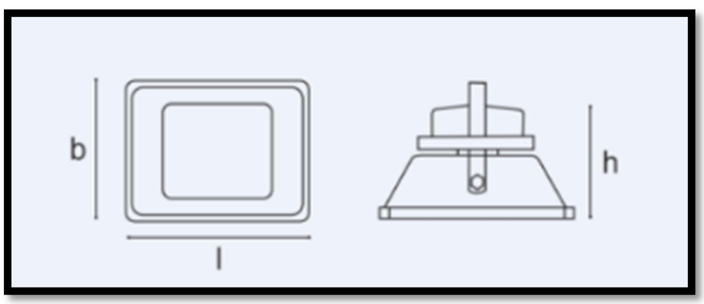


Figure 13: Fixture Dimension

Figure 13 shows the different dimensions of the luminaire that actually used in project.

Fixture Height	128mm
Fixture Length	270mm
Fixture Width	220mm

For fixing/mounting the fixture in a proper way, dimensions are required to be known well.

Table 03 - Technical Data (Electrical Data)

Nominal wattage Tolerance (±5%)	100W
Rated input voltage	240Vac
Operating voltage range	120-300Vac
Power factor	>=0.95
ITHD	<=10%
Input frequency	50Hz
Hi Pot Protection	1.5KVac
Driver Efficiency	>=90%

Surge Protection	10KV
High voltage Cut off	>=330 +-20 VAC
Current foldback at Low Voltage	<=150 +-10 VAC
Phase to phase Protection	Yes
Over Voltage Protection	Yes
Thermal Protection	Yes
Short Circuit Protection	Yes
Operating mode	Constant Current

Table 03 shows the electrical data of this floodlight, where it can be seen that the total power consumption of the fixture is 100 watt & it has an input voltage of 240 volt with an operating range of 120-300 Vac. It has a surge protection over 10KV i.e. the driver is capable of protecting against electrical surges or spikes that reach up to and exceed 10,000 volts (10 kilovolts) with power factor >=0.95 means a very high percentage of the electrical power is being effectively converted into useful work output. In simpler terms, it indicates that the electrical system is very efficient with minimal energy loss.

ITHD ≤ 10% means that the Total Harmonic Distortion of the current is less than or equal to 10%. Total Harmonic Distortion (THD) is a measure of the distortion in a waveform caused by harmonics, which are higher frequency components superimposed on the fundamental frequency.

High voltage cut off >= 330 ±20 VAC means that the device or system has a protective feature that will disconnect or shut down the power supply when the voltage exceeds a certain threshold, specifically in the range of 310 to 350 volts AC (alternating current). Hi Pot Protection 1.5KVac typically refers to high potential (hi-pot) testing, a common safety test for electrical insulation.

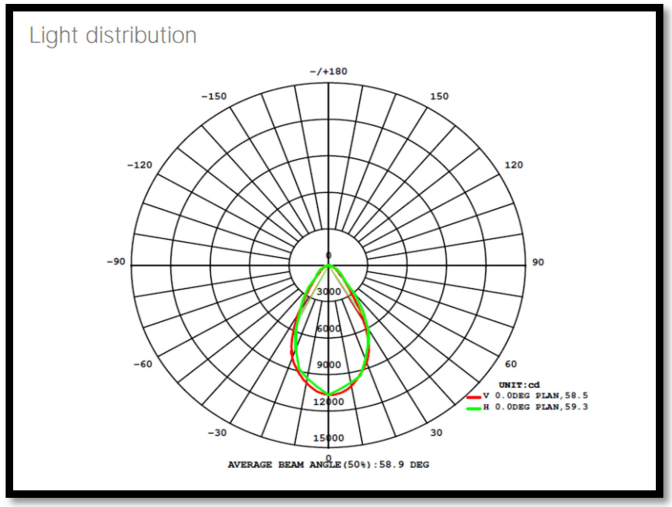
Table 04 - Photometric data

Colour temperature(±200K)	5700K
Luminous flux Tolerance (±5%)	11500
Luminous efficacy Tolerance (±5%)	115
Colour rendering index (CRI)	>70
Beam angle	60°

Table 04 shows the photometric data of this fixture. Here , it can be seen that , the CCT for this laminar 5700k (the light source has a colour temperature of 5700 Kelvin with a permissible variation of ±200 Kelvin.) relates to the colour temperature of a light source, indicating its appearance in terms of warmth or coolness of the light it emits and CRI >70 indicates that the light source has good colour rendering capabilities, making it suitable for many general lighting applications where high colour accuracy is not critical but still important. This specification ensures that colour appear natural enough for most practical purposes, striking a balance between quality, efficiency, and cost.

Luminous flux Tolerance (±5%) 11500 lux means that the light output of a lighting device is consistent and reliable, with the actual output allowed to vary between 10925 lux and 12075 lux. This specification is crucial for maintaining the quality and effectiveness of lighting in various applications.

Beam angle 60° means that the light emitted from the source is concentrated within a narrow cone of 60 degrees.



0

Figure 14: Photometric characteristics of lighting fixture

Figure 14 shows to represent the photometric characteristics of lighting fixtures. In this graph where the concentric circles represent luminous intensity (candela, cd) and the radial lines represent angles (in degrees) from 0° to 360°.

Red Line (C0 - C180): Represents the luminous intensity distribution in one plane (usually the vertical plane).

Blue Line (C90 - C270): Represents the luminous intensity distribution in a perpendicular plane to the red line's plane (usually the horizontal plane).

Such lighting diagrams are essential for lighting designers to understand how a fixture will perform in a real-world setting.

4.1.3. Working Steps

Typically same as Type 1 building.

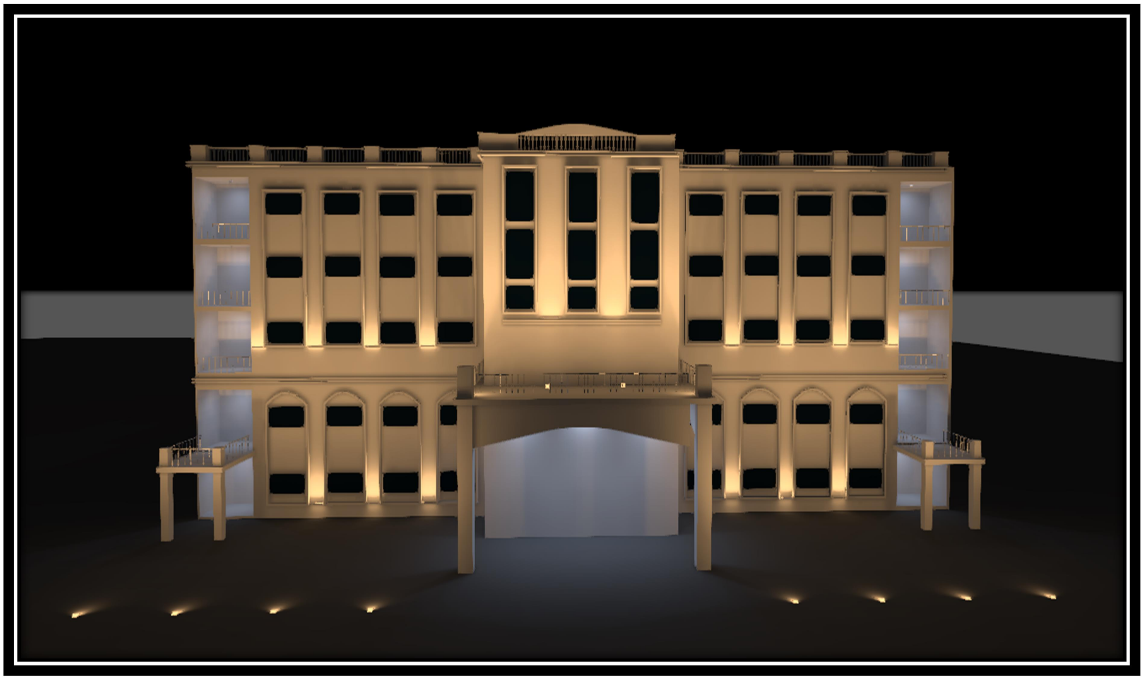


Figure 15: Picture after simulation

4.1.3. Lighting Pollution Comparison chart.

Table 05 (Lighting Pollution Comparison chart)

Light Pollution comparison between 15 deg and 60 deg beam angle Flood Light		
Position	For 15 deg Beam angle	For 60 deg Beam angle
Vertical (Avg Lux)	6.37	7.69
Horizontal (Avg Lux)	28.8	34.5

Table 05 shows the pollution comparison chat where we can see the horizontal and vertical average lux level of the building surrounding for understand the pollution level. This comparison chart helps us to understand the impact of different lighting fixtures and techniques on light pollution. By comparing these impacts, we can choose options that minimize unwanted light pollution, protecting the night sky and reducing disturbances to neighbouring properties and natural habitats. Here It can be seen the difference between 15 degree and 60 degree beam angle lenses use. Anyone can do this question why we couldn't use 8 degree or 12 degree beam angle lens? If we were to use such a lens here, it would create an overly narrow beam angle light throw where the design would be distorted due to this light effect [5].

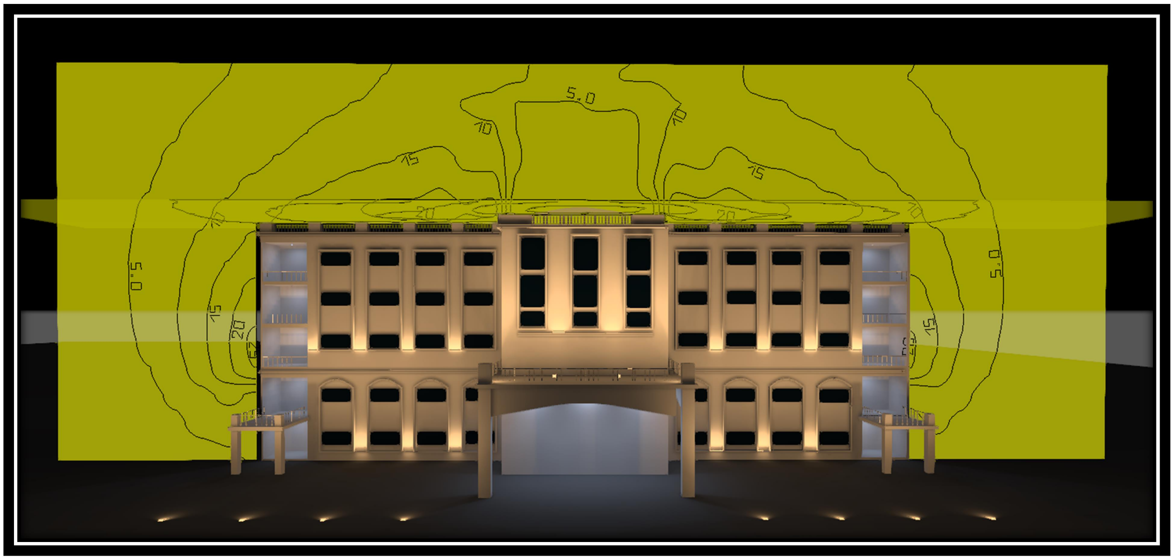


Figure 16 – Pollution measurement

To measure the pollution level of the building surrounding a horizontal and a vertical calculation surface placed around and above the building as shown in the figure no 16. As per IESNA 2010 this building area considered as a No Ambient Lighting zone (LZ0) where the natural environment will be seriously and adversely affected by lighting. In this type of zone the vertical and horizontal recommended illuminance target have to be 0 but in this project while using 15 degree beam angle floodlight the vertical Avg. lux level – 6.37 lux and horizontal Avg. lux level 28.8 lux. The lux level of this case study higher with respect to IESNA standard.

4.1.4. Price Comparison

Table – 06
(Estimation for Type 1 Building)

Quotation					
Project name - XYZ					**DT-dd.mm.yyyy**
Sl. No.	**Product Details**	**Product Image**	**Quantity**	**Unit Price**	**Amount**
1	**Floodlight - 100 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 60 deg beam angle. Length of this fixture - 80mm and height - 200 mm, Width - 115mm**		12	5225.00	62700.00

2	**Wall washer - 30 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 24 deg beam angle. Length of this fixture - 1200mm and height - 80 mm, Width - 80mm**		16	7800.00	124800.00
		Taxable Amount			187500.00
		18% GST			33,750.00
		Net Amount			**2,21,250**

Table – 07
(Estimation for Type 2 Building)

Quotation					
Project name - XYZ					**DT- dd.mm.yyyy**
Sl. No.	**Product Details**	**Product Image**	**Quantity**	**Unit Price**	**Amount**
1	**Floodlight - 100 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 60 deg beam angle. Length of this fixture - 80mm and height - 200 mm, Width - 115mm**		12	7250.00	87000.00
2	**Wall washer - 30 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 24 deg beam angle. Length of this fixture - 1200mm and height - 80 mm, Width - 80mm**		16	7800.00	124800.00
		Taxable Amount			211800.00
		18% GST			38,124.00
		Net Amount			**2,49,924**

These two tables show the price values of individual luminaires. There is not that much difference between a quote for a Type 1 building and a quote for a Type 2 building. The only slight difference is the lens itself. All prices have been collected from a particular brand price list. More or less every company rates their discount in the market for taking orders from end clients, so here 40% discount is considered as unit price [19].

4.2. Facade Design 2.

The case study has been done using floodlights with two different beam angles. One is narrow beam angle (15 degree beam angle) (Ref. to Page no 18) and the second one is medium wide beam angle (60 degree beam angle). Here, 2 types of building have been considered. Type 1 building for 15 degree narrow beam angle floodlight and Type 2 building for 60 degree medium wide beam angle floodlight.

4.2.1. Type 1 Building

Design with 15 degree beam angle Flood Light:-

Luminaire Used – Narrow Beam angle Floodlight - 100 watt

Figure 17: Model of the Floodlight Fixture

Figure 17 shows the body of the original floodlight with 15 degree narrow beam angle, made of pressure Die-cast aluminium housing with a clear diffuser.

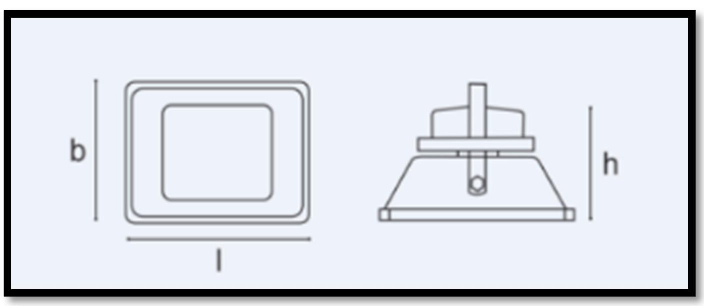


Figure 18: Fixture Diamension

Figure 18 shows the different dimensions of the luminaire that actually used in project.

Fixture Height	128mm
Fixture Length	270mm
Fixture Width	220mm

For fixing/mounting the fixture in a proper way, dimensions are required to be known well.

Table 08 - Technical Data (Electrical Data)

Nominal wattage Tolerance (±5%)	100W
Rated input voltage	240Vac
Operating voltage range	120-300Vac
Power factor	>=0.95
ITHD	<=10%
Input frequency	50Hz
Hi Pot Protection	1.5KVac
Driver Efficiency	>=90%
Surge Protection	10KV
High voltage Cut off	>=330 +-20 VAC
Current fold back at Low Voltage	<=150 +-10 VAC
Phase to phase Protection	Yes
Over Voltage Protection	Yes
Thermal Protection	Yes
Short Circuit Protection	Yes
Operating mode	Constant Current

Table 08 shows the electrical data of this floodlight, where it can be seen that the total power consumption of the fixture is 100 watt & it has an input voltage of 240 volt with an operating range of 120-300 Vac. It has a surge protection over 10KV i.e. the driver is capable of protecting against electrical surges or spikes that reach up to and exceed 10,000 volts (10 kilovolts) with power factor >=0.95 means a very high percentage of the electrical power is being effectively converted into useful work output. In simpler terms, it indicates that the electrical system is very efficient with minimal energy loss.

ITHD ≤ 10% means that the Total Harmonic Distortion of the current is less than or equal to 10%. Total Harmonic Distortion (THD) is a measure of the distortion in a waveform caused by harmonics, which are higher frequency components superimposed on the fundamental frequency.

High voltage cut off >= 330 ±20 VAC means that the device or system has a protective feature that will disconnect or shut down the power supply when the voltage exceeds a certain threshold, specifically in the range of 310 to 350 volts AC (alternating current). Hi Pot Protection 1.5KVac typically refers to high potential (hi-pot) testing, a common safety test for electrical insulation.

Table 09 - Photometric data

Colour temperature(±200K)	5700K
Luminous flux Tolerance (±5%)	11500
Luminous efficacy Tolerance (±5%)	115
Colour rendering index (CRI)	>70
Beam angle	15°

Table 09 shows the photometric data of this fixture. Here , it can be seen that , the CCT for this laminar 5700k (the light source has a colour temperature of 5700 Kelvin with a permissible variation of ±200 Kelvin.) relates to the colour temperature of a light source, indicating its appearance in terms of warmth or coolness of the light it emits and CRI >70 indicates that the light source has good colour rendering capabilities, making it suitable for many general lighting applications where high colour accuracy is not critical but still important. This specification ensures that colour appear natural enough for most practical purposes, striking a balance between quality, efficiency, and cost.

Luminous flux Tolerance (±5%) 11500 lux means that the light output of a lighting device is consistent and reliable, with the actual output allowed to vary between 10925 lux and 12075 lux. This specification is crucial for maintaining the quality and effectiveness of lighting in various applications.

Beam angle 15° means that the light emitted from the source is concentrated within a narrow cone of 15 degrees.

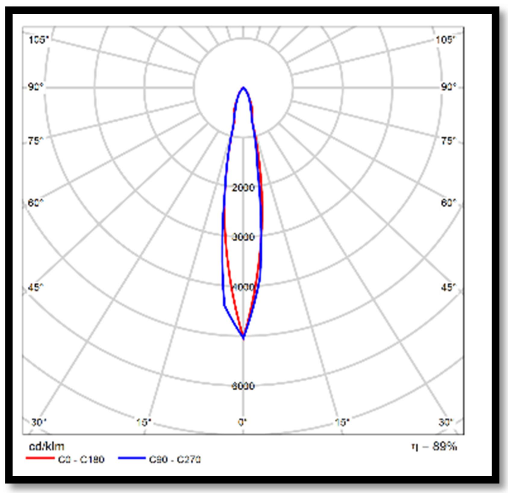


Figure 19: Photometric characteristics of lighting fixture

Figure 19 shows to represent the photometric characteristics of lighting fixtures. In this graph where the concentric circles represent luminous intensity (candela, cd) and the radial lines represent angles (in degrees) from 0° to 360°.

Red Line (C0 - C180): Represents the luminous intensity distribution in one plane (usually the vertical plane).

Blue Line (C90 - C270): Represents the luminous intensity distribution in a perpendicular plane to the red line's plane (usually the horizontal plane).

Such lighting diagrams are essential for lighting designers to understand how a fixture will perform in a real-world setting.

4.2.2. Working Steps

Step 1

First I visited the site and spoke to the site engineers. After getting their inputs on the front lighting I suggested this floodlight and assured that "I will submit a suitable lighting design for this space".

After that some pictures were clicked for my reference. Here I have attached some of them.

Figure 20: Front view of actual Building

Figure 21: Side view of actual Building

Step 2

After that I formatted this image in AutoCAD software. And scaled as per their suggestion.

Step 3

Then I drew every block of the building in dialux evo software and decorated the building as shown in picture.

Figure 22: After completing the construction work- building picture

Step 4

After completing the building construction work, I had drawn a linear arrangement of this floodlight. Here I took 15 degree narrow beam angle floodlight for better outcome. I kept some of them far away from the building to focus the middle area of the building and kept some luminaries in front of the building to highlight the lower part and kept some linear wall washer luminaires upward balcony for highlight the upper part of the building.

Step 5

After completing this action, the simulation was performed by Dialox Evo. Here I have attached some result images of this building. In between I had to draw a calculation surface to understand light pollution.

Figure 23 (a)

Figure 23 (b)

Figure 23 (c)

Figure 23 (d)

Figure 23: Picture after simulation 01: 360 view

Figure 24: Picture after simulation 02

Figure 23 and 24 shows the simulated work output, getting from DiaLUX EVO. Here the major work has been done by floodlights and some wall washer used to highlight the beam of the building. Distance between the floodlight position and building is 12.7 meter.

4.2.2. Type 2 Building

Design with 60 degree beam angle Flood Light:-

Luminaire Used – Medium Wide Beam angle Floodlight - 100 watt

Figure 25: Model of the Floodlight Fixture

Figure 25 shows the body of the original floodlight with 60 degree Medium wide Beam angle, made of pressure Die-cast aluminium housing with a clear diffuser.

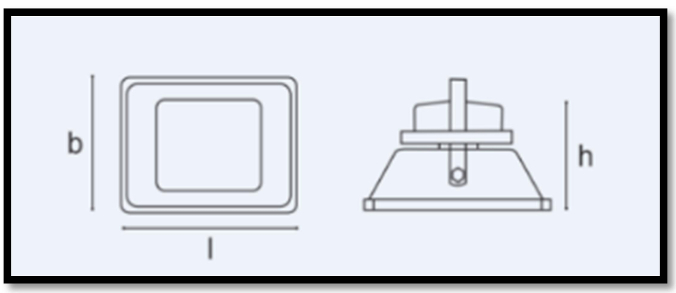


Figure 26: Fixture Dimension

Figure 26 shows the different dimensions of the luminaire that actually used in project.

Fixture Height	128mm
Fixture Length	270mm
Fixture Width	220mm

For fixing/mounting the fixture in a proper way, dimensions are required to be known well.

Figure 26 shows to represent the photometric characteristics of lighting fixtures. In this graph where the concentric circles represent luminous intensity (candela, cd) and the radial lines represent angles (in degrees) from 0° to 360°.

Red Line (C0 - C180): Represents the luminous intensity distribution in one plane (usually the vertical plane).

Blue Line (C90 - C270): Represents the luminous intensity distribution in a perpendicular plane to the red line's plane (usually the horizontal plane).

Such lighting diagrams are essential for lighting designers to understand how a fixture will perform in a real-world setting.

Table 10 - Technical Data (Electrical Data)

Nominal wattage Tolerance (±5%)	100W
Rated input voltage	240Vac
Operating voltage range	120-300Vac
Power factor	>=0.95
ITHD	<=10%
Input frequency	50Hz
Hi Pot Protection	1.5KVac
Driver Efficiency	>=90%
Surge Protection	10KV
High voltage Cut off	>=330 +-20 VAC
Current foldback at Low Voltage	<=150 +-10 VAC
Phase to phase Protection	Yes
Over Voltage Protection	Yes
Thermal Protection	Yes
Short Circuit Protection	Yes
Operating mode	Constant Current

Table 10 shows the electrical data of this floodlight, where we can see the Nominal wattage – 100 watt, it has an input voltage of 240 volt with an operating range of 120-300 Vac. It has a surge protection over 10KV with power factor >=0.95. Rest of same as table no 08.

Table 11 - Photometric data

Colour temperature(±200K)	5700K
Luminous flux Tolerance (±5%)	11500
Luminous efficacy Tolerance (±5%)	115
Colour rendering index (CRI)	>70
Beam angle	60°

Table 11 shows the photometric data of this fixture, here it can be seen the CCT for this laminar 5700k and CRI >70. Luminous efficacy of this fixture 115 lumen/watt, Beam angle - 60°.

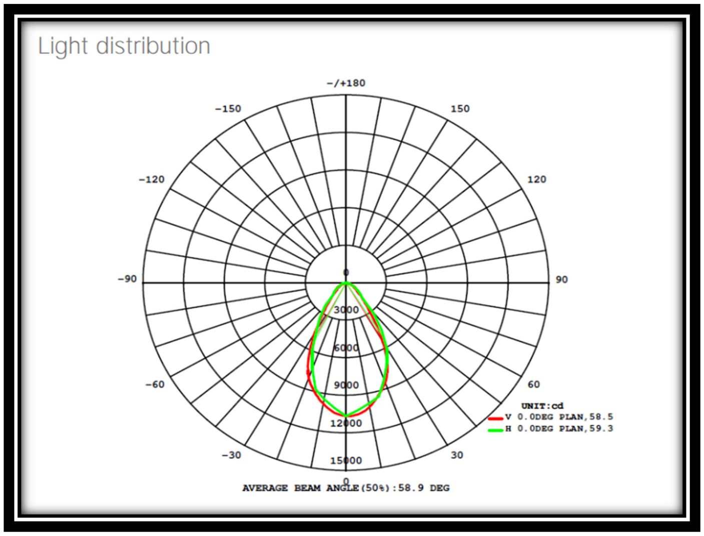


Figure 27: Photometric characteristics of lighting fixture

Figure 27 shows to represent the photometric characteristics of lighting fixtures. In this graph where the concentric circles represent luminous intensity (candela, cd) and the radial lines represent angles (in degrees) from 0° to 360°.

Red Line (C0 - C180): Represents the luminous intensity distribution in one plane (usually the vertical plane).

Blue Line (C90 - C270): Represents the luminous intensity distribution in a perpendicular plane to the red line's plane (usually the horizontal plane).

Such lighting diagrams are essential for lighting designers to understand how a fixture will perform in a real-world setting.

4.2.3. Working Steps

Typically same as Type 2 building.

Figure 28: Picture after simulation

Figure 28 shows the final simulation with 60 degree beam angle floodlight.

4.2.3. Lighting Pollution Comparison chart.

Table 12 (Lighting Pollution Comparison chart)

Light Pollution comparison between 15 deg and 60 deg beam angle Flood Light		
Position	For 15 deg Beam angle	For 60 deg Beam angle
Vertical (Avg Lux)	5.94	9.08
Horizontal (Avg Lux)	38.2	48.4

Table 12 shows the pollution comparison chat where we can see the horizontal and vertical average lux level of the building surrounding for understand the pollution level. This comparison chart helps us to understand the impact of different lighting fixtures and techniques on light pollution. By comparing these impacts, we can choose options that minimize unwanted light pollution, protecting the night sky and reducing disturbances to neighbouring properties and natural habitats. Here we can see the difference between 15 degree and 60 degree beam angle lenses use. Anyone can do this question why we couldn't use 8 degree or 12 degree beam angle lens? If we were to use such a lens here, it would create an overly narrow beam angle light throw where the design would be distorted due to this light effect.

Figure 29 – Pollution measurement

To measure the pollution level of the building surrounding a horizontal and a vertical calculation surface placed around and above the building as shown in the figure no 29. As per IESNA 2010 this building area considered as a No Ambient Lighting zone (LZ0) where the natural environment will be seriously and adversely affected by lighting. In this type of zone the vertical and horizontal recommended illuminance target have to be 0 but in this project while using 15 degree beam angle floodlight the vertical Avg. lux level – 5.94 lux and horizontal Avg. lux level 38.2 lux. The lux level of this case study higher with respect to IESNA standard [5].

4.2.4. Price Comparison

Table – 13
(Estimation for Type 1 Building)

Quotation					
Project name - XYZ					DT- dd.mm.yyyy
Sl. No.	**Product Specification**	**Product Image**	**Quantity**	**Unit Price**	**Amount**
1	**Floodlight - 100 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 15 deg beam angle. Length of this fixture - 80mm and height - 200 mm, Width - 115mm**		11	7250.00	79750.00
2	**Wall washer - 30 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 24 deg beam angle. Length of this fixture - 1200mm and height - 80 mm, Width - 80mm**		6	7800.00	46800.00
		Taxable Amount			126550.00
		18% GST			22,779.00
		Net Amount			**1,49,329**

Table – 14
(Estimation for Type 2 Building)

Quotation					
Project name - XYZ					DT- dd.mm.yyyy
Sl. No.	**Product Specification**	**Product Image**	**Quantity**	**Unit Price**	**Amount**
1	**Floodlight - 100 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 60 deg beam angle. Length of this fixture - 80mm and height - 200 mm, Width - 115mm**		11	5225.00	57475.00

2	**Wall washer - 30 watt - IP 66 product made of Aluminium dia cast, The range is suitable for various applications around buildings, ideal for facade lighting as well as lighting gardens, paths near to buildings, garages, entrance ways, security lighting and drives, fixture efficacy of 110 lm/w. CCT of this luminaire - 3000k/5700k with 24 deg beam angle. Length of this fixture - 1200mm and height - 80 mm, Width - 80mm**		6	7800.00	46800.00
		Taxable Amount			104275.00
		18% GST			18,769.50
		Net Amount			**1,23,045**

These two tables show the price values of individual luminaires. There is not that much difference between a quote for a Type 1 building and a quote for a Type 2 building. The only slight difference is the lens itself. All prices have been collected from a particular brand price list. More or less every company rates their discount in the market for taking orders from end clients, so here 40% discount is considered as unit price [19].

Chapter 5

(Conclusion, Challenges and Future Scope)

5.1. Conclusion

A lot have been learned about facade lighting working with the mentioned projects. During the projects, knowledge gained on various aspects, such as different photometry of light, types of lenses and their uses, and building creation in Dialux. The relationship between light pollution and photometry was also understood.

According to IESNA 2010, data on landscape and façade lighting are provided. However, these guidelines are not applied to façade lighting in India.

But in this particular project some references have been considered for identifying the light pollution occurred surrounding the building area. As per IESNA low ambient zone (LZ0) nearly fit according these buildings.

In my personal opinion that these guidelines should be properly maintained when conducting this type of lighting. Doing so could reduce sky glow and other forms of lighting pollution, and the LPD standards should be maintained as per norms.

5.2. Challenge Faced

It can be concluded that, in the process of completing this work, numerous challenges were encountered, such as:

i. The beam angle could not be correctly positioned to achieve the desired lighting effect.

ii. Obstructions were faced when attempting to place the fixture on the ground and balcony.

Upon extensive study, the solution was discovered. The task could be successfully accomplished by drawing reference lines and positioning a laser at the fixture's top. Additionally, an angle bracket, which was hung from the balcony to securely hold the fixture, was arranged.

5.3. Future Scope of Work

A lot of time was taken by these projects. Had more time been allotted, automation for energy efficiency could have been done on these projects, and had the budget been slightly higher, RGB LED fixtures would have been utilized, and DMX controllers worked with. This would have enabled the creation of any desired scene.

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