DESIGN AND ANALYSIS OF A SPORTS LIGHTING SYSTEM FOR A FOOTBALL PLAYGROUND

A Dissertation submitted in partial fulfillment in the requirements for the degree of

Master of Engineering
in
Illumination Engineering

Submitted by

BISWANIL KHAN

Exam Roll No. M4ILN24004
Registration No. 163497 of 2022 – 2023

Under the Guidance of

Prof. (Dr.) BISWANATH ROY

ELECTRICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY
KOLKATA 700032

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JADAVPUR UNIVERSITY
FACAULTY OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

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THESIS SUPERVISOR

Prof. (Dr.) BISWANATH ROY

ILLUMINATION ENGINEERING SECTION
ELECTRICAL ENGINEERING DEPARTMENT
JADAVPUR UNIVERSITY
KOLKATA

Prof. (Dr.) BISWANATH ROY

HEAD OF THE DEPARTMENT
ELECTRICAL ENGINEERING DEPARTMENT
JADAVPUR UNIVERSITY
KOLKATA

Prof. (Dr.) DIPAK LAHA

DEAN
FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY
KOLKATA

JADAVPUR UNIVERSITY
FACAULTY OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

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NAME: BISWANIL KHAN

EXAMINATION ROLL NUMBER: M4ILN24004

THESIS TITLE: DESIGN AND ANALYSIS OF A SPORTS LIGHTING SYSTEM FOR A FOOTBALL PLAYGROUND

SIGNATURE:

DATE:

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ABSTRACT

Lighting is an essential element in our daily life. Based on the modern-day research on lighting, design related to lighting, it is proven that inadequate lighting gives us bad visual effects, poor viewing environment, uncomfortable visuals, low feeling, low attention towards our job, stress and mostly it affects our circadian rhythm. We need good lighting design to overcome these affects and to keep our eyes safe.

Efficient lighting design for a football playground is crucial to ensure optimal visibility for players as well as spectators and to enhance the performance of the players.

This study mainly focuses on the lighting design of a football playground and analyze whether the simulated values that is achieved matches with the recommended values in the standards or not. This research employs various computational simulations, provide various design models with new techniques and various configurations. It also includes luminaires selection, luminaires placement, beam angles of the luminaires and photometric and electrical parameters of the luminaires. Factors like average illuminance values, uniformity of illumination across the playing area, uniformity gradient and unified glare rating is also discussed here. Practical considerations such as maintenance requirements and environmental impact are also considered.

Through comparative analysis and simulations, this study aims to identify the most suitable lighting solution that balances performance, energy efficiency, and cost-effectiveness.

The findings of this research contribute to the advancement of sports lighting technology, providing valuable insights for engineers, lighting designers, and stakeholders involved in the construction and renovation of football playgrounds. Ultimately, the goal is to create a well-lit environment that enhances safety, performance, and enjoyment for both athletes and spectators alike.

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INTRODUCTION

Football is one of the most popular sports globally. The time of playing often get extended into the evening hours, which demand adequate illumination of playgrounds and gallery to ensure optimal visibility and safety for players and spectators as well. The design and analysis of sports lighting system for a football playground represents critical aspects of infrastructure planning, aiming not only to meet functional requirements but also to enhance the overall sporting and viewing experience.

Effective sports lighting design involves a complex interplay of factors such as illuminance levels, uniformity of light distribution, glare control, energy efficiency, and compliance with international standards. Unlike conventional lighting applications, sports lighting must accommodate fast-paced movements, varying player positions, and the need for accurate perception of the playing environment, all under changing weather conditions. Through a systematic approach involving simulation tools and empirical data, this investigation aims to address critical questions such as the ideal placement and orientation of luminaires, the impact of lighting on player performance, and the mitigation of potential hazards such as glare and light pollution. Furthermore, considerations for sustainability, including energy efficiency and the environmental impact of lighting systems, will be integral to the proposed design solutions.

Ultimately, the findings of this research are expected to contribute significantly to the field of sports lighting design, providing valuable insights and practical guidelines for engineers, architects, lighting designers, and stakeholders involved in the planning and development of football playgrounds. By optimizing lighting conditions, this study endeavours to create a safe, more visually comfortable, and enjoyable environments for both participants and spectators of a night football match.

OBJECTIVES

The primary objective of this study is to explore and analyse the different aspects of designing sports lighting specifically for a football playground. The purpose of sports lighting system is to create a luminous environment where paying objects can be seen clearly by the players, officials, umpires, spectators, and TV/Media crew.

Here are the main objectives for doing this simulation: -

a. Illumination Levels: Determine the ideal illuminance levels across the football field to ensure adequate visibility for players, officials, and spectators during evening matches.

b. Ensure Uniform Light Distribution: Design lighting configurations that provide uniform illumination throughout the playing area, minimizing shadows and ensuring consistent visibility for all areas of the field.

c. Minimize Glare and Light Spillage: Analyze and mitigate glare to prevent discomfort for players and spectators, while also minimizing light spillage beyond the playing field to reduce light pollution.

d. Lighting Energy Efficiency: Develop lighting designs that maximize energy efficiency using efficient luminaires, controls, and possibly renewable energy sources, aiming to reduce operational costs and environmental impact.

e. Enhance Color Rendering: To evaluate lighting solutions which will render accurate color hence providing good picture quality for broadcasting.

f. Enhance Player Performance and Safety: Design lighting that enhances player visibility and safety, enabling accurate judgment of game situations and reducing the risk of injuries due to poor visibility.

g. To ensure Compliance with the Standards.

CHAPTER 1: FUNDAMENTALS OF SPORTS LIGHTING

1.1 SPORTS LIGHTING

Today sports have become the world's largest entertainment industry surpassing the conventional forms of entertainment such as films, concerts, and many others. It accomplishes people irrespective of age, sex, cast, religion, and culture. Sports is the only thing that bring harmony and unity among peoples irrespective of their religion and caste across the world [3].

This lighting design industry consist of mainly two types of people, namely professional users, and recreational users. The players, officials and the sponsors fall under professional users. Rest of the people like spectators those who get involved for having fun and enjoyment and they paly casually mainly to stay fit and to have local competitions, falls under the category of recreational users.

In tropical countries like India and other Arab countries, where the climate is hot and humid, it became essential to schedule the matches after dusk. This helps the players as well as spectators to enjoy the match.

To conduct any match after dusk, it become essential to install artificial lighting system which will provide clear visuals in the absence of natural daylight. Now just putting the lights and switching it on to have visual is not enough to conduct any match. We need as well as we should ensure good quality lighting which will satisfy the need of players, umpires, officials, and spectators. Here comes the sports lighting design.

Good quality sports lighting ensures and meet all the requirements related for having a proper vision and it also helps in enhancing the performance of the players, and provide participation and satisfaction to the spectators.

Lastly the sports lighting design should be done in such a way so that it satisfies the requirement of payers, umpires, officials, television and media crew and spectators present in the gallery.

1.2 NECESSITY OF SPORTS LIGHTING

Sports lighting is not just about illuminating the playground and providing good visuals to the players, umpires, officials, and spectators. It plays a crucial role in functionality, economic impact on sports facilities and events and safety. Therefore, investing in quality sports lighting is often considered a necessity rather than a luxury for any modern sports venue.

Sports lighting serves several important purposes that are crucial for both players and spectators:

a. Extended Playing Hours: Sports lighting allows activities to take place after daylight hours, enabling flexibility in scheduling practices and matches. This is especially important in seasons or regions where daylight hours are limited.

b. Enhanced Visibility: Proper lighting ensures that players can see clearly, reducing the risk of injuries due to poor visibility. It also enables spectators to follow the action more easily.

c. Broadcasting and Media Coverage: Apart from the spectators present in the stadium, there are many peoples watching the game live on their televisions. Therefore, adequate lighting is essential for capturing high-quality images and videos for broadcasting and media coverage. This helps in popularizing sports events and reaching a wider audience.

d. Safety and Security: Well-lit sports facilities contribute to the safety of players, officials, and spectators by reducing the risk of accidents and providing a secure environment. This is particularly important for larger venues hosting events attended by large crowds.

e. Quality of Play: Lighting affects the quality of play by ensuring that participants can accurately judge distances, trajectory of the ball, and the movements of other players. This enhances the competitive nature of sports and allows athletes to perform at their best.

f. Economic Benefits: Sports facilities with proper lighting can attract more events, tournaments, and competitions, thereby benefiting the local economy through increased tourism, hospitality services, and revenue from ticket sales. Good sports make easier for the management to get a greater number of sponsors.

1.3 TERMS RELATED TO SPORTS LIGHTING

Below are some terms that are related to sports lighting [2]:

1. Luminaire: It is the complete lighting unit consisting of a lamp or lamps, ballast, reflector, and housing.

2. Luminous flux (Φ): It is the total amount of visible light emitted from a light source measured in lumens (lm).

3. Luminous intensity (I): It is the total amount of visible light emitted per unit solid angle from a light source, measured in lumen per steradian or Candela (Cd).

4. Illuminance (E): It is the amount of visible light incident on a surface area. Its unit is lumen per square metre or Lux.

5. Luminance (L): It is the amount of visible light intensity that gets reflected from a unit surface area in a particular direction. Its unit is Lumen per steradian per square metre or Candela per square metre (Cd/m^2).

6. Uniformity: It refers to the consistency of light levels across a sports field or playing area. Good uniformity ensures that there are no overly bright or dark spots. It is expressed as the ratio of E_{min}/E_{max} (U1) and E_{min}/E_{avg} (U2). U1 relates to adaptation range which contributes towards visual performance and U2 relates to visual comfort.

5. Glare: Excessive brightness or contrast that causes discomfort or reduces visibility. Glare can affect both players and spectators.

6. Correlated Color Temperature (CCT): A characteristic of light that describes its warmth or coolness, measured in Kelvin (K). Sports lighting typically uses light in the range of 4000K to 6000K, which is cool white to daylight.

7. Color Rendering Index (CRI): A measure of how accurately a light source renders colors compared to natural daylight. Higher CRI values indicate better color rendering.

8. Floodlight: A type of luminaire designed to emit a broad beam of light, often used to illuminate sports fields or large areas.

9. Pole Height: The height of lighting poles or structures from which luminaires are mounted. Pole height affects light distribution and uniformity on the playing surface.

10. Lighting Design: The process of planning and designing the placement and configuration of luminaires to achieve optimal lighting performance for a sports facility.

11. Dark Sky Compliance: Refers to lighting fixtures and designs that minimize light pollution by directing light downward and reducing skyglow.

12. Luminous Efficacy: It is defined as the amount of luminous flux emitted from a light source per unit watt power consumption. Energy-efficient sports lighting systems reduce operational costs and environmental impact. Its unit is lumen per watt.

13. Televised Sports lighting: Televised sports lighting refers to specialized lighting systems designed to ensure optimal visibility and image capture for broadcast and recording of sporting events. These lighting systems are crucial for producing high-quality visuals that enhance viewer experience and provide accurate coverage of the action. Mainly the International and National matches require this design.

14. Non – Televised Sports lighting: It is the general sports lighting design that ensure good visual and comfort for the players, officials, and spectators. In this type of sports lighting design, mainly practice matches are carried on which do not require broadcasting.

Understanding these terms is essential for designing, installing, and maintaining effective sports lighting systems that meet the specific requirements of different sports and venues.

1.4 KEY FACTORS OF SPORTS LIGHTING

The main purpose of sports lighting design is to create optimal Lighting environment that supports performance, community engagement, sustainability, and safety.

The key factors of sports lighting are as follows:

a. Lighting Quality and Quantity: Ensure sufficient illumination (lux) across the playing area with good uniformity to enhance visibility for players and spectators. The lighting should be glare-free and provide accurate color rendering (high CRI).

b. Energy Efficiency: Utilize energy-efficient luminaires and control systems to minimize operational costs and environmental impact. LED technology is often preferred for its efficiency and longevity.

c. Control Systems: Implement lighting control systems such as dimming, scheduling, and remote management to optimize energy usage and adapt lighting levels for different activities or events.

d. Uniformity and Distribution: Achieve uniform light distribution across the playing surface and minimize spill light to surrounding areas or the night sky. Proper aiming and placement of luminaires on poles or structures are crucial.

e. Compliance and Regulations: Ensure compliance with local regulations and standards for sports lighting, including light trespass, glare control, and dark sky initiatives.

f. Maintenance and Longevity: Choose fixtures that are durable and that require minimal maintenance to ensure consistent performance over time. Consider accessibility for maintenance tasks such as lamp replacement.

g. Player Comfort and Safety: Avoid glare and shadows that could affect player performance or safety. Proper lighting also enhances the visibility of fast-moving objects (e.g., balls) during gameplay.

h. Budget and Cost Considerations: Balance initial installation costs with long-term operational savings and benefits.

i. Aesthetics and Community Considerations: Lighting design should complement the architectural and environmental context of the venue.

CHAPTER 2: SPORTS LIGHTING LUMINAIRE

2.1 LUMINAIRE AND SPORTS LIGHTING LUMINAIRE

LUMINAIRE: A luminaire is a complete lighting unit that consist of a Lamp or Lamps along with different parts designed to distribute the light, protect, and position the lamps and connect them to the power supply. Luminaire typically refers to a light fixture, that is decorative or stylish in nature. It can also be used to describe any device that produces light, often used in interior design or architectural contexts.

Types of sports lighting Luminaires:

- LED Floodlights: Modern and efficient, LED floodlights offer high luminous efficacy, long life, and low maintenance. They provide uniform, bright illumination with minimal light spill and are increasingly used in new installations.
- Metal Halide Floodlights: These are traditional sports lighting fixtures known for their high-intensity output and color rendering. They are often used in larger sports facilities but are being gradually replaced by LEDs due to their shorter lifespan and higher energy consumption.

Fig 1. LED Floodlights

Fig 2. Metal Halide Floodlights

SPORTS LIGHTING LUMINAIRE: These are specialized light fixtures designed to illuminate sports fields, stadiums, and sports arena. Sports lighting luminaires are designed mainly to create an optimal playing environment for athletes, spectators, and broadcasters alike, combining technological advancements with specific design considerations to fulfil the needs of sports venues.

Some key factors about sorts lighting luminaires:

- Design and Optics: Sports lighting luminaires are designed with specific optics to control light distribution and minimize glare. This is crucial to ensure uniform illumination of the playing surface and to meet the lighting standards required for different sports.
- Control System: Modern sports lighting system incorporate advanced control system which enables us to adjust light levels and schedule lighting operations according to the match requirements and it also help us in energy and space management.
- Regulations and Standards: The luminaires which we shall use in our design must comply fulfil the standards set by the organizations such as Illumination Engineering Society (IES) and sports governing bodies. These standards dictate parameters such as light levels, uniformity, glare control, and colour rendering.
- Environmental Considerations: Generally Metal Halide Lamps were commonly used due to their high light output and Luminous efficacy. However, with advancements in LED technology, we are using LED luminaires to illuminate sports field. LED sports lighting luminaires contribute to energy savings and reduced environmental impact compared to traditional lighting technologies. They typically have longer lifespans, reducing the frequency of maintenance and replacement.

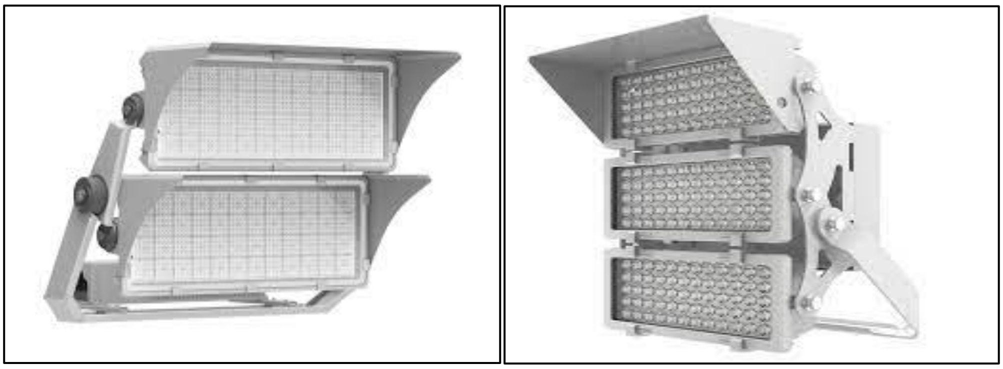


Fig 3. Sports Lighting Luminaire

2.2 COMPONENTS OF A LUMINAIRE

A Luminaire or a lighting fixture consists of several components, that work together to illuminate a particular place or space. These components will vary depending upon the type and design of the luminaire.

Some of the key components of a luminaire are discussed below:

- The fixture body or Housing: This is the outer casing or enclosure of the luminaire, which houses and protect the internal components. It can be made from materials such as metal, plastic, or glass.
- The light source: Light source of a luminaire is the lamp from which visible light is produced. Incandescent Lamps, Fluorescent Lamps, and the Light Emitting Diode (LED) are the various light sources available in the market.
- Reflector or Refractor: This component is used to control and direct the light emitted from the light source. It may be a reflective surface (reflector) or a lens-like material (refractor) that helps in distributing the light evenly and helps in reducing glare.
- Diffuser or Lens: These are mainly used to modify the light distribution and to minimize the glare or to create some special effect. These are mainly made up of clear or frosted glass or plastic materials.
- Ballast or Driver: In case of Fluorescent Lamps or High Intensity Discharge (HID) Lamps such as Metal Halide or Sodium Vapour Lamp, ballast is used mainly to regulate the current flowing through the lamp. Drivers are used in case of LEDs to regulate the voltage and current supply.
- Power supply and wiring: we use wires to connect the luminaire with the socket from where current is supplied to the lamps through wirings.
- Mounting Hardware: we typically mount luminaires on ceilings, walls, and poles. To mount the luminaire we need screws, clams, clips, brackets etc. to fix and secure the luminaire in that place.

2.3 IP AND IK RATINGS OF A LUMINAIRE

Electrical and electronic components are very much sensitive to the atmospheric dust particles and water. To save our valuable instruments from those harmful particles and water we rate our instruments accordingly to know in which condition we will use that instrument with a certain IP rating to keep the instrument safe. The International Electrotechnical Commission (IEC) has developed the Ingress Protection (IP) Ratings which grade the resistance of the instruments against the intrusion of dust and water.

The Ingress Protection (IP) rating of a luminaire indicates the level of protection against the intrusion of solid particles like dirt and dust and liquids.

The IP Code is composed of two numerals values. The first numeral refers to the protection against solids and is rated on a scale ranging from 0 (no protection against dust) to 6 (no intrusion of dusts). The second numeral rates the protection against liquids and uses a scale from 0 (no protection) to 9 (highest protection against liquid intrusion).

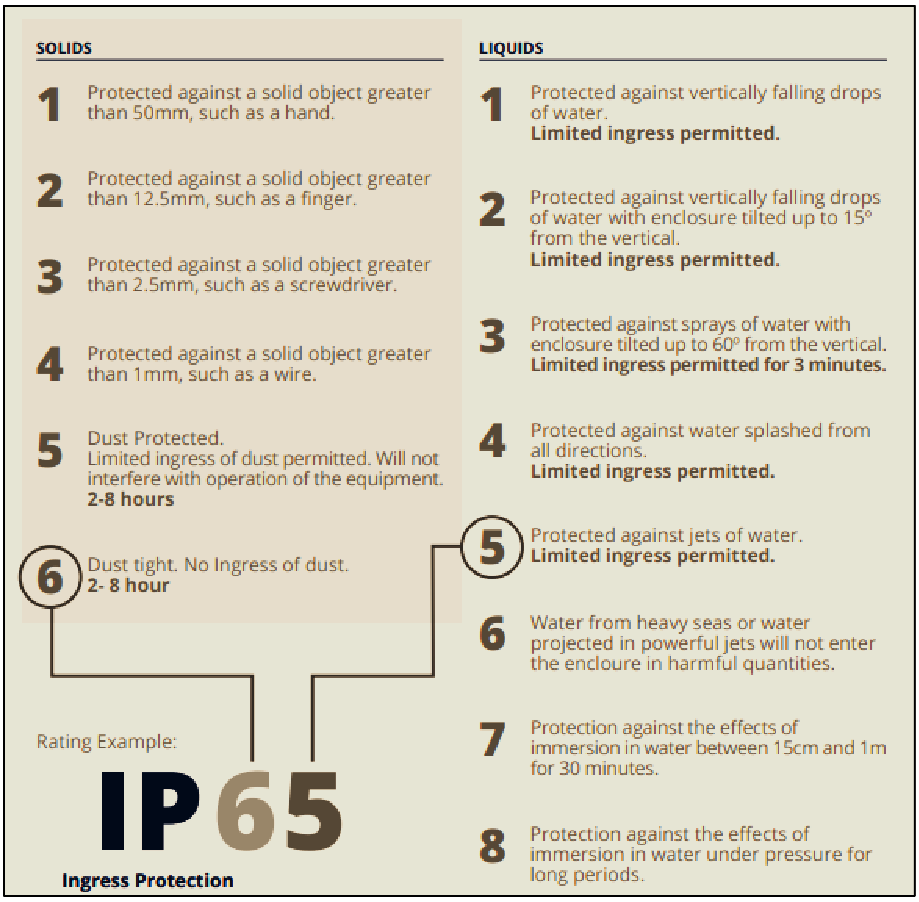


Fig 4. IP Chart

The Impact Protection (IK) Rating of a luminaire indicates its resistance to mechanical impact or shock. It measures the luminaires' ability to withstand external mechanical forces and protect its internal components. The IK rating is expressed as a numerical value ranging from IK00 to IK10, representing different levels of impact resistance.

Each IK rating corresponds to a specific energy level, which determines the luminaire's ability to withstand the impact without hampering its functionality.

Soe IK ratings are as follows:

- IK00 - There is no Protection.
- IK01 - Protected against 0.14 joules of impact. (this is the equivalent to the impact of a 0.25kg mass dropped from 56mm above)
- IK02 - Protected against 0.2 joules of impact. (Equivalent to the impact of a 0.25kg mass dropped from 80mm above)
- IK03 - Protected against 0.35 joules of impact. (Equivalent to the impact of a 0.2kg mass dropped from 140mm above)
- IK04 - Protected against 0.5 joules of impact. (Equivalent to the impact of a 0.25kg mass dropped from 200mm above the impacted surface)
- IK05 - Protected against 0.7 joules of impact. (Equivalent to the impact of a 0.25kg mass dropped from 280mm above the impacted surface)
- IK06 - Protected against 1 joules of impact. (Equivalent to the impact of a 0.25kg mass dropped from 400mm above the impacted surface)
- IK07 - Protected against 2 joules of impact. (Equivalent to the impact of a 0.5kg mass dropped from 400mm above the impacted surface)
- IK08 - Protected against 5 joules of impact. (Equivalent to the impact of a 1.7kg mass dropped from 300mm above the impacted surface)
- IK09 - Protected against 10 joules of impact. (Equivalent to the impact of a 5kg mass dropped from 200mm above the impacted surface)

- IK10 - Protected against 20 joules of impact. (Equivalent to the impact of a 5kg mass dropped from 400mm above the impacted surface)

The IK10 rated luminaire will resist maximum impact and the resistance towards the impact goes on decreasing as the numeral value start decreasing from 10, 9, 8, 7 …., 0.

2.4 PHOTOMETRIC AND ELECTRICAL PARAMETERS

The photometric features of a luminaire refer to the characteristics of the light output of a luminaire and its light distribution. These features are very important in determining how the light is dispersed, its intensity distribution, its Correlated Color Temperature (CCT), Color Rendering Index (CRI) and overall performance.

Photometric Features are stated below:

- BEAM ANGLE: The Beam Angle of a Luminaire refers to the angular extent of the light beam transmitted by the luminaire. Technically, Beam angle is an angle over which the luminous intensity drops to 50% of its peak intensity.

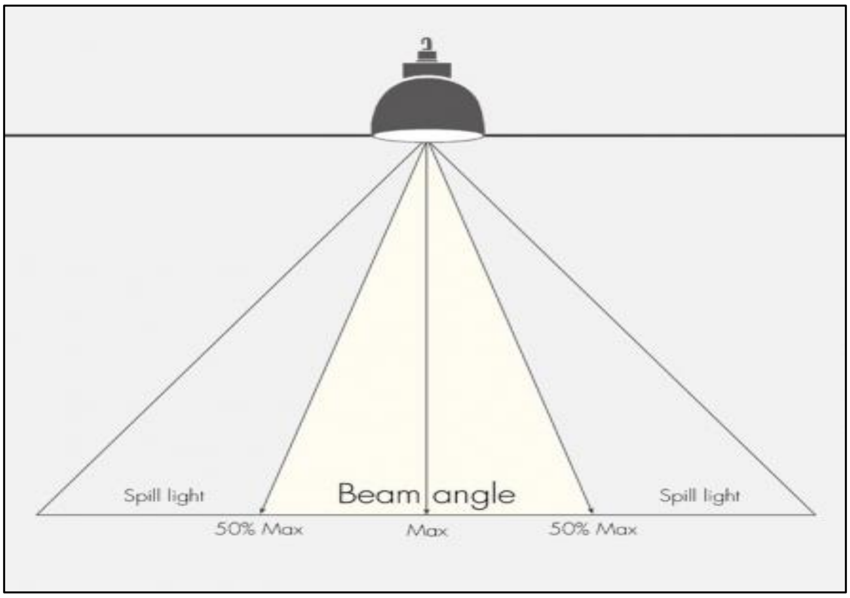


Fig 5. Representation of Beam Angle

It is important to note that the specific beam angle required for a given application depends on various factors such as the size of the space that we want to illuminate, the mounting height of the luminaire, the desired illumination levels, and the lighting goals. Selection of the appropriate beam angle is very crucial to achieve the desired lighting effect and all other design parameters.

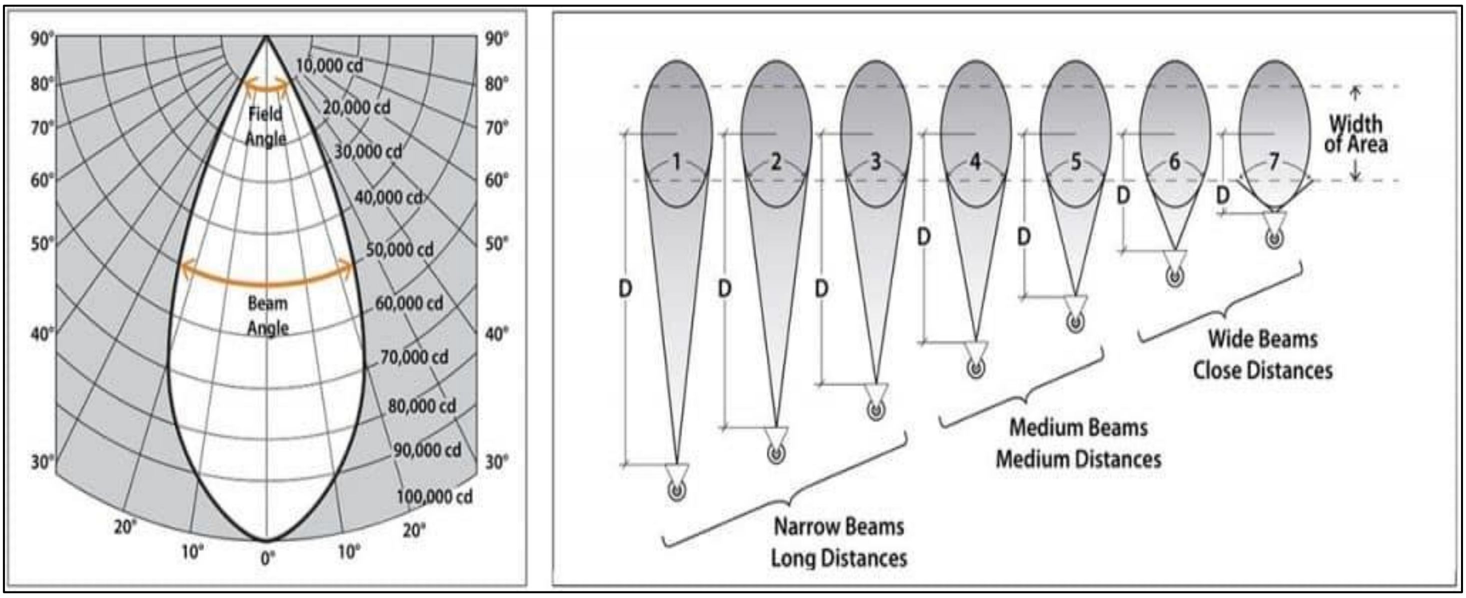


Fig 6. Different types of Beam Angle [9]

Beam Type	Field Angle Range (degrees)	Projection Distance (D)
Type 1	10 to 18	240 ft and greater
Type 2	> 18 to 29	200 to 240 ft
Type 3	> 29 to 46	175 to 200 ft
Type 4	> 46 to 70	145 to 175 ft
Type 5	> 70 to 100	105 to 145 ft
Type 6	> 100 to 130	80 to 105 ft
Type 7	> 130 and up	Under 80 ft

- LUMINOUS FLUX: The amount of total visible light emitted from a Luminaire in all direction. It is a measure of the overall brightness of the light output and it is measured in Lumens (lm). It quantifies the total amount of radiant power emitted by the luminaire, weighted according to the sensitivity of the human eye to different wavelengths of light.

- CCT: Correlated color temperature (CCT) is a measurement used in lieu of color temperature for lights that do not approximate a blackbody radiator (that is, they emit light through processes other than thermal radiation). Both fluorescent lights and LED lights fall under this category and thus are evaluated using CCT. Correlated color temperature is a specification used to describe the dominant color tone for non-blackbody light emitters such that they can be accurately compared with those light emitters that do approximate blackbody radiation (like incandescent bulbs). It is measured in Kelvin (K).

The CCT value has three types of range. One is known as Warm White (<3000 K) another is Neutral White (3000 K to 4000 k) and Cool White (>4000 K).

Fig 7. CCT Range

- CRI: The Color Rendering Index (CRI) is a measurement of the light's ability to reveal the actual color of the object as compared with the ideal light source i.e. natural light. The value of CRI ranges from 0 to 100, more the value better will be the original color revealing.

The Electrical characteristics and specifications of the luminaire includes parameters that are related to power supply, electrical efficiency, and control options.

Electrical parameters are stated below:

- VOLTAGE AND POWER SUPPLY: Luminaires typically operate at low voltage such as 12V or 24V DC, or high voltage such as 120V or 240V AC. The voltage and power supply of the luminaire should be compatible with the available electrical infrastructure and power source.

- POWER CONSUMPTION: The power consumption of a luminaire is typically specified in watts (W) and indicate the power required to operate the luminaire at its rated performance.

- POWER FACTOR: It is a measure of how effectively a luminaire converts the incoming electrical power into useful work. It is defined as the ratio of real power (measured in watts, W) to apparent power (measured in volt-amperes, VA) in an AC (alternating current) electrical system. It ranges from 0 to 1. A PF of 1 (or 100%) indicates all the electrical energy supplied by the source is being used effectively by the load without any waste. A PF less than 1 indicates there is some reactive power flowing in the circuit, which leads to inefficiencies in the distribution system and requires larger equipment for the same amount of real power.

1. Real Power (W): Also known as active power, it represents the actual power consumed by the electrical load to perform useful work, such as lighting, heating, or operating machinery. Real power is what is billed by utility companies.
2. Apparent Power (VA): Apparent power is the product of the RMS (Root Mean Square) voltage and current in an AC circuit, without considering the phase angle between voltage and current. It is the combination of real power and reactive power.
3. Reactive Power (VAR): Reactive power is the component of apparent power that does not perform useful work but is necessary for magnetizing components in electrical equipment. It is measured in volt-amperes reactive (VAR)

CHAPTER 3: SPORTS LIGHTING DESIGN AND STANDARDS

3.1 DESIGN CONSIDERATIONS OF SPORTS LIGHTING

LIGHTING DESIGN: The processes of creating and implementing to achieve the specific light level and aesthetic within a space is known as lighting design. Lighting design involves selecting and positioning the luminaires, determine the color of light and its intensity and how the luminaire interacts with objects, architecture and peoples using that space.

Lighting Design includes factors like:

1. Ensuring adequate illuminance level for the activities, tasks, and visual requirements of the peoples.

2. Lighting design enhance the visual effect and aesthetic of the space with the help of creative use of light and shadow.

3. It helps us in minimizing energy consumption related to lighting.

4. It reduces glare and ensure appropriate level of brightness.

SPORTS LIGHTING DESIGN: The main purpose of sports lighting design is to illuminate space that is related to sports such as sorts venues, playgrounds, outdoor fields, stadiums, arenas, indoor courts etc, the goal of sports lighting design is to provide adequate and uniform light levels across the playing area for the players, officials, and spectators to ensure optimal visibility.

Sports lighting design includes factors like:

1. Sports lighting provide proper illuminance level according to the international standards.

2. The major area of focus in sports lighting design is to provide proper illuminance uniformity to omit the adaptation problems, excellent gradient and minimum glare for the professionals related to sports.

3. Another factor is of Luminaire selection. Sports lighting design demands luminaires which have excellent lumen output, good luminous efficacy, proper color rendering properties and durable structure with proper IP and IK ratings and proper cut-off angles to avoid light spillage.

4. Sports lighting designers work closely with architects, engineers, and sports facility managers to create lighting solutions that enhance the playing experience, support broadcast requirements, and provide a safe and enjoyable environment for participants and spectators alike.

CONSIDERATIONS FOR SPORTS LIGHTING DESIGN:

Sports lighting involves several critical considerations to ensure optimal performance, lighting efficiency and safety.

- Type of Activity: Sports events are generally divided into two groups, namely "Aerial Sports" and "Ground Level sports."
  In Areal sports the playing objects may be in air as well as in the ground, for example Football, cricket etc.
  In Ground level sports the playing objects are in the ground or sometimes at small heights from the ground, for example Swimming, Field Hockey etc.

- Level of competition: we have classified the level of competition broadly into three parts, as
  1. Top level competition - International Level (Category - I)
  2. Medium level competition - National level (Category - II)
  3. Low level competition - Recreational and practice level (Category - III)

  According to the different standards and guidelines, different competition level requires different lighting levels and we will have to select one before designing.
- Size of the Object: The illuminated field serves as a visual background for the players, officials, and spectators. Objects like players, umpires, playing items like ball, bat etc have different dimensions. To have a proper view against the illuminated playground we need proper light level. The smaller the size, the more difficult the visual and consequently higher should be the lighting level.
- Speed of Action: as the perception of speed for human eye increase with illumination level, sports involving higher speed of action demands higher illumination level. High speed games like cricket,

require high illumination level for human visual system as well as for the cameraman to follow the object.

- Pole Placement: Positioning of the poles to mount the luminaires is an important factor and designers should consider it. According to the International standard FIFA, there are certain rules of placing the poles around the football field.
    1. To avoid excessive glare around the goal line, particular attention should be paid to the zone within 15° of either side of the goal line. Luminaires, as used in column or tower installations, should not be placed in this zone.

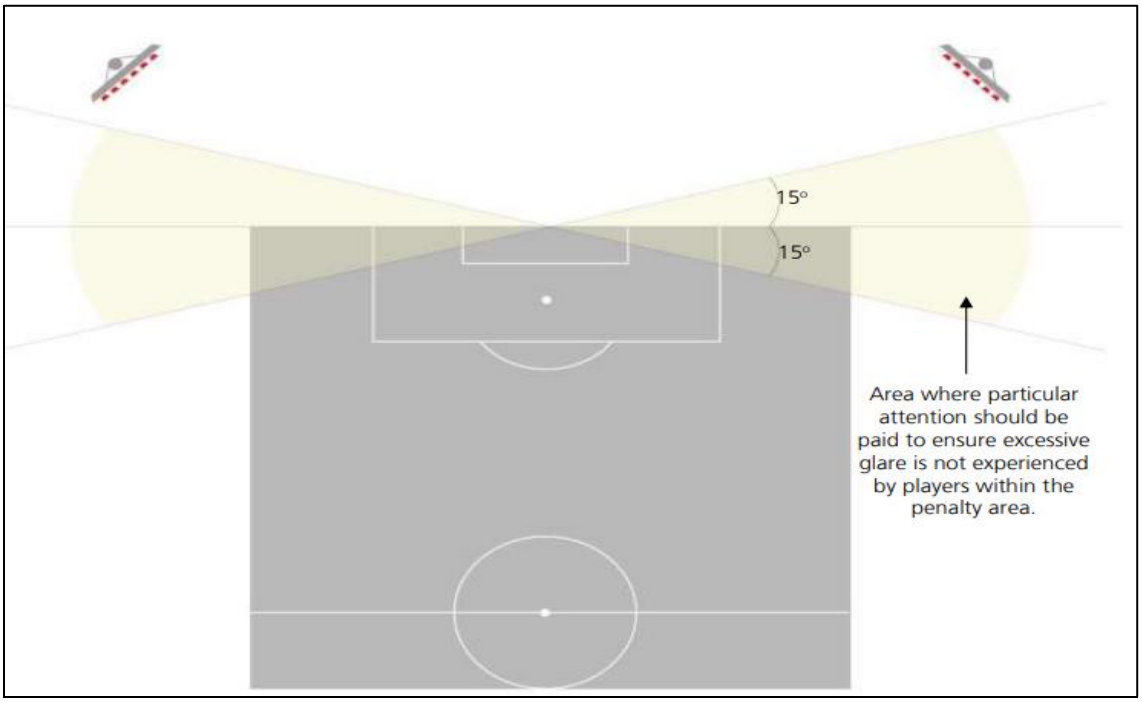


Fig 8. Recommended Pole Placing [1]

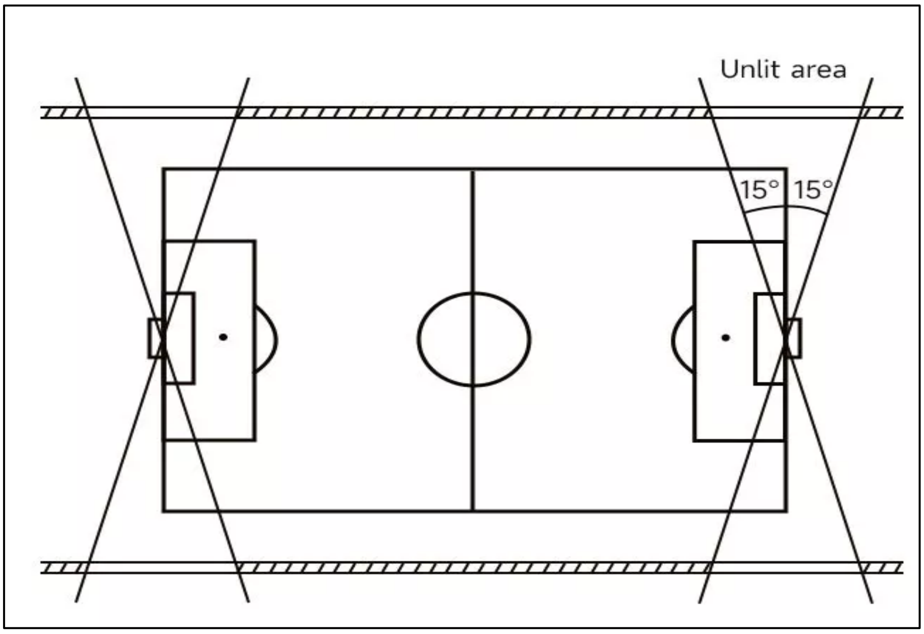


Fig 9. Schematic view of pole placing [8]

2. Poles should be placed around the field with a clearance of 4m from the total area.

- Luminaire Mounting: In sports lighting design, the mounting of luminaires plays a critical role in achieving optimal visibility, uniformity, and efficiency across the playing field or sports venue. According to the International standard FIFA:

    1. The luminaires should not be mounted less than 25° or more than 45° above the centre of the pitch.

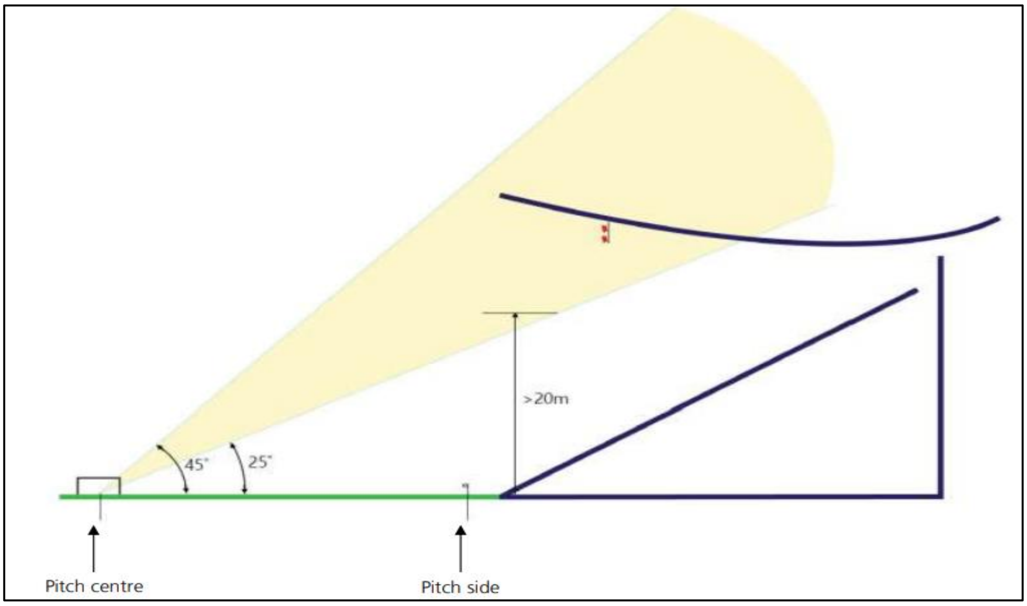


Fig 10. Luminaire mounting [1]

2. Luminaires should be mounted at least 20-25m above the surface of the pitch.

3. Luminaires with an asymmetric light distribution may be used along the pitch sides to produce good illuminance levels and uniformity along the adjacent pitch perimeter.

- Luminaires Focus Points: According to the international standard FIFA, to avoid discomfort glare being experienced by players and officials, a rule of thumb during the design process is to ensure that luminaires focus-point angle should not be more than 70° from the line perpendicular to the pitch, as in the diagram below.

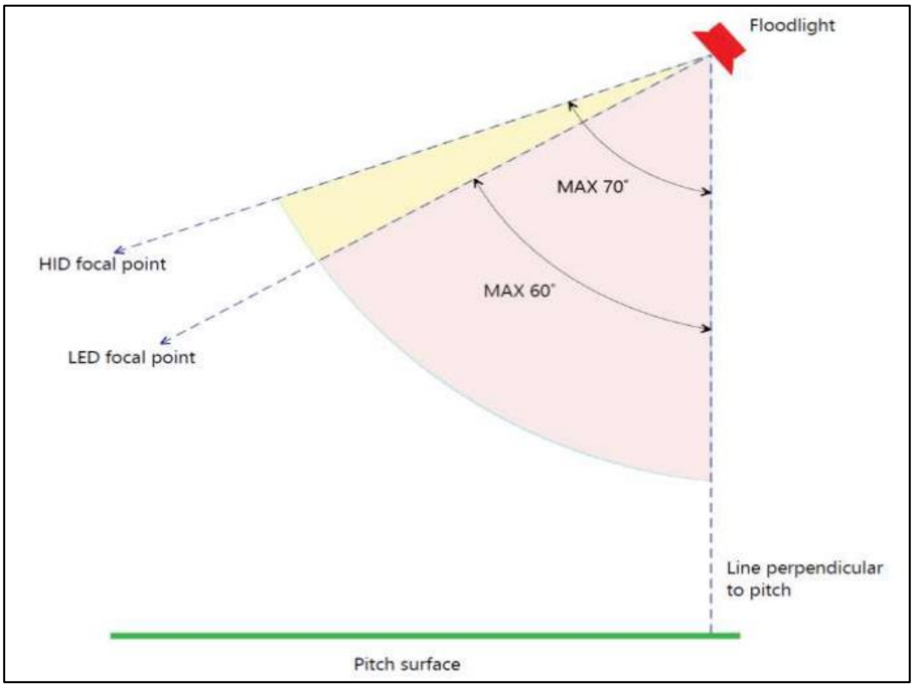


Fig 11. Luminaire focus point [1]

3.2 APPROACH TO DESIGN SPORTS LIGHTING

To design any sports lighting, we require a systematic approach to ensure that all technical, functional, and aesthetic aspects are adequately addressed.

Here is a structured approach to design any sports lighting:

1. Requirement Understanding: Gather detailed requirements from the client or stakeholders. This includes understanding the type of sports to be played, the level of competition. We should also assess the environmental factors such as location (indoor or outdoor), surrounding light conditions, and any local regulations regarding light pollution.

2. Site visit: Study the layout of the sports field. Identify key areas that require specific lighting attention, such as playing areas, spectator areas, and surrounding spaces.

3. Lighting design criteria: There are many standards namely CIE, IESNA, FIFA etc according to which we design sports lighting. We will also have to determine the required light levels according to the standards and we should look after the type of match is to be played.

4. Technology selection: At present there are many lighting design simulation software such as DIALux evo, DIALux 4.13, Agi 32 etc, with the help of which we can simulate our design. We can select any one according to our compatibility.

5. Luminaire selection: To get proper values of our design parameters we will have to select luminaires with high lumen package, good color rendering properties and high efficiency.

6. Compliance and Documentation: Ensure the lighting design meets relevant standards and regulations, including local lighting ordinances, sports federation requirements. We shall Prepare comprehensive documentation including lighting layout plans, specifications of fixtures and control systems, photometric calculations, and maintenance requirements for future reference.

7. Testing and Commissioning: We should conduct an on-site test and conduct a trial test. After that we should implement our design.

3.3 SPORTS LIGHTING DESIGN PARAMETERS

Sports lighting design involves several key parameters optimal visibility, performance, and energy efficiency. We shall achieve all the parameters values according to the international standards like FIFA (International Federation of Association Football), NLC (National Lighting Code) etc.

The design parameters for sports lighting are discussed below [3]:

1. Horizontal illuminance (Eh): The Horizontal illuminance is the illuminance on the horizontal plane. In sorts lighting the illuminated field is the major part of the field of view for both the players and spectators, thus it is the horizontal illuminance on the ground level that chiefly serves to establish the adaptation state of the eye. This illuminated field is the visual background for the players, spectators, and cameras. Hence, the quality criteria for the horizontal illuminance should be more stringent and we should achieve the illuminance level according to the standards.

2. Vertical illuminance (Ev): The Vertical illuminance is essential for viewing objects in the vertical plane. It is characterized not only by its magnitude but also by its direction. Although there are infinite number of planes from the perspective of players, spectators, or television cameras, but we consider only four planes normal to four principal directions of the playing field and at a height of 1.5m from the ground.

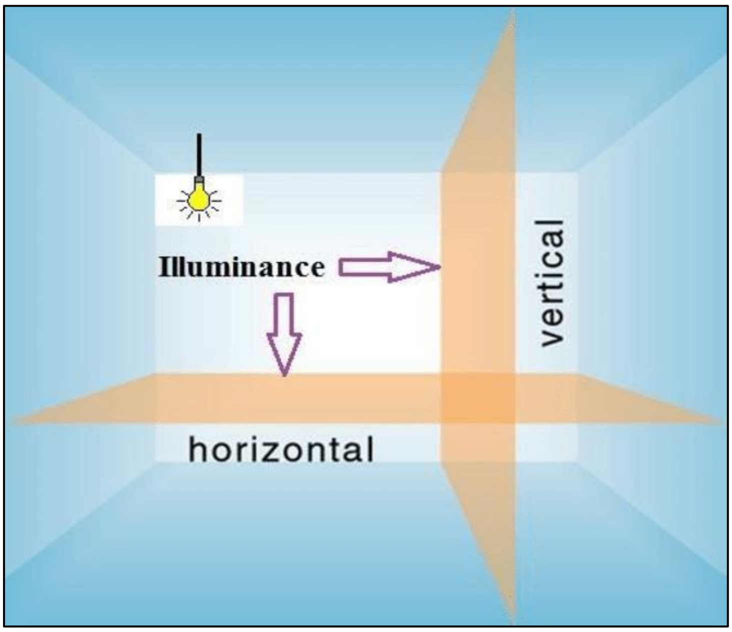


Fig 12. Horizontal and Vertical illuminance

3. Vertical illuminance with respect to camera (Ev_{cam}): It represent the illuminance at a point on a vertical plane facing camera location, i.e. the vertical plane is normal to the line joining the point of measurement and the centre of camera aperture. So, in most of the cases the plane is inclined rather than perpendicular to the playground.

vertical illuminance required for players and spectators are usually achieved, if the requirements regarding the horizontal illuminance is achieved. Vertical illuminance at 1.5mtr above the ground level facing towards the main and secondary camera forms the basis of the lighting requirement for CTV and filming.

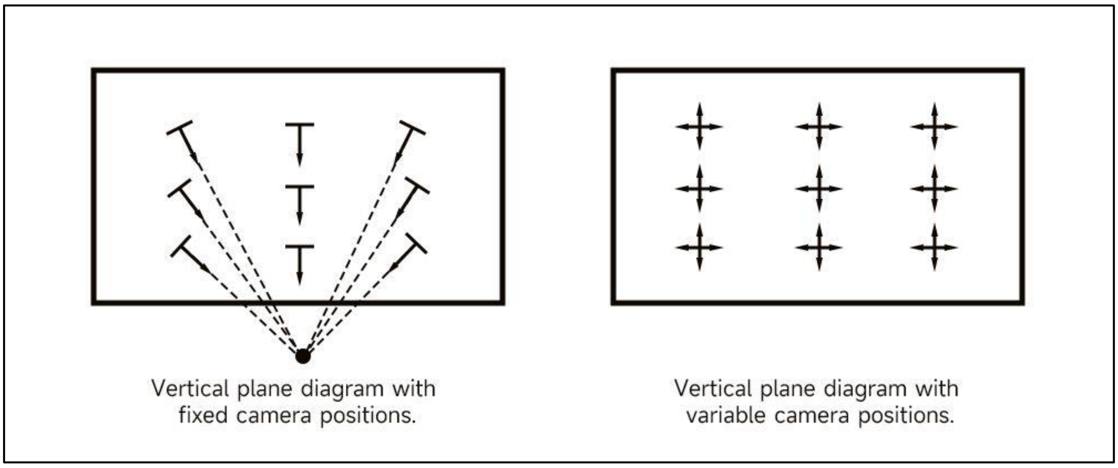


Fig 13. Camera Vertical illuminance [3]

4. Uniformity of illuminance: Uniformity in lighting means equal distribution of light in that space. Good illuminance uniformity in horizontal and vertical planes are important to avoid adaptation problem for players and spectators and adjustment problem for cameras while panning across the field for different directions of view. Uniformity is expressed as the ratio of minimum to maximum illuminance also known as (U1) and minimum to average illuminance also known as (U2). U1 relates to adaptation range and U2 relates to visual comfort.

5. Illuminance Gradient: Illuminance gradient means change in illuminance values over distance. Uniformity controls the overall visual conditions over the field and illuminance gradient prevents gradual change in lighting level

between closely space points. A gradient of horizontal illuminance of maximum 25% change per 5m is recommended.

Fig 14. Excellent gradient

Fig 15. Poor gradient

6. Ratio of average horizontal and vertical illuminance (Eh_{avg} / Ev_{avg}): To have a comfort vision against the background of illuminated playground, proper contrast shall be maintained between the objects and their background. This contrast depends upon the ratio of average horizontal and vertical illuminance. To have comfortable viewing condition and good picture quality the value of Eh_{avg} / Ev_{avg} should be greater than 0.5 and less than 2.0.

7. Glare: Glare occur due to an excessively large Luminance Contrast which exists in the field of view. It depends on the difference of source and background luminance. Glare is of two types, namely Disability glare and Discomfort glare. In case of disability glare, we can hardly see the objects and in case of discomfort glare we can see the object but we feel stress in our eyes. Glare can be minimized by using proper luminaires and proper positioning of the luminaires.

The calculation of Glare Rating is dependent upon two lighting parameters, one is the veiling luminance produced by the luminaires (L_{vi}) and the veiling luminance produced by the environment (L_{ve}).

L_{ve} can be approximated from the average horizontal field illuminance (Eh_{av})

Veiling luminance produced by the environment (L_{ve})= $0.335 \times Eh_{av} \times (\rho/\pi)$

Where ρ = the field reflectance.

Veiling luminance produced by the luminaire (L_{vi}) = $\sum_{i=1}^{n} \frac{E_{eye,i}}{\theta_1^2}$

where E_{eye} is the illumination on the eye produced by the source and θ is the angle between the direction of the view and direction of light incidence.

$$GR = 27 + 24 \log [L_{vi} / (L_{ve})^{0.9}]$$ [4]

A maximum GR value of 50 is required to have a comfortable view.

8. Modelling and Shadows: The three-dimensional appearance of playing objects is revealed by the suitable combination of light and shadow which is called modelling effect. This effect is achieved by lighting from multiple directions resulting variation of illuminances at different vertical planes. The modelling effect is dependent upon the direction from which the light is coming and the type of luminaire used i.e. luminaire with narrow or wide beam angle. Shadows are of two types; one is hard shadow and the other is the soft shadow.

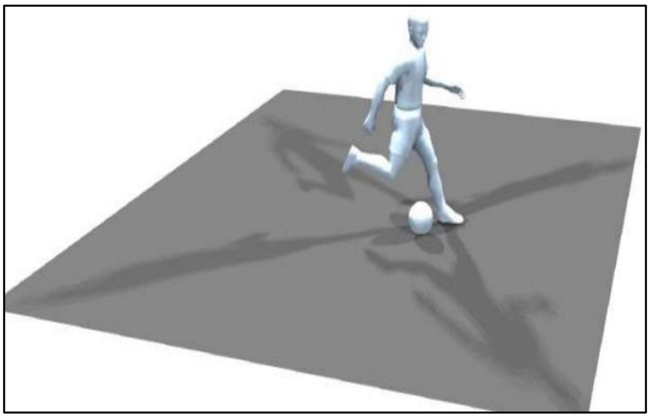


Fig 16. Hard shadow [1]

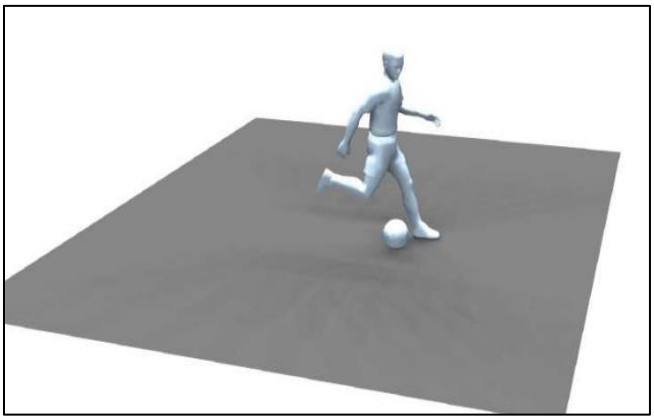


Fig 17. Soft shadow [1]

9. Color appearance and color rendering: Color temperature and Color rendering properties of lamp are very important parameters for sports lighting design. To broadcast a day and night match, color temperature of lamp should be such that it ensures minimum apparent color changes when daylight is replaced by artificial light according to our standards, the CCT of the lamp should be more than 5000K. The color rendering property of the lamp should be more than 80 so that true color of the objects is reproduced.

10. Light pollution: Sports lighting design should be such that it should fulfil all the design criteria of the field and the spectator gallery and at the same time the spill light should be minimum. By using proper baffles and by correct placement of the luminaires, we can minimize the spill light hence reduced lighting energy consumption. Modern day floodlights are equipped with anti-glare internal baffle which reduces upward spill of light, thus improves the beam efficiency.

Fig 18. Luminaires with baffles

10. Maintenance Factor: The light output of the luminaires gradually decreases with time. During designing we should consider the maintenance factor to get accurate Lux values throughout the period of its lifecycle. It is expressed as a percentage and is applied to the initial illuminance level to calculate the maintained illuminance level.

Maintenance factor depends on the following factors:

- Lamp Lumen Depreciation (LLD): Lumen output of the lamp decreases over the time. Manufacturers provide data on how much light output decreases over the lamp's lifespan.
- Luminaire Dirt Depreciation (LDD): The accumulation of dirt, dusts, and contaminants on the light fixtures over the time reduces the amount of light that passes through the luminaire and reaches the target.

3.4 NATIONAL AND INTERNATIONAL CODE AND STANDARDS

Sports lighting design must adhere to various national and international code and standards to ensure proper lighting, performance, safety, and energy efficiency. To ensure this lighting designers should follow the different national and international code and standards [1][2].

Here are the codes and standards which we should follow during designing:

1. International Commission on Illumination (CIE).
2. International Federation of Association Football (FIFA).
3. National Lighting Code (NLC).

According to these standards we should achieve the following values of the respective sports lighting parameters:

PARAMETERS	INTERNATIONAL LEVEL (Televised only)	NATIONAL LEVEL		PRACTICE LEVEL
		Televised	Non - Televised	
Average Horizontal Illuminance (Eh_{avg}) (Lux)	1500 - 3000	1000 - 2000	500 - 700	500
Average Vertical Illuminance (Ev_{avg}) (Lux)	1200 - 1800	1000	350	NA
Average camera Vertical Illuminance ($Evcam_{avg}$) (Lux)	1000 - 1800	1000	NA	NA
Uniformity U1 (E_{min}/E_{max}) [For Horizontal]	> 0.5	> 0.4	> 0.3	> 0.3
Uniformity U2 (E_{min}/E_{avg}) [For Horizontal]	> 0.7	> 0.7	> 0.6	> 0.5
Uniformity U1 (E_{min}/E_{max}) [For Camera Vertical plane]	0.5	0.3	NA	NA
Uniformity U2 (E_{min}/E_{avg}) [For Camera Vertical plane]	0.7	0.6	NA	NA
Glare Rating (GR)	< 50	< 50	< 50	< 50
Color Rendering (Ra)	> 80	> 80	> 70	> 20
Color Temperature (CCT) (K)	4000 - 6000	4000 - 6000	4000 - 5000	3000 - 5000
Maintenance Factor (MF)	0.9 for LED 0.8 for others	0.9 for LED 0.8 for others	0.9 for LED 0.8 for others	0.9 for LED 0.8 for others

The above recommended values should be achieved to ensure proper lighting, enhance performance and energy efficient design.

3.5 DIFFERENT SCHEMES OF SPORTS LIGHTING DESIGN

1. NON – TELEVISED SPORTS LIGHTING DESIGN

Non – televised sports lighting refers to design and implementation of lighting system mainly focused to illuminate the sporting events that are not broadcasted on television. It focuses primarily on enhancing visibility and safety for players and spectators in live settings. Practice level match and some national level match falls under this category.

Key factors of non-televised sports lighting design:

a. Ensure sufficient illumination for players to see clearly and react effectively.

b. To create a balanced lighting condition that allows them to follow the action comfortably without any distraction or dark spots.

c. Placing of the camera is not considered, as there is not a matter of broadcasting.

d. Requirement of the illumination level is not too high.

2. TELEVISED SPORTS LIGHTING

Televised sports lighting refers to the specialized design and implementation of lighting systems tailored specifically for sporting events that are broadcasted on television. Unlike non-televised sports lighting, televised sports lighting must meet additional requirements to ensure optimal viewing quality for television audiences.

Some key factors are:

a. Excellent illumination level is required for proper viewing.

b. Illuminance uniformity should be good and illuminance gradient should be negligible.

c. Camera positioning is very important for live telecasting.

d. We should use luminaires which possesses high color rendering and good correlated color temperature.

e. Glare should be controlled by using proper luminaires and baffles.

CHAPTER 4: SPORTS LIGHTING DESIGN OF A FOOTBALL GROUND.

4.1 OVERVIEW OF A FOOTBALL STADIUM

A football stadium is a specialized venue designed primarily for hosting football matches. The architectural design of these stadiums is such that it can create an electrifying atmosphere for spectators while providing all essential facilities for players, officials, and media.

Here, I have considered the Vivekananda Yuba Bharati Krirangan, commonly known as the Salt Lake Stadium which is situated at Kolkata, West Bengal.

The Salt Lake Stadium was established in 1984. The stadium covers an area of 76.40 acres and with a seating capacity of 85,000 it is the largest football stadium in India. It is operated by Department of youth services and sports and it is owned by the Government of West Bengal.

It was renovated in 2011, 2014 and 2016, which resulted a huge decrease in the seating capacity to 85,000 from 1,20,000. Before renovation, it was the largest football stadium in the world.

The prestigious tournament FIFA U – 17 WORLD CUP was hoisted in our country, India. There were many venues across our country where matches were played, among those the Salt Lake Stadium was also present. The final match of FIFA U – 17 world cup was played on 28th October, 2017 at the Salt Lake stadium, Kolkata making it a very special one [6].

The salient features of the stadium are unique synthetic track for athletic meets, electronic scoreboard, main football arena measuring 105m x 70m, elevators, VIP enclosures, peripheral floodlighting arrangement from the roof-top, air-conditioned VIP rest room and Conference Hall. Other features of the stadium are also commentary boxes for All India Radio and TV along with several platforms for TV cameras, press boxes, dormitories, and AC. Rooms.

The illumination level of the stadium is approximately 1500 Lux which is achieved by incorporating 624 numbers of metal halide lamps, each of 2KW power rating.

Some visuals of the stadium are shown below.

Fig 19. The Salt Lake stadium [6]

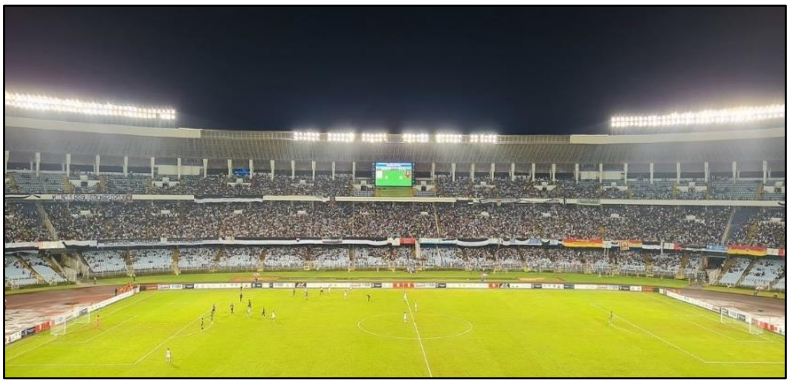


Fig 20. Illuminated stadium [6]

Fig 21. Aerial View of the Stadium [6]

Fig 22. FIFA officials visit [6]

4.1.1 PLAYING AREA

The playing area of a football ground is generally referred as pitch. The pitch has specific dimensions and features that are standardized by football governing bodies like International Federation of Association Football (FIFA). Standard dimension of playing area is 105m × 68m.

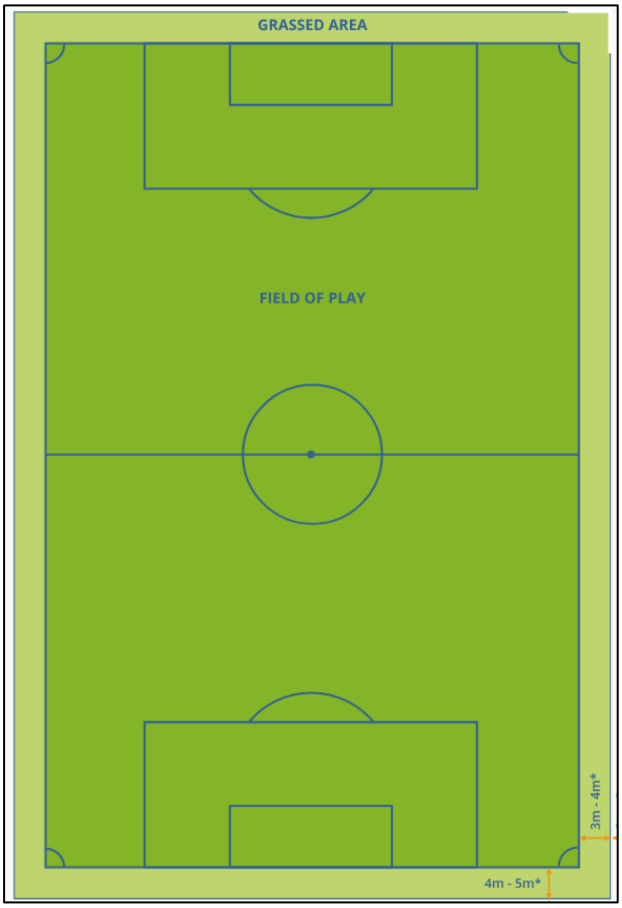
According to FIFA:

1. The dimensions of the field of play should be 108 meters in length and 68 meters in width and it must be rectangular in shape.

2. The field of play should be level without any undulation. Any inclination in surface should be a maximum of 5º.

3. Any markings within the playing area should be with continuous line.

4. The field of play shall only be marked with corner flags. A flag post, at least 1.5m high, with a non-pointed top and a flag, shall be placed at each corner.



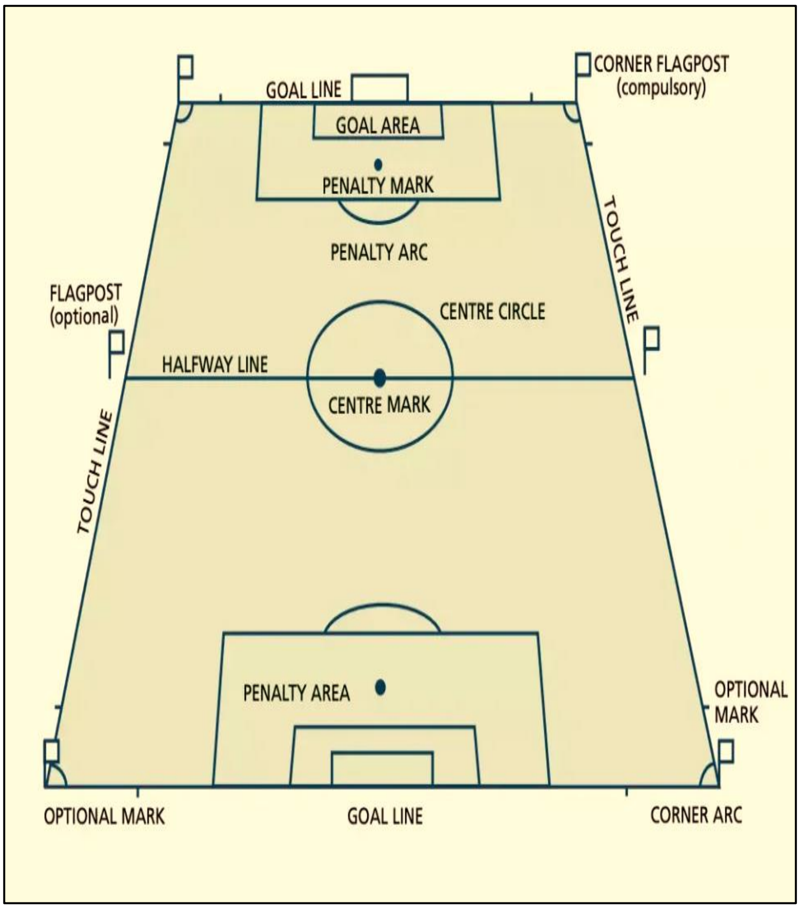


Fig 23. Playing Area

4.1.2 GALLERY OR SPECTATOR SEATING AREA

The gallery or spectator seating area of a football stadium is a crucial component designed to accommodate viewers comfortably while offering excellent views of the match. Here is an overview of what we can typically find in this area:

1. Seating type i.e. premium seats such as in the VIP boxes, standard seats that are arranged in rows with aisles for easy access.

2. Ramps and elevators which ensure easy access to different levels of seating for all spectators.

3. Barriers and guardrails to ensure spectator safety and control crowd.

4. The seating area may be covered by a roof or a canopy to protect spectators from weather elements like rain and sunlight.

Fig 24. Spectator Seating Area

4.1.3 SPECTATOR AMENITIES AND FACILITIES AREA

The amenities and facilities area of a football stadium is designed to enhance the overall match-day experience, offering convenience, comfort, and entertainment for all attendees while meeting safety, accessibility, and operational standards.

An overview of amenities and facilities area of a stadium:

1. Food Court: There are several food stalls present throughout the stadium concourses offering a variety of food items such as pizza, burger, sandwich,

beverages etc. Some stadiums also have premium restaurant type dining areas, lounges and bar for VIP ticket holders and guests.

2. Multiple restrooms areas for both men and women equipped with modern washrooms, hand dryers, paper towels etc.

3. Player and Team facilities: Separate changing rooms and locker facilities are providing to the players for dress changing and keep personal belongings in a safe place. Adjacent areas are also present for warm up.

4. Media and Broadcast facilities: There are press boxes equipped with desks, internet access, power sockets etc. where journalists, reporters and media personnel are present to cover the match.

5. Broadcast Studios: Studios for television and radio broadcasters to conduct live broadcast and commentary during the match.

6. Transportation and parking facilities are also there to facilitate spectators, officials, players, and all others related to the event.

Fig 25. Food court

Fig 26. Broadcasting Room

Fig 27. Dressing Room

4.1.4 TOTAL AREA OF THE GROUND

The total area of the football stadium includes the football playing pitch or the playing area, surrounding space where advertising boards are present, the stadium and all the surrounding area. The total area of the ground, therefore, encompasses not only the dimensions of the playing field but also all the infrastructure, spectator areas, and support facilities necessary for the operation of the stadium.

Fig 28. Aerial view of a sports arena

4.2 SPORTS LIGHTING DESIGN METHODOLOGY

4.2.1 CLIENT MEET AND VISITING THE SITE

The first step to design any lighting scheme is to do a meeting with the client and try to understand their requirements and to recommend them the values of the parameters that should be maintained according to different standards. Secondly, we should have a visit to the site in person to inspect the site which will make it easier for us to plan and design accordingly.

The following procedure shall be followed:

1. Review the project brief and specify the requirements related to lighting design of a football playground.

2. Clarify all the lighting standards which are followed during sports lighting design, safety standards and energy efficiency.

3. Briefing about the constraints like maintenance requirements, environmental impact, and budget constraints.

4. Study the site plans and do a thorough site inspection.

5. Evaluate electrical supply capabilities that might impact the lighting design.

6. To consider environmental factors such as winds, which could affect the placement of the lighting fixtures.

4.2.2 INPUT DATA

To design a sports lighting scheme for a football playground involves considering several factors to ensure adequate visibility and safety for players, officials, and spectators.

Here are some typical inputs required for sports lighting design:

1. Dimensions and Layout of the football playground. According to International Federation of Association Football, the standard dimensions of the field shall be of 105m in length and 68m in width. The layout of the football playground includes the spectators stands, walkways, poles etc.

2. The level of football match that will be played in the football ground. There are three levels of any match, one is the international level match

(played between any two countries), one is the National level match (generally played between different clubs of a country) and the practice match in which the players do warm up and practice before the tournaments.

3. Lighting Standards and Regulations. We must follow the FIFA lighting guide to design a sports lighting scheme of any football playground across the globe.

4. Lighting control scheme that we will use to control the illuminance level of the playing area. In a particular football playground, a football match of either national or international level will take place, and according to the standards both national and international level match requires different Lux level. Hence, we should control the light output to save lighting energy consumption and flexible the light output according to our requirements.

5. Details about the Lighting Fixtures that we will use in our design. Specifications such as operating voltage and current, wattage, lumen output, color temperature, color rendering, beam angle, IP and IK class, Luminous Efficacy of that fixture. Type of fixture, for example LED, Metal Halide etc.

6. Maintenance and Longevity of the luminaires which we will incorporate in our design. We should input the maintenance factor (MF), which is the measure of how much percentage of the initial lumen output of the luminaire is available at the end of its service life, that will help us in deciding how efficient and economical the luminaire is. The impact of MF in lighting budget is huge.

7. The mounting height of the light fixtures.

8. Pole placing positions and number of luminaires per pole according to FIFA lighting guide.

9. Luminaires arrangement and Luminaire aiming.

10. Placing of the Glare Rating (GR) observer at a height of 1.75m above the pitch surface according to FIFA lighting guide.

4.2.3 LUMINAIRES SELECTION

To select the Light Fixtures to illuminate a football playground involves several considerations to ensure good illuminance level at field, to minimize Glare Rating, to enhance Uniformity for both visual performance as well as visual comfort and finally to be energy efficient in nature. The performance of the luminaire should be considered as carefully as its cost, and in long term a well well-designed, well-constructed luminaire will be cheaper than a poor-quality luminaire

Factors we should consider during Luminaire Selection:

1. We should refer to various sports lighting Standards like FIFA to select proper luminaires for illuminating the football field.

2. To measure the Reflectance Factor of the field before selecting any luminaire. Fields having good reflectance factor require luminaires with lower lumen package and we shall consider luminaires with higher lumen package for fields with lower reflectance, to avoid discomfort viewing.

3. The beam angle and the light distribution of a luminaire has a huge impact in our lighting design. Luminaires with narrow beam provides lesser light spillage as compared with luminaires with wide beam light distributions. Spill light is a cause of light pollution.

4. Luminaires with proper optics and shielding help us in minimizing glare and ensure safety and comfort of the players.

5. The Correlated Color Temperature (CCT) and Color Rendering Index (CRI) of the lamp used in the luminaire has huge impact in our lighting design. According to the sports lighting standards the CCT of the lamp shall be in between 5000K to 6000K and CRI of the lamp should be greater than 80.

6. The luminaires should be with high IP and IK ratings so that it can withstand any type of weather conditions and the requirement of maintenance shall be low as much as possible.

7. The Luminaire should possess high Luminous efficacy, i.e. the lumen output per watt power supply shall be high.

8. Luminaires with adjustable light output should be used in sports lighting design. This will enable us to use the same football playground to host international, national as well as practice level match.

9. We shall also look after the size, finish and appearance, thermal management, accessibility to the various components for maintenance and aesthetics of the luminaire.

4.2.4 DESIGNING TOOLS

To do any kind of work we need some tools, instruments with the help of which we can complete that work in a faster way and with high efficiency.

To design and implement a sports lighting scheme in a football playground, at first, we design a lighting scheme by following the international standards, we calculate the different lighting parameters, number of luminaires we will require to illuminate the field, luminaires mounting height and positioning of the poles, after that we input those in various lighting software available and do the simulation.

It is very much important to simulate the design and compare the results with the standards, before final installation. Software simulation helps us in minimizing the error at the time of final installation and help us in achieving the desired values during the post installation test.

Some lighting design software presently available are listed below:

1. DIALux 4.13
2. DIALux evo
3. AGi32

This software allows us to create a virtual scene where we can input the measured dimensions and the desired space will be created. We can also input the mounting height, pole positions, luminaires IES files and many other data to develop a space in which we want to design a lighting scheme. This software also provide comprehensive photometric analysis and lighting calculations, provides 3D modelling capabilities for visualizing light layout, calculates average horizontal and vertical illuminances, uniformity, illuminance gradient, glare rating analysis, daylight contribution and many more. We can also generate exportable report for documentation purpose.

Benefits of using lighting simulation software are:

1. By simulating various lighting designs virtually, it reduces the rework needed to correct the mistakes if any, during the installation of the lighting fixtures. Simply lighting design simulation reduces the hit and trail method of mounting, aiming, and placing of the lighting fixtures.

2. Software enables the creation of detailed 3D models of lighting layout and high-quality rendering capabilities provide realistic representations of

lighting effect which in turn helps in easy decision making to choose a particular design.

3. Software generates comprehensive reports and documentation, which includes photometric data, lighting calculations, supporting project documentation and regulatory requirements.

4. Simulation provide accurate and precise values of all the parameters of lighting design which allows the designers to visualize how much light we will achieve after installation and to compare the values with the standards.

Some instruments that we use to measure the actual values of the crucial parameters after final installation of the luminaires are as follows:

1. Luxmeter: It is an instrument which is used to measure the illuminance level of the working plane. We can measure the illuminance level of both the horizontal and vertical plane with this meter. It uses a photoreceptor cell (white circle like structure as shown in Fig 30), which captures all the incoming light and then the meter converts this light into electric current, and after measuring the electric current, the device calculates the illuminance value and display the value on the screen in Lux.

Fig 29. A Luxmeter

2. CL – 70F: It is an instrument which is used to measure the CCT, CRI and SPD of a lamp. It also has photoreceptor cell which sense the light.

Fig 30. A CL – 70F meter [7]

4.2.5 DESIGN METHODOLOGY

To design any lighting scheme, the first and foremost step of any lighting designer is to have a formal discussion with the client to get the essence of what function the area of the space would serve for and hence to provide an idea about what design we shall do to meet the requirements.

Following by the client meet the following procedures shall be followed to design any lighting scheme for that area or space:

1. After the client meet, we shall ask for the AutoCAD file of the project. This layout provides us the exact length, width and height of area which helps us in proper selection and arrangement of the luminaires. This layout is extremely important for interior lighting design, like any room, office building, seminar hall, stadiums etc.

2. As a lighting designer we should study the guidelines related to lighting and we should study all the relevant lighting standards for both interior and exterior lighting design in detail. We generally follow the National Lighting Code (NLC), IS-3646 (for interior lighting design such as rooms), IS-1944

(for exterior lighting design such as road ways), CIE (International commission on Illumination). For this project I followed the NLC and FIFA guidelines.

3. After studying the guidelines and relevant documents and obtaining the AutoCAD layout, we will use the various lighting design simulation software present like DIALux 4.13, DIALux evo, Agi32 etc. to simulate the design and see whether we are achieving the recommended values of the various lighting parameters or not.

5. Illumination design of the Playing Area of the Football Playground.

The following steps are involved in sports lighting design of the Playing Area of the football field:

STEP 1 – To decide the type of match to be played i.e. whether it is an international level match or national level match or practice session will be carried on.

STEP 2 – Measuring the dimensions of the field. According to FIFA or any national and international standards the playing area should be of 105 metre in length and 68 metre in width.

STEP 3 – Deciding the illuminance level required on the horizontal as well as vertical plane according to the standards.

STEP 4 – Determining the mounting height of the lighting fixtures. The mounting height is determined by a specific formula, $H = d \times \tan\theta$, where H is the Mounting Height, d is the distance between the centre of the field and the base of the mast and θ is the elevation angle whose value ranges from 20^{o} to 25^{o}.

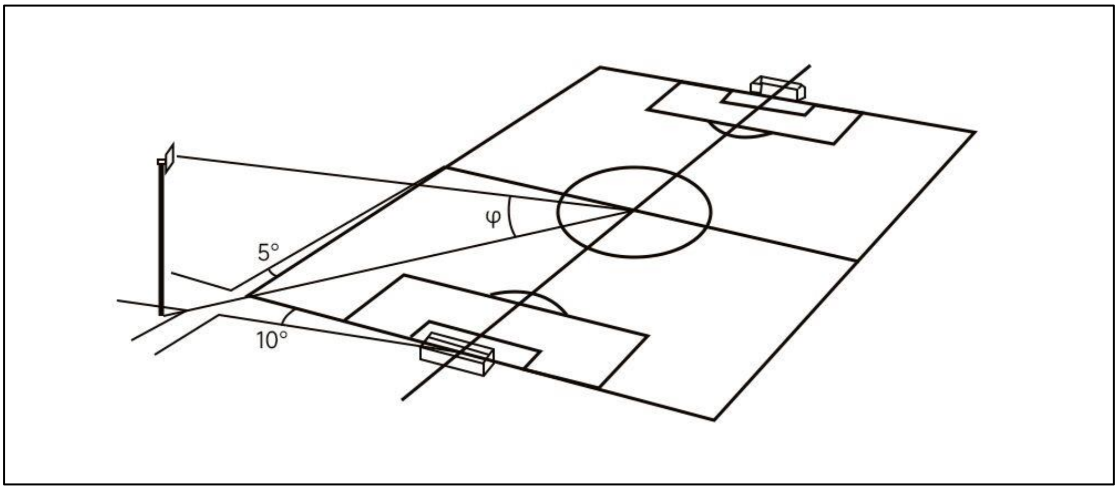


Fig 31. Schematic diagram of the mounting height [8]

STEP 5 – Determining the pole placing positions to mount the luminaires. When using a sideline arrangement, the lights should not be placed within 15 degrees of the centre point of the goal line along the baseline. When using a corner arrangement, the angle between the line connecting the base of the light pole to the midpoint of the sideline and the sideline should not be less than 5 degrees, and the angle between the line connecting the base of the light pole to the midpoint of the baseline and the baseline should not be less than 15 degrees. There should be a clearance of 8 metre from the boundary of the playing area to the base of the pole. According to this FIFA has provided the coordinates of placing the poles around the field. Figure no. 32 & 33 shows the pole placing positions.

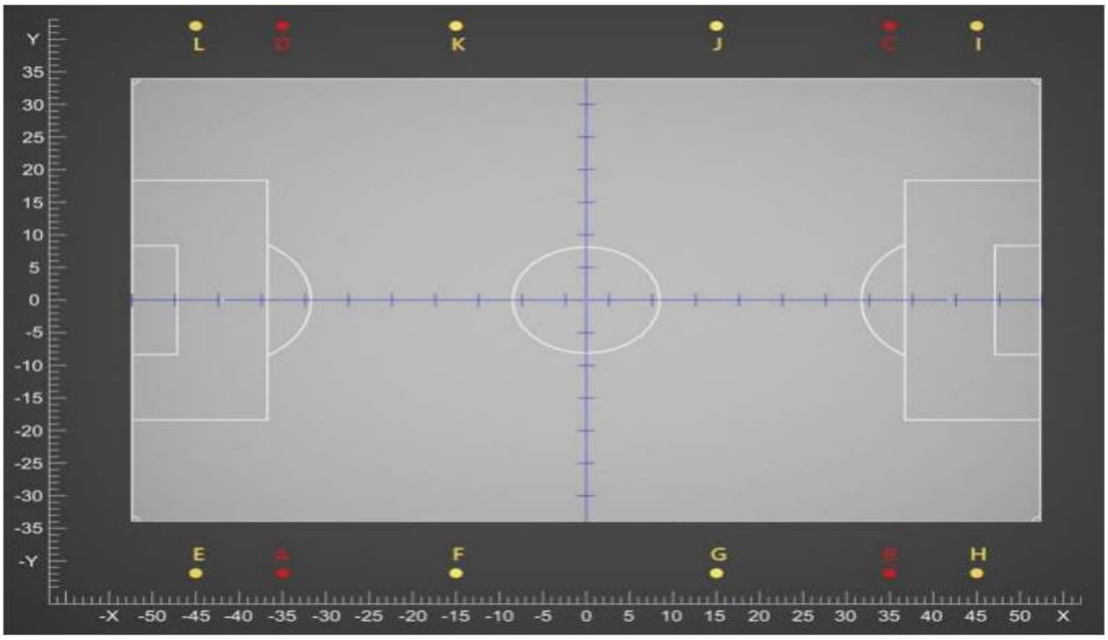


Fig 32. Pole placing coordinates [1]

STEP 6 – Selecting the luminaires. Luminaires is chosen based upon the level of match to be held, optics of the luminaires to reduce the glare, beam angle, luminous efficacy, IP & IK ratings, and weight of the luminaire.

STEP 7 – To select the maintenance factor of the luminaires that we will use. According to International Federation of Association Football (FIFA) the MF (Maintenance Factor) with a value of 0.90 is considered while we use LED luminaires and a value of 0.80 is considered while we use other types of luminaires.

STEP 8 – To find the number of luminaires we need to illuminate the playing area of the football field. Quantity of luminaires required has a huge impact on the budget required to design a lighting scheme for the football playground.

We use the below mentioned mathematical expression to find the number of luminaires we will need to illuminate the field.

$$E = \frac{N\ .\ \phi\ .\ CU\ .\ MF}{Area\ of\ the\ field}$$

Where,

E = Average illuminance value mentioned in the standards in Lux.

N = Number of Luminaires we will require.

Φ = Luminous Flux emitted from the luminaire in Lumen.

CU = Coefficient of Utilization.

MF = Maintenance Factor.

We may need a greater number of luminaires than the value of N we got after solving the equation, at the time of simulation of the lighting design that we have done.

STEP 9 – We will input all the data to the software and do the lighting design accordingly. The software provides us an option to paste a calculation grid where calculation of the illuminance value will take place. The positions of the grid points are also mentioned in the standards and, according to FIFA the longitudinal distance between two grid point should be 13.57 metre and transverse distance should be 14.50 metre for Practice session and for any national or international level or televised match the longitudinal distance should be 9.545 meter and transverse distance should be 9.714 metre. According to NLC (National Lighting Code) the grid size should be 5 m × 5 m. Fig. 34 & 35 is showing how the grid points should be placed to get proper illuminance level.

STEP 10 – Now we will simulate the design and see what values we are achieving for the different crucial lighting parameters and modify the design accordingly.

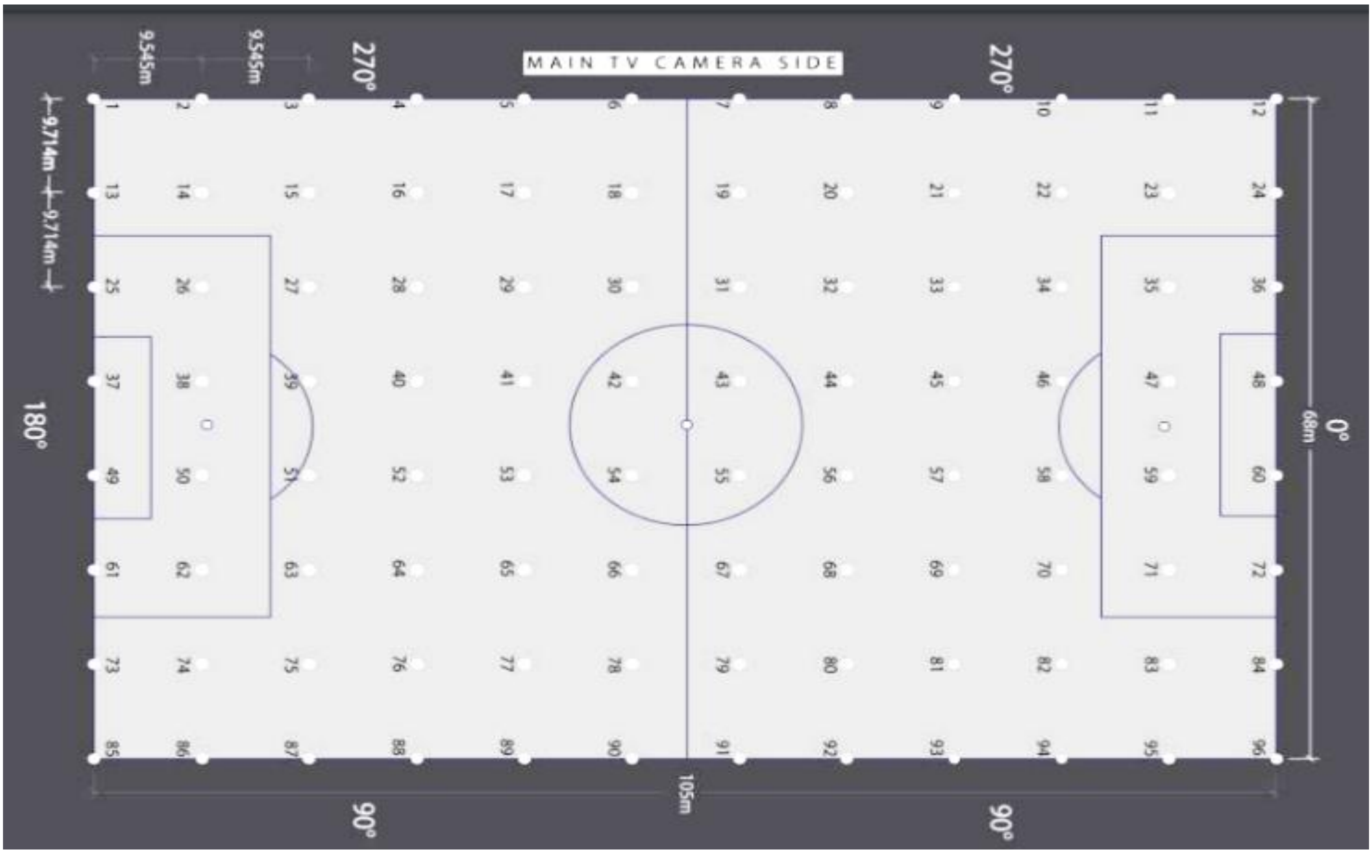


Fig 33. Grid points placing Acc. To FIFA for televised match [1]

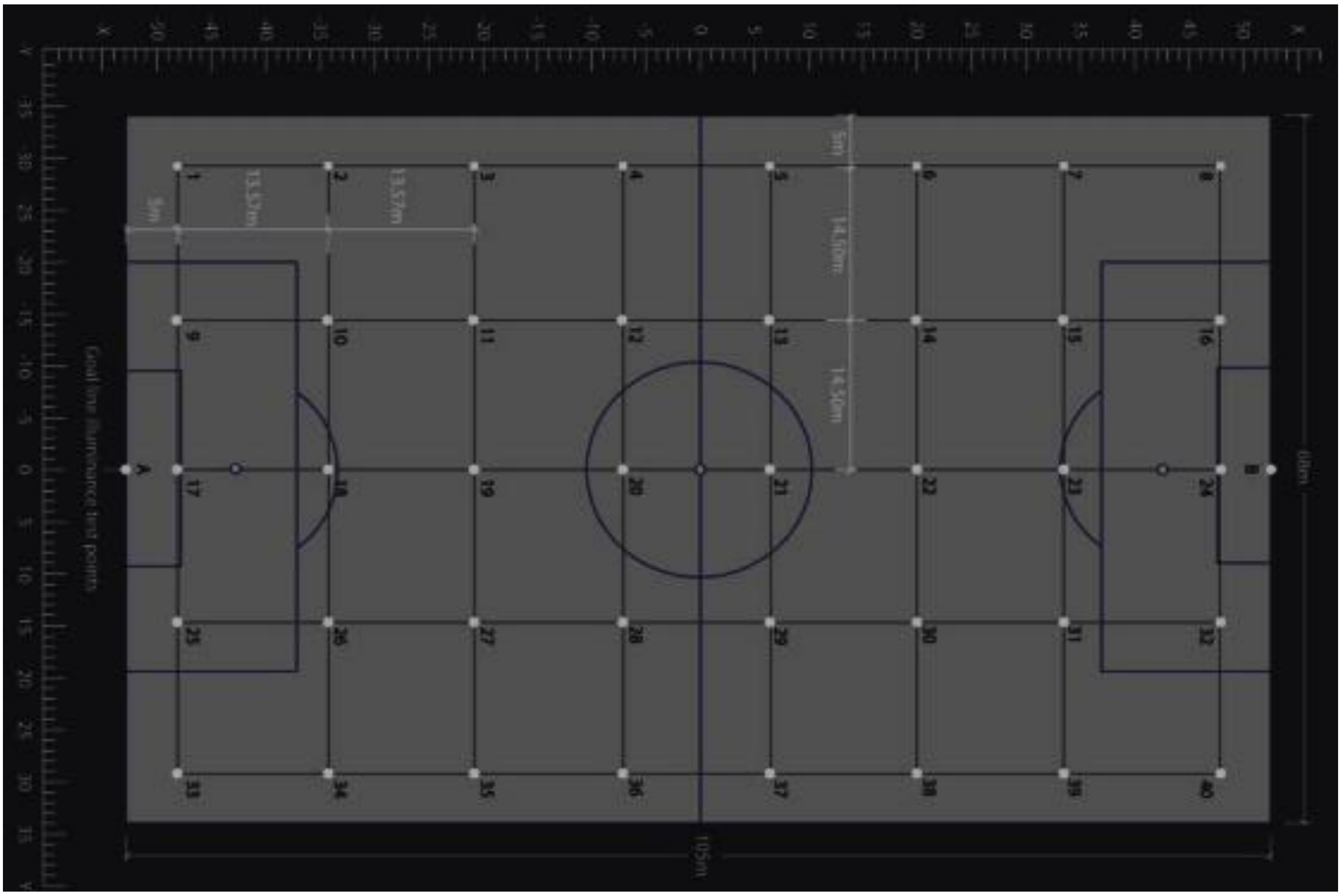


Fig 34. Grid points placing Acc. To FIFA for practice session [1]

4.2.6 GENERATING THE REPORTS

After completing the lighting design, we simulate the design to see the values of the parameters related to lighting and do the needful. This is generated in form of a report by the software. This report contains all the details related to lighting of the playing area of the football field.

Here we have done three lighting design for the same field for three different purposes.

CASE 1: Lighting Design for Practice Session and simulating it.

CASE 2: Lighting Design for national level match simulating it.

CASE 3: Lighting Design for national level match which will be broadcasted and simulating it.

CASE 4: Lighting Design for international level match which will be broadcasted and simulating it.

Let us study the report generated by the software (DIALux 4.13) for

CASE 1:

<u>PRACTICE LEVEL MATCH</u>

Playing Area = 105m by 68m

4 Pole System.

Targets to be Achieved according to the national and international standards, NLC & FIFA:

Average Horizontal Illuminance, Eavg = 500 Lux

Uniformity, U2
(U2 = Emin\Emax) > 0.3

Uniformity, U0
(U0 = Emin\Eavg) > 0.5

Glare Rating (GR) < 50

Considered values: -

Maintenance Factor = 0.9
Coefficient of Utilization = 0.8

Luminaire Used: SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº, IP65, 1200W, 5700K.

Lamps: 1 x

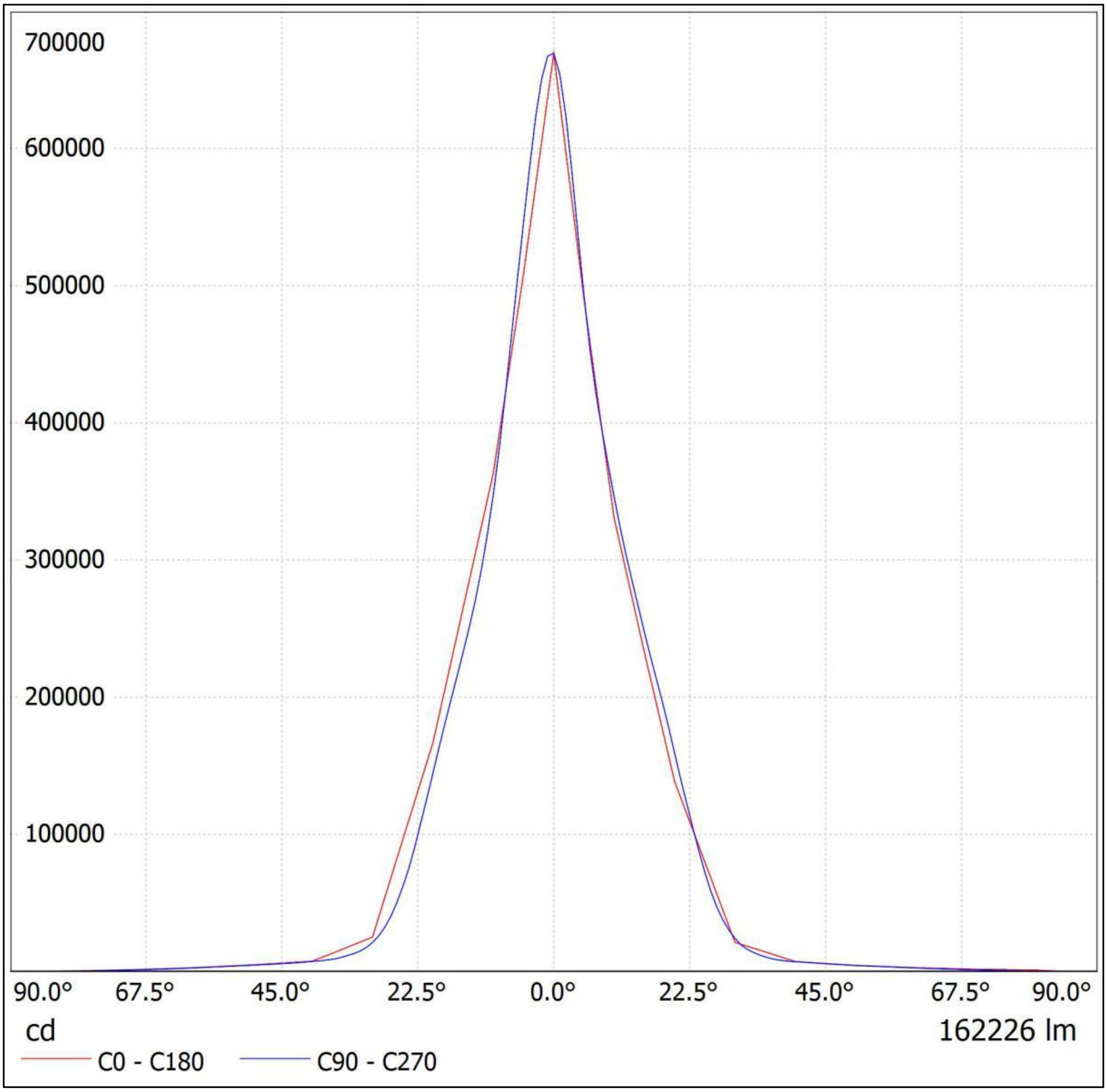


Fig 35. Linear Curve of the Luminaire used.

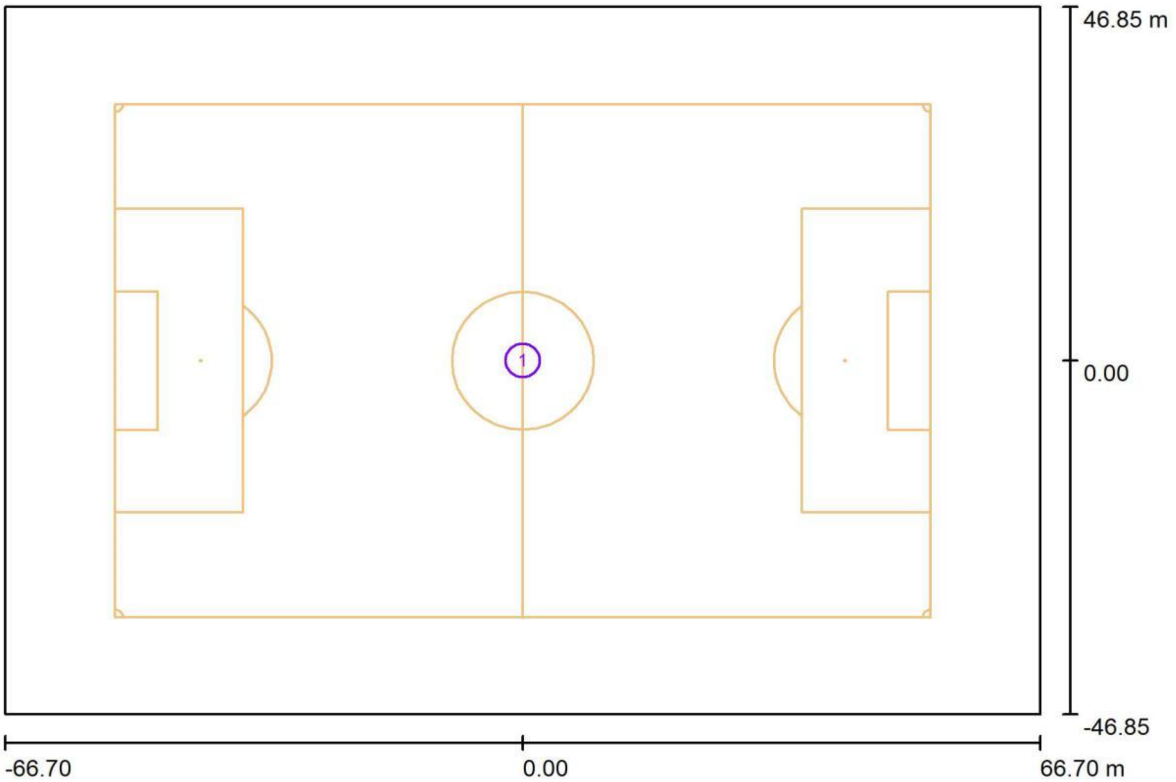
Planning data

Light loss factor: 0.80, ULR (Upward Light Ratio): 2.5%

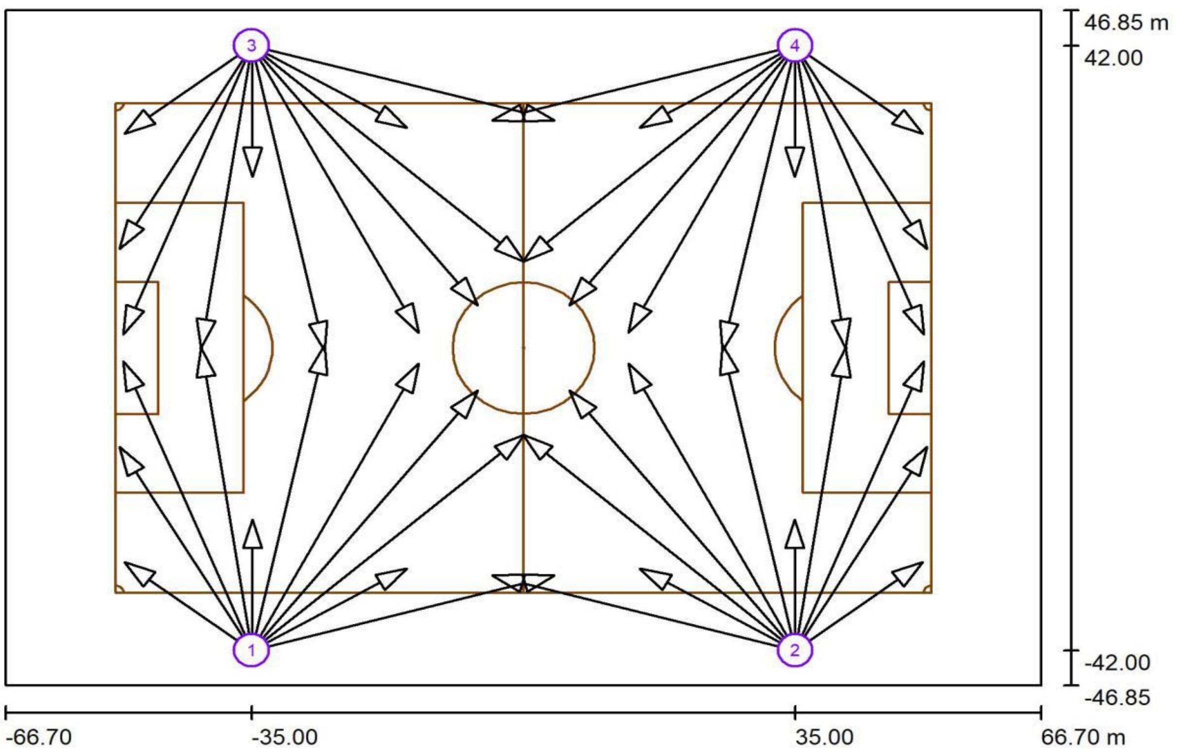
Luminaire Parts List:

No.	Pieces	Designation (Correction Factor)	ϕ (Luminaire) [lm]	ϕ (Lamps) [lm]	P [W]
1	44	SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº IP65 1200W 5700K (1.000)	162226	162226	1233.9
			Total: 7137956	Total: 7137956	Total: 54292.0

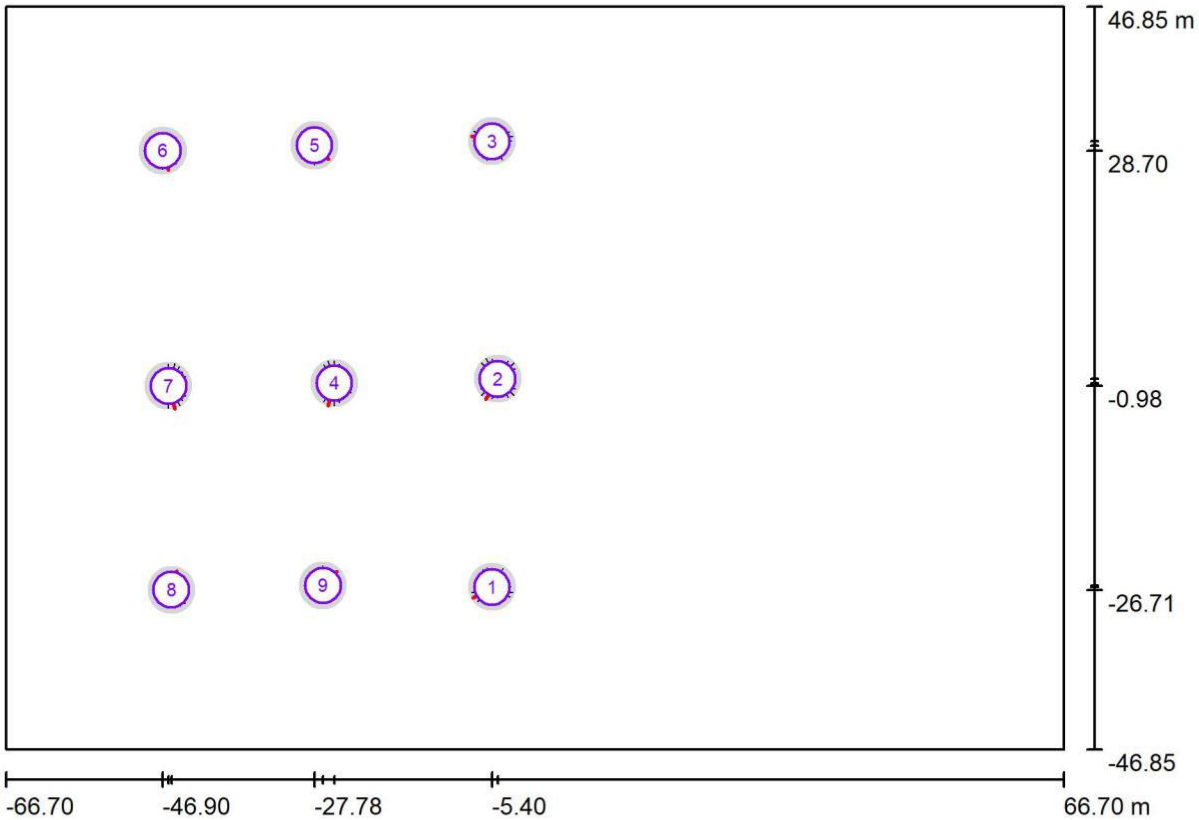
Sport Sites layout plan:



Sports Luminaires Coordinates List:



GR Observer (Results Overview)



GR Observerlist

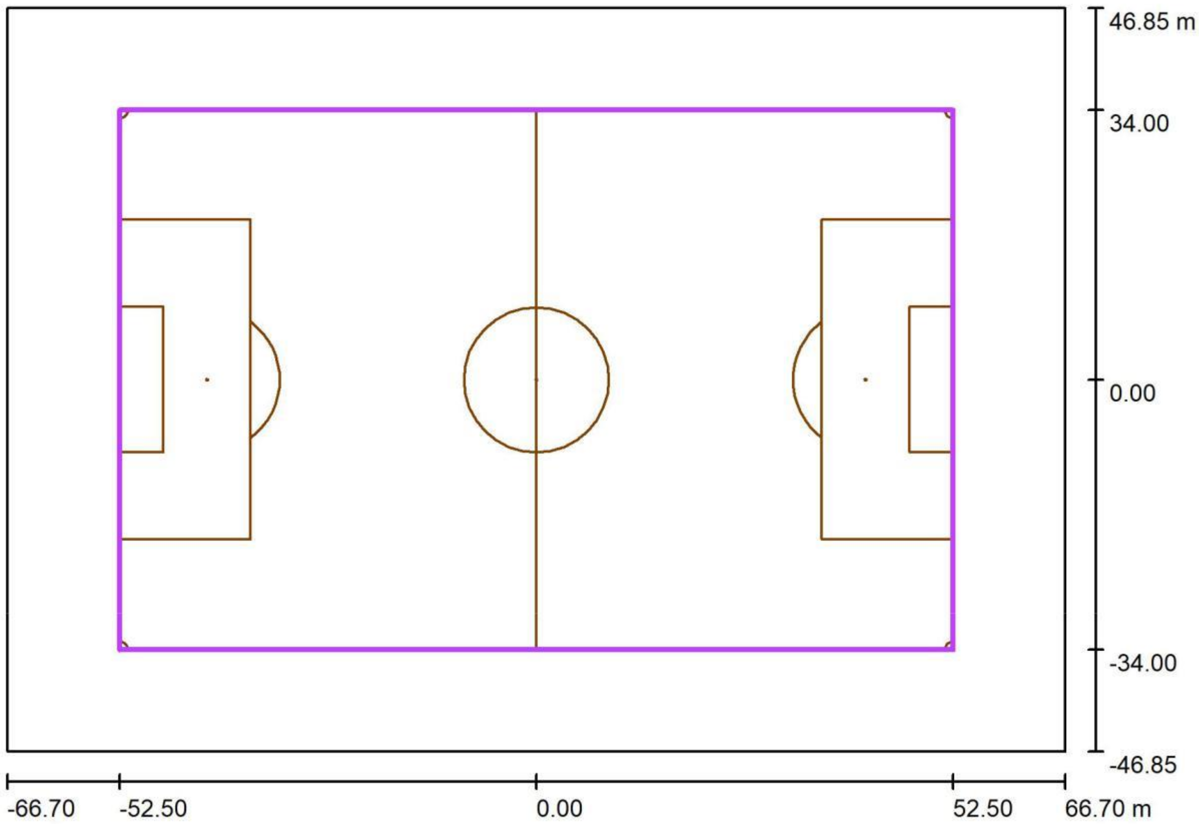
No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	-5.400	-26.355	1.750	0.0	360.0	15.0	-2.0	37 2)
2	GR Observer 2	-4.700	-0.089	1.750	0.0	360.0	15.0	-2.0	40 2)
3	GR Observer 3	-5.400	29.900	1.750	0.0	360.0	15.0	-2.0	36 2)
4	GR Observer 4	-25.300	-0.625	1.750	0.0	360.0	15.0	-2.0	39 2)

GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
5	GR Observer 5	-27.785	29.393	1.750	0.0	360.0	15.0	-2.0	33 2)
6	GR Observer 6	-46.900	28.700	1.750	0.0	360.0	15.0	-2.0	33 2)
7	GR Observer 7	-46.200	-0.983	1.750	0.0	360.0	15.0	-2.0	40 2)
8	GR Observer 8	-45.832	-26.713	1.750	0.0	360.0	15.0	-2.0	33 2)
9	GR Observer 9	-26.713	-26.177	1.750	0.0	360.0	15.0	-2.0	33 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Calculation Grid for Playing Area according to FIFA Summary:



Results overview

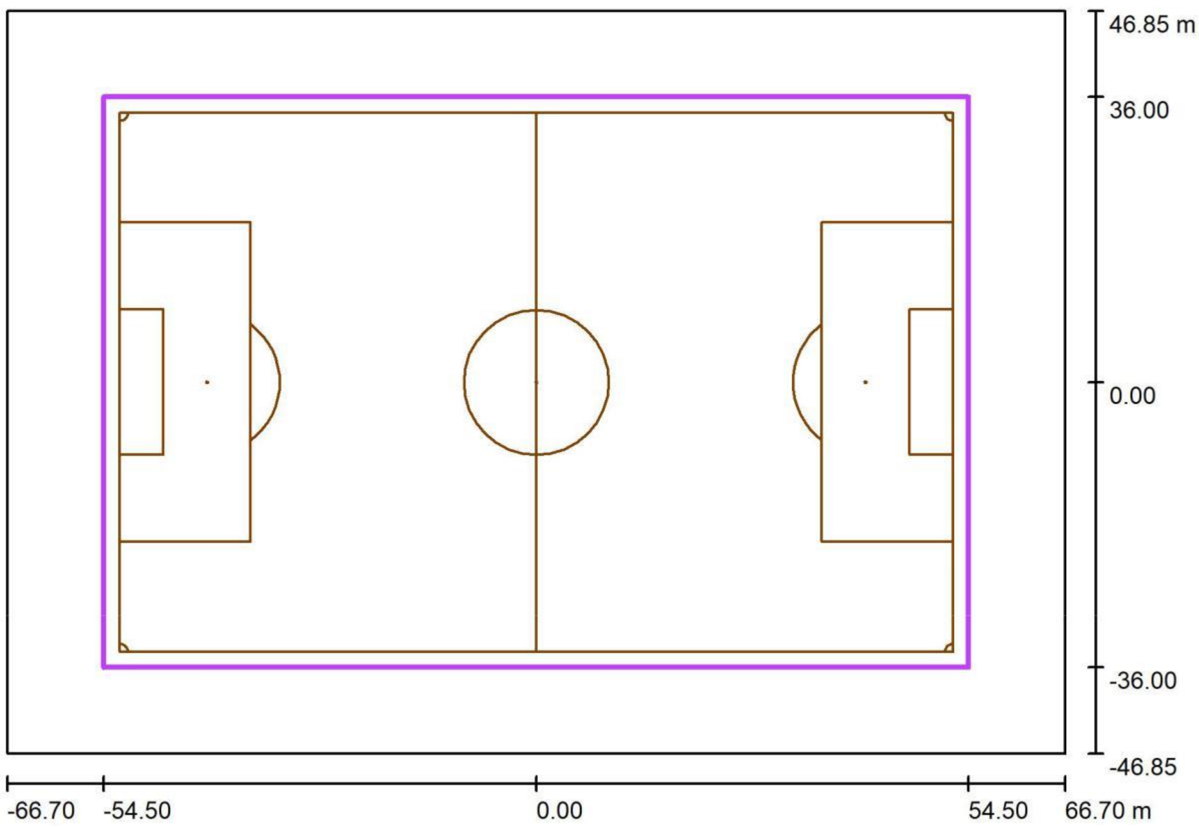
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	521	415	593	0.80	0.70	/	0.000	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 8 x 5 Points

Calculation Grid for Total Area according to FIFA Summary:



Results overview

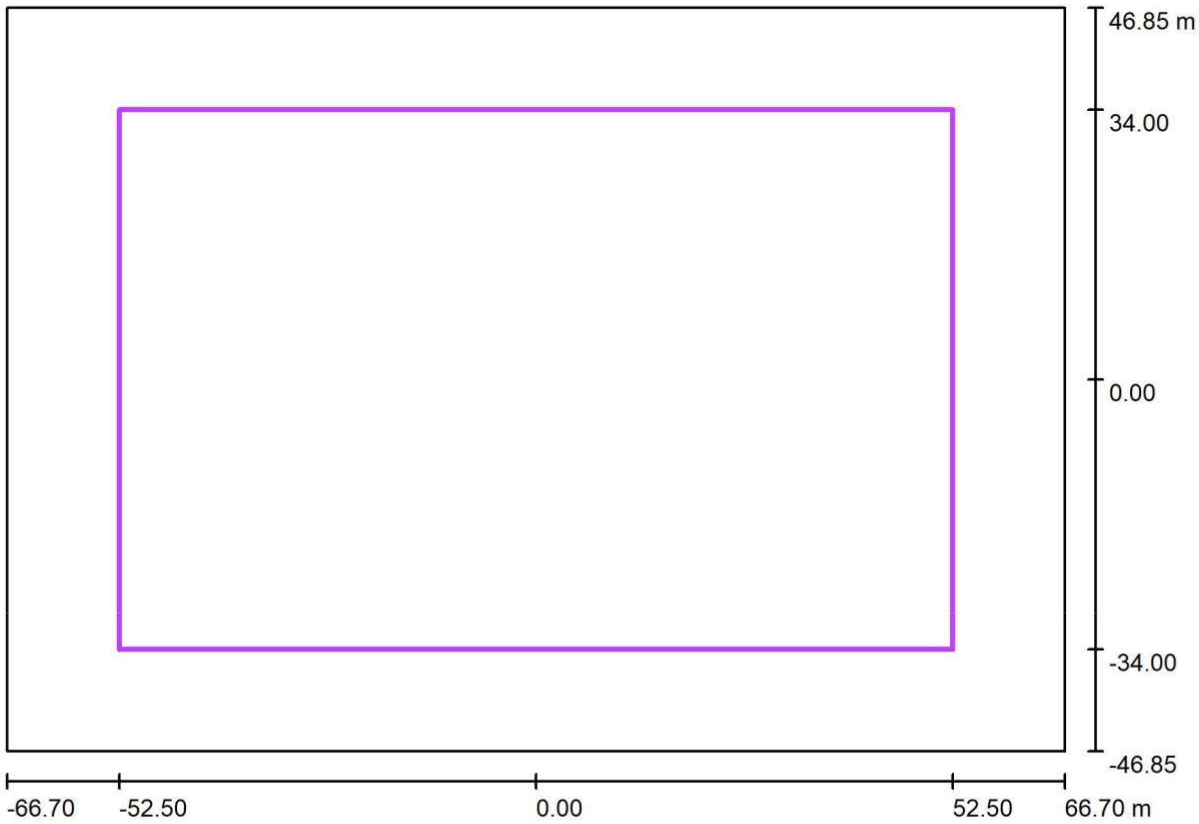
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	507	365	723	0.72	0.51	/	0.000	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 21 x 13 Points

Calculation Grid for Playing Area according to NLC Summary:



Results overview

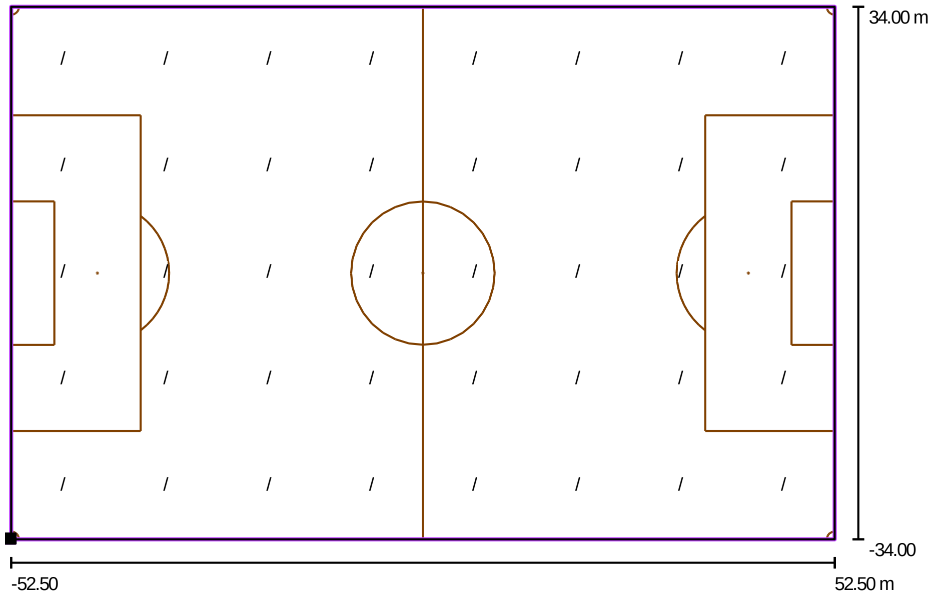
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	509	381	713	0.75	0.53	/	0.000	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 22 x 14 Points

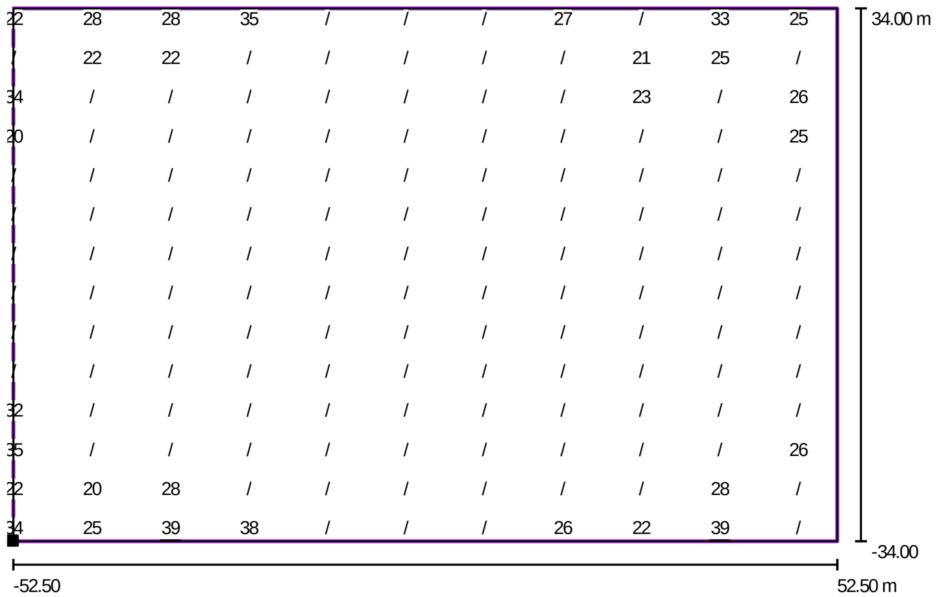
Gradient Graphics (E, Horizontal) for Playing Area in FIFA recommended Calculation Grid:



Maximum Change: 9%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

Gradient Graphics (E, Horizontal) for Playing Area in NLC recommended Calculation Grid:



Maximum Change: 39%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

CASE 2:

NATIONAL LEVEL MATCH

Condition: Non-Televised

Playing Area = 105m by 68m

8 Pole System.

Targets to be Achieved according to the national and international standards, NLC & FIFA:

Average Horizontal Illuminance, Eavg = 500 - 700 Lux

Average Vertical Illuminance, Ev_{avg} = 350 Lux

Uniformity, U2
(U2 = Emin\Emax) > 0.3

Uniformity, U0
(U0 = Emin\Eavg) > 0.6

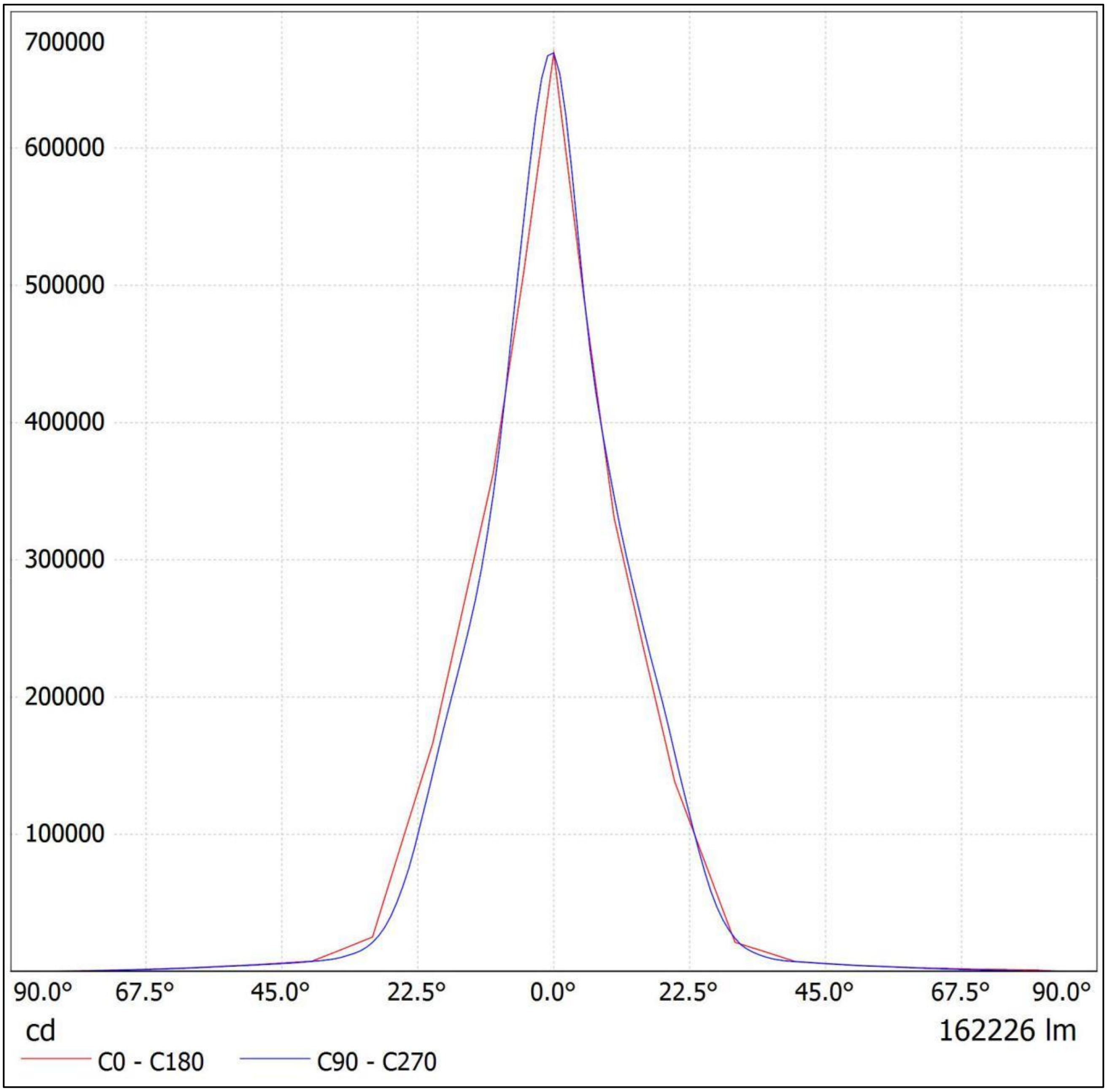
Glare Rating (GR) < 50

Considered values: -

Maintenance Factor = 0.9
Coefficient of utilization = 0.8

Luminaire Used: SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº, IP65, 1200W, 5700K.

Lamps: 1 x



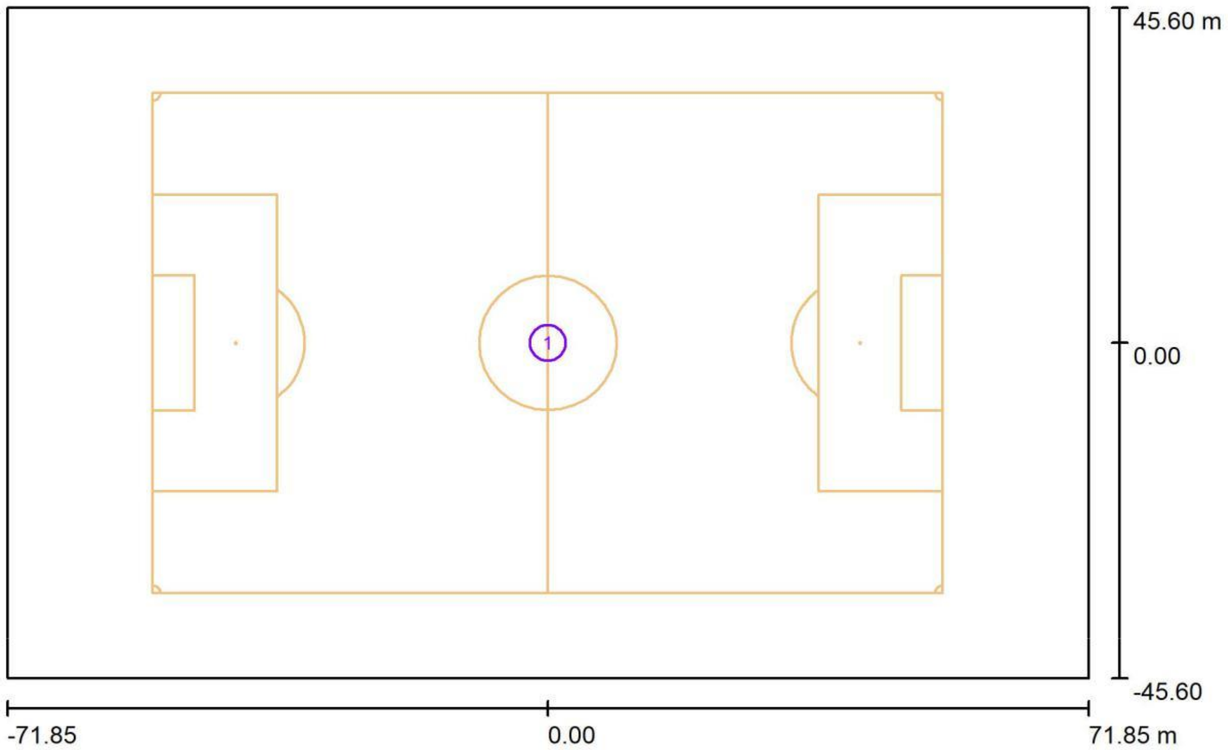
Planning data

Light loss factor: 0.80, ULR (Upward Light Ratio): 5.5%

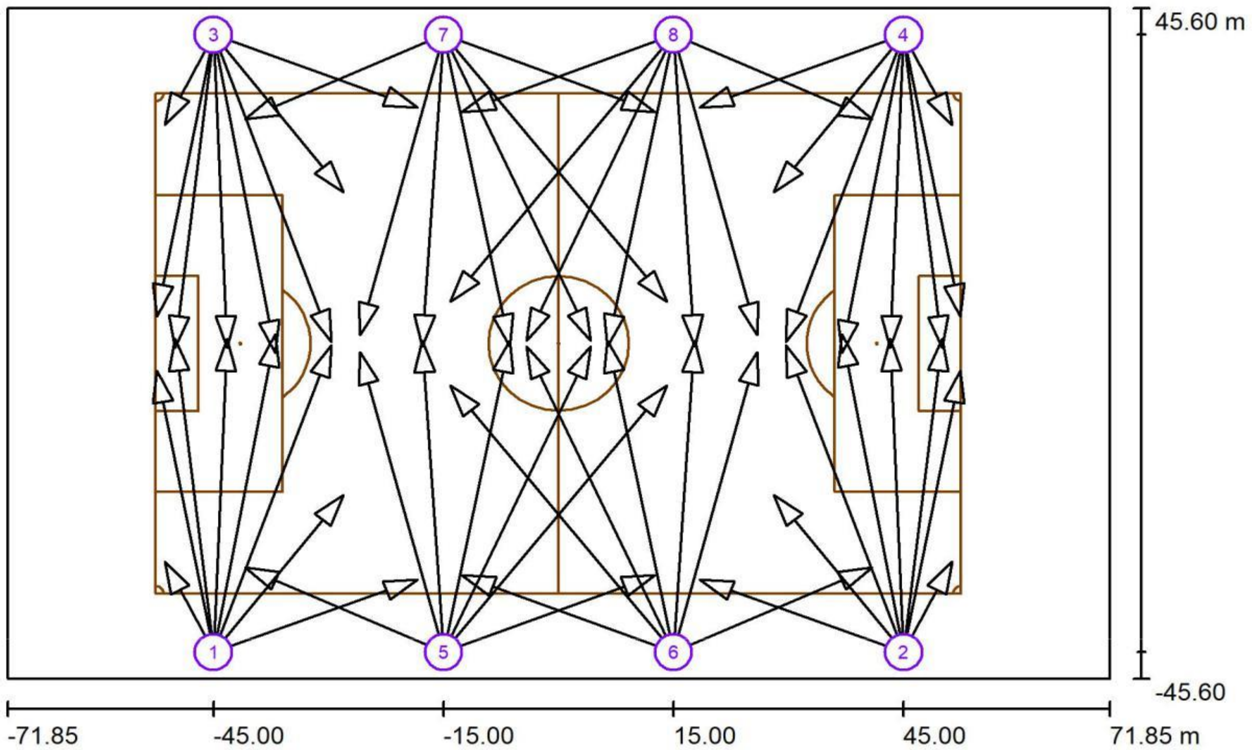
Luminaire Parts List:

No.	Pieces	Designation (Correction Factor)	ϕ (Luminaire) [lm]	ϕ (Lamps) [lm]	P [W]
1	60	SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº IP65 1200W 5700K (1.000)	162226	162226	1233.9
			Total: 9733576	Total: 9733576	Total: 74034.6

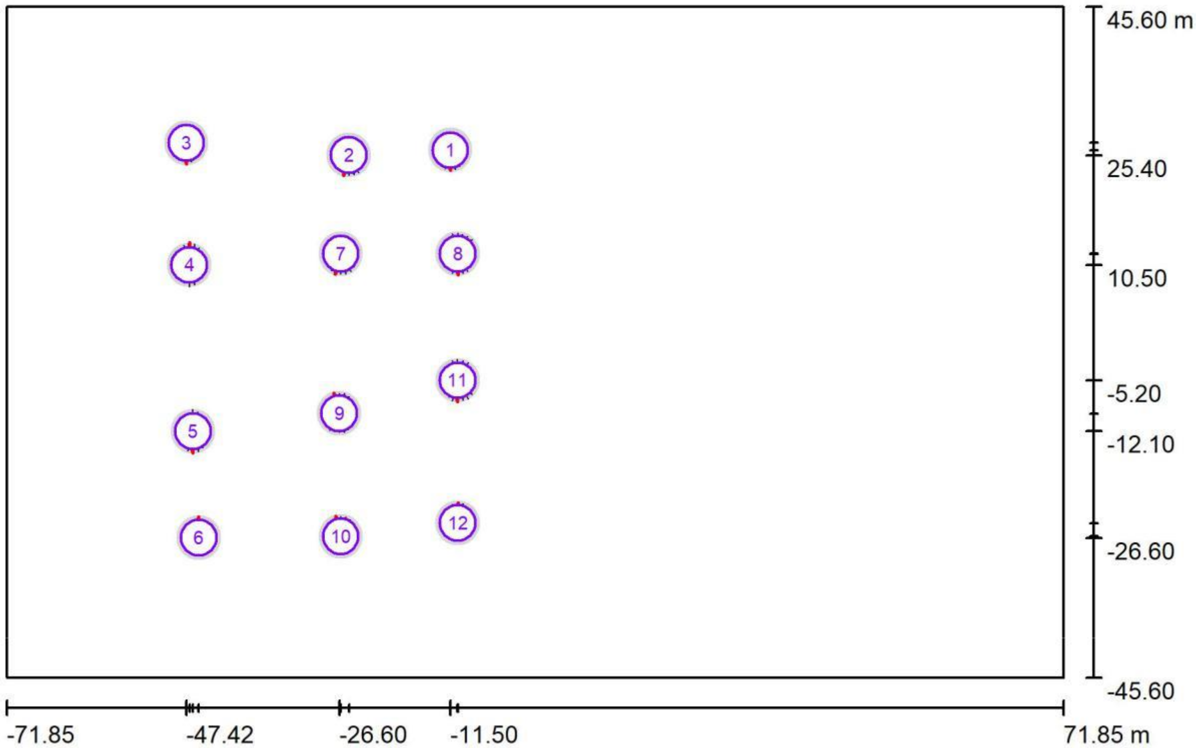
Sport Sites layout plan:



Sports Luminaires Coordinates List:



GR Observer (Results Overview):



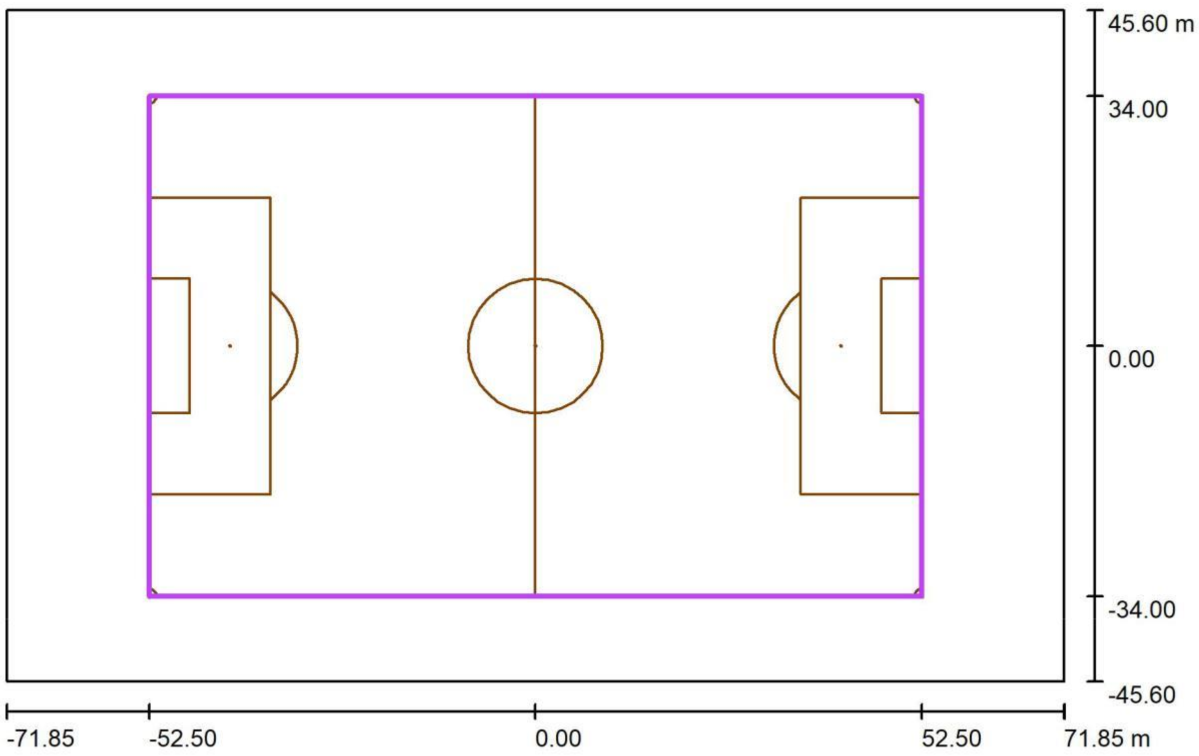
GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	-11.500	26.100	1.500	0.0	360.0	15.0	-2.0	45 2)
2	GR Observer 2	-25.300	25.400	1.500	0.0	360.0	15.0	-2.0	46 2)
3	GR Observer 3	-47.417	27.100	1.500	0.0	360.0	15.0	-2.0	46 2)
4	GR Observer 4	-47.000	10.500	1.500	0.0	360.0	15.0	-2.0	49 2)

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
5	GR Observer 5	-46.500	-12.100	1.500	0.0	360.0	15.0	-2.0	49 2)
6	GR Observer 6	-45.700	-26.600	1.500	0.0	360.0	15.0	-2.0	47 2)
7	GR Observer 7	-26.400	12.000	1.500	0.0	360.0	15.0	-2.0	47 2)
8	GR Observer 8	-10.500	12.025	1.500	0.0	360.0	15.0	-2.0	47 2)
9	GR Observer 9	-26.600	-9.700	1.500	0.0	360.0	15.0	-2.0	47 2)
10	GR Observer 10	-26.400	-26.400	1.500	0.0	360.0	15.0	-2.0	46 2)
11	GR Observer 11	-10.507	-5.200	1.500	0.0	360.0	15.0	-2.0	47 2)
12	GR Observer 12	-10.500	-24.597	1.500	0.0	360.0	15.0	-2.0	45 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Calculation Grid for Playing Area according to FIFA Summary:



Results overview

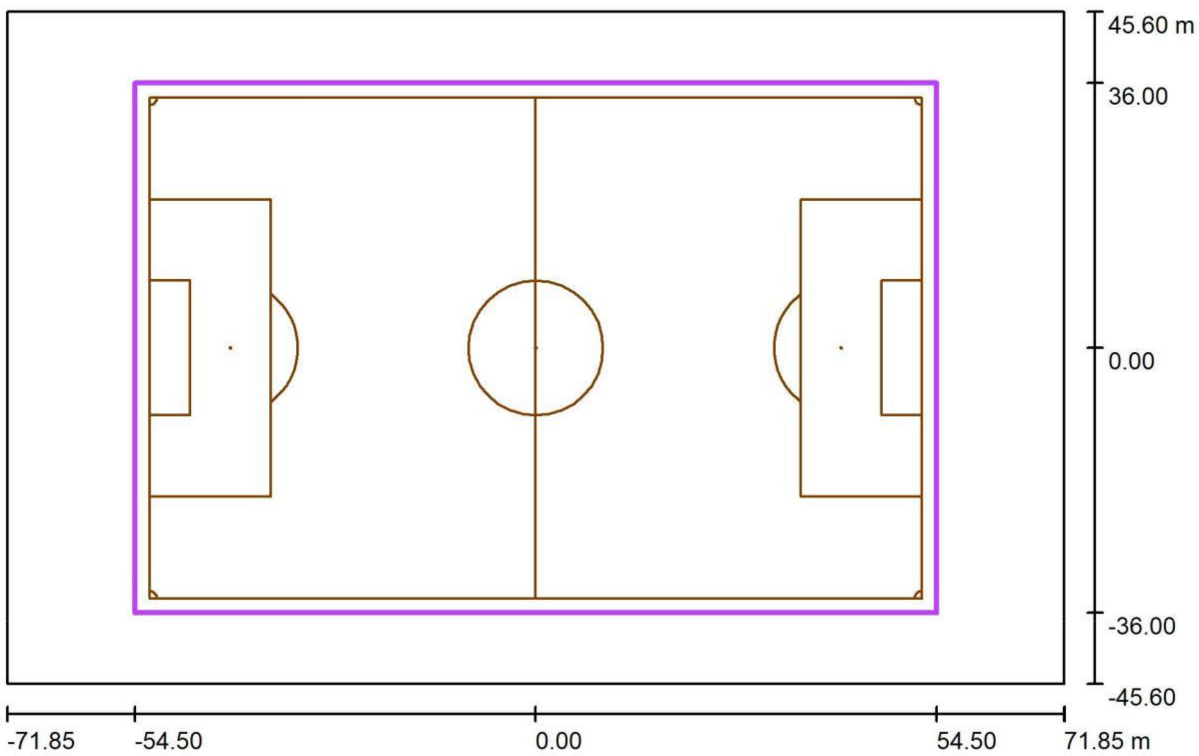
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	688	592	792	0.86	0.75	/	0.000	/
2	vertical, 0.0°	385	75	527	0.19	0.14	1.79	1.500	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 8 x 5 Points

Calculation Grid for Total Area according to FIFA Summary:



Results overview

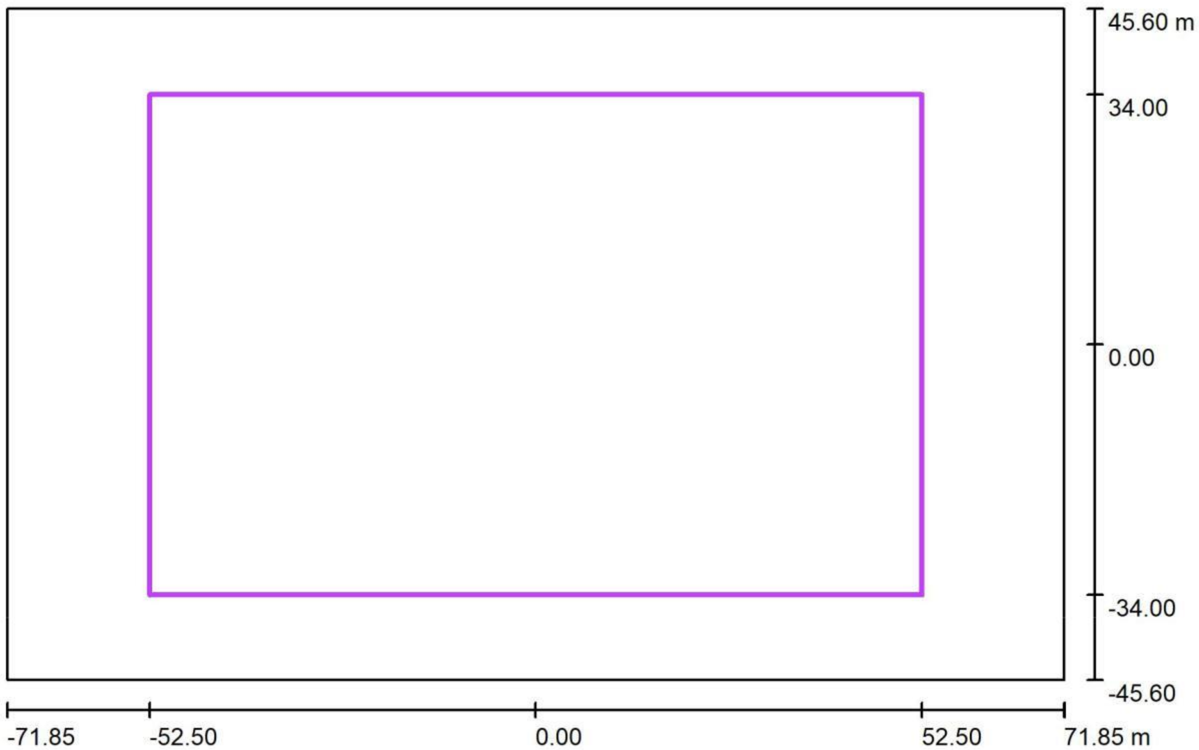
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	669	446	856	0.67	0.52	/	0.000	/
2	vertical, 0.0°	388	56	654	0.14	0.09	1.72	1.500	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 21 x 13 Points

Calculation Grid for Playing Area according to NLC Summary:



Results overview

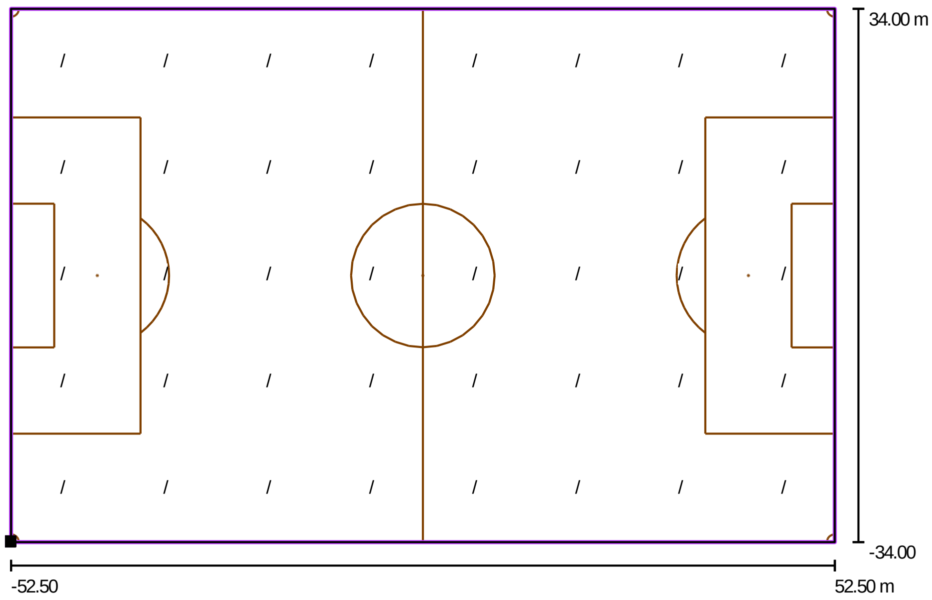
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	671	505	835	0.75	0.61	/	0.000	/
2	vertical, 0.0°	388	50	659	0.13	0.08	1.73	1.500	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 22 x 14 Points

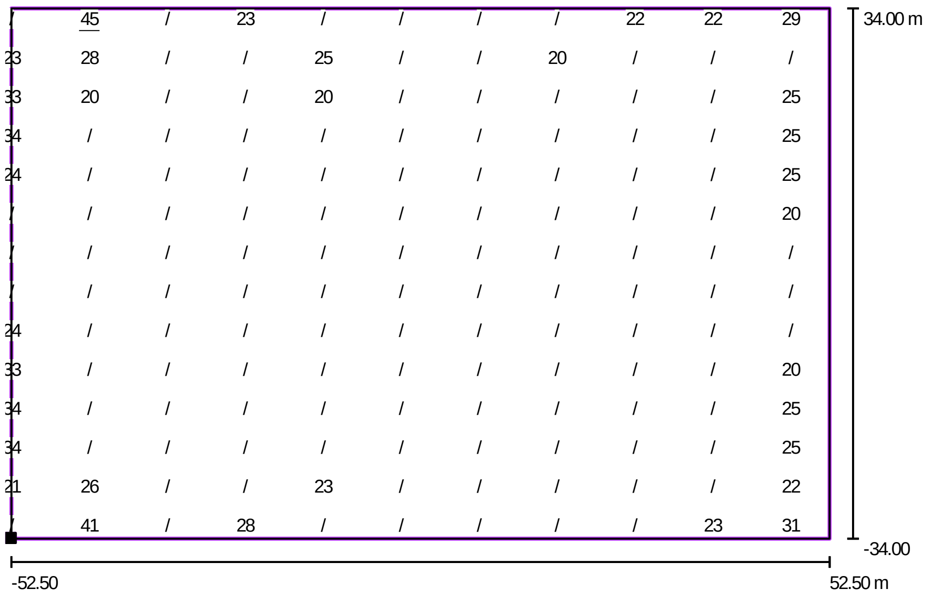
Gradient Graphics (E, Horizontal) for Playing Area in FIFA recommended Calculation Grid:



Maximum Change: 8%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

Gradient Graphics (E, Horizontal) for Playing Area in NLC recommended Calculation Grid:



Maximum Change: 45%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

CASE 3:

<u>NATIONAL LEVEL MATCH</u>

Condition: Televised

Playing Area = 105m by 68m

6 Pole System.

Targets to be Achieved according to the national and international standards, NLC & FIFA:

Average Horizontal Illuminance, Eavg = 1000 - 2000 Lux

Average Vertical Illuminance, Ev_{avg} = 1000 Lux

Average Camera Vertical Illuminance, Ev_{cam} = 1000 Lux

Uniformity, U2
(U2 = Emin\Emax) > 0.4

Uniformity, U0
(U0 = Emin\Eavg) > 0.7

U2 for Camera Vertical Plane = 0.3

U0 for Camera Vertical Plane = 0.6

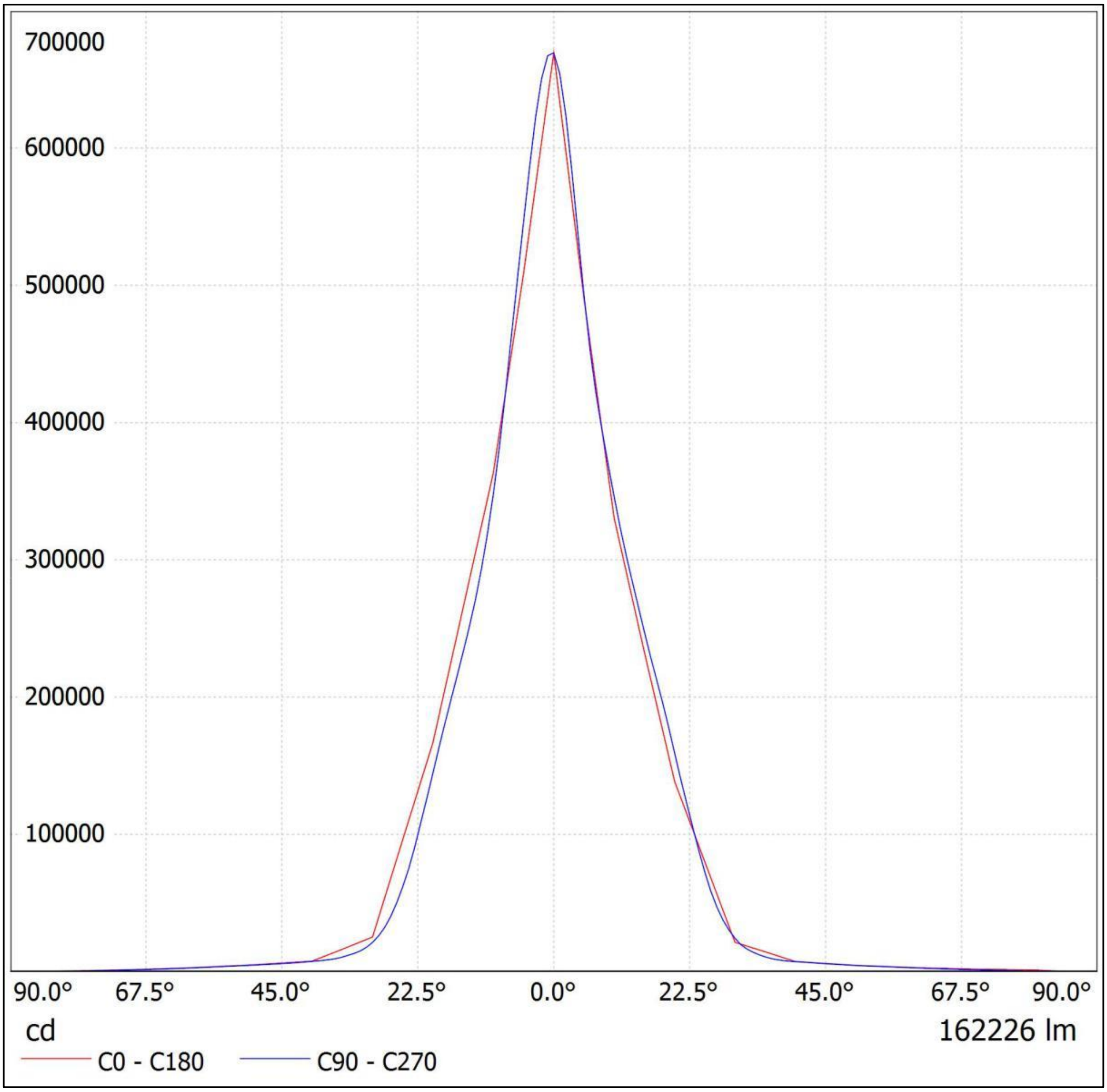
Glare Rating (GR) < 50

Considered values: -

Maintenance Factor = 0.9
Coefficient of utilization = 0.8

Luminaire Used: SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº, IP65, 1200W, 5700K.

Lamps: 1 x



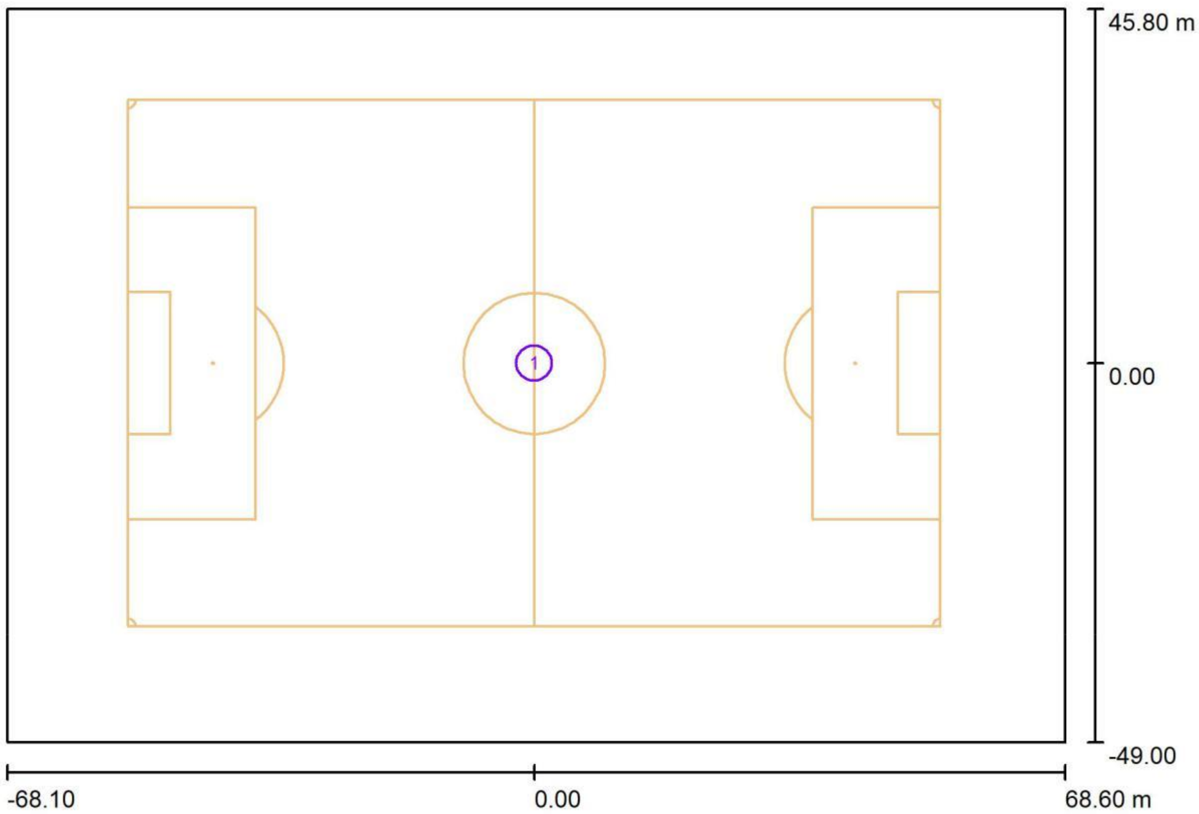
Planning data

Light loss factor: 0.80, ULR (Upward Light Ratio): 7.5%

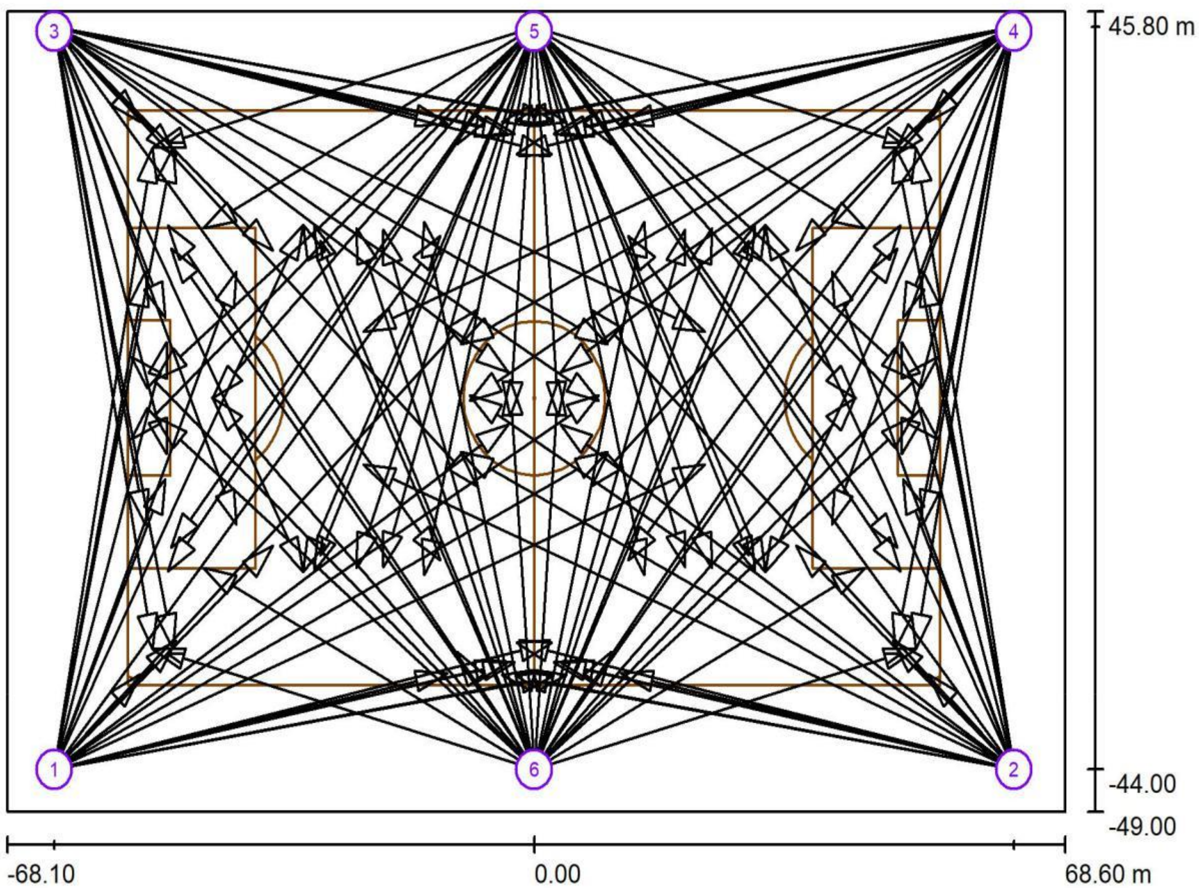
Luminaire Parts List:

No.	Pieces	Designation (Correction Factor)	ϕ (Luminaire) [lm]	ϕ (Lamps) [lm]	P [W]
1	152	SILVERSUN FLC1200FW Floodlight Round High Mast 25Âº IP65 1200W 5700K (1.000)	162226	162226	1233.9
			Total: 24658393	Total: 24658393	Total: 187554.3

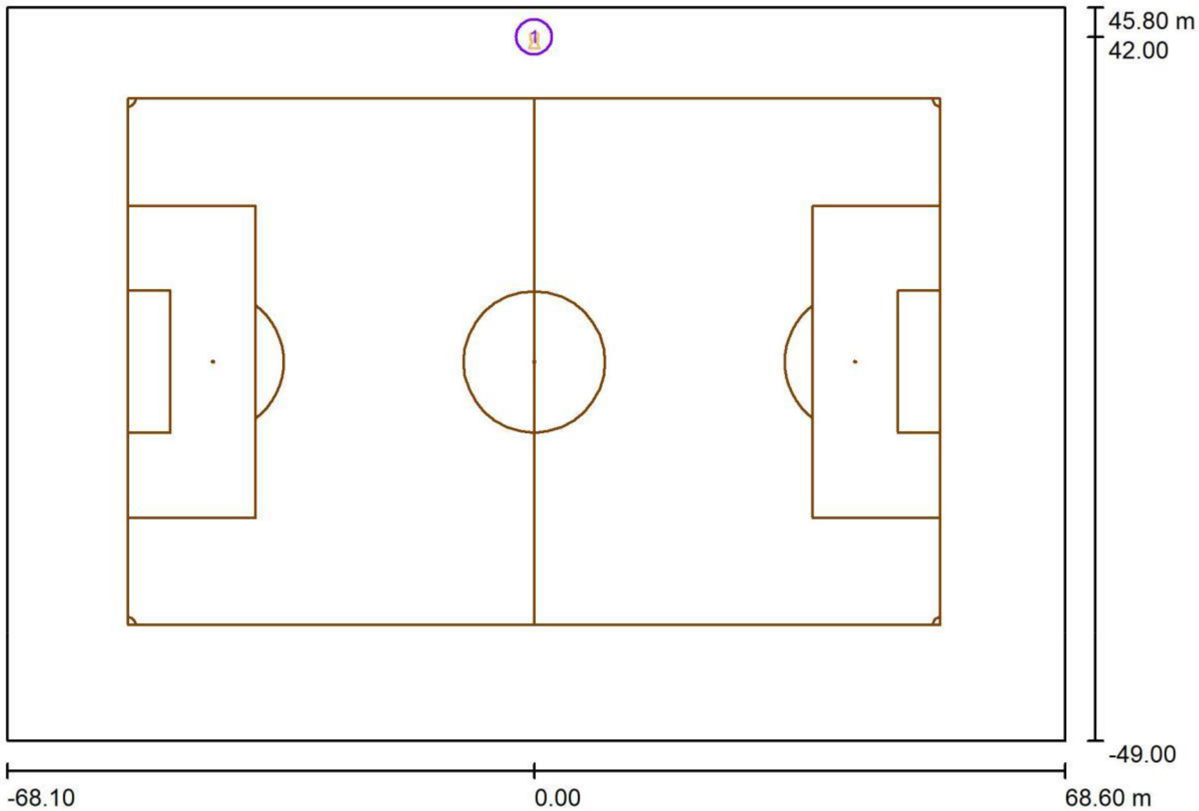
Sport Sites layout plan:



Sports Luminaires Coordinates List:



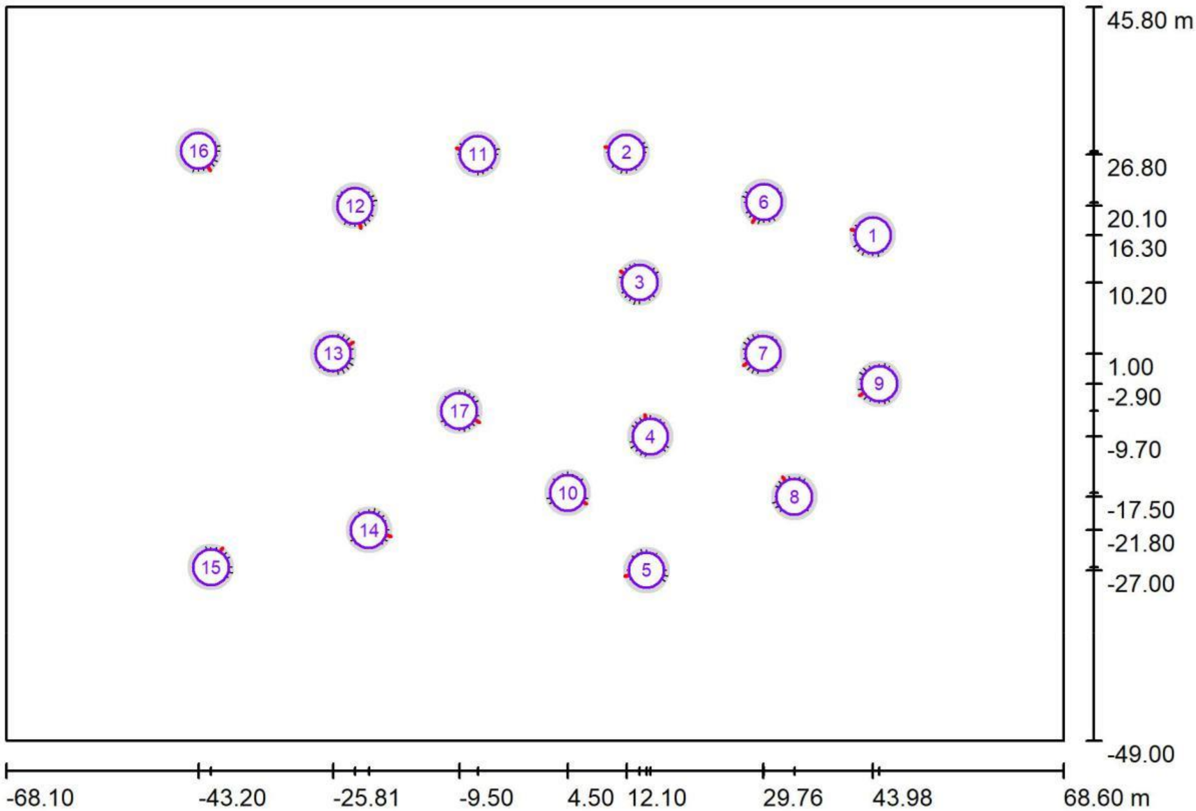
TV Cameras (Coordinates List)



List of the TV Cameras

No.	Designation	Position [m]		
		X	Y	Z
1	TV Camera 1	0.000	42.00	10.000

GR Observer (Results Overview):



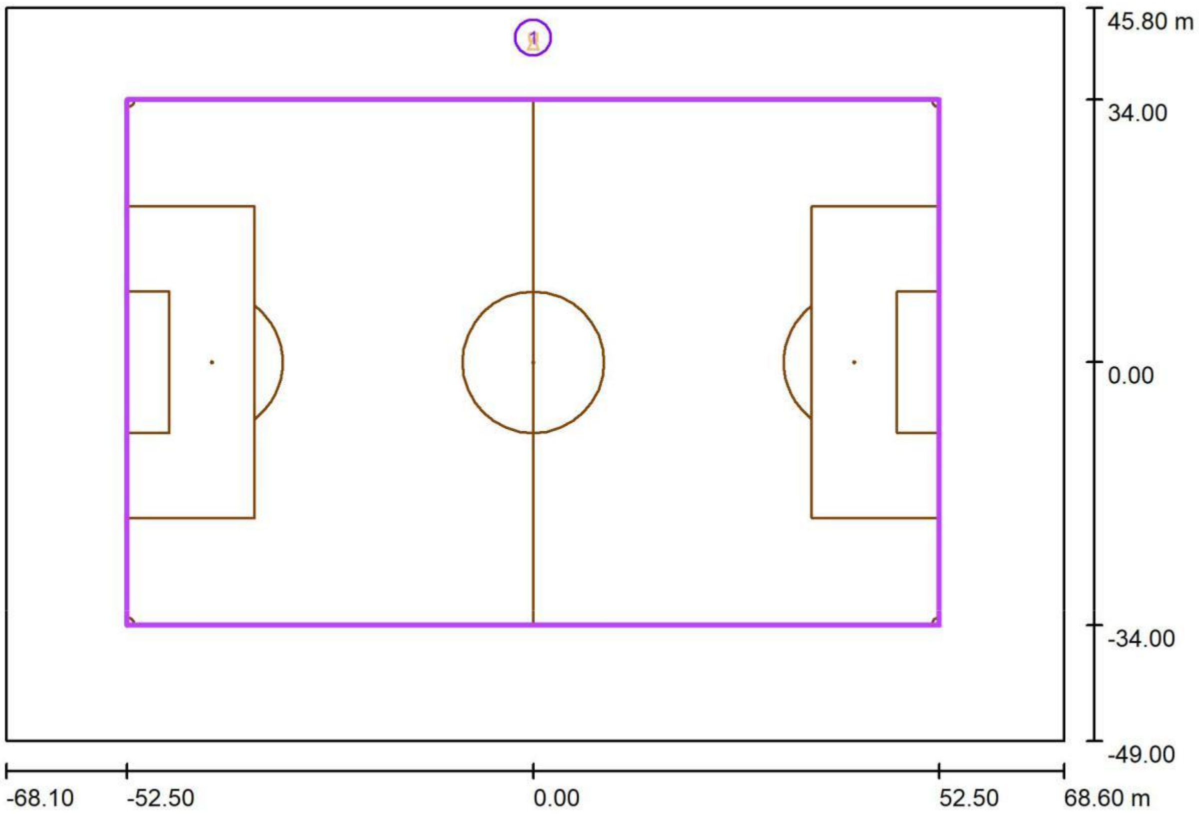
GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	43.983	16.300	1.500	0.0	360.0	15.0	-2.0	44 2)
2	GR Observer 2	12.100	27.000	1.500	0.0	360.0	15.0	-2.0	43 2)
3	GR Observer 3	13.800	10.200	1.500	0.0	360.0	15.0	-2.0	44 2)
4	GR Observer 4	15.200	-9.700	1.500	0.0	360.0	15.0	-2.0	44 2)

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
5	GR Observer 5	14.700	-27.000	1.500	0.0	360.0	15.0	-2.0	43 2)
6	GR Observer 6	29.888	20.594	1.500	0.0	360.0	15.0	-2.0	45 2)
7	GR Observer 7	29.757	1.000	1.500	0.0	360.0	15.0	-2.0	45 2)
8	GR Observer 8	33.800	-17.500	1.500	0.0	360.0	15.0	-2.0	45 2)
9	GR Observer 9	44.800	-2.900	1.500	0.0	360.0	15.0	-2.0	44 2)
10	GR Observer 10	4.500	-17.000	1.500	0.0	360.0	15.0	-2.0	42 2)
11	GR Observer 11	-7.100	26.800	1.500	0.0	360.0	15.0	-2.0	44 2)
12	GR Observer 12	-23.000	20.100	1.500	0.0	360.0	15.0	-2.0	45 2)
13	GR Observer 13	-25.809	1.000	1.500	0.0	360.0	15.0	-2.0	45 2)
14	GR Observer 14	-21.200	-21.800	1.500	0.0	360.0	15.0	-2.0	44 2)
15	GR Observer 15	-41.600	-26.600	1.500	0.0	360.0	15.0	-2.0	44 2)
16	GR Observer 16	-43.200	27.200	1.500	0.0	360.0	15.0	-2.0	44 2)
17	GR Observer 17	-9.500	-6.400	1.500	0.0	360.0	15.0	-2.0	44 2)

2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Calculation Grid for Playing Area according to FIFA Summary:



Results overview

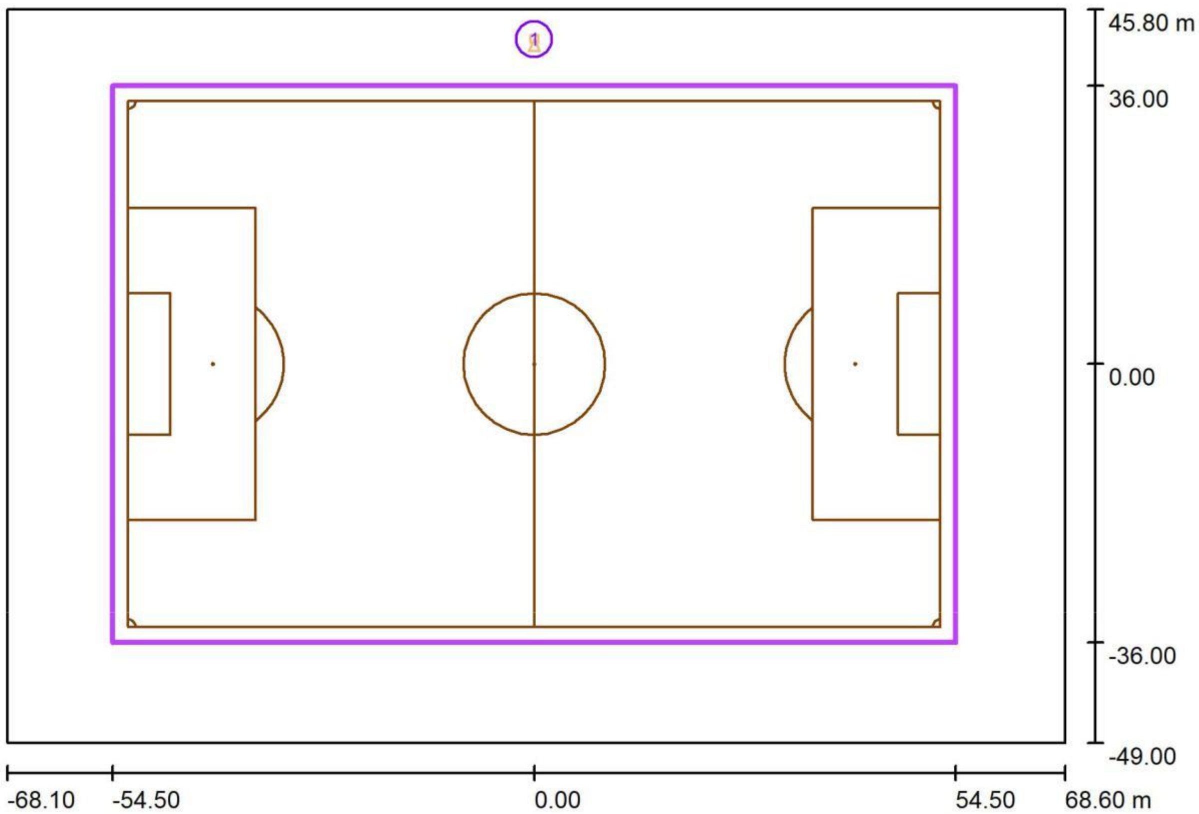
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1296	1086	1452	0.84	0.75	/	0.000	/
2	vertical, 0.0°	1070	475	1554	0.44	0.31	1.21	1.500	/
3	Camera	1237	711	1787	0.57	0.40	1.05	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 12 x 8 Points

Calculation Grid for Total Area according to FIFA Summary:



Results overview

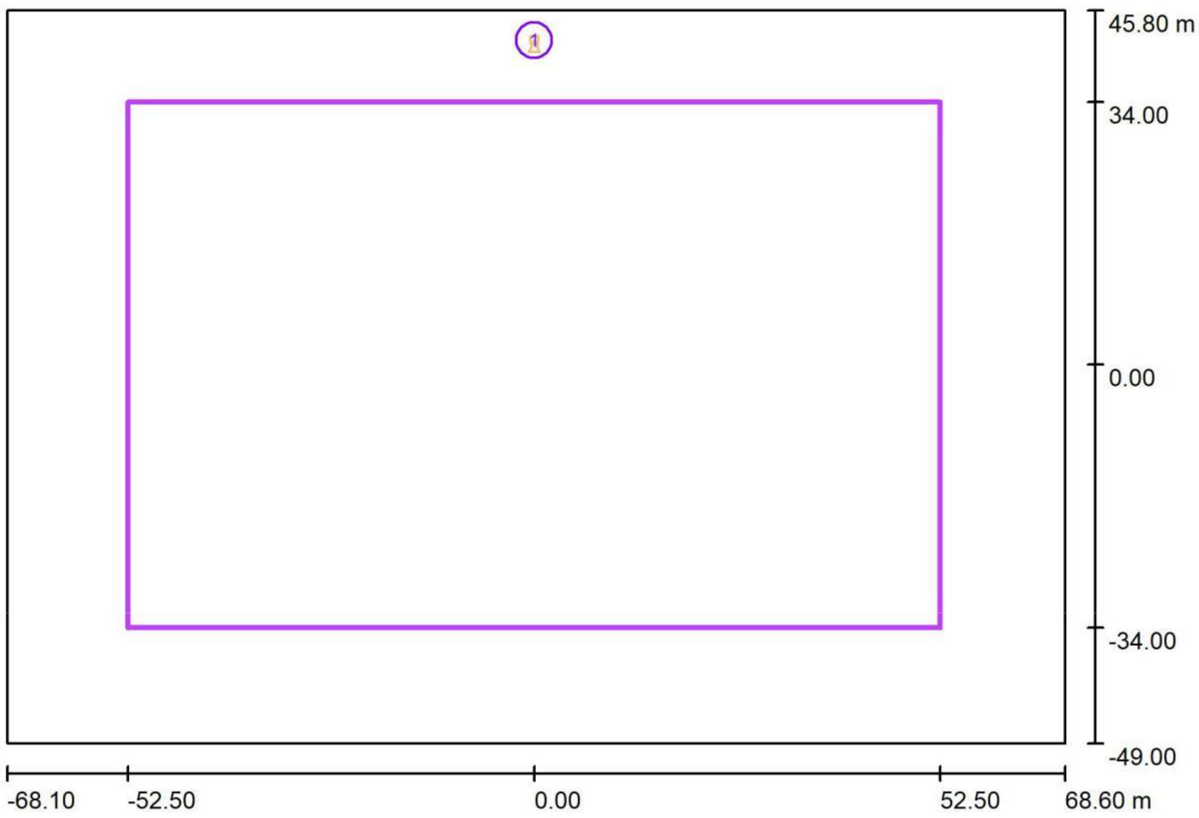
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1328	1138	1465	0.86	0.78	/	0.000	/
2	vertical, 0.0°	1102	496	1583	0.45	0.31	1.21	1.500	/
3	Camera	1279	738	1823	0.58	0.40	1.04	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 21 x 13 Points

Calculation Grid for Playing Area according to NLC Summary:



Results overview

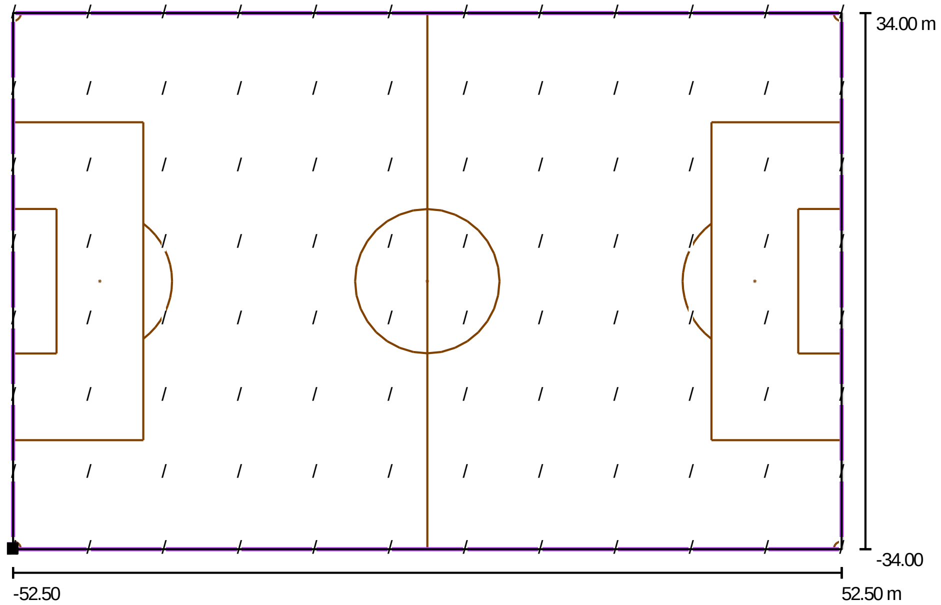
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1330	1141	1471	0.86	0.78	/	0.000	/
2	vertical, 0.0°	1101	469	1571	0.43	0.30	1.21	1.500	/
3	Camera	1287	751	1823	0.58	0.41	1.03	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 22 x 14 Points

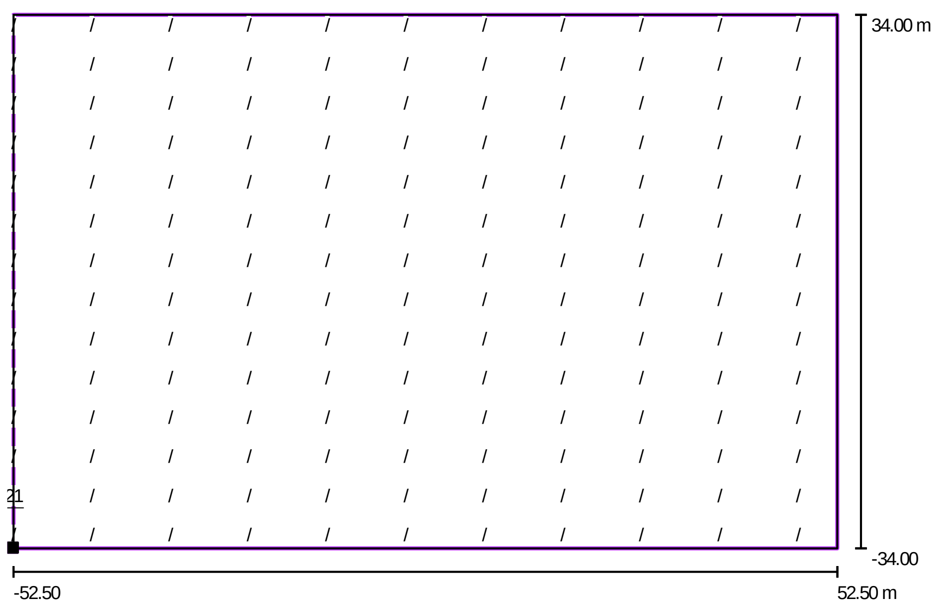
Gradient Graphics (E, Horizontal) for Playing Area in FIFA recommended Calculation Grid:



Maximum Change: 12%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

Gradient Graphics (E, Horizontal) for Playing Area in NLC recommended Calculation Grid:



Maximum Change: 21%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

CASE 4:

<u>INTERNATIONAL LEVEL MATCH</u>

Condition: Televised

Playing Area = 105m by 68m

6 Pole System.

Targets to be Achieved according to the national and international standards, NLC & FIFA:

Average Horizontal Illuminance, Eavg = 1500 - 3000 Lux

Average Vertical Illuminance, Ev_{avg} = 1200 - 1800 Lux

Average Camera Vertical Illuminance, Ev_{cam} = 1000 - 1800 Lux

Uniformity, U2
(U2 = Emin\Emax) > 0.5

Uniformity, U0
(U0 = Emin\Eavg) > 0.7

U2 for Camera Vertical Plane = 0.5

U0 for Camera Vertical Plane = 0.7

Glare Rating (GR) < 50

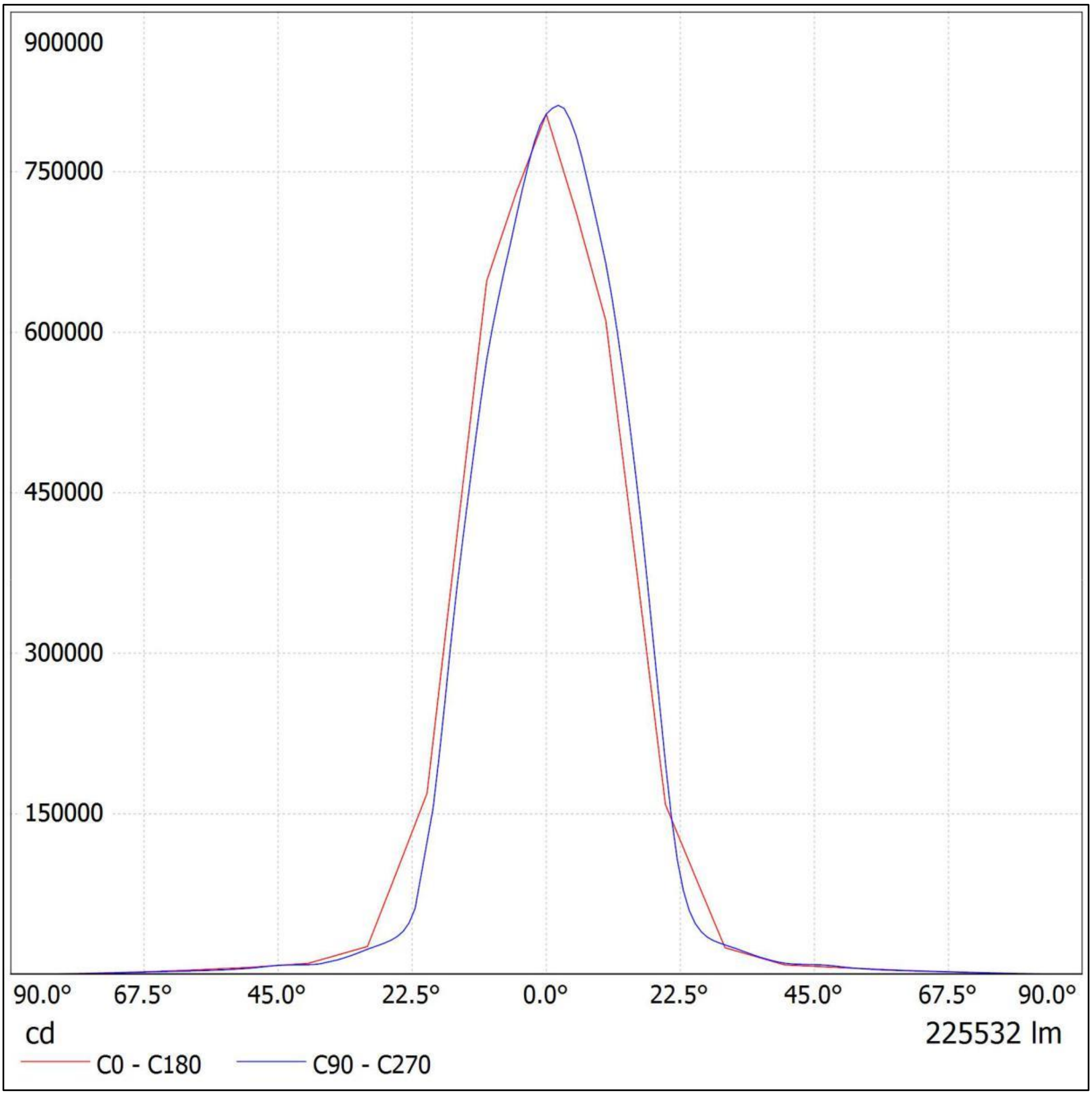
Considered values: -

Maintenance Factor = 0.9
Coefficient of utilization = 0.8

Luminaire Used: SILVERSUN FLM1500FW Flood Light High Mast 30Âº IP65

1500W, 5700K

Lamps: 1 x



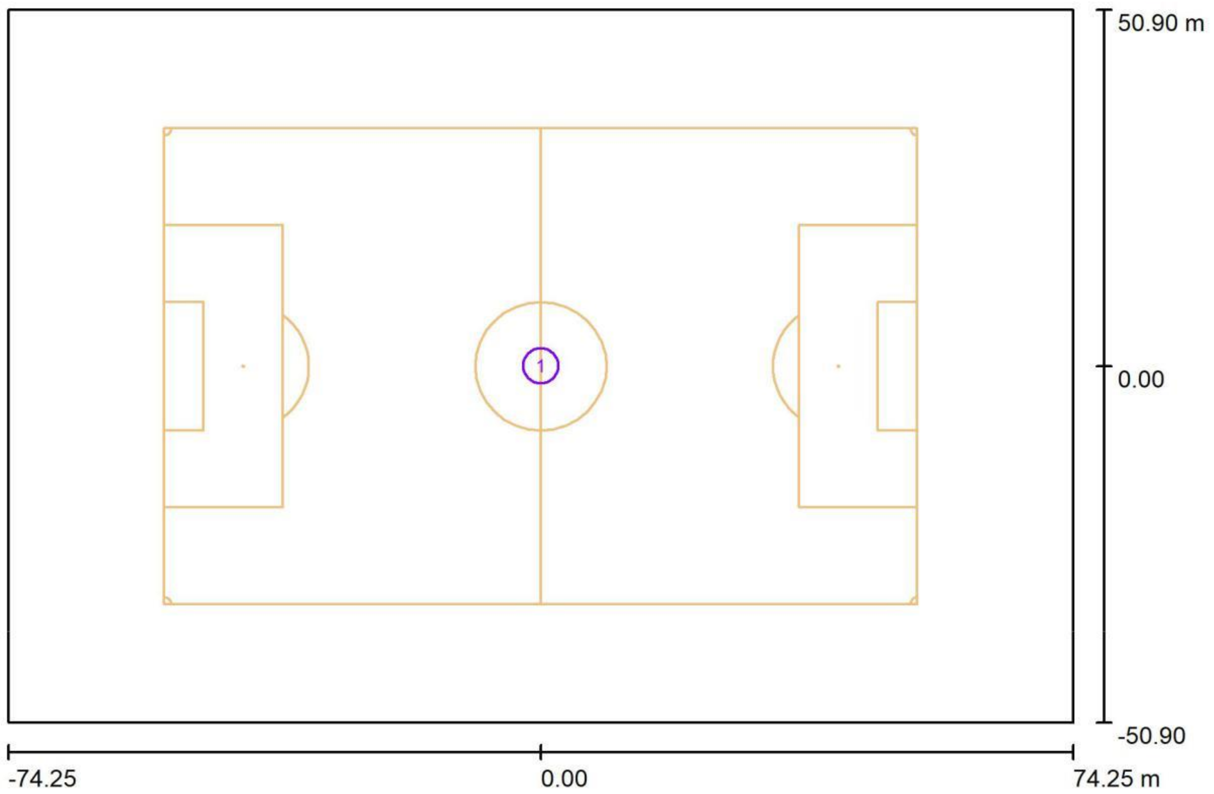
Planning data

Light loss factor: 0.80, ULR (Upward Light Ratio): 3.5%

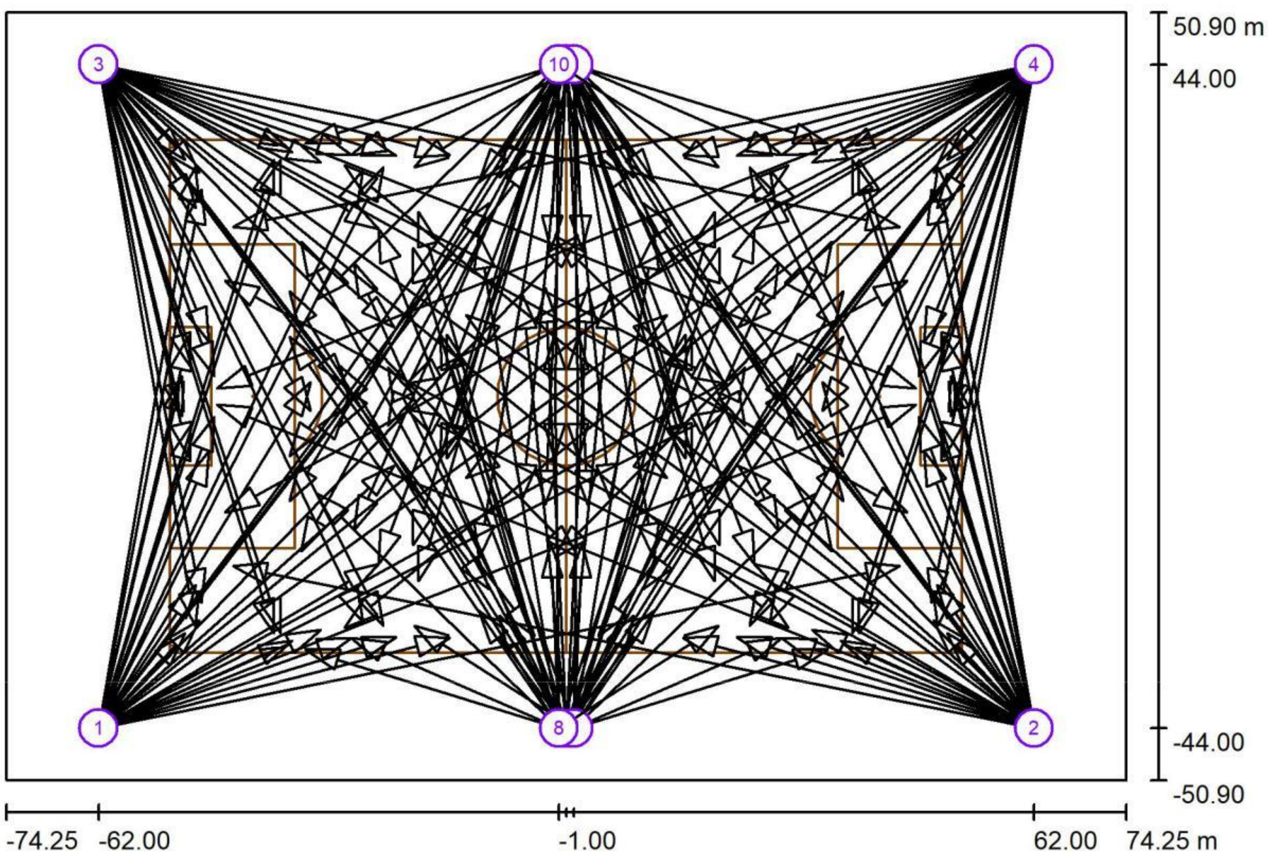
Luminaire Parts List:

No.	Pieces	Designation (Correction Factor)	ϕ (Luminaire) [lm]	ϕ (Lamps) [lm]	P [W]
1	224	SILVERSUN FLM1500FW Flood Light High Mast 30Âº IP65 1500W, 5700K	225532	225532	1530.4
			Total: 50519127	Total: 50519127	Total: 342807.4

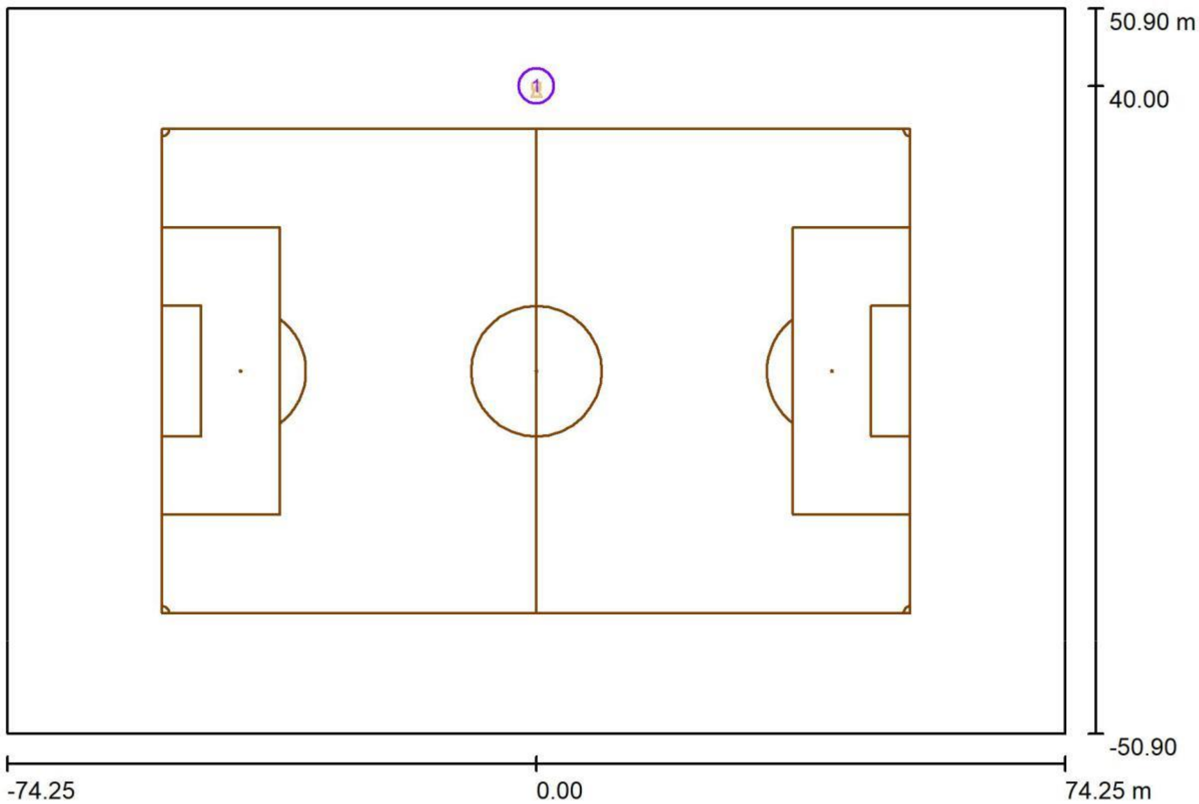
Sport Sites layout plan:



Sports Luminaires Coordinates List:



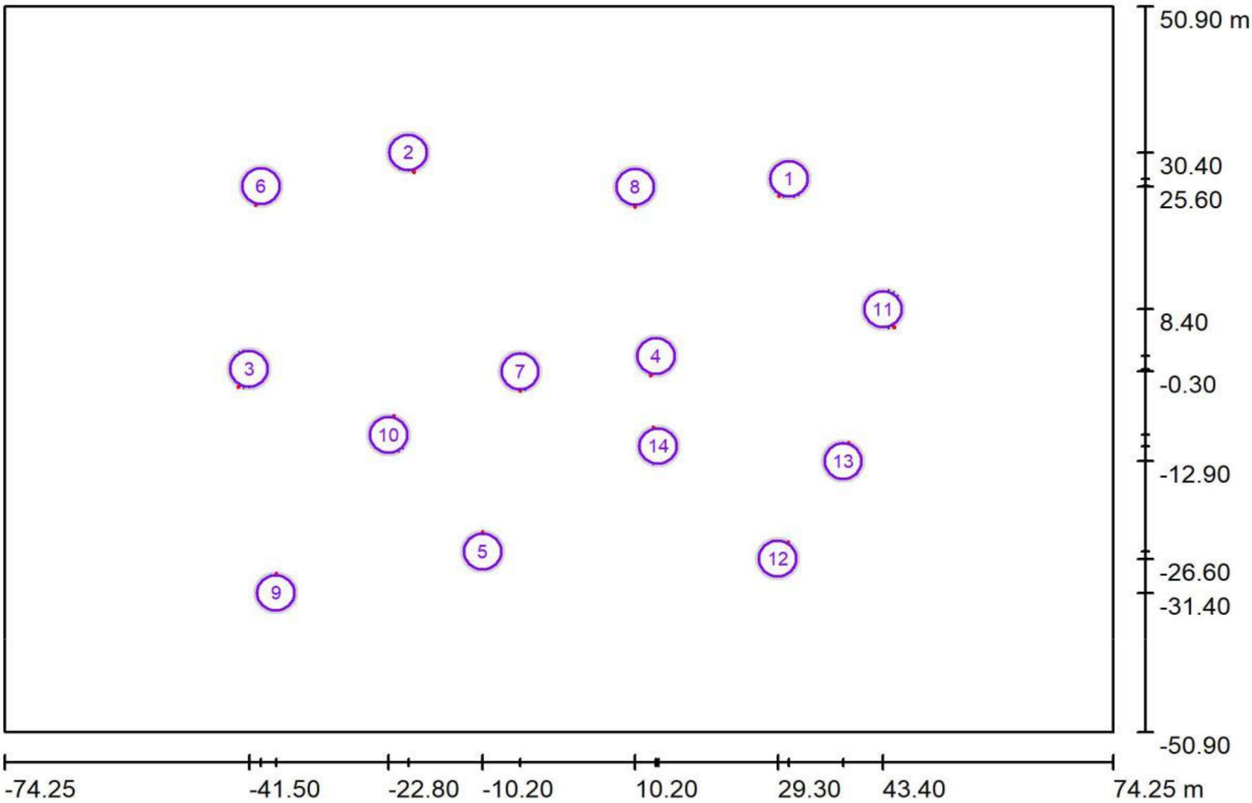
TV Cameras (Coordinates List)



List of the TV Cameras

No.	Designation	Position [m]		
		X	Y	Z
1	TV Camera 1	0.000	40.00	10.000

GR Observer (Results Overview):



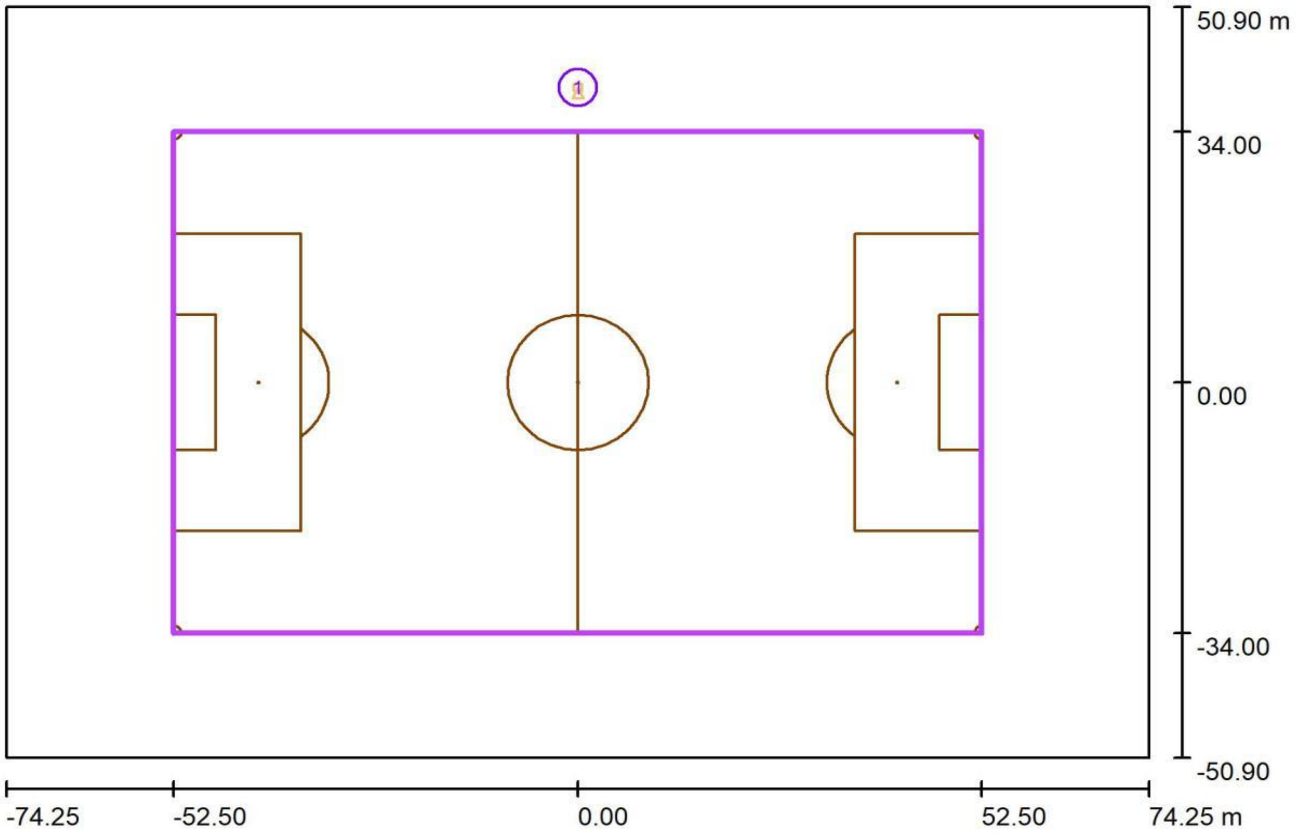
GR Observerlist

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
1	GR Observer 1	30.800	26.700	1.500	0.0	360.0	15.0	-2.0	50 2)
2	GR Observer 2	-20.170	30.400	1.500	0.0	360.0	15.0	-2.0	52 1)
3	GR Observer 3	-41.500	0.000	1.500	0.0	360.0	15.0	-2.0	52 1)
4	GR Observer 4	13.000	1.845	1.500	0.0	360.0	15.0	-2.0	50 1)

No.	Designation	Position [m] X	Y	Z	Viewing sector [°] Start	End	Increment	Slope angle	Max
5	GR Observer 5	-10.200	-25.600	1.500	0.0	360.0	15.0	-2.0	51 1)
6	GR Observer 6	-39.900	25.700	1.500	0.0	360.0	15.0	-2.0	49 1)
7	GR Observer 7	-5.200	-0.300	1.500	0.0	360.0	15.0	-2.0	49 1)
8	GR Observer 8	10.200	25.600	1.500	0.0	360.0	15.0	-2.0	51 1)
9	GR Observer 9	-37.896	-31.400	1.500	0.0	360.0	15.0	-2.0	50 1)
10	GR Observer 10	-22.800	-9.200	1.500	0.0	360.0	15.0	-2.0	50 1)
11	GR Observer 11	43.400	8.400	1.500	0.0	360.0	15.0	-2.0	54 1)
12	GR Observer 12	29.300	-26.600	1.500	0.0	360.0	15.0	-2.0	49 1)
13	GR Observer 13	38.048	-12.900	1.500	0.0	360.0	15.0	-2.0	49 1)
14	GR Observer 14	13.300	-10.800	1.500	0.0	360.0	15.0	-2.0	50 1)

1) The equivalent veil luminance of the environment has been calculated precisely.
2) The calculated equivalent veil luminance of the environment is based on the assumption of a complete diffuse reflection behavior of the environment (acc. EN 12464-2).

Calculation Grid for Playing Area according to FIFA Summary:



Results overview

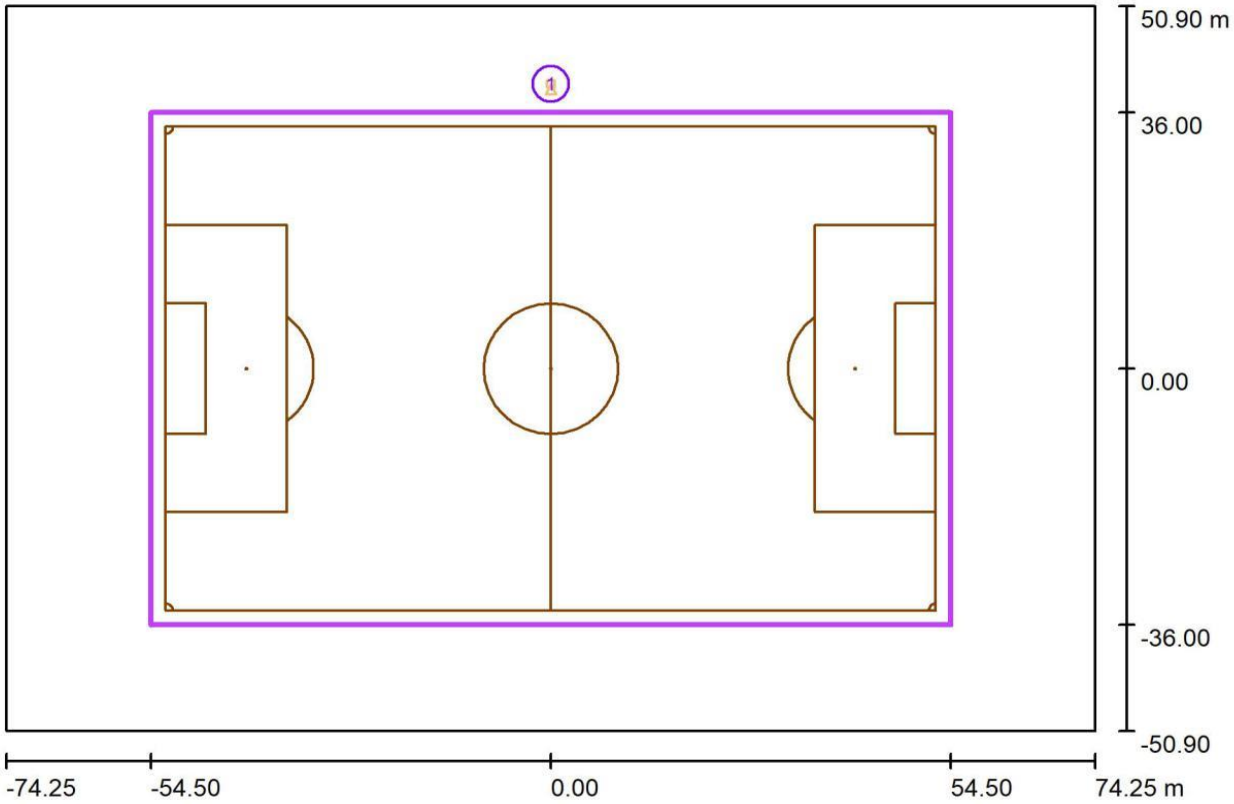
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1884	1569	2324	0.83	0.68	/	0.000	/
2	vertical, 0.0°	1291	687	2118	0.53	0.32	1.46	1.500	/
3	Camera	1645	625	2864	0.38	0.22	1.15	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 12 x 8 Points

Calculation Grid for Total Area according to FIFA Summary:



Results overview

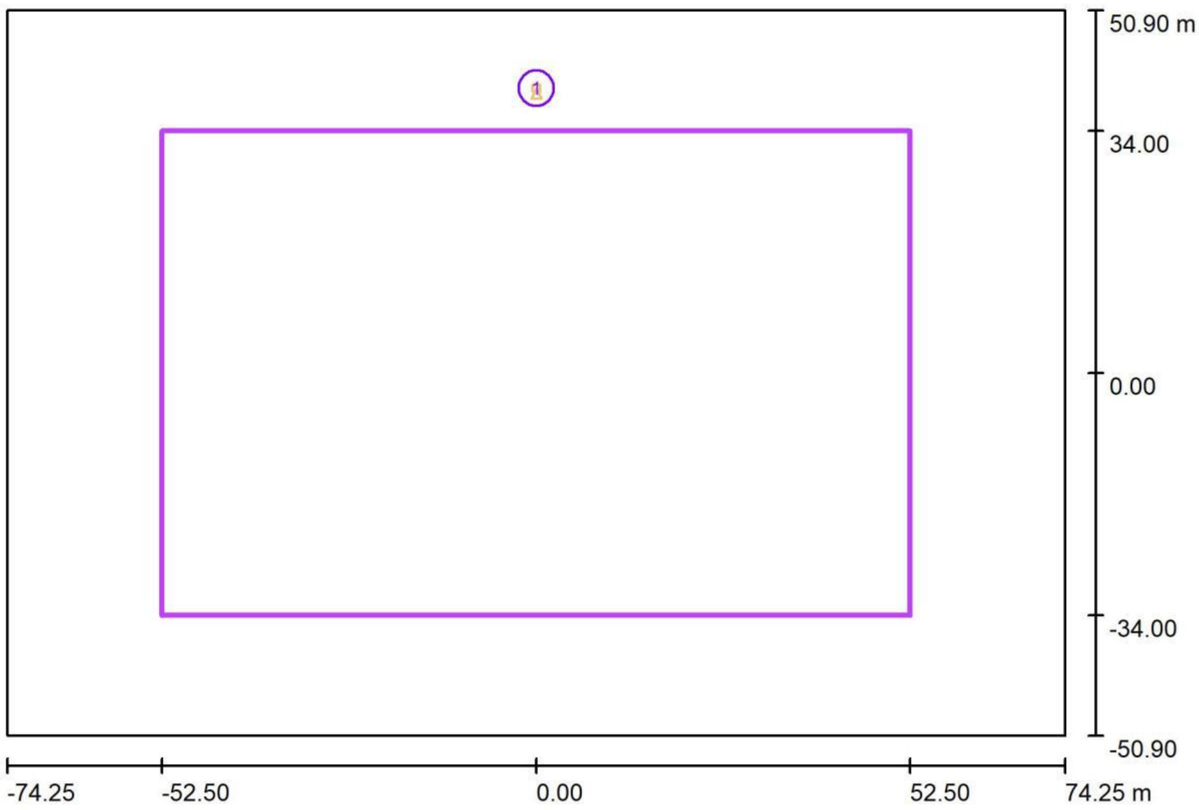
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1921	1410	2328	0.73	0.61	/	0.000	/
2	vertical, 0.0°	1333	708	2126	0.53	0.33	1.44	1.500	/
3	Camera	1710	640	3012	0.37	0.21	1.12	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 21 x 13 Points

Calculation Grid for Playing Area according to NLC Summary:



Results overview

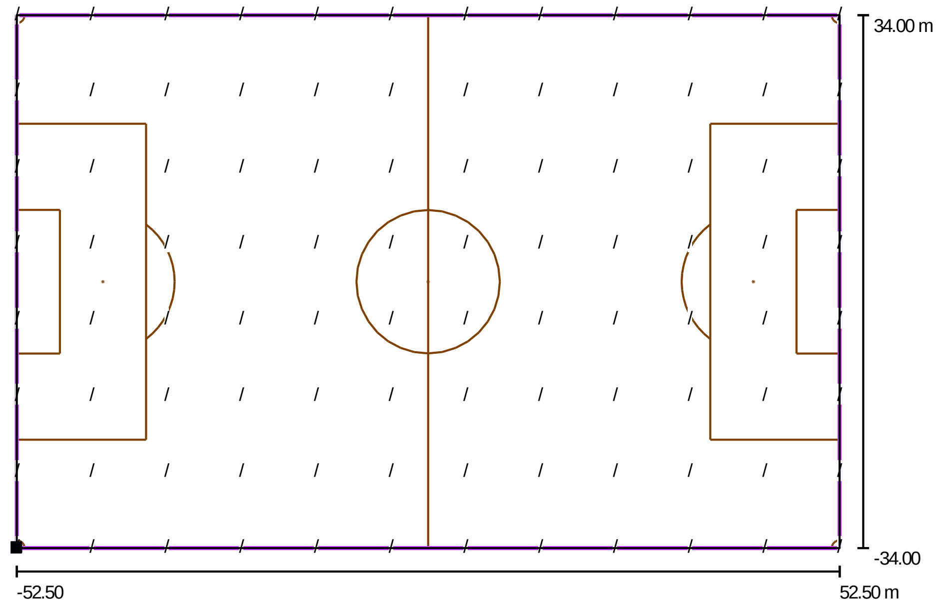
No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	u0	E_{min} / E_{max}	E_{hm} / E_m	H[m]	Camera
1	horizontal	1924	1576	2333	0.82	0.68	/	0.000	/
2	vertical, 0.0°	1331	706	2121	0.53	0.33	1.45	1.500	/
3	Camera	1718	635	2992	0.37	0.21	1.12	1.500	1

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance,

H = Measuring Height

Grid: 22 x 14 Points

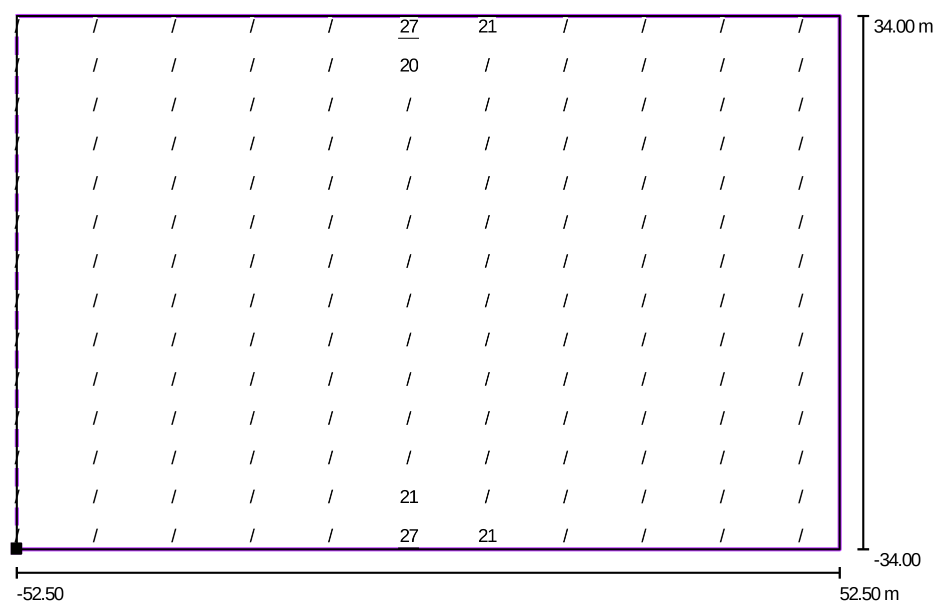
Gradient Graphics (E, Horizontal) for Playing Area in FIFA recommended Calculation Grid:



Maximum Change: 15%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

Gradient Graphics (E, Horizontal) for Playing Area in NLC recommended Calculation Grid:



Maximum Change: 27%

Selected Limit Value: 20% (Values below this limit value are not output.)
Distance for the Gradient Grid: 5.000 m

CHAPTER 5: RESULT ANALYSIS

5.1 INTRODUCTION

Result analysis is a process of interpreting and examining the data obtained from the research, experiment, simulation, and survey to draw the conclusions and insights.

The purpose of analysing is to provide a complete understanding of the data collected, assess its implications, and determine whether the values that we expected is achieved or not.

Analysing the results of the lighting design of a football playground evaluates how effectively the lighting design that we did meets, the desired standards and requirements for visibility, safety, and performance.

In this chapter we will compare the values of all the photometric parameters with the lighting code and standards to see the difference and comment on that.

The parameters which we will have to analyse are given below:

- Horizontal illuminance.
- Vertical illuminance.
- Camera vertical illuminance.
- Uniformity.
- Glare rating.
- Number of grid points in the calculation grid.
- Luminous efficacy of the luminaire used.
- Power consumption of the luminaire.
- ULR (Upward Light Ratio)

5.2 COMPARING AND ANALYZING THE DATA

Dimensions of the area to be illuminated:

Length: 105m

Width: 68m

Number of luminaires required to illuminate this area is approximated by the formulae given below:

$$E = \frac{N \,.\, \phi \,.\, CU \,.\, MF}{Area\ of\ the\ field}$$

Where,

The average horizontal illuminance value is represented by E in Lux. The value of E is mentioned in the standards like FIFA, NLC etc.

Φ is the Lumen output of the luminaire.

CU is the Co-efficient of utilization.

MF is the Maintenance Factor.

Area of the field is 105m × 68m

Details of the luminaire we have used to illuminate the field:

A. SILVERSUN FLC1200FW

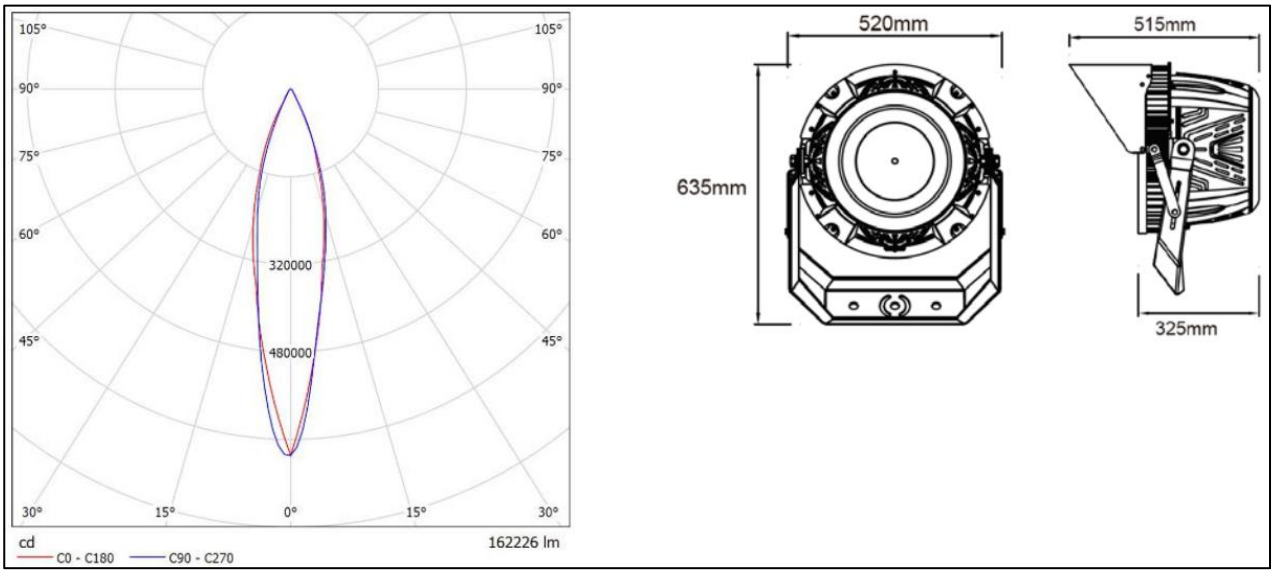


Fig 36. Light distribution and dimension of SILVERSUN FLC1200FW [10 a]

LUMINOUS DATA

Luminous flux	162000 lm
Efficiency	135 lm/W
Colour rendering index CRI	≥70
Colour temperature	5700K

ELECTRICAL DATA

Power	1200W
Rated voltage	100 – 277 V AC
Frequency	50/60Hz
Power factor	≥0.95
Harmonic distortion THD	<20%
Inrush current	13.4A
Max units per MCB C16	1
Dimmable	1-10V

OPTICAL DATA

Beam angle	25°
Diffuser model	Optical Lens
Diffuser material	Polycarbonate

MECANICAL DATA

Body material	Aluminium
Body colour	Black RAL9004
IP protection rate	IP65
IK protection rate	IK10

B. SILVERSUN FLM1500FW

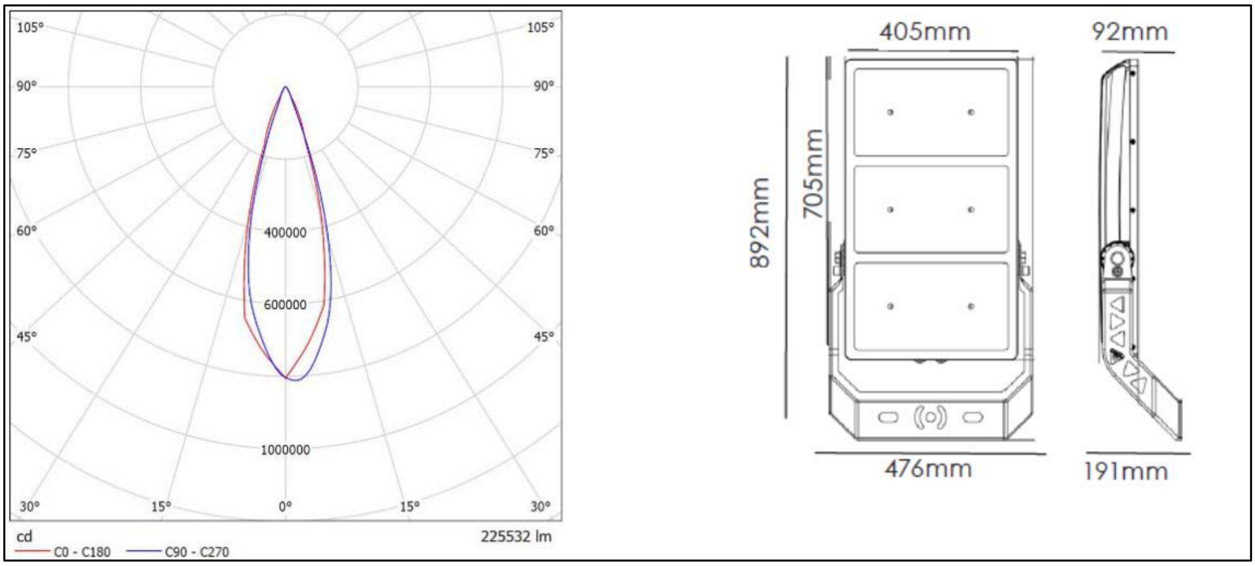


Fig 37. Light distribution and dimension of SILVERSUN FLM1500FW [10 b]

LUMINOUS DATA

Luminous flux	225000 lm
Efficiency	150 lm/W
Colour rendering index CRI	≥70
Colour temperature	5700K

ELECTRICAL DATA

Power	1500W
Rated voltage	100 – 277 V AC
Frequency	50/60Hz
Power factor	≥ 0.95
Harmonic distortion THD	<20%
Inrush current	26A
Max units per MCB C16	1
Dimmable	1-10V

OPTICAL DATA

Beam angle	30°
Diffuser model	Optical Lens
Diffuser material	Polycarbonate

MECANICAL DATA

Body material	Aluminium
Body colour	Grey RAL9004
IP protection rate	IP66
IK protection rate	IK10

CASE 1: PRACTICE LEVEL MATCH

We have used SILVERSUN FLC1200FW luminaire to illuminate the field.

Number of luminaires we will require to illuminate the football playground are:

We know,

Φ = 162000 lumens , E = 500 lux , CU = 0.8 , MF = 0.9 , Area = 105m×68m

Therefore, according to the mathematical expression,

$$E = \frac{N \,.\, \phi \,.\, CU \,.\, MF}{Area\ of\ the\ field}$$

The number of luminaires, N is: 30 (approx.)
According to the design report, I have used 44 number of luminaires to get the mentioned values of the sports lighting parameters.

Difference in number of luminaires used is:

= 44 – 30
= 14

Total power consumed to illuminate the field: 1200 W × 44 = 52800 W

Upward light ratio is 2.5%, which is 64.2% less than the maximum permissible value of 7%.

The comparison:

<table>
<tr><td colspan="9">Target Values and Grid points according to FIFA:</td></tr>
<tr><td>Horizontal illuminance (Lux)</td><td>Vertical illuminance (Lux)</td><td>Camera Vertical illuminance (Lux)</td><td>Uniformity, U2 (Emin\Emax)</td><td>Uniformity, U0 (Emin\Eavg)</td><td>Uniformity, U2 (Emin\Emax) (Camera)</td><td>Uniformity, U0 (Emin\Eavg) (Camera)</td><td>Glare rating</td><td>No. of grid points</td></tr>
<tr><td>500</td><td>NA</td><td>NA</td><td>> 0.3</td><td>> 0.5</td><td>NA</td><td>NA</td><td><50</td><td>40</td></tr>
<tr><td colspan="9">Target Values and Grid points according to NLC:</td></tr>
<tr><td>Horizontal illuminance (Lux)</td><td>Vertical illuminance (Lux)</td><td>Camera Vertical illuminance (Lux)</td><td>Uniformity, U2 (Emin\Emax)</td><td>Uniformity, U0 (Emin\Eavg)</td><td>Uniformity, U2 (Emin\Emax) (Camera)</td><td>Uniformity, U0 (Emin\Eavg) (Camera)</td><td>Glare rating</td><td>No. of grid points</td></tr>
<tr><td>200</td><td>NA</td><td>NA</td><td>NA</td><td>0.6</td><td>NA</td><td>NA</td><td><50</td><td>308</td></tr>
<tr><td colspan="9">Values Achieved after simulating the design:</td></tr>
<tr><td colspan="9">A. According to FIFA prescribed Calculation Grid (9.54m × 9.71m)</td></tr>
<tr><td>Horizontal illuminance (Lux)</td><td>Vertical illuminance (Lux)</td><td>Camera Vertical illuminance (Lux)</td><td>Uniformity, U2 (Emin\Emax)</td><td>Uniformity, U0 (Emin\Eavg)</td><td>Uniformity, U2 (Emin\Emax) (Camera)</td><td>Uniformity, U0 (Emin\Eavg) (Camera)</td><td colspan="2">Glare rating</td></tr>
<tr><td>521</td><td>NA</td><td>NA</td><td>0.7</td><td>0.8</td><td>NA</td><td>NA</td><td colspan="2">Max: 40
Min: 33</td></tr>
<tr><td colspan="9">B. According to NLC prescribed Calculation Grid (5m × 5m)</td></tr>
<tr><td>509</td><td>NA</td><td>NA</td><td>0.53</td><td>0.75</td><td>NA</td><td>NA</td><td colspan="2">Max: 40
Min: 33</td></tr>
<tr><td colspan="9">Percentage Change:</td></tr>
<tr><td>Horizontal illuminance (Lux)</td><td>Vertical illuminance (Lux)</td><td>Camera Vertical illuminance (Lux)</td><td>Uniformity, U2 (Emin\Emax)</td><td>Uniformity, U0 (Emin\Eavg)</td><td>Uniformity, U2 (Emin\Emax) (Camera)</td><td>Uniformity, U0 (Emin\Eavg) (Camera)</td><td colspan="2">Glare rating</td></tr>
<tr><td colspan="9">1. For FIFA (All in Percentage)</td></tr>
<tr><td>4.2 more</td><td>NA</td><td>NA</td><td>57.14 more</td><td>133.34 more</td><td>NA</td><td>NA</td><td colspan="2">Max: 20
Min: 34</td></tr>
<tr><td colspan="9">2. For NLC (All in Percentage)</td></tr>
<tr><td>154.5 more</td><td>NA</td><td>NA</td><td>NA</td><td>25 more</td><td>NA</td><td>NA</td><td colspan="2">Max: 20
Min: 34</td></tr>
</table>

CASE 2: NATIONAL LEVEL MATCH

Condition: Non - Televised

We have used SILVERSUN FLC1200FW luminaire to illuminate the field.

Number of luminaires we will require to illuminate the football playground are:

We know,

Φ = 162000 lumens , E = 700 lux , CU = 0.8 , MF = 0.9 , Area = 105m×68m

Therefore, according to the mathematical expression,

$$E = \frac{N\ .\ \phi\ .\ CU\ .\ MF}{Area\ of\ the\ field}$$

The number of luminaires, N is: 43 (approx.)
According to the design report, I have used 60 number of luminaires to get the mentioned values of the sports lighting parameters.

Difference in number of luminaires used is:

= 60 – 43
= 17

Total power consumed to illuminate the field: 1200 W × 60 = 72000 W

Upward light ratio is 5.5%, which is 21.42% less than the maximum permissible value of 7%.

The comparison:

Target Values and Grid points according to FIFA:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points
500 - 700	350	NA	> 0.3	> 0.6	NA	NA	<50	40
Target Values and Grid points according to NLC:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points
500	NA	NA	NA	0.7	NA	NA	<50	308
Values Achieved after simulating the design:								
A. According to FIFA prescribed Calculation Grid (9.54m × 9.71m)								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	
688	385	NA	0.75	0.86	NA	NA	Max: 49 Min: 45	
B. According to NLC prescribed Calculation Grid (5m × 5m)								
671	NA	NA	NA	0.75	NA	NA	Max: 49 Min: 45	
Percentage Change:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	
1. For FIFA (All in Percentage)								
37.6 more than 500lux	10 more	NA	150 more	43.33 more	NA	NA	Max: 2 Min: 10	
2. For NLC (All in Percentage)								
34.2 more	NA	NA	NA	7.14 more	NA	NA	Max: 2 Min: 10	

CASE 3: NATIONAL LEVEL MATCH

Condition: Televised

We have used SILVERSUN FLC1200FW luminaire to illuminate the field.

Number of luminaires we will require to illuminate the football playground are:

We know,

Φ = 162000 lumens , E = 1000 - 2000 lux , CU = 0.8 , MF = 0.9 ,

Area = 105m×68m

Therefore, according to the mathematical expression,

$$E = \frac{N\ .\ \phi\ .\ CU\ .\ MF}{Area\ of\ the\ field}$$

The number of luminaires, N is: 142 (approx.)

According to the design report, I have used 152 number of luminaires to get the mentioned values of the sports lighting parameters.

Difference in number of luminaires used is:

= 152 – 142
= 10

Total power consumed to illuminate the field: 1200 W × 152 = 182400 W

Upward light ratio is 7.5%, which is 7.14% more than the maximum permissible value of 7%.

The comparison:

Target Values and Grid points according to FIFA:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points
1000 - 2000	1000	1000	> 0.4	> 0.7	0.3	0.6	<50	96
Target Values and Grid points according to NLC:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points
1500 - 3000	1000	1200 - 2200	> 0.4	> 0.7	0.7	0.8	<50	308
Values Achieved after simulating the design:								
A. According to FIFA prescribed Calculation Grid (9.54m × 9.71m)								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	
1296	1070	1237	0.75	0.84	0.40	0.57	Max: 45 Min: 42	
B. According to NLC prescribed Calculation Grid (5m × 5m)								
1330	1101	1287	0.78	0.86	0.41	0.58	Max: 45 Min: 42	
Percentage Change:								
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	
1. For FIFA (All in Percentage)								
29.6 more than 1000lux	7 more	23.7 more	87.5 more	20 more	33.33 more	5 less	Max: 10 Min: 16	
2. For NLC (All in Percentage)								
11.33 less than 1500lux	10.1 more	7.25 more than 1200lux	48.71 more	22.85 more	41.42 less	27.5 less	Max: 10 Min: 16	

CASE 4: INTERNATIONAL LEVEL MATCH

Condition: Televised only

We have used SILVERSUN FLM1500FW luminaire to illuminate the field.

Number of luminaires we will require to illuminate the football playground are:

We know,

Φ = 225000 lumens , E = 1500 - 3000 lux , CU = 0.8 , MF = 0.9 ,

Area = 105m×68m

Therefore, according to the mathematical expression,

$$E = \frac{N\ .\ \phi\ .\ CU\ .\ MF}{Area\ of\ the\ field}$$

The number of luminaires, N is: 133 (approx.)

According to the design report, I have used 224 number of luminaires to get the mentioned values of the sports lighting parameters.

Difference in number of luminaires used is:

= 224 – 133
= 91

The comparison:

Target Values and Grid points according to FIFA:									
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points	
1500 - 3000	1200 - 1800	1000 - 1800	> 0.5	> 0.7	0.5	0.7	<50	96	
Target Values and Grid points according to NLC:									
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating	No. of grid points	
1500 - 3000	1000	1200 - 2200	> 0.4	> 0.7	0.6	0.7	<50	308	
Values Achieved after simulating the design:									
A. According to FIFA prescribed Calculation Grid (9.54m × 9.71m)									
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating		
1884	1291	1645	0.68	0.83	0.22	0.38	Max: 54 Min: 49		
B. According to NLC prescribed Calculation Grid (5m × 5m)									
1924	1331	1718	0.68	0.82	0.21	0.37	Max: 54 Min: 49		
Percentage Change:									
Horizontal illuminance (Lux)	Vertical illuminance (Lux)	Camera Vertical illuminance (Lux)	Uniformity, U2 (Emin\Emax)	Uniformity, U0 (Emin\Eavg)	Uniformity, U2 (Emin\Emax) (Camera)	Uniformity, U0 (Emin\Eavg) (Camera)	Glare rating		
1. For FIFA (All in Percentage)									
25.6 more than 1500lux	7.59 more than 1200lux	64.5 more than 1000lux	30 more	18.57 more	56 less	45.71 less	Max: 8 Min: 2		
2. For NLC (All in Percentage)									
28.27 more than 1500lux	33.1 more	30.15 more than 1200lux	70 more	17.14 more	65 less	47.14 less	Max: 8 Min: 2		

5.3 DESIGN CHALLENGES

The challenges faced by the lighting scheme designers are as follows:

- To achieve adequate illumination throughout the football field, specially in the playing area.
- Designers must ensure that light levels are sufficient for the intended activities such as visibility of the players, football, goal posts, markings in the field and most importantly to provide clear visibility for the broadcasting camera in case of football playground.
- Another important task for the designers is pole positioning, mounting height and aiming of the luminaires. Proper pole positioning and mounting of the luminaires is of utmost importance to achieve proper light level.
- Not only the light level, a designer must ensure uniform light distribution which will help the players and spectators for comfortable viewing and minimize the veiling illuminance so that glare is reduced.
- Lighting system for sports purpose is costly and huge amount of investment is required for this purpose. Hence, the selection of luminaires, number of poles required to install those luminaires and the pole height is very much crucial from the economical point of view. Poles are very much costly as compared to luminaires. Designers always search for luminaires with high luminous efficacy and with high IP ratings.
- The major challenge is to balance energy efficiency i.e. low energy consumption and sustainable luminaires with desired lighting quality. Selecting energy efficient lighting technologies, lighting controls, and optimizing lighting output reduces energy consumption but a designer must ensure that energy saving measures do not compromise visual comfort or the intended design concept.

CONCLUSION

To see and identify anything we need light, light may be the available daylight or the light emitted from the artificial source like a bulb, LEDs that we have developed. Daylight is not available 24 by 7 but in this fast and furious, competitive, modern 21st century we need light to work day and night.

Light plays a crucial role in design and visual performance. It has the power to transform and enhance our perception of spaces, objects, and colors. By using various lighting techniques, different pole placements and light arrangements and lighting control we can optimize the lighting for various condition according to our requirements.

A well-executed lighting system addresses key aspects such as uniform illumination, minimization of glare, and energy efficiency. By implementing advanced technologies and adhering to sports lighting standards, such as those outlined by FIFA, NLC and other relevant guidelines, the lighting can be enhanced.

Furthermore, considering the environmental impact and long-term sustainability of the lighting system is crucial. Integrating energy-efficient solutions, such as LED fixtures and smart control systems, not only reduces operational costs but also aligns with broader sustainability goals.

In conclusion, the design of sports lighting for a football playground is a process that requires a careful balance of technical specifications, safety considerations, and user experience. We know that effective lighting design enhances the playability of the field, ensures player safety, and improves the overall spectator experience. So in this design we have done our level best to ensure all the desires are fulfilled.

Ultimately, a thoughtfully designed sports lighting system contributes significantly to the functionality and appeal of the football playground. It creates a safe and enjoyable environment for players and spectators alike, thereby fostering a positive sports experience. Future developments in lighting technology and design will likely continue to enhance these benefits, paving the way for even more innovative and effective solutions in sports facility illumination.

FUTURE SCOPE

Some developments and upgradations which are possible and those can be done in the upcoming days to enhance the sports lighting:

- Advancements in LED Technology: The continuous evolution of LED technology promises improvements in efficiency, lifespan, and light quality. Future research could focus on optimizing LED systems for dynamic and adaptive lighting, such as varying light intensities based on game conditions or time of the match.
- Smart Lighting Systems: The integration of smart technologies and IoT (Internet of Things) in sports lighting systems can enable real-time monitoring and control. Future developments might include systems that adjust lighting based on weather conditions, player movement, or even crowd density, enhancing both performance and energy efficiency.
- Sustainability and Energy Efficiency: Research shall focus on developing lighting solutions that are not only energy-efficient but also use renewable energy sources such as solar energy. This might include integrating solar-powered lights or exploring new materials with a lower environmental impact.
- Enhanced Light Distribution and Glare Control: Innovations in optical design could further improve light distribution and reduce glare. Future designs might use adaptive optics and more sophisticated control systems to provide constant illumination and at the same time to lower the light pollution by using baffles to arrest spill lights.
- Human-Centric Lighting: The concept of human-centric lighting is very much new. Previously the impact of lighting on human eye and brain was not considered in general, but now we are considering this factor and new luminaires are being developed. Future research could explore how lighting conditions affect players' performance, attention during the game, stress, eye health etc aiming to optimize lighting for better health.

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