SOME STUDIES ON LIGHTING DESIGN OF SPORTS COMPLEX OF AN EDUCATIONAL INSTITUTION

A thesis submitted towards partial fulfilment of the requirements for the degree of

Master of Technology (Illumination Technology and Design)

Submitted by

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of his **M.Tech. (Illumination Technology and Design)** studies during academic session 2019-2022.

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CHAPTER 1

1 Preamble

1.1 History of Sports

History and significance of sports amongst ancient civilizations Sports have been around for centuries, dating back to 776 BC with the first Olympic Games. There is nothing absolutely like the euphoric exciting of a sporting event. Or perhaps, the great sense of attainment, that you gain as a player after slam dunking the final point of the game. Ancient civilizations like the Egyptian, Greeks and Mayans all had a sport they enjoyed taking part in. They were created to bring people together and assist them settle variance or conflicts in a systematic manner. Great leaders of the ancient world saw an interest in sports and made it part of their rule to promote the human's natural competitiveness. Since then, new sports have come up and also new reasons for one to play. New sports develop every day all over the world.

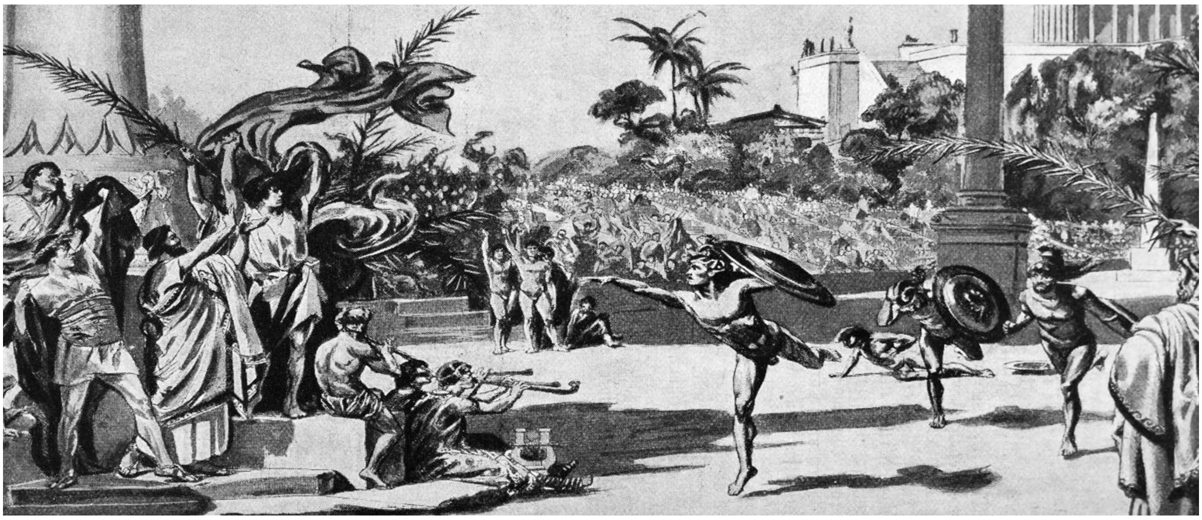


Fig 1.1: Ancient Olympic Games Picture

Sports whip up people to share in a group dynamic, whether they are supporting a team or championing athletes who have reached their maximum potential. Sports highlight everything that makes us human. Our drive, goal, passion, power, and potential to reach eminence. However, if you thought sports was always fun and games, you would be wrong. Back in ancient times sports had a rather important role to play in society and was never intended as a form of entertainment.

Everywhere in social media and magazines you will find images of well known athletes and their achievements. Not much history has been left behind by these famous civilizations except for some cave paintings and stories passed down through generations. However, these sports have helped new ones all over the world flourish and the competitive aspect has been kept intact with some modifications to minimize some of its historical brutality.

Let’s travel back in time and explore the origins of sports so we can discover how it became the cultural phenomenon that it is today.

1.2 Sports Through the Ages

1.2.1 The First Evidence of the Sports in The Society

How long ago do we think the first sports event was held? We might think that sports became an adore part of society in the Victorian Era or perhaps medieval times. After all, we know there was tourney as well as boxing during this time in England. Evidence shows sports existed long before there was even civilization. Ancient cave drawings seem to show sprinting races and wrestling matches that date back over fifteen thousand years. These can be found everywhere from France to Mongolia. We might think that back then, sports were not a popular activity for the masses. But drawings from 7000 BCE portray a wrestling match with a crowd neighbouring it. As such, it’s clear that sports were certainly an overriding part of society before we built villages and cities.

It is unknown exactly why sports became popular during this time. Though it is certainly possible that it was used in some cases as a way to keep fit and avoid predators, and in others as a way to bring social groups together.

1.2.2 The Earliest Sports

Arguably, the earliest sport was wrestling with stone slabs in Japan depicting men in wrestling stances. For instance, one stone slab holds a drawing of a man with another in a tight arm grip. These slabs are believed to date back to around 3000 BCE, and as such, it can be concluded that both wrestling and sprinting sports were prevalent activities during this time.

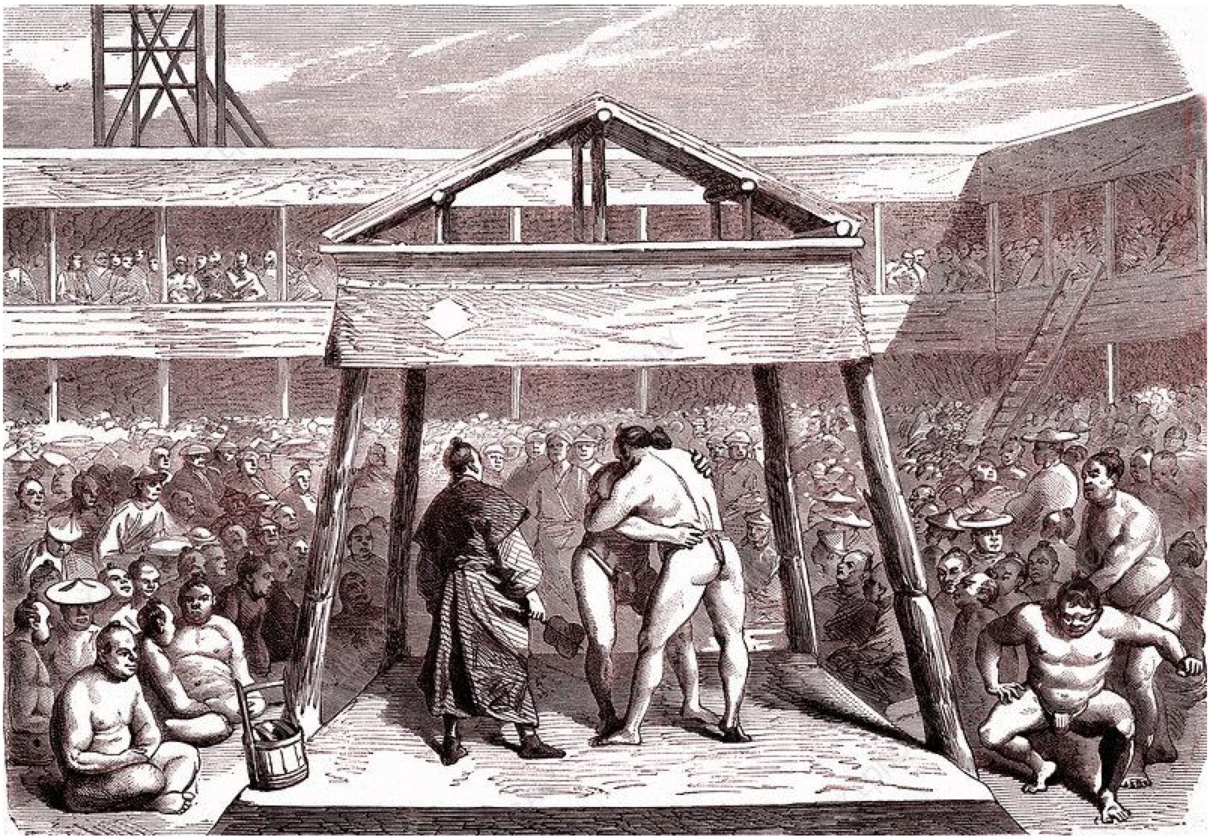


Fig-1.2: Wrestling and Grappling, Japan

In Sumerian civilization, there is evidence of fishing dating back to around the same time, with hooks like those we use today dug up in ancient caves. As such, it’s quite possible that this civilization used to hold tournaments to see how many fish they could catch.

In Egypt, there was evidence of sports dating back to 2000 BCE. Depictions of pharaohs playing many of the sports that we know today have been discovered, including javelin throwing and some form of long jumping. Indeed, many of the sports that we know from the Olympics seem to have been around at that time. Of course, this type of activity was only available for the upper classes of society, and this is one of the ways sports has evolved. Today sports are watched, played and enjoyed by everyone.

Since we mentioned the Olympics, it should not come as a surprise that the earliest evidence of sporting tournaments is found in Greece. Many ancient Greek writings note sports being played and enjoyed, often depicted as something for the wealthy and noble. Since these individuals had no need to perform manual labour, sports might have been their way of keeping fit.

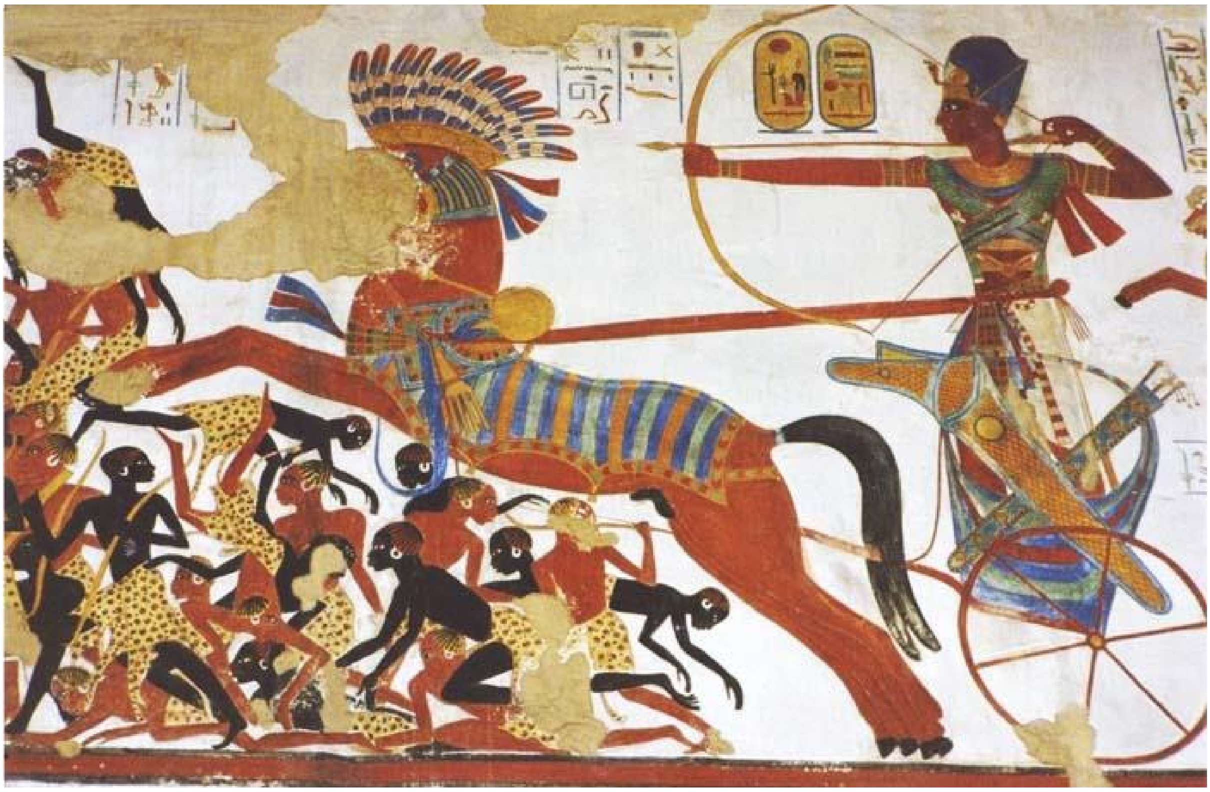


Fig-1.3: Team Sports in Ancient Egypt

1.2.3 The Olympic Games

The Olympic Games were born in 776 BCE, with several sporting events familiar to us, such as javelin throwing, discus throw, and wrestling. Of course, there were others that have long since passed from society including chariot racing. These games lasted until 393 CE, and it is interesting to note that they were not as inclusive as they are today. In fact, only freeborn Greek men could participate, though some women were allowed to participate in certain sports. It is also worth pointing out that, like today, sports in Greece were linked to both religion and patriotism. When you watch a football game, it has become the norm for the game to begin with someone singing the National Anthem, which itself mentions god. Of course, in ancient times the religious aspects of sports were slightly more apparent and distinct. After all, the Olympics originated as a celebration of the Greek god Zeus, and the Greeks gave the tournament a dense mythology.

Today, the Olympics is celebrated all over the world with 200 countries participating. It is amazing to think that this sports celebration has been embedded in society for thousands of years and highlights how important sports are and always have been in society.

1.2.4 Medieval Sports

Through the middle ages, sports became very popular in England, Ireland and many countries throughout Europe. However, these sports were nothing like the ones we play today. Even the early incarnation of soccer was far more violent and bloody. Arguably the most famous sport during this time was jousting. Jousting was another sport played by the nobles and upper class of society. For working-class families, it was all about the ball games, and it is these sports that have generally survived, thrived and evolved to what we know them as today. Though, there were others too, like Horse racing, believed to be particularly popular with the royals. These days, spectators from all walks of life are delighted to line up, watch the races and hopefully earn a buck or two on the winner.

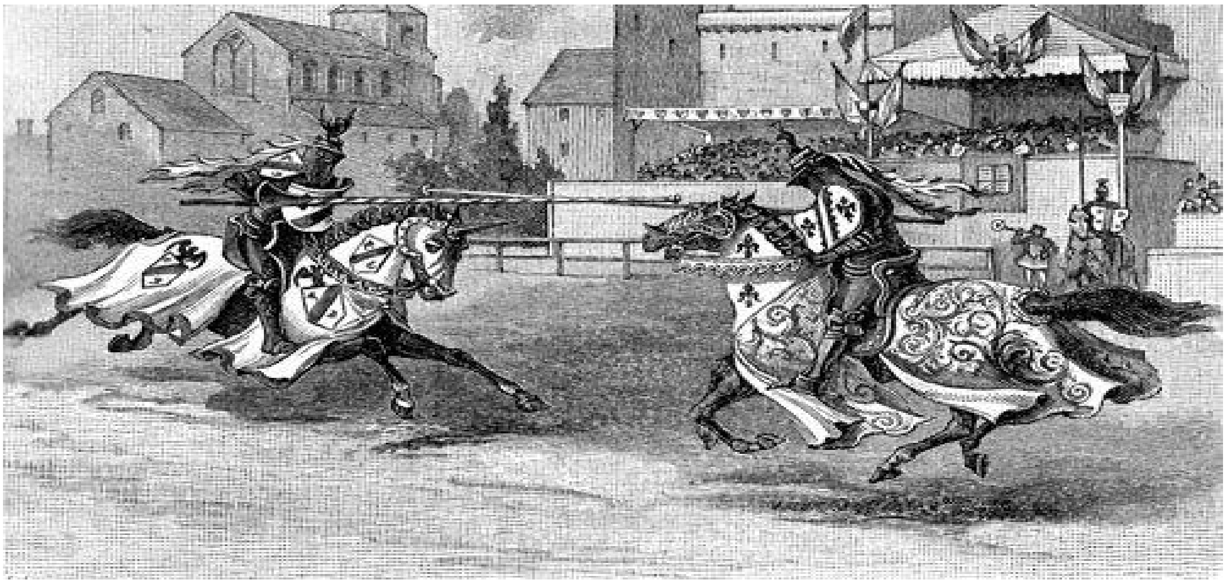


Fig-1.4: Two knights jousting at a tournament, England

1.2.5 The Evolution of Team Sports

We might have noticed that many of the sports that we have mentioned are played by individuals or one on one. Team sports began to become popular far later, and many historians believe western society is responsible for the growth and popularity of team-based sports, including American football. We're going to explore the history of American sports in more detail a little further down.

Indeed, it seems it's the British that is primarily responsible for the spread of team-based sports. During the time of the British empire, sports would develop in Britain and then spread to countries that Britain had claimed. European colonialism has also played a part and helped spread certain team based sports. For instance, it is all but certain to be the reason why cricket is so popular is Australia. In Britain, it's quite possible that the popularity of team-based sports grew from the bans of other forms of entertainment. During Puritan rule, theatres were shut down and restricted. As such, the public turned their attention to sports instead that were still accepted under the puritan rule.

However, that is certainly not the only factor that has played a part in the development and growth of sports as part of society. Dating back to the medieval times, crowds gathered to witness their favourite athletes and cheer for the winners. However, until the industrial revolution, there was no way for these celebrations to spread across the country or indeed the globe. This changed with the invention of the printing press in 1440, and much later the introduction of the radio. Further advancement in machinery and technology ensured that the media could celebrate sports, and pushed the importance of professional athletes and sporting events, helping them reach the level of prestige and honour that they have today.

1.2.6 A Sporting Event That Rocked the World

There have been many sporting events through the ages that have rocked and shaped the world, though, there is one that certainly comes to mind as a defining point in the history of humanity. In December 1914, on Christmas day, in the middle of a War that stretched for miles along the front line, there was a truce. It began with soldiers on both sides of the line singing carols. It evolved into soldiers meeting in the middle for a game of soccer. The Christmas Truce, as it is known, was not the first truce that occurred on the western front, but it is the one that most have heard of. It again highlights the power that sports can have. That even in the middle of a long, painful and devastating war, it can be something that brings people together, even for just a short period.

1.3 Sports in India

The history of sports in India is believed to be 8000 years old, from the time of Indus Valley civilization. Indians were one of the most modern and developed civilizations in the ancient period.

In fact, many historians are still astonished by the civilizations' neat architecture, hygiene, and overall sense of town planning. However, they didn't stop there. many pieces of evidence suggest that the people played an early form of chess and invented dice.

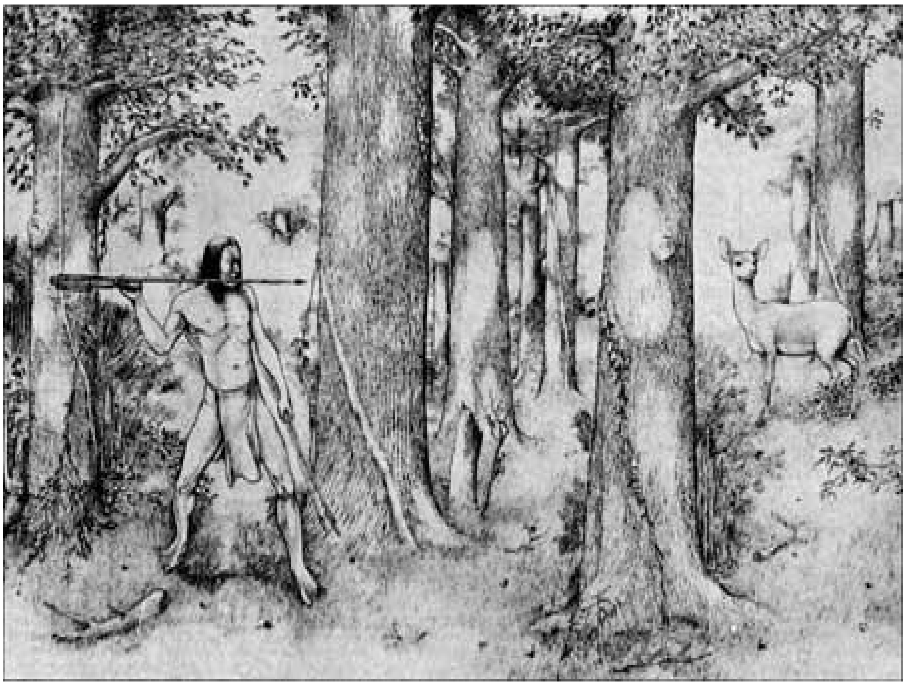


Fig-1.5: Indian Fishing and Hunting

The existence of seals recovered from the sites of Indus valley and other artefacts also proves the fact that hunting and boxing were practiced then.

Around 975 B.C. the love for chariot-racing and wrestling was common in both in India and Greece, where the Olympics was first introduced.

During Vedic India, dehvada or the body-way is defined as "one of the ways to full realization". In times of Rig-Veda, Ramayana, and Mahabharata, the men of stature and circumstance got competent with each other in chariot-racing, archery, horsemanship, military tactics, wrestling, weight-lifting, swimming and hunting.

From the time Indian Vedic history is recorded, the relationship between the Guru (teacher) and his student (hisyo) has been considered an integral part of the history of sports in India.

Sports in India reached new heights when Buddhism came into practice. Tiruvedacharya in Villas Mani describes many fascinating games. They are archery, equitation, hammer-throwing, and chariot-racing.

During Manas Olhas (1135 A.D.), Someshwar writes about Bhrashram (modern-day weight-lifting), Bhramanshram (walking in today's time), and also about Mall-Stambha (the sport of wrestling).

One can easily notice that today's Olympic disciplines are sophisticated versions of ancient games played in India. Chess, wrestling, polo, archery, and hockey (possibly an alter version of polo) are some of the games believed to have originated in India and are a part of the great history of sports in India.

In 1721 AD, a bunch of British sailors decided to play a game of cricket on India's western seaboard, Cambay. Cricket became the first English sport introduced in India.

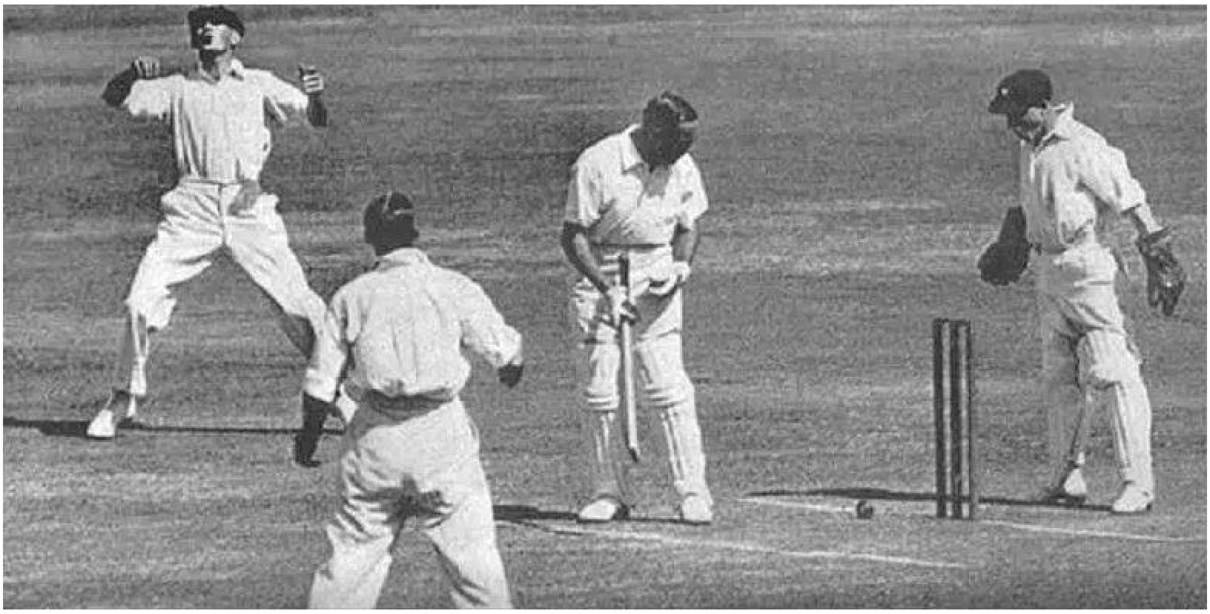


Fig-1.6: Cricket match between India and British in 1721

Our elites used to learn cricket in schools before the independence era and the grassroots audience used to replicate it turning the game into religion now. The game of Polo transformed into a rule-based form in Manipur during the 19th century. Later it found its path to Europe & North America in the 21st century.

Mohan Bagan, the oldest football club, was established in 1889 AD. It grew from strength to strength after 1911 when the Bengal crowd reacted to British jibes in a physical culture movement. This lead to a win in the Indian Football Association final. India has been a world champion at some point in Cricket, Kabaddi, Chess, Hockey, Wrestling, Billiards & Badminton.

1.4 Definition of Sports Lighting

Sports lighting is a type of lighting that is used to illuminate large areas for sports events. Artificial lighting is required when a game is being played after sunset, indoors or in an enclosed environment. The purpose of sports lighting is to provide ample lighting on the playing arena to ensure great visibility for both - the players as well as the audience. A good artificial lighting provides comfortable viewing environment to the players, umpires, referees, media crews, and spectators, as well as those who are enjoying the event telecast.

1.5 A History of Sports Lighting

The very first sports lighting were temporary setups, as it has been the case with any new technology, weren't known for their reliability. At same time, they weren't always used for night hours.

Sports lighting came into existence in England, part of United Kingdom. Now England as it would be known to most, is famous for what is called "British weather" characterized mostly by cloudy skies and occasional rains. In addition, the location of United Kingdom on the globe is closer to the Arctic Circle (though not as close as Scandinavian nations or Russia) than most other countries of Europe, leading to shorter daylight hours and at the same time being scant of daylight. Under such conditions, conducting sports events was a real challenge even at daytime.

One of the measures which were taken to counter the above problem was to incorporate the usage of artificial lights in the stadium, powered by dynamos. The first-ever event to witness such was a game of Polo between two different clubs at Fulham, London in the year 1878. In the same year, similar technique was used for a game of football at Bramall Lane stadium4 at Sheffield, South. Such methods though were new at the time, however weren't reliable ones either; dynamos weren't efficient enough, light levels were unsatisfactory at several times, resulting in the experiment of using artificial light a failure, leading to a halt on the lighting and hence discontinuing of sporting events under bad weather conditions.

Fig-1.7: Highbury Stadium in London, 1951

Sports lighting remained dormant for a long period of time due to inefficient electric devices and non-emergence of high-power lamps. However, it was revived once again in year 1932, in a practice session of Arsenal FC where it was utilized purely on an experimental basis. In 1951, first-ever football match was played under floodlights in the same home ground of Arsenal.

Following this massive breakthrough, usage of floodlights in sports lighting became mainstream. Following this, year 1955 witnessed the football match between England and Spain happen in Wembley Stadium, the first international sporting event under floodlights, and exactly a year later, floodlights became an integral part irrespective of kind and importance of sporting tournaments with incorporating it in Football League.

The year 1984 saw the first ever One Day International (ODI) cricket match held under floodlights at Sydney, and the same year saw India hoisting similarly in Feroze Shah Kotla Ground, New Delhi, between India and Australia.

1.6 A Brief history of sports lighting luminaires

1.6.1 Early Lighting innovations and the first night games

The ancient Olympic Games in Greece marked one of the first official sporting events. But the famous Olympic torch, which dates back to the original Games, did not bring light to the events. Instead, the ceremonial torch reflected the sun's rays with a parabolic mirror. While the fire continued to burn throughout the Games, it provided only symbolic value. Once night fell, competitions ended for the day due to a lack of visibility.

Night games were not possible until much later, after Thomas Edison's invention of the carbon-thread incandescent bulb in 1879. Sports enthusiasts were quick to jump on this new technology and the possibility of playing games under the lights.

But the first baseball game played at night was not a professional competition but a simple, friendly game between employees from two Boston department stores. Just one year after Edison patented his carbon-filament incandescent lamp, these innovators set up three wooden towers equipped with electric lights with the power of 90,000 candles.

These early floodlights lacked the brightness of modern sports lighting, but as the sun set on the night of September 3, 1880, these players made history as the first to play baseball at night, under artificial lights.

Although revolutionary at the time, these incandescent lamps did not emit much more light than the candles they sought to replace, and the teams were forced to play cautiously, with minimal visibility after the sun set.

Fig-1.8: Vintage flood light luminaire

Professional baseball players wouldn't compete at night for another 50 years. In the meantime, both amateur and professional baseball and football teams attempted to incorporate new lighting technology into their games.

The first night football game took place in 1892 but was stopped at the halfway point due to the low visibility provided by the incandescent lights.

In the early 1900s, Irving Langmuir improved Edison's bulb by creating the tungsten-filament incandescent bulb. This lamp was brighter and longer lasting than the carbon-filament bulb, and it made night games feasible for professional teams. Shortly after these tungsten bulbs became available, professional sports teams began to implement artificial lighting in their stadiums.

On November 3, 1929, the NFL incorporated floodlights into its games. Six thousand fans packed into Rhode Island's Kinsley Park Stadium, where the Chicago Cardinals faced off against the Providence Steam Rollers as the sun set. However, because the lights were not bright enough to fully illuminate a brown football, the ball was painted white; the next day, reporters commented that the game resembled two teams of men throwing around a large egg.

By 1930, the Depression was already taking its toll on baseball teams, and many were nearing bankruptcy. Because games took place during the day, they were difficult or impossible for working Americans to attend. Desperate to save his team, J.L. Wilkerson, owner of the Kansas City Monarchs, decided to play games at night so that fans could come after work. Using six 50-foot tall floodlights with electric tungsten filament bulbs, Wilkerson made his idea a reality. Wilkerson managed to triple the attendance of Monarch games that season, though his efforts made him unpopular among the local police force.

The major leagues followed suit soon afterward in 1935 with Cincinnati Reds manager Leland MacPhail's $50,000 investment (equivalent to $850,000 today) in huge floodlights. Before, the Reds attracted a meager 3,000 spectators per game; the team's first night game attracted 20,000 fans.

Less than a decade later, more than half of the MLB teams had installed lights in their stadiums.

1.6.2 Changing the game: stadium lighting powered by metal halide lamps and LEDs

The next innovation in lighting technology that impacted sports was Gilbert Reiling's 1959 invention of the metal-halide lamp, which was released to the public in 1962. These lights offered a more pleasant, neutral color, and were more efficient than incandescent bulbs. In the years after their invention, sports lighting adopted metal-halide lamps into their floodlights to illuminate night games.

Fig- 1.9: 400W Metal Halide

The same year as the release of metal-halide lamps, inventor Nick Holonyak., Jr., created the first LED lights using a red diode. However, white LED lights, invented by using blue diodes, did not come along until 1990.

The years that immediately followed these inventions saw widespread incorporation of floodlights and lighting fixtures in baseball, hockey, football, soccer, tennis and basketball stadiums, as well as racetracks.

If early sports lighting professionals struggled to find lamps that were bright and long lasting, today's experts aim to identify lights that will provide a better viewing experience for fans, align with live broadcast technology and conserve energy while lessening a stadium's carbon footprint.

These developments have been playing out in sports lighting since the 1990 advent of the white LED:

- **1992** – Charlotte Motor Speedway became the first track to install lighting to host night races. Racetrack lighting fixtures must be diffuse and reduce glare on windshields to reduce driver risk.

- **2008** – MLB partnered with the National Resources Defence Council (NRDC) to go green and strive for Leadership in Energy and Environmental Design (LEED) certification by reducing the league's carbon footprint and working toward more sustainable sports arenas.

- **2012** – The Oncenter War Memorial stadium contracted Eaton's Ephesus Lighting, becoming the first professional hockey arena in the United States to install LED lights. LED lights made the stadium brighter, the ice whiter and the colors more vibrant. Forbes reported that the stadium saves 75-85 percent on overall energy costs, with an 87 percent reduction in energy consumption.

- **2015** – The Seattle Mariners became the first MLB team to incorporate LED stadium lighting at Safeco Field.

- **2015** – University of Phoenix Stadium in Glendale, Arizona made history as the first National Football League (NFL) venue to adopt LED lighting from Eaton's Ephesus Lighting. This stadium also served as the host for Superbowl XLIX in 2015, the first football championship played under LED lights.

These teams were among the first to make the switch to LED lights, but they will hardly be the last. Fans and athletes alike can appreciate the increased visibility that LEDs provide. Light from LEDs is brighter, more unfiltered and closer to natural sunlight than metal halide lights and other lighting fixtures. They reduce shadows and glare on the field while providing better, more natural color. Even sports fans watching from home benefit, as LED lights eliminate flicker in high definition broadcasts.

Sports lighting has come a long way since early electric lights, games stopped at halftime due to darkness and footballs painted white for visibility.

Modern lighting innovations have helped changed the games we love by helping ensure we don’t miss a play as we cheer on our favourite teams into the night.

Fig-1.10: LED light

CHAPTER-2

2. Aims & Objective of The Sports Lighting

The function of lighting for sports is primarily to make what is going on highly visible to participants and spectators, without discomfort to either. Sports can be played both outdoors and indoors. Outdoor facilities range from large multi-use stadia to village tennis courts. Indoor facilities range from multi-use sports halls to single-use swimming pools. Some sports, such as football, rugby, cricket, tennis and golf are big business while others, such as archery and curling are specialist interests. Big businesses often depend on sales of television rights for a significant proportion of their income. In such circumstances, the lighting also has to serve the needs of television transmission so that the spectators watching via a screen can see what is going on.

Fig-2.1: New Stadium Lighting

The purpose of sports lighting is to provide lighting that allows a sport to take place safely (i.e. designed to suit the speed of play and size of any objects used in the sport) and provide good viewing conditions, both in visibility of the sports action and comfort of the audience. Points of note are:

- For all sports a good level of modelling is required. Modelling is the effect of light and shadow produced when light flows from one main direction (known as key light) and additional lower levels of lighting flow from other directions (known as fill light), producing a coherent three-dimensional image of a scene. If there is insufficient key light and all the lighting is fill light objects become flat with little discernible detail. If there is insufficient fill light harsh shadowing will occur, obscuring areas in the field of view. Both cases will cause a reduction in the ability of sports participants to correctly see and react to events on the field of play, and will also cause problems for spectators and television cameras.

- For high-speed sports the elimination of any stroboscopic effects from high intensity discharge sources is important. Stroboscopic effects may make a moving object appear stationary, or make the object seem to jump from one position to another. For these sports the use of high frequency control gear is recommended.

- Lighting requirements are defined by EN 12193. Additional requirements may be defined by sports governing bodies such as FIFA, Olympic Delivery Authorities, etc. and by television authorities, such as Sky. Some sports (notably FIFA regulations for football) also define requirements for uniformity gradient (UG). This is measure of the rate of change of illuminance across an area, and is expressed as the ratio between the illuminance levels of two adjacent measurement points. That is

UG =E measurement point 1 / E measurement point 2

- It is essential that players' comfort and performance are not hindered by the pitch illuminance system.
- The ability of match officials to perform effectively should not be hindered by the pitch illuminance system.
- A spectator should be able to watch and enjoy the match without suffering any discomfort caused by the pitch illuminance system.
- The pitch illuminance system should provide a level of illuminance that enables television broadcasters to operate effectively, in line with the requirements set out for the relevant illuminance level.
- The pitch illuminance system must be reliable and effective for the given location. The specific conditions that are relevant for the stadium location should be carefully assessed.
- The pitch illuminance system should provide a long-term solution that is both efficient and cost-effective.

- The environmental impact of a pitch illuminance design solution should be carefully assessed. The design team should be committed to achieving an environmentally responsible solution.
- Every sports stadium is unique. Consequently, each stadium will require a design solution that is appropriate for the relevant stadium and illuminance level.
- The stadium's infrastructure and design will have a significant impact on the type of pitch illuminance system that can be applied. A four-corner tower/column system will not generally meet requirements for illuminance level A stadium.
- Modern artificial lighting systems are able to provide high-quality illuminance conditions on the pitch and may potentially be integrated into the architectural design of the stadium.
- The artificial lighting system may also be used to create lighting effects for stadium events and pre/post-match lighting effects.
- A stadium lighting design should always take account of the latest technological requirements for broadcast television.
- A stadium lighting design should always assess the lighting equipment and technology that is available and consider if it is appropriate for the desired lighting solution

- EN 12193 defines requirements based on the lighting class (I, II, or III). This is derived from the level of competition, international and national, regional, local, training and recreational. At the lower standard of play there is flexibility with the light source options (i.e. high pressure sodium, metal halide) but at class II and III metal halide light sources with high colour rendering abilities are required.

- Each sport has a playing area that is the principal playing area (the area inside the line marking for tennis or football for example) and a total area that is defined as the principal playing area, plus an additional safety outside the principal playing area.

- Lighting levels for sports are normally defined in terms of the minimum average horizontal illuminance on a reference plane, and a uniformity of illuminance. In some instances, the plane of illuminance will be relevant to the sport and the spectator viewing distance, or TV camera-viewing plane. Here the normal to camera illuminance and vertical illuminance will be relevant.

- As some sporting areas are large, have the need for high levels of illuminance or are used for a long period in the day, highly efficient lighting systems are required to keep energy consumption low. Maintenance is also important to ensure system efficiency and functionality and therefore all lighting equipment should be safely accessible and maintainable throughout life.

- When lighting exterior sports facilities to achieve good uniformity lighting equipment must be mounted on masts of sufficient height to ensure floodlight aiming angles are no greater than 70°. This will ensure a high utilisation of lamp flux, minimum electrical load, and lower installed costs. When designing lighting for sports facilities it is important to minimise obtrusive and spill light.

All sports facilities require safety lighting (that is lighting designed to allow safe movement of players and spectators in the event of a power failure or emergency). Relevant guidelines form the sport’s governing bodies should be consulted for this information.

CHAPTER-3

3. Area of the studies

From soccer stadiums to fitness centres – sports and leisure amenities are a big investment, costly to build and costly to run and the soundness of that investment hinges on how much the amenities are used. It takes more than just architectural allure to ensure acceptance, however. Users need to feel comfortable, especially recreational users, most of whom only have time for sport in the evenings, i.e. when it is usually dark. That is where lighting comes in.

Fig-3.1: A typical football ground

Sport is also a popular form of recreation for nonparticipants, as evidenced by the rising spectator figures registered at sporting events and the high viewing ratings of sports broadcasts on television. Here too, lighting is vital. So whether sports and leisure amenities are for indoor or outdoor activities, they need good lighting: for exercise, practice and training, for matches and competitions, for spectator events and television broadcasts. And the lighting needs to be designed with careful attention to detail, taking account of the nature of the sport in question, the speed of players' movements, the size and speed of balls, the position of spectators.

Fig-3.2: View of an illuminated football ground

So it's nice to know that good lighting is not expensive. In both the public and the private sector, sports and leisure facility operating costs are kept low by modern energy-efficient lighting systems. The payback time of such systems is thus short – especially where facilities are well patronised, where they add to the recreational profile of the town or region, where they act as a magnet for tourists.

The illumination needs of the outdoor playing area and the spectator stands are achieved through high mast lighting. The key lighting designing parameters are luminaires quantity and photometry. The quantity of the luminaires for the sports arena is approximated using Lumen Method. Institutions like the Illuminating Engineering Society of North America (IESNA) the International Commission of Illumination (CIE), the British Standard (BIS) are working in close proximity to quantify the illumination levels for sports events to take place safely. Again the independent sports authorities, like Federation Internationale de Football Association (FIFA) are also coming up with minute details regarding lighting for different sports events under different conditions.

The International sports stadium have provisions to host three basic standards of sports events which are segregated according to Classes of Play. There are two Classes of Play where lighting should be matching HDTV covering standards. Whereas another two Classes are non-television category of events. These categories of sports events can also be broadly split into Practice Session, National Event and International Event.

Fig-3.3: A typical tennis stadium

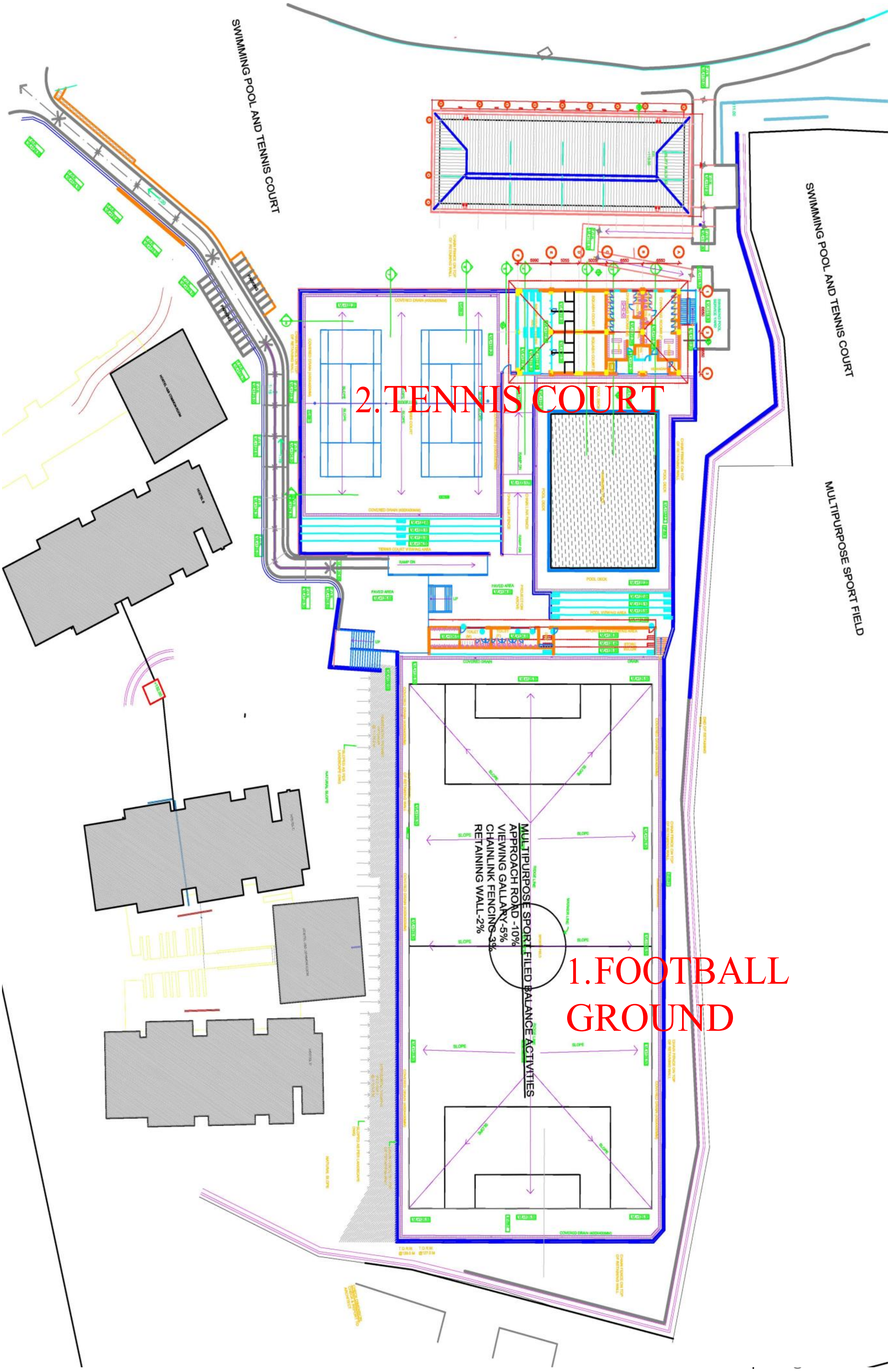
The requirements for lighting are also different for these three different categories of sports activities. International Events require high levels of horizontal and vertical plane illumination across the sports arena. Whereas National sports events can be also of two types depending upon coverage by television. Practice session does not attract any television coverage. In general, it is observed that any sort of television coverage of the sports events requires both horizontal and vertical illumination over the sports arena.

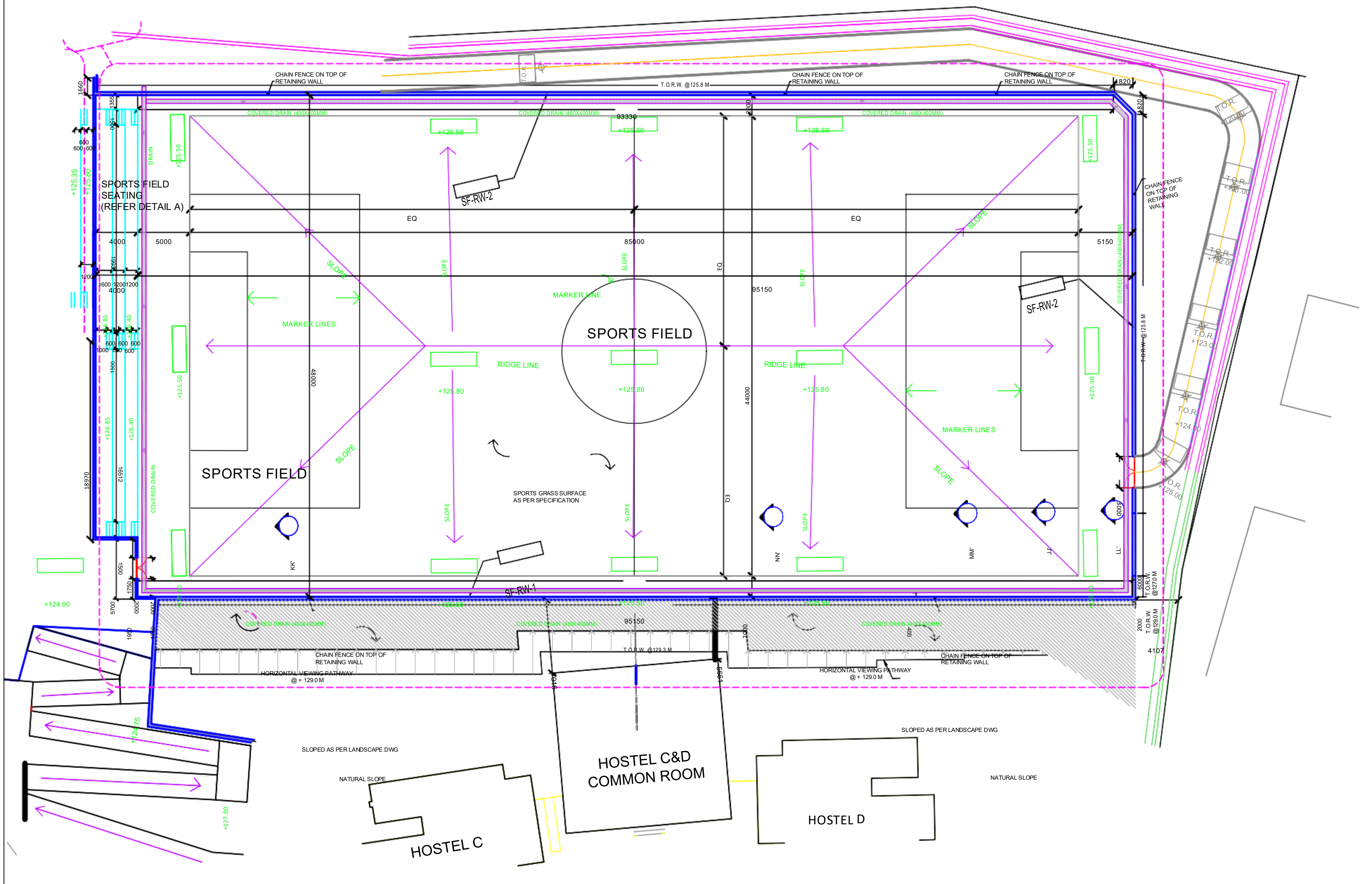
The illumination levels for different sports events are standardized by IESNA and CIE. The Lighting Parameters i.e., the Average Horizontal Illumination, Minimum Horizontal Illumination, Maximum Horizontal Illumination, Horizontal Over all Uniformity, Horizontal Transverse

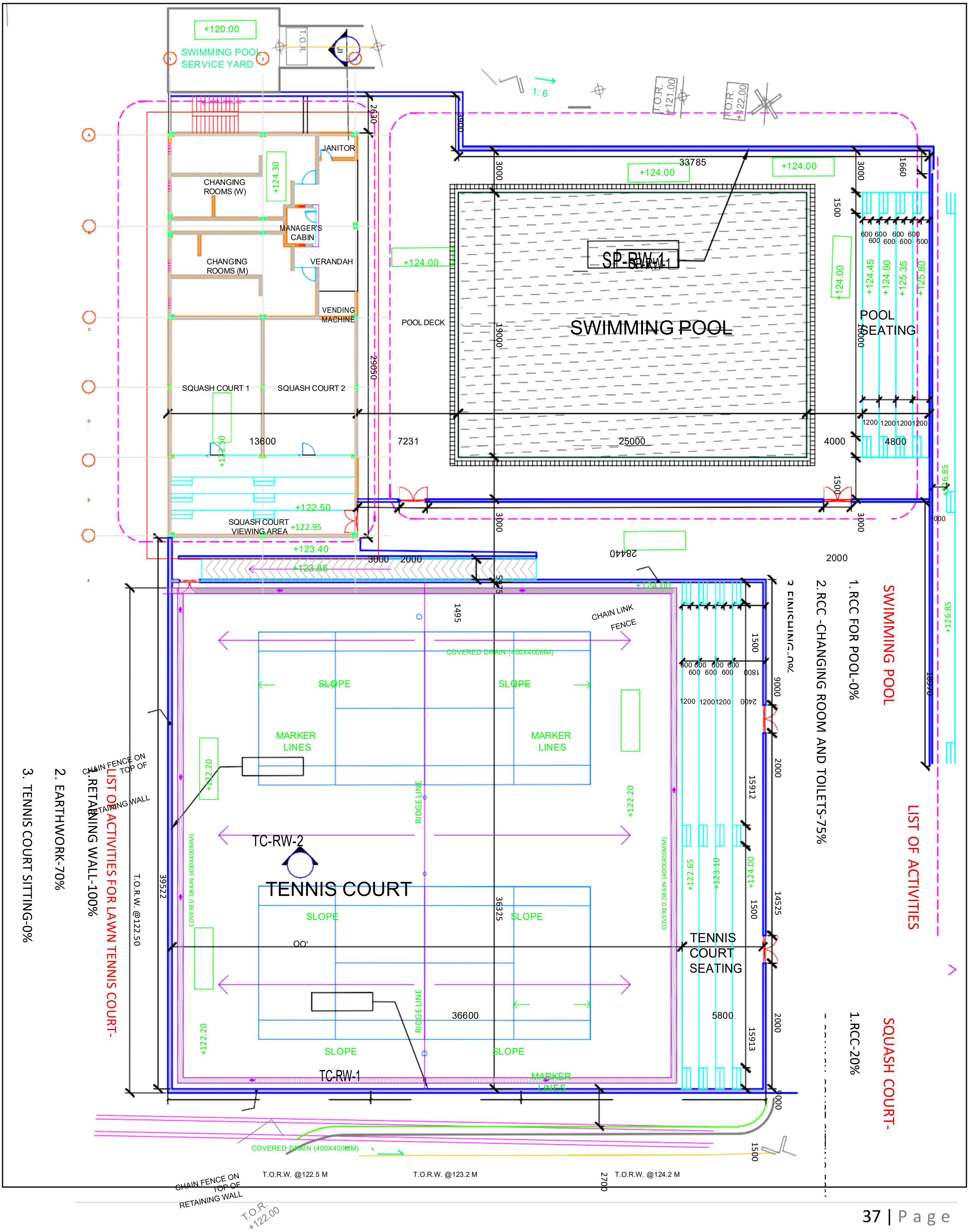
Uniformity, Vertical Overall Uniformity, Vertical Transverse Uniformity values are specified for different sports activities under different Classes of Play.

Thus the key challenge faced by any lighting professional is the selection of the optimum set of horizontal and vertical aiming angles for all the luminaires. This is to ensure that the desired illumination levels either on horizontal plane or both on horizontal and vertical plane across the sports arena are achieved. Good sports lighting designing is about maximum utilization of artificial light sources and uniform distribution of illumination. Sports lighting is to satisfy the needs of the Players and Umpires/Officials, so that they can perform at their best skills and abilities. The lighting ambience should also ensure the Spectators participation and satisfaction. Apart from the spectators' presence at the stadium, there are millions of people watching the games live on their television, miles away from the actual playing arena. Therefore, good quality of image transmission on Television network is an essential aspect of sports lighting to make the viewers feel the real action happening at the venue. The design solutions are also validated through software like CalcuLux, DIALux, AGi32.

In this thesis paper we will discuss the lighting design of Indian Institute of Management (IIM), Calicut Sports Complex. This sports complex has a football ground, a tennis court, a swimming pool and a squash court. The main topics we will discuss here are tennis court lighting and football ground lighting. The main thing to keep in mind while lighting these two places is that the lighting will be for the educational complex. Every stadium has different requirements, may be a stadium is being used to play practice matches, may be that stadium is being built to play matches at the national level, may be that stadium is being built for him to broadcast live on TV. But here we will try to design these two playgrounds for educational sports purpose and the other is for national level matches to be played. A picture has been added below to show where we are designing the lighting of those playgrounds.


SWIMMING POOL AND TENNIS COURT
SWIMMING POOL AND TENNIS COURT
MULTIPURPOSE SPORT FIELD
2.TENNIS COURT
MULTIPURPOSE SPORT FILED BALANCE ACTIVITIES
APPROACH ROAD -10%
VIEWING GALLARY-5%
CHAINLINK FENCING-3%
RETAINING WALL-2%
1.FOOTBALL
GROUND


CHAIN FENCE ON TOP OF RETAINING WALL
T.O.R.W. @125.8 M
COVERED DRAIN (400X400MM)
SPORTS FIELD SEATING (REFER DETAIL A)
SF-RW-2
EQ
85000
93330
95150
5000
5150
4000
48000
44000
MARKER LINE
MARKER LINES
SPORTS FIELD
RIDGE LINE
SLOPE
+125.50
+125.80
SPORTS GRASS SURFACE AS PER SPECIFICATION
SF-RW-1
+124.00
HORIZONTAL VIEWING PATHWAY @ + 129.0 M
SLOPED AS PER LANDSCAPE DWG
NATURAL SLOPE
HOSTEL C&D COMMON ROOM
HOSTEL C
HOSTEL D



LIST OF ACTIVITIES FOR LAWN TENNIS COURT-

1. RETAINING WALL-100%
2. EARTHWORK-70%
3. TENNIS COURT SITTING-0%

LIST OF ACTIVITIES

SWIMMING POOL

1. RCC FOR POOL-0%
2. RCC -CHANGING ROOM AND TOILETS-75%
3. FINISHING-0%

SQUASH COURT-

1. RCC-20%

CHAPTER-4

4. Sports Lighting Parameter & Standard

Now a days Outdoor or Indoor sports are popular as those were never ever before. The number of international sport competitions or events are increasing day by day. Such events are grabbing the attention of every one of all ages. The major international sports events are like Olympic Games, Football World Cup, Commonwealth Games, Cricket World Cup and some other International Championships. These are becoming more and more famous these days. The events involve players, spectators and supports staffs on the ground. The international events like Football or Cricket matches attract more or less than one lakh spectators. Along with obtaining good viewing conditions, the safety security concerns are integrated to manage such events. Sports lighting should provide optimum illumination over the sports arena that allows a sport to take place safely (i.e. level of illumination to cope up with the speed of play and size of playing objects used in the sport) and provide good viewing conditions, both in visibility of the sports action and comfort of the spectators. Henceforth aims are achievement of optimum visibility for participants and spectators (including television) and integration well with the surrounds. Thus sports lighting designing is an engineering problem of achieving predefined horizontal and vertical plane illumination over the playing area by accurately aiming luminaires.

Fig-4.1: Olympics Opening Ceremony

Many cities have large outdoor professional sports venues. It is impossible to mitigate the impact they have on the surrounding areas. The amount and type of illumination are driven by television broadcasting requirements, and glare control of the luminaries is essentially impossible or not effective.

Every outdoor sports played at night requires lighting. That is without exception people need to see the games, as they always have since Roman times, and quality sport lights provide them with optimal visibility regardless of their positions in the stands. Sport lighting also meets the very real need for player safety. The Illuminating Engineering Society of North America (IESNA) has a Sports and Recreational Areas Lighting Committee.

High mast lighting is the efficient way of lighting specially meant for large-scale areas such as airports, dockyards, large industrial areas, shopping centres, car parks and especially outdoor sports arenas as Football, Cricket Stadiums. There is a huge range of applications in outdoor sports lighting designing.

Fig-4.2: FIFA World Cup Stadium

High must equipment are put together for specific combinations of masts and lanterns to meet any lighting requirements. They are provided with a fixed head frame to carry the luminaries, which then have to be maintained by means of a platform decks. The Head Frame contains the luminaires which are used to illuminate the sports arena. The luminaires are arranged in a manner that is appropriate for the type of sports to be played. For example, for football luminaires should not be positioned behind the goal area. The appropriate horizontal and vertical illuminance level needs to be determined in conjunction with the necessary uniformity and glare control. Consider the sports being played and the various normal viewing angles. For example, when players are serving in tennis, they do not want luminaires at the far end of the court to be in their line of vision when they hit the ball. The illuminance is accepted in the practice of sports lighting as quantitative characteristic providing the required visibility level. When the proper luminaires are selected and the lighting system is designed correctly, the sufficient illuminance level in vertical planes is proved as well.

Fig-4.3: T20 World Cup Final at MCG

4.1 Lighting Parameters

Knowing the general user requirements, it is possible to determine the lighting criteria for each of the different level of activity. The purpose of this section therefore is to identify these lighting criteria and, wherever possible, to derive the lighting parameters of interest in each case.

Table-4.1: Classification of Standard

Level of Activity	Class I	Class II	Class III
Inter- and National Competition	•		
Regional Competition	•	•	

Local Competition	•	•	•
Training		•	•
Recreational			•

A great lighting system does more than just illuminate the field of play. Among other things, it also makes stadium visitors generally comfortable in their surroundings and ensures a successful television broadcast for spectators watching at home.

But beyond those simple imperatives, sports lighting is a complex business. International, national, regional, and local competitions all have their different lighting requirements; practice sessions and recreational sports call for different lighting regimes than competitive and professional events do. A sporting facility's capacity and the distances from which spectators are viewing the action also come into play in lighting. This variety of interests explains why the CEN Standards are organized into different so-called classes, classes that happen to be consistent with TV broadcasting standards.

Given the many factors involved in providing excellent lighting at a sporting venue, it might be useful to define the key considerations that sports lighting professionals need to take into account.

4.1.1 Horizontal illuminance

The illuminated playing surface takes up a major part of the field of view for anyone in a sporting venue, whether players, officials or spectators. Horizontal illuminance (Eh) represents the illuminance on this horizontal plane at ground level. It serves primarily to create a stable visual background against which the eye can discern players and objects.

For non-televised lighting classes, an average horizontal illuminance of between 50-100 lux and 750 lux is required, depending on the sport in question and on the lighting class. For televised competitions, the vertical illuminance level is more important than the horizontal illuminance level; to ensure that the television picture has a well-balanced brightness, the ratio between the average vertical and horizontal illuminance should match as closely as possible, but shouldn't exceed a 0.5 to 2 ratio. The horizontal illuminance shouldn't be less than half the vertical illuminance or greater than twice the vertical illuminance.

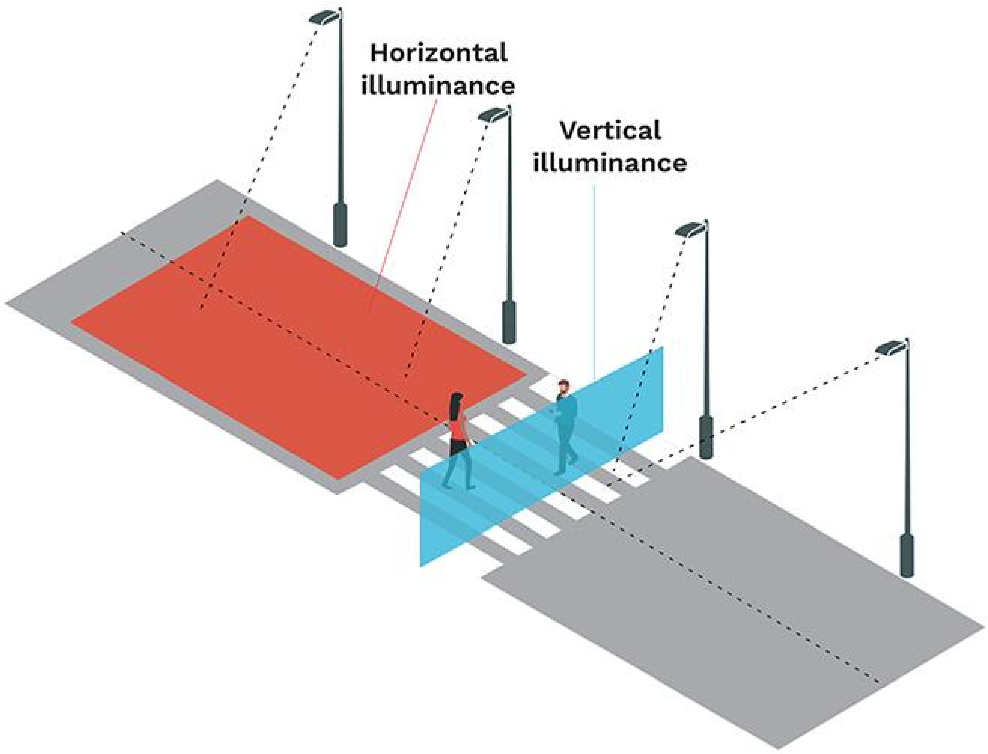


Fig-4.4: Horizontal illuminance & Vertical illuminance

4.1.2 Vertical illuminance

The athletes in any particular sporting event, as well as the ball they're using, can be understood as vertical surfaces. This means that we need to keep vertical illuminance (Ev) primarily in mind when we light them.

To guarantee an optimal view and make it possible for the human eye to identify players from every direction, we should generally measure Ev at a height of 1.5 meters, which corresponds approximately to the faces of the players.

Experience shows that there's an intimate relationship between vertical and horizontal illuminance. For sports with no specific vertical illuminance criteria, vertical illuminance will be sufficient if the required horizontal illuminance is achieved, and if the lighting design rules are followed.

Televised events involve exceptions to this rule of thumb; vertical illuminance has a major influence on the quality of a final television or film picture. Television broadcasting generally calls for an average Ev of between approximately 1000 lux and 2000 lux.

4.1.3 Uniformity

Ensuring uniformity is important in avoiding adaptation problems for both players and spectators. If uniformity is inadequate, certain objects or player details might be difficult to see from certain positions.

Uniformity is expressed as

- the ratio of the lowest to the highest illuminance (U1 = Emin/Emax)
- the ratio of the lowest to the average illuminance (U2 = Emin/Eaverage)

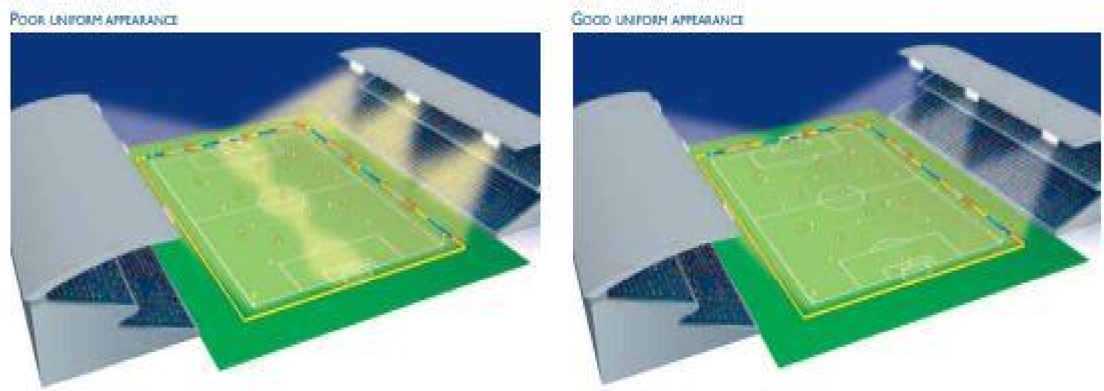


Fig-4.5: Poor Uniformity & Good Uniformity

In non-televised situations, the uniformity of the horizontal illuminance is generally specified as between 0.5 to 0.7 (Emin/Eaverage) depending on sport and lighting class.

In televised situations, high uniformity is necessary for smooth and natural-looking scenes, especially in this era of HDTV; horizontal illuminance is generally 0.8, whereas vertical illuminance in the direction of fixed cameras requires a uniformity value of 0.7 (Emin/Eaverage).

Even when the uniformity ratios as we've defined them are acceptable, changes in illuminance can be disturbing if they happen too quickly. This problem is most likely to arise when a television camera pans. The illuminance uniformity for TV/film coverage at a certain grid point thus has to be expressed as a percentage change from the average adjacent grid points. This is called the uniformity gradient.

A common uniformity gradient value for both horizontal and vertical illuminance in the direction of main cameras of ≤20% on a 4m calculation grid might ensure smooth panning between one area to another.

4.1.4 Glare restriction

Glare is a subjective factor for which CIE has, on the basis of extensive field research, developed a practical evaluation system for use in outdoor sports applications (**CIE 112 : Glare evaluation system for use within outdoor sports and area lighting**).

CIE 112 defines a so-called glare rating factor (GR) ranging from 10 to 90 on the assessment scale. The lower the glare value, the better the glare perception for the players in a sporting event.

A maximum GR value of 50 is generally specified for sports projects.

Fig-4.6: Excessive Glare

4.1.5 Modelling and shadows

Modelling refers to lighting's ability to reveal form and texture. Modelling ability is particularly important in providing a pleasant overall impression of the athletes and objects in the field of play, not to mention of the spectators in the stands. An installation where light comes from only one direction will result in harsh shadows and poor modelling.

4.1.6 Color properties

The color properties of luminaires have two important aspects:

- The color appearance of the light. This is the color impression of the total environment that the light source creates.

- The color rendering properties of the light source used, or the CIE Color Rendering Index (CRI). This describes how faithfully a light source can reproduce a range of colors.

  An indication of a lamp's color appearance can be obtained from its correlated color temperature as measured in degrees Kelvin (K), which vary mainly between 2000 and 6500K. The lower the color temperature, the "warmer" the color impression of the light is; the higher the color temperature, the "cooler" or more bluish the impression of the light is.

  Sports lighting generally requires a color temperature of between 4000 and 6500 K.

  The color rendering properties of a light source can be indicated by its Color Rendering Index, expressed as a numerical value between 0-100. A light source with a CRI of 100 will represent scene colors faithfully, with daylight as the standard of comparison. Color perception is highly relevant in most sports applications.

  While some of the color distortions that artificial lighting causes are acceptable for non-televised activities, TV broadcasting requires highly accurate color rendition.

  The transition from conventional lighting to LED lighting gave rise to a discussion of whether CRI remains the correct color fidelity metric for television broadcasting. It was developed based on the human eye response curve and for a set of pastel colors, and isn't necessarily appropriate for sports broadcast cameras that transmit images rich in saturated colors.

  The European Broadcasting Union (EBU) has developed the Television Lighting Consistency Index (TLCI), which is based on camera response. TLCI is gaining popularity among broadcasters as a color metric specifically designed for their needs. Discussion of this topic is ongoing, but there's a general consideration that it should be easy to get colors right with a TLCI>80.

4.1.7 Flicker

A particular problem for super slow-motion cameras is a 50Hz flicker, due to the phasing of the light.Cameras perceive light level changes due to the uneven ratio between the camera scanning frequency and the alternating amplitude of artificial lights powered by mains frequency.

This effect, which is visible only during slow-motion replay, is called the flicker effect.

Sports federations have started to incorporate a so-called flicker factor into their lighting recommendations. To avoid any visible slow-motion image flicker, a flicker factor of less than 3 percent is recommended.

Fig-4.7 Flicker Free Image & Flicker Image

4.1.8 Safety lighting for participants

European norm **EN 12193:2018 Light and lighting,Sports lighting** is classified in these ICS categories requires that certain sporting events that might prove dangerous to continue in the absence of lighting be suspended to ensure participant safety.

The lighting level for use during the stoppage of an event is a percentage of the level for that class (5 percent or 10 percent*). Safety lighting is to come into play when the general lighting fails and there's a power shortage for at least the period of time that the norm specifies. (This can be 30, 60, or 120 seconds, depending on the sport.)

The sports in question are swimming, indoor gymnastics, indoor and outdoor equestrian sports, speed skating, bobsledding and tobogganing, ski jumping, Alpine skiing, and bicycle racing.

4.1.9 Continuity lighting

Given the capital-intensive nature of professional sports and television coverage, it’s crucial that sports federations or organizing committees ensure an event’s continuity even if a power failure occurs.

It’s therefore a requirement at the majority of professional competitions that a primary power supply disruption automatically trigger a secondary power supply in a way that creates no disruption to the lighting of the field of play.

The main points to consider are these:

- The time delay involved in switching from one power source to another, taking into account luminaires’ re-strike times.

- The need to maintain a lighting level sufficient to maintain broadcasting continuity.

Sports federations or organizing committees usually define these criteria.

4.1.10 Lighting the spectator areas

Adequate horizontal illuminance is key to ensuring spectators’ safety of movement as they enter or leave the stands and other premises.

For safety purposes, and to make it possible for spectators to orient themselves effectively, a stadium must be equipped with an emergency lighting system approved by relevant local authorities for use in the event of a general lighting failure in any part of the stadium to which the public or staff have access.

EN1838 for emergency lighting is relevant here. In addition, European norm EN 12193 recommends a minimum value of 10 lux in the spectator area, to ensure spectator comfort.

4.1.11 Spectator area lighting during TV broadcasts

It can happen that, to suit its production style, a TV broadcaster will specify a spectator-area lighting level as a ratio of the field of play lighting level.

If dedicated luminaires are being used to illuminate areas for spectators, they should have a color temperature that matches as closely as possible the color temperature of the field of play's lighting. The flicker factor should also be similar to that of the field of play's lighting.

4.1.12 Controlling spill light

Stray light from outdoor lighting installations can disturb people in the vicinity: drivers on adjacent roads, for example, and inhabitants of nearby houses. Local authorities or municipalities sometimes maintain their own guidelines on such matters.

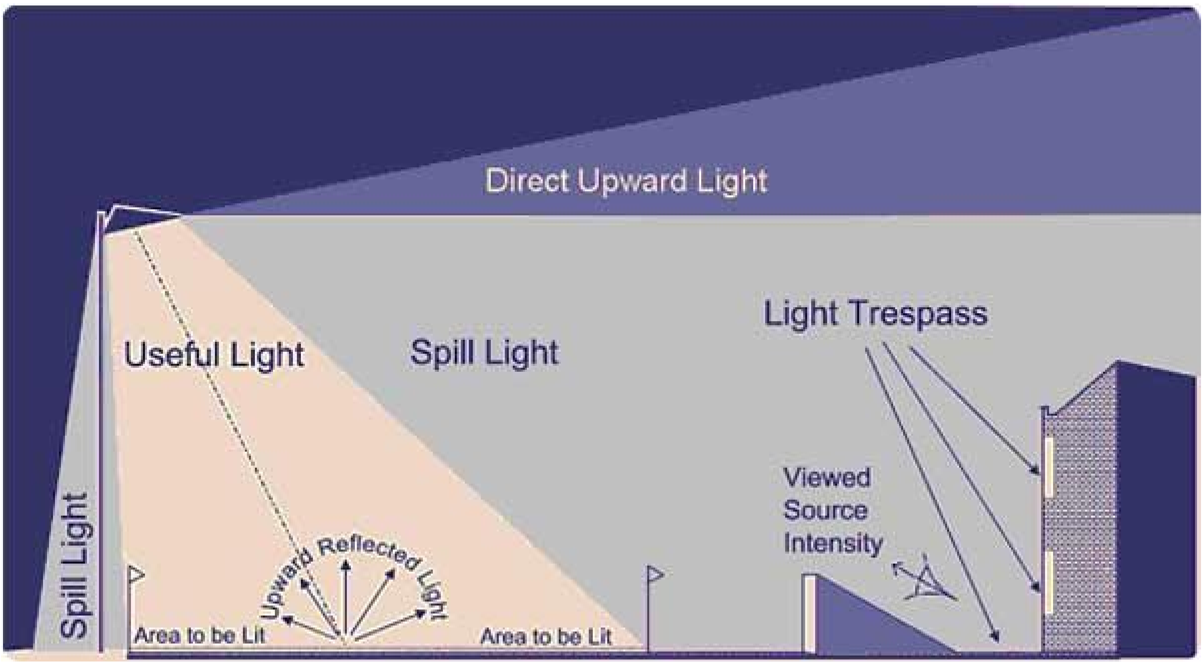


Fig-4.8: Spill light & other light pollution components

Where no guidelines exist, European norm EN 12193 has defined obtrusive light limits based on CIE recommendations. The key criteria here are vertical illuminance on properties, the luminaire intensity in a potentially obtrusive direction of each light source, the quantity of light emitted above the horizontal plane that passes through the centre of the luminaire, and the level of glare that area drivers experience.

4.2 Football Ground Lighting Standard

4.2.1 The football field and its dimensions

According to the stipulations from FIFA a football field should have specific minimum and maximum dimensions:

The length (touch line) has to be minimum 90 metres (100 yds.) and maximum 120 metres (130 yds.).The width (goal line) has to be minimum 45 metres (50 yds.) and maximum 90 metres (100 yds.).

For international matches the rules are somewhat stricter: The length has to be minimum 100 metres and maximum 110 metres.The width has to be minimum 64 metres and maximum 75 metres.

In 1800s, the fields could be up to 100 yards wide and 200 yards long. The boundaries were only marked by flags until 1882 when boundary lines, as well as a halfway line (the centre circle became a standard five years later), on the turf were enforced.

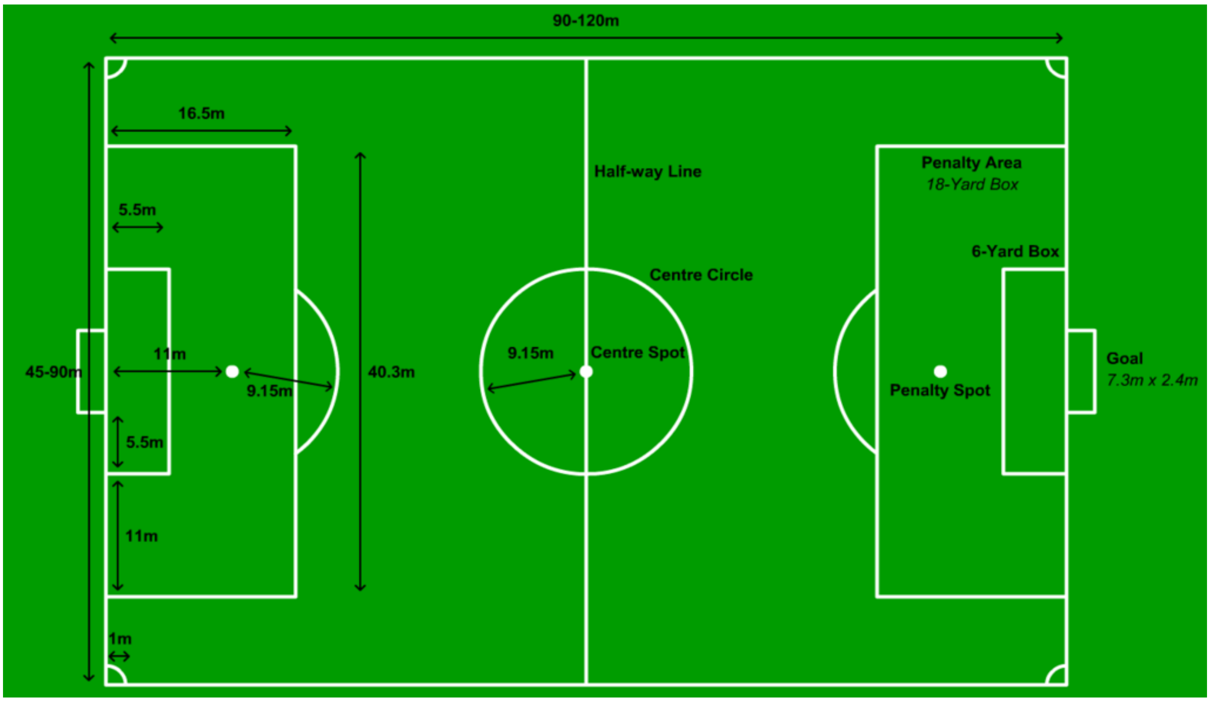


Fig-4.9: Football ground dimension

4.2.2 Sports Lighting Classes

As the competence level of athletes increases so does the speed of the action; the visual task becomes more difficult, requiring more light of a higher quality.

In general, five levels of sporting activity are recognized: international and national competition, regional competition, local competition, training, and recreational. These levels are related to the standards of play and the viewing distances of the spectators. These five levels do not all require the

same quality of lighting. Lower standards are clearly acceptable for recreation than for national competitions. To cover all five activity levels, three lighting classes are defined

- **Class I**: Top-level competition such as national and international matches, which generally involve large spectator capacities with potentially long viewing distances. Top-level training may also be included in this class. National games with about 750 lux horizontal illuminance and 0.7 uniformity**.** This is for professional stadiums for national to international use, ground lux changes >1500 lux**,** uniformity U1 at 0.6, and U2 around 0.8.

- **Class II**: Mid-level competition such as regional or local club matches which generally involve medium-size spectator capacities with medium viewing distances. High-level training may also be included in this class. Used in some leagues and clubs with approximately 500 lux horizontal illuminance and 0.6 uniformity. Football field lighting standard and regulation for semi-professional stadiums.

- **Class III**: Low-level competition such as local or small club matches which do not usually involve spectators. General training and recreation also come into this class. Lowest standard class and is for training and recreation use **200 lux** horizontal illumination and **0.5 uniformity**. Some high school football grounds and high school sports lighting are classified in this lot.

4.2.3 Luminaire mounting positions

The positioning of floodlight luminaires has a huge impact on the pitch illuminance conditions. This is one of the primary concerns when evaluating the design process. The luminaire mounting positions will have a direct impact on the pitch illuminance level and uniformity for all planes. The mounting positions will also have an impact on the creation of player shadows and the visual comfort experienced by players, officials and spectators.

In recent years, architectural requirements and design aesthetics have challenged the previous illuminance design guidelines. New stadiums are often designed and constructed in ways which require the pitch illuminance system to perform to the required standard while also remaining true to the architectural design.

Table-4.2: Luminaire mounting position

	‘Position	Guidance
A	Corners – column/tower floodlight array	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. Multiple luminaires, as used in column or tower installations, should not be placed in this zone.
B	Corners – linear floodlight array	If the installation design requires luminaires to be positioned within 15° of the goal line, the luminaires’ focal point should be outside the penalty area. Luminaires positioned outside the 15° zone may be focused on the penalty area. This is only suitable for linear floodlight arrays.
C	Pitch perimeter – lateral distance to luminaire position	An adequate lateral distance between the luminaire mounting positions and the goal lines and side lines should be maintained in order to achieve the required vertical illuminance level around the perimeter of the pitch.

D	Pitch sides – luminaire mounting zone	The luminaires should be mounted at an angle of no less than 25° and no more than 45° above the centre of the pitch.
E	Pitch perimeter – second linear row	The luminaires should be mounted at an angle of no less than 25° and no more than 45° above the centre of the pitch. In order to achieve improved vertical illuminance around the perimeter of the pitch, it may be necessary to install an additional linear row of luminaires with a greater lateral distance from the pitch.
F	Luminaire focus point angle	In order to avoid discomfort glare being experienced by players and officials, a general rule during the design process is to ensure that luminaires' focus point angle is less than 70° from the line perpendicular to the pitch.
G	Pitch sides – luminaire mounting positions	Stadium structures should not impede the luminous flux of the pitch lighting system and cause shadows to be cast on the pitch.
H	Behind penalty area – luminaire mounting zone	To maintain good visual conditions both for attacking players in front of the goal and for the goalkeeper, luminaires should be mounted more than 60° from the goal line when in line with the penalty area.
I	Behind penalty area – luminaire mounting zone	Luminaires positioned behind the goal and parallel to the penalty area should be mounted greater than 60° from the goal line.
J	Behind goal line – second linear row	An adequate lateral distance between the luminaire mounting position and the goal lines should be maintained in order to achieve the required vertical illuminance level around the perimeter of the pitch. In some cases, a second linear run of luminaires may be installed under a stadium roof canopy to assist in this area.

Diagrams of design guidelines

A. Corners – column/tower floodlight array

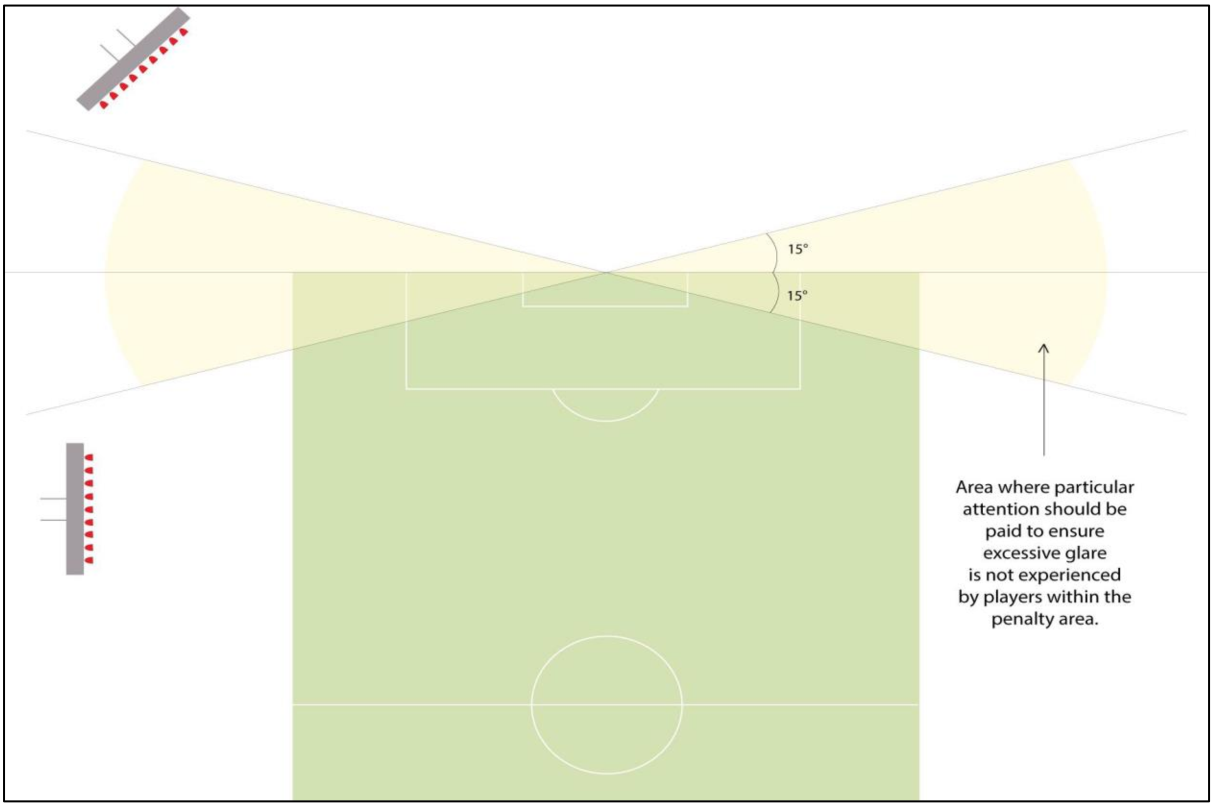


Fig-4.10: Corners column/tower floodlight array

When pitch illuminance is provided by means of corner columns or towers with multiple luminaires in a group (as is generally seen in columns and towers), the luminaires should not be mounted within 15° of either side of the goal line (see diagram above).

Large multiple arrays of luminaires provide greater levels of discomfort glare and should not, therefore, be positioned in these areas. A consecutive line of luminaires with more than two rows is considered, for this purpose, to be a 'large multiple array'.

B. Corners – linear floodlight array

As regards players in the penalty area, the discomfort glare produced by a linear run of luminaires is considered to be within an acceptable level if the luminaires' focus points are such that players can stand in the penalty area and look towards the corners without hindrance.

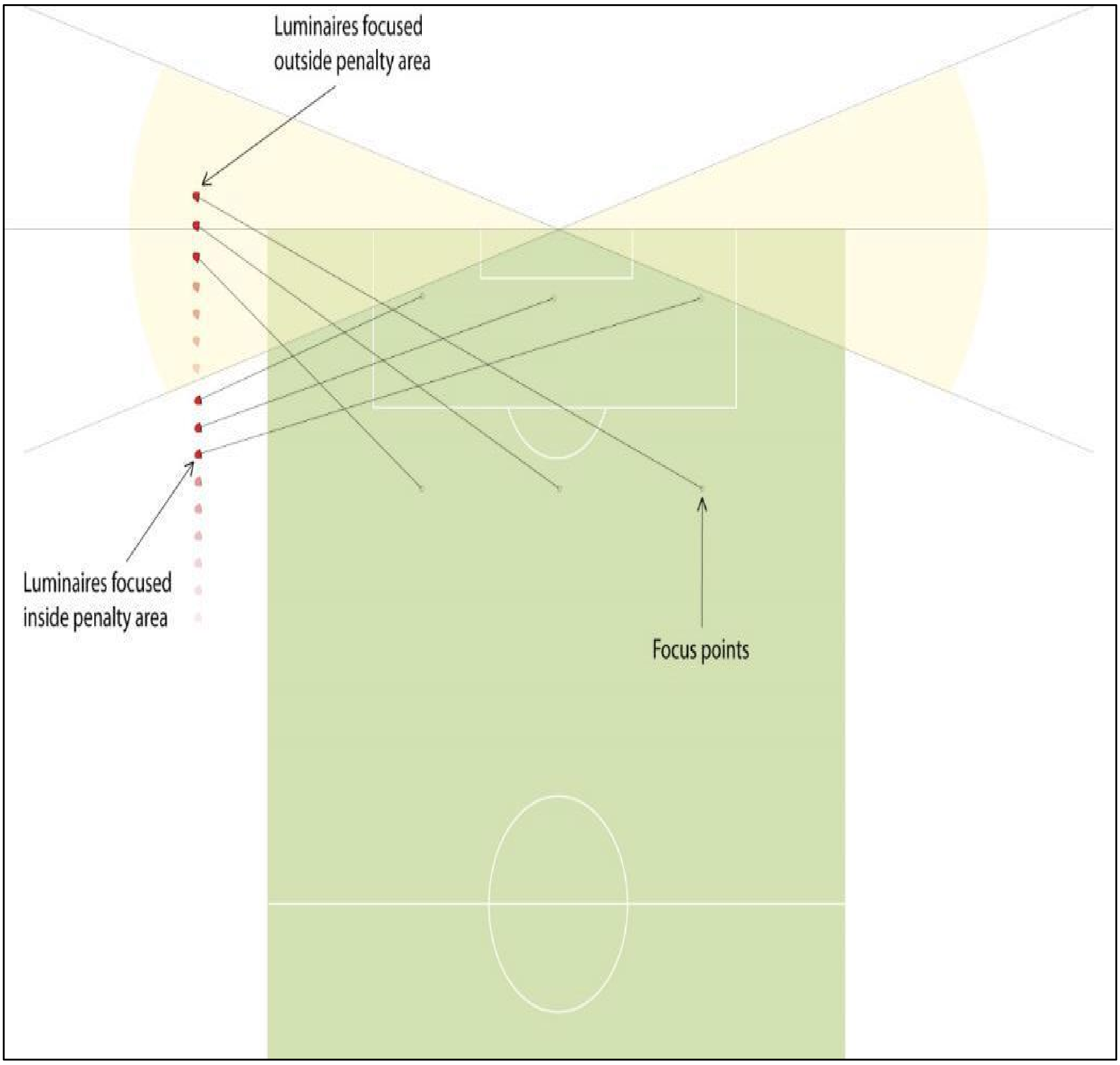
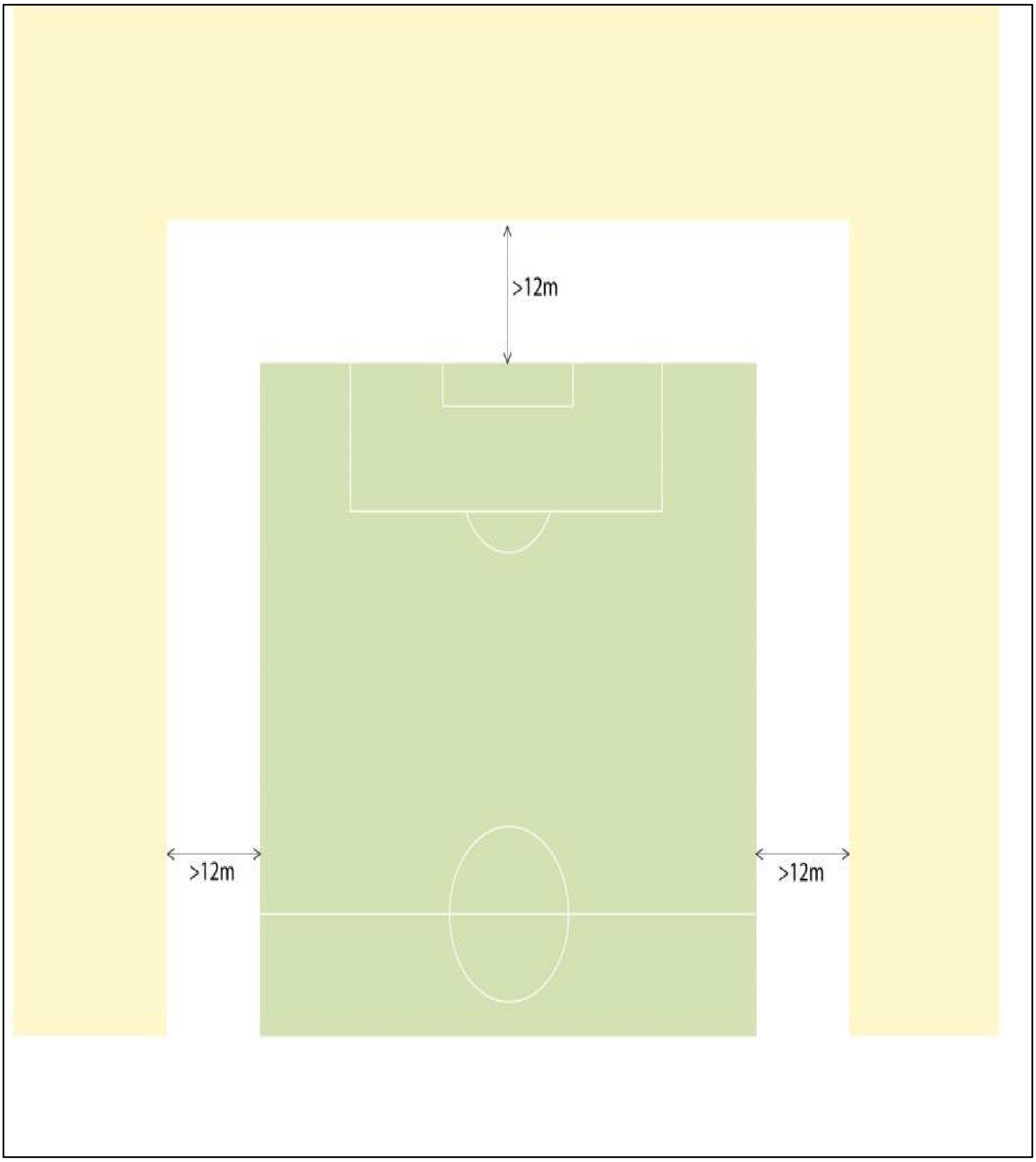


Fig-4.11: Corners linear floodlight array

Luminaires mounted within 15° of the goal line should be focused away from the penalty box, as indicated in the diagram above.
Multiple arrays of luminaires should not be positioned within 15° of either side of the goal line.
A linear array of luminaires used for this purpose should not comprise more than two rows.

C. Pitch perimeter – lateral distance

In order to achieve the required vertical illuminance around the perimeter of the pitch, the luminaires should have a mounting position with a minimum



lateral distance from the pitch perimeter of greater than12m.

Fig-4.12: Pitch perimeter – lateral distance

D. Pitch perimeter – luminaire mounting zone

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

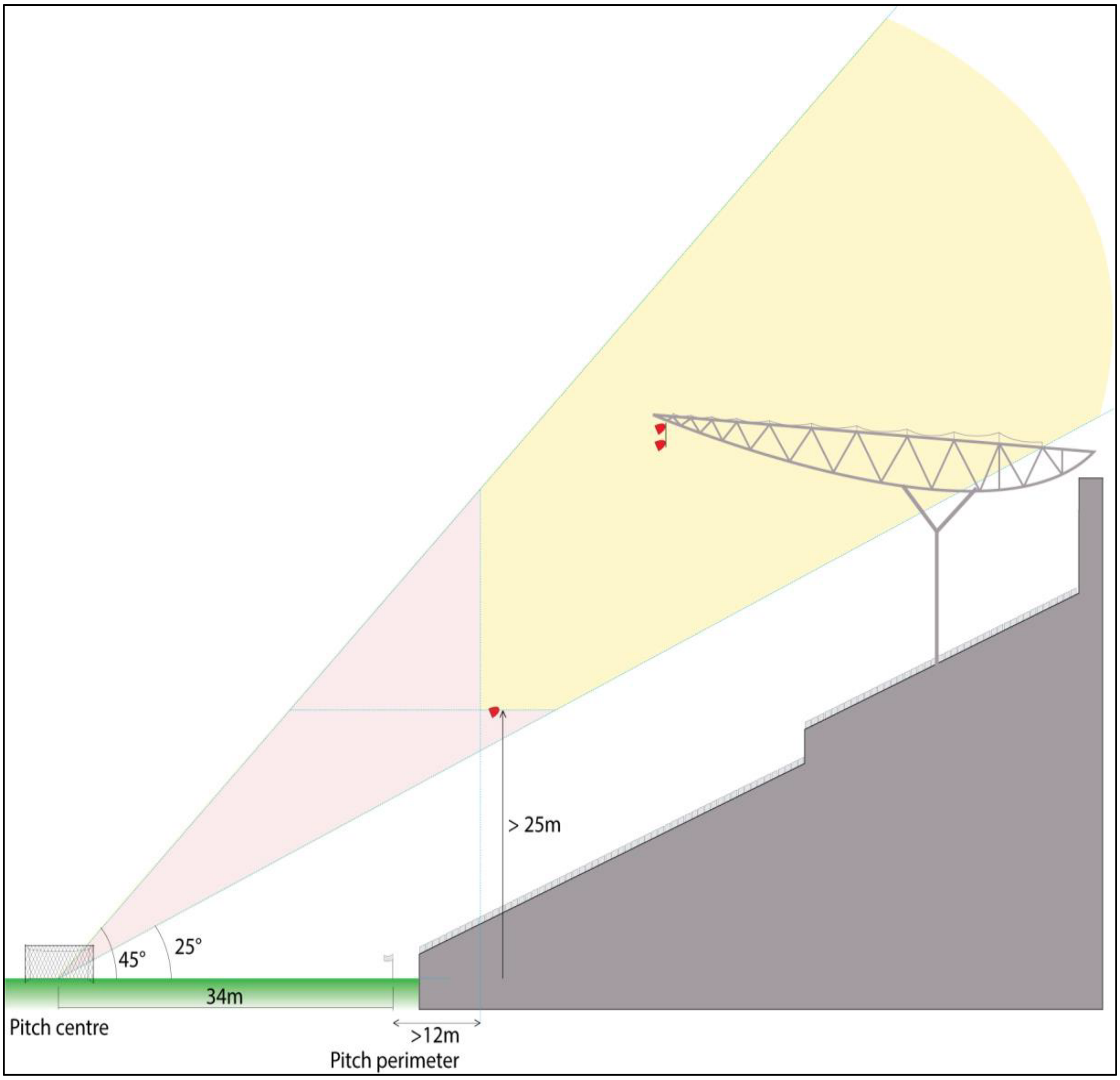


Fig-4.13: Pitch perimeter – luminaire mounting zone

This will generally ensure that illuminance conditions comply with UEFA's guidelines.

If possible, luminaires should be mounted at least 20–25m above the surface of the pitch. If this is not possible, it is important to develop a design solution that considers the implications of that reduced height and takes it into account.

One way to ensure that players' discomfort glare is kept below 50 is to limit the angle of a floodlight's tilt to 70°. However, the structural design of some stadiums may make this impossible. In all glare rating evaluations, evidence should be provided of how the glare rating is kept below 50.

E. Pitch perimeter – second linear row

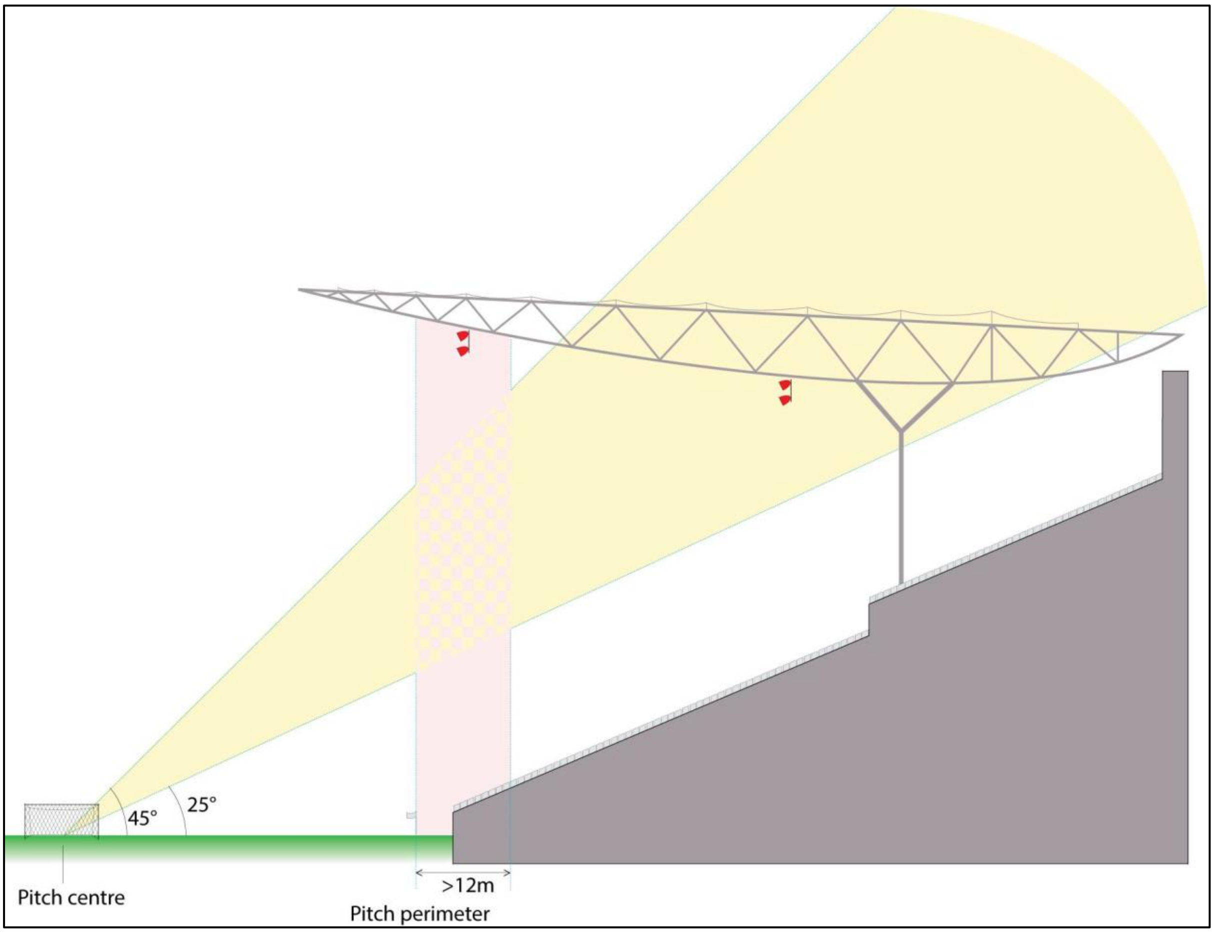


Fig-4.14: Pitch perimeter – second linear row

If the stadium design or existing installation requires luminaires to be positioned within a lateral distance of 12m of the perimeter of the pitch, or if the vertical illuminance requires improvement, a second linear run of luminaires should be used to achieve the required vertical illuminance around the perimeter of the pitch.

F. Luminaires' focus point angle

In order to avoid discomfort glare being experienced by players and officials, a general rule during the design process is to ensure that luminaires' focus point angle is no more than 70° from the line perpendicular to the pitch, as in the diagram above. This is a good general guideline, but it will not always be possible owing to the constraints of the stadium's design.
The above guidance is particularly relevant to point source illuminance systems, as generally seen with high-intensity discharge lamps. However, it may be necessary to re-evaluate this guidance when using LED luminaires, which will generally have large arrays of LEDs producing direct point source luminous flux.

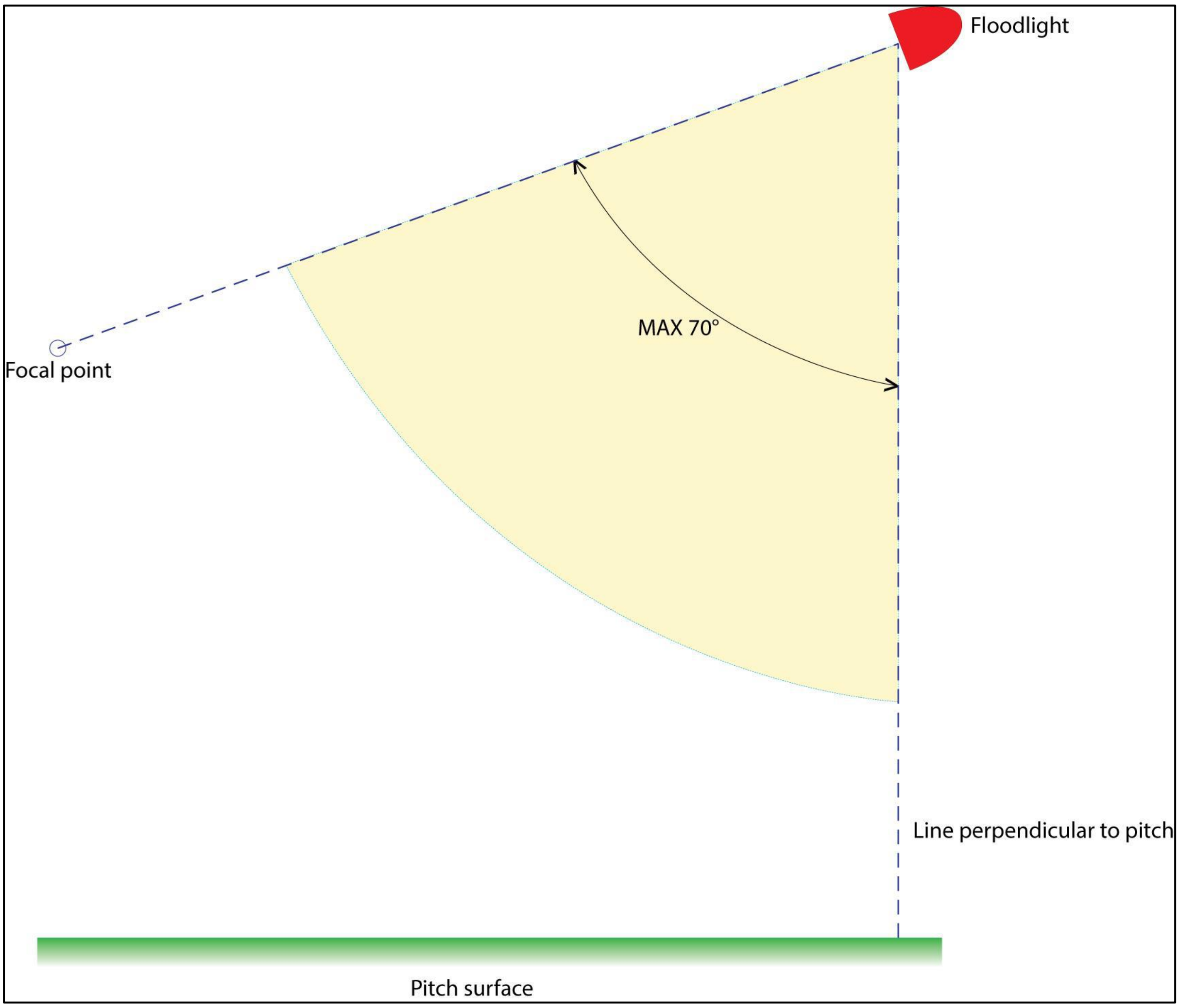


Fig-4.15. Luminaires' focus point angle

G. Pitch sides – luminaire mounting position

Stadium structures should not impede the luminous flux of the pitch lighting system and cause shadows to be cast on the surface of the pitch. Care should be taken to ensure that the luminous flux projection lines to the pitch surface are completely clear.

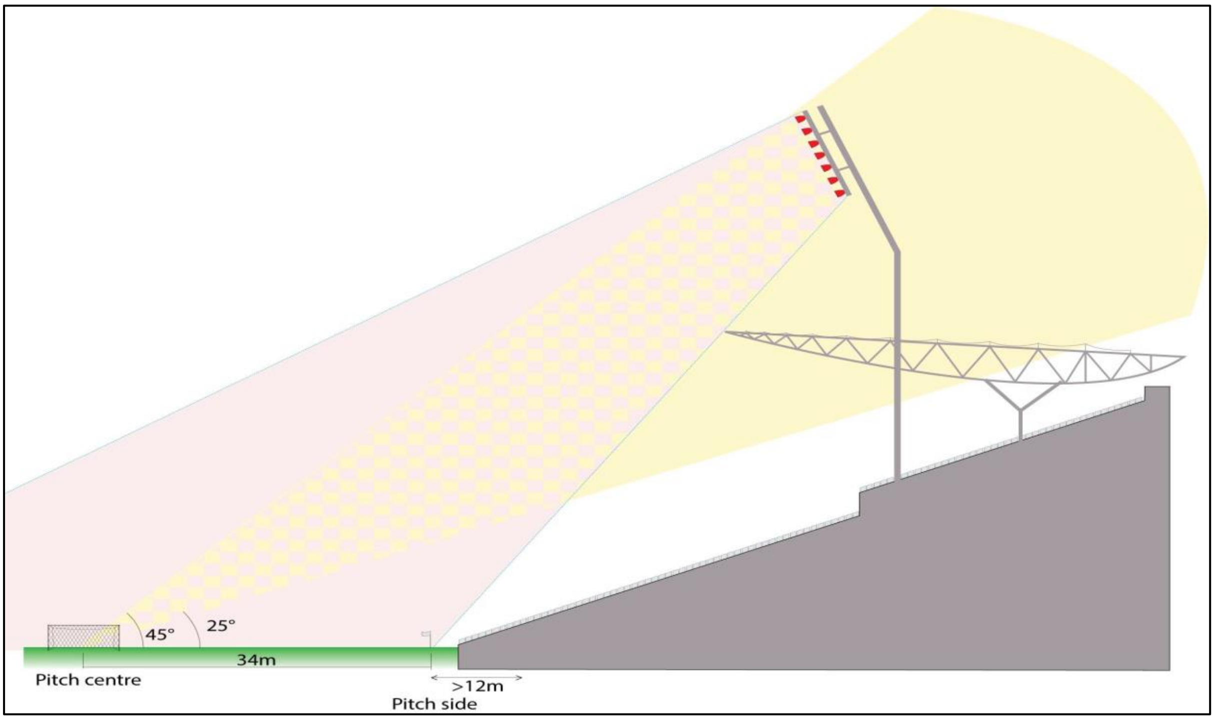


Fig-4.16: Pitch sides – luminaire mounting

H. Behind penalty area – luminaire mounting zone

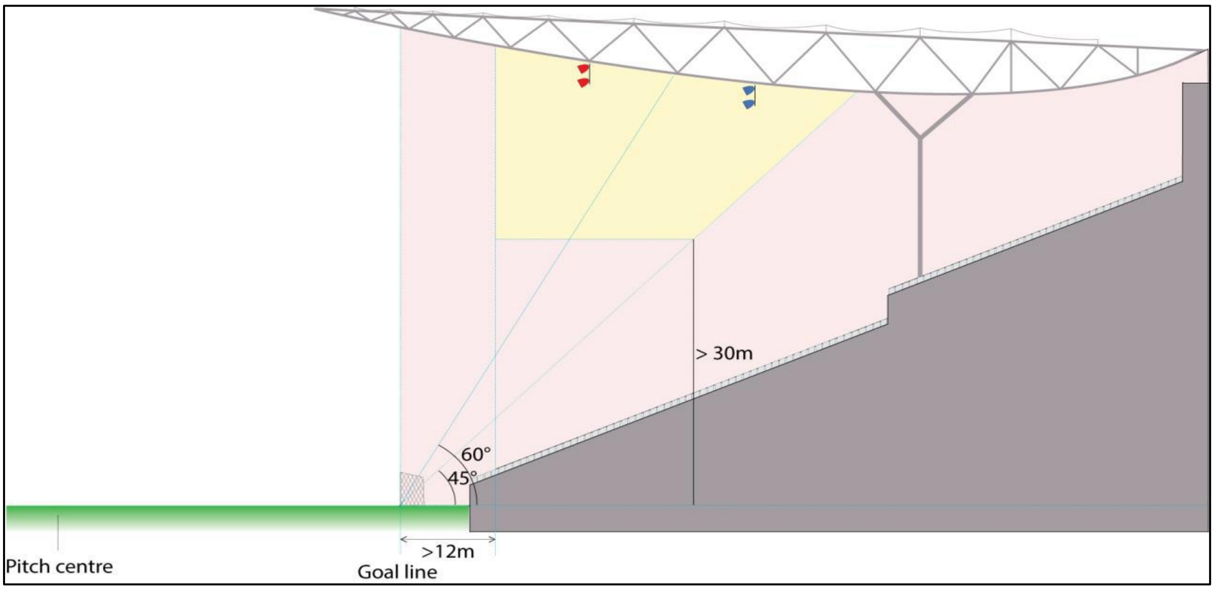


Fig-4.17: Behind penalty area – luminaire mounting zone

In order to avoid discomfort glare being experienced by attacking players looking towards the goal, additional provision is made by increasing the installation angle of luminaires directly behind the penalty area (as shown in the diagram above).

I. Behind penalty area – luminaire mounting zone

Luminaires positioned behind the goal and parallel to the penalty box as indicated in Section 6.8 should be mounted more than 60° from the goal line when in line with the penalty area, as indicated in the diagram above.
If only a single linear line of luminaires is used, the minimum lateral distance from the goal line should be 12m.
Luminaires that are not in line with the penalty box may be mounted at an angle of more than 45° from the goal line.

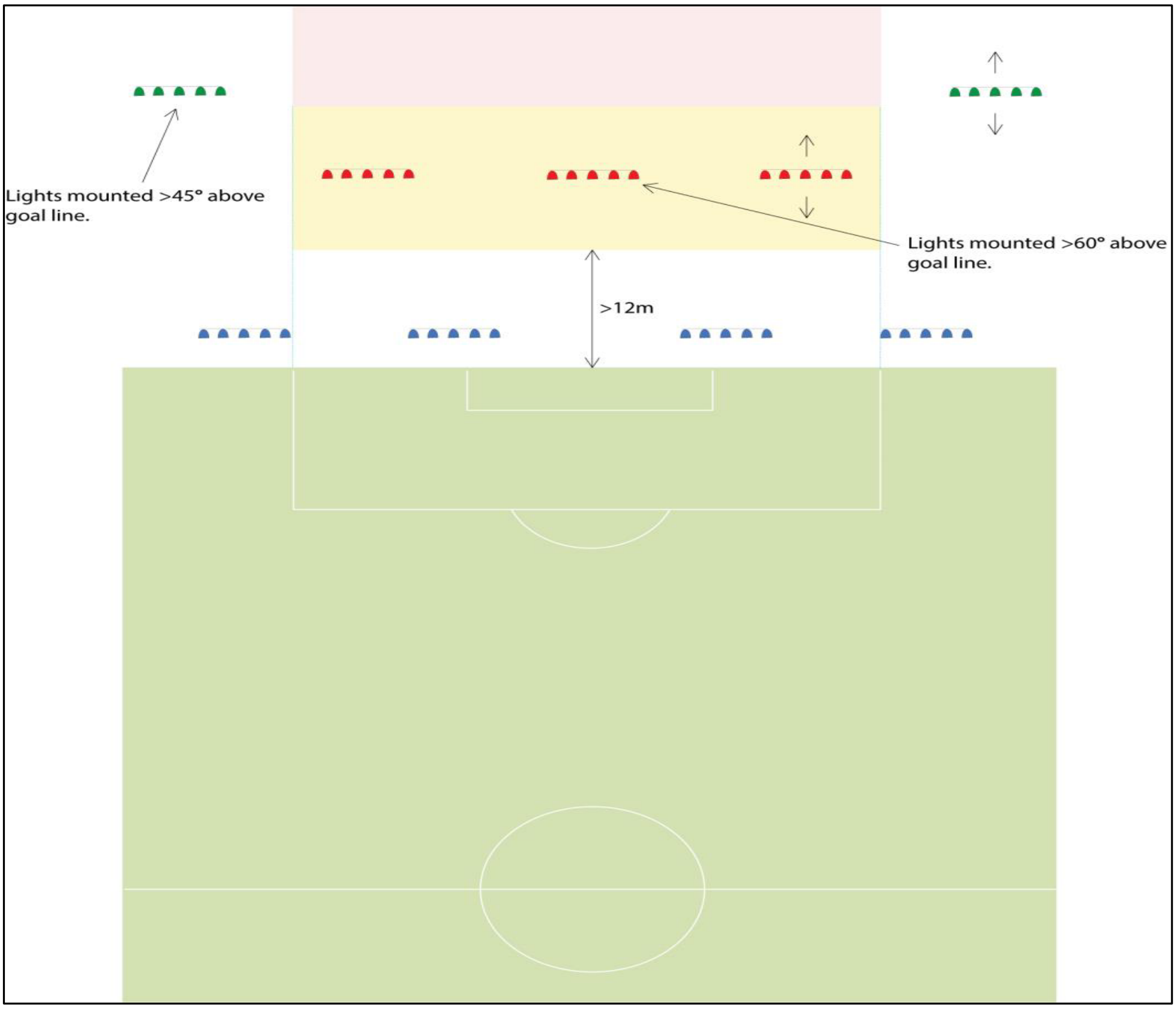


Fig-4.18: Behind penalty area – luminaire mounting zone

J. Behind goal line – second linear row

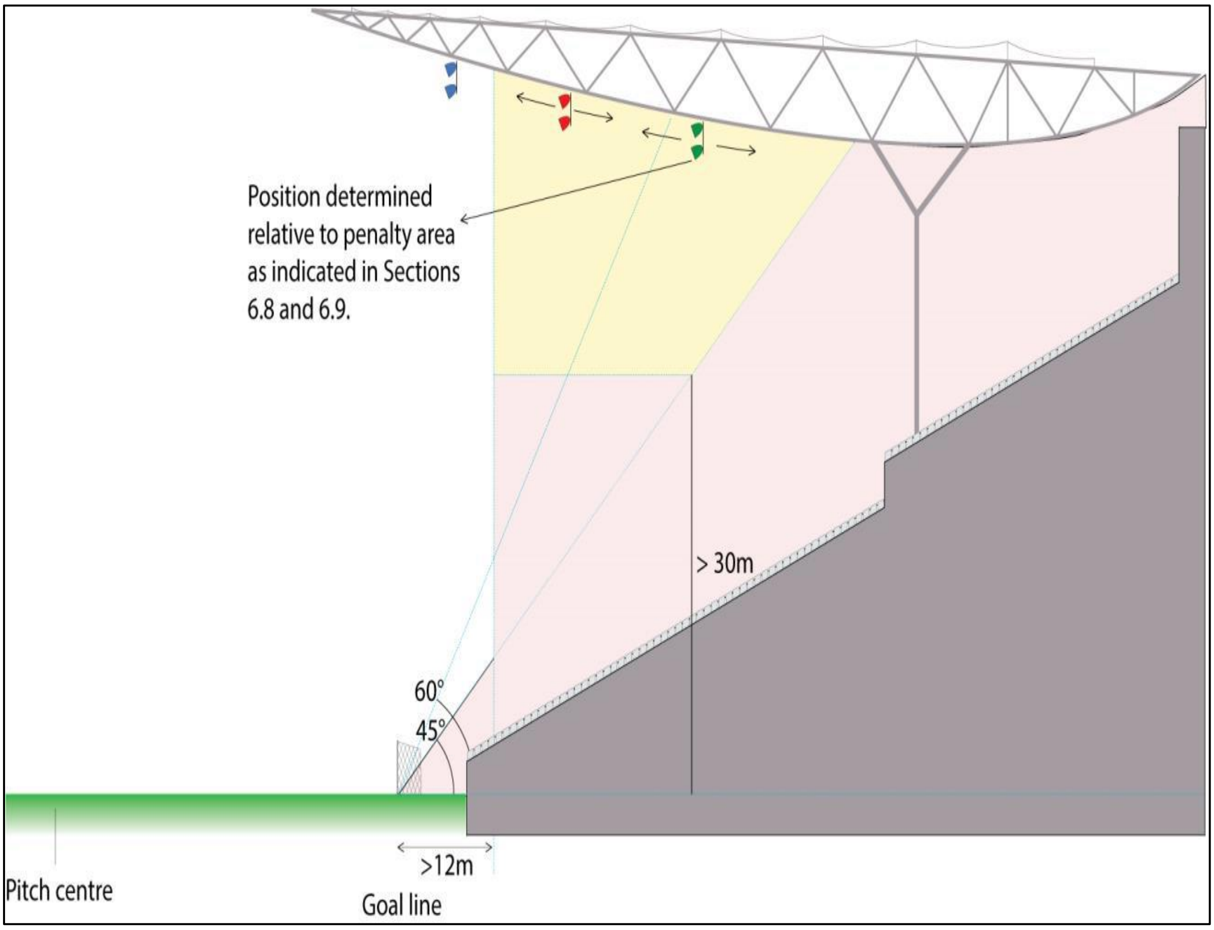


Fig-4.19: Behind goal line – second linear row

If the stadium design or existing installation requires luminaires to be positioned within a lateral distance of 12m from the goal line (as indicated by the blue luminaires in the diagram above) or if the vertical illuminance requires improvement, a second linear run of luminaires should be used to achieve the required vertical illuminance along the goal line and within the penalty area. Luminaires positioned directly behind the penalty area should be mounted at an angle of more than 60° (as indicated by the red luminaires in the diagram above). Outside the area parallel to the penalty area, luminaires may be mounted at an angle of more than 45° (as indicated by the green luminaires).

Where possible, all luminaires behind the goal line should be a minimum of 30m above the pitch surface. If this is not possible, it is important to develop a design solution that considers the implications of that reduced height and takes it into account.

4.2.4 Uniformity

A critical element of a pitch illuminance system is the uniformity of illuminance across the whole pitch in reference planes.

The uniformity of illuminance can be defined as how evenly light is distributed over a given reference plane.

The uniformity of illuminance is expressed using two illuminance ratios: U1 and U2.

U1 The total illuminance range, from minimum to maximum, that a person or camera will be exposed to. The U1 value will contribute to the visual performance experience.

U2 The difference between a person's normal adapted exposure and the lowest illuminance level on the given plane. The U2 value will contribute to the visual comfort experience.

Horizontal uniformity of illuminance

U1h A measure of horizontal uniformity of illuminance – the ratio of minimum horizontal illuminance to maximum horizontal illuminance across all 96 reference points.

U2h A measure of horizontal uniformity of illuminance – the ratio of minimum horizontal illuminance to average horizontal illuminance across all 96 reference points.

Vertical uniformity of illuminance

U1v-(angle°) A measure of vertical uniformity of illuminance on the specified reference plane – the ratio of minimum vertical illuminance to maximum vertical illuminance across all 96 reference points.

U2v-(angle°) A measure of vertical uniformity of illuminance on the specified reference plane – the ratio of minimum vertical illuminance to average vertical illuminance across all 96 reference points.

It should be noted that UEFA's requirements are the minimum standards for the various illuminance levels. Experience shows that uniformity values that are calculated during the design process are a good guide, but are often higher than the values measured after the illuminance system has actually been installed. UEFA recommends that the illuminance uniformity values that are calculated during the design process are higher than the minimum requirements to allow for potential declines when real values are measured.

4.2.5 Glare

A. Glare

Glare is the sensation produced by luminance within the field of vision that is so much stronger than the eyes are used to that it causes annoyance, discomfort and/or impaired visibility and visual performance.

B. Discomfort glare

Discomfort glare is caused by direct glare from luminaires which are too bright, inadequately shielded or too large in size. It is also caused by reflected glare from specular surfaces lit by other sources (which in a stadium may be the sun).

When the eye has got used to the dark, it is particularly susceptible to the impairment and depression of central vision when a bright light enters the field of vision.

C. Evaluation of glare

The method of determining the glare effect of a light source or a group of light sources is complicated. Glare will certainly increase as the number of light (or glare) sources increases and the size of the light (or glare) source increases. The size, luminance and position of light sources will all affect the level of glare that is experienced.

Glare is a subjective factor, for which a practical evaluation system has been devised for outdoor sports applications by the International Commission on Illumination (CIE) on the basis of extensive field tests. The CIE 112-1994 Glare Evaluation System for Use within Outdoor and Area Lighting – defines a glare rating (GR) with an assessment scale of 10 to 90. The lower the glare rating, the better the glare situation.

The validity of this system is restricted to viewing directions below eye level, and it is mainly used for predicting the degree of glare. During the lighting design phase, a glare assessment based on CIE 112-1994 should be carried out. Calculations should be made for observer positions using the grid points on page 58. Assessments should be made every 15°, starting from 0° or 180°, over a total of 360°. Observer positions should be 1.75m above the pitch surface.

The maximum glare rating and the corresponding direction should be displayed for each observer position.

4.2.6 Pitch illuminance switch mode (PISM)

The pitch illuminance system should be pre-programmed with various different modes. The number of modes may vary from stadium to stadium. The list below provides a few examples:
Mode 1: Full match mode (FMM)
Mode 2: Match continuity mode (MCM)
Mode 3: Training mode (TM)
Mode 4: Maintenance mode (MM)

A. Full match mode

This involves the pitch illuminance system operating in a manner that satisfies the requirements specified for the relevant UEFA illuminance level.

B. Match continuity mode

This mode should automatically be activated when the primary power supply fails. The pitch illuminance system should switch to the MCM and perform in accordance with (or above) the minimum standards specified for the relevant UEFA level.
In terms of the uniformity of illuminance, U1 must be greater than 0.5 on the horizontal plane and 0.4 on the vertical plane. It is not considered necessary to evaluate U2 for the MCM.
The MCM is essential and should be part of the design process. In order for this mode to operate successfully, the power supply facilities and options available must be carefully considered during the design process.

C. Training mode

This involves the pitch illuminance system operating with an average horizontal illuminance of 500 lux.

D. Maintenance mode

This involves the pitch illuminance system operating with an average horizontal illuminance of 250 lux.

4.2.7 Colour temperature

‘Colour temperature’ describes the feeling or appearance of how warm (red) or cool (blue) a certain type of illumination appears to be. It is measured in kelvins (K).
Digital camera technology allows video-produced media to be altered to ‘gain’ colour and contrast, as required to produce the desired colour quality. The required colour temperature range varies depending on the stadium illuminance level, with the minimum and maximum levels across all levels being 4,200K and 6,200K respectively.
It is often necessary to start the broadcasting of a football match in daylight and finish with all the pitch illuminance provided by the floodlighting system. On these occasions, the artificial lighting should generally be used at the beginning of the broadcast to allow a gradual change from daylight to artificial illuminance. During this period, the broadcast engineers will be able to make minor adjustments to the camera settings as required.

- *Colour temperature guide*

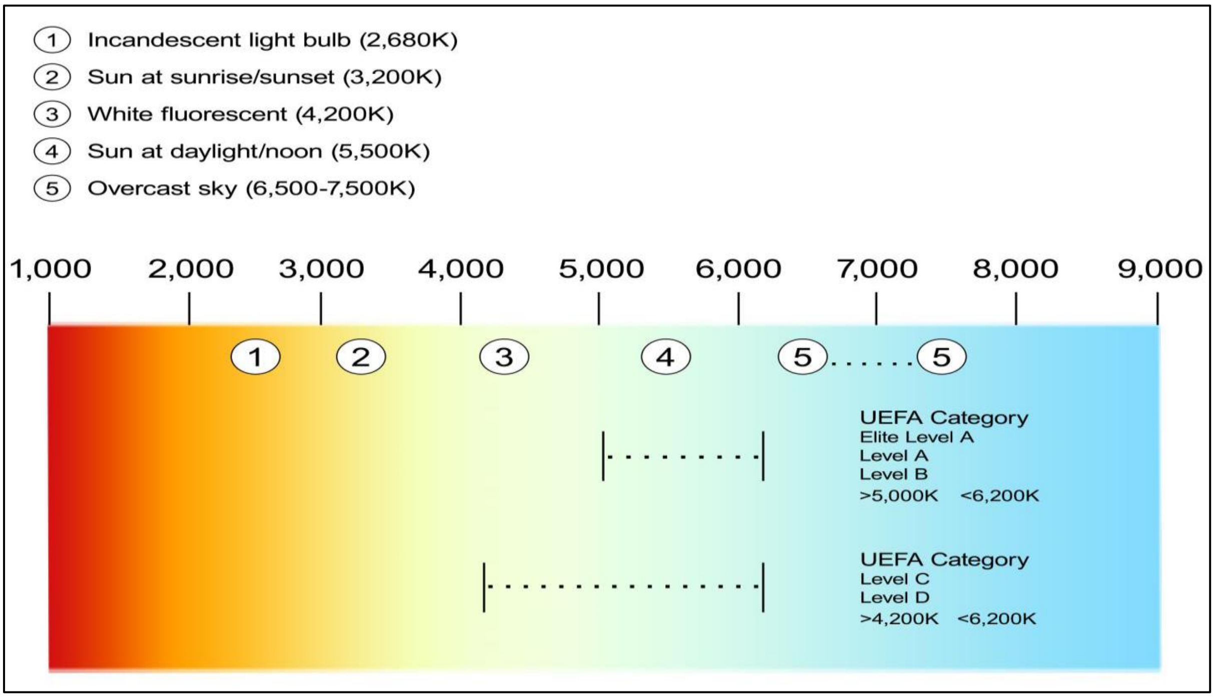


Fig-4.20: Colour temperature guide image

4.2.8 Colour rendering

Colour rendering, which is expressed as a score between 0 and 100 Ra on the Colour Rendering Index (CRI), describes how a light source makes the colour of an object appear to human eyes and how well subtle variations in colour shades are revealed. The higher the CRI rating, the better the colour rendering.

FIFA requirements stipulate that for good colour production by the artificial illumination system, the CRI rating needs to be ≥ 80 for level A and level B stadiums, ≥ 70 for level C stadiums and ≥ 65 for level D stadiums.

4.2.9 Player shadows

Artificial shadows on the pitch caused by floodlighting systems detract from visual clarity for both spectators and television broadcasters. The shadows impinge upon the viewing experience and should be eliminated where possible or reduced to soft shadows.

During the pitch illuminance design process, it is important to evaluate the production of player shadows and eliminate any hard shadows. This will generally be done by using multiple light sources from various locations for each area of the pitch. This will mean that shadows are reduced and players will benefit from good illuminance modelling around their entire bodies. This will be essential to provide the adequate vertical illuminance and uniformity on all planes.

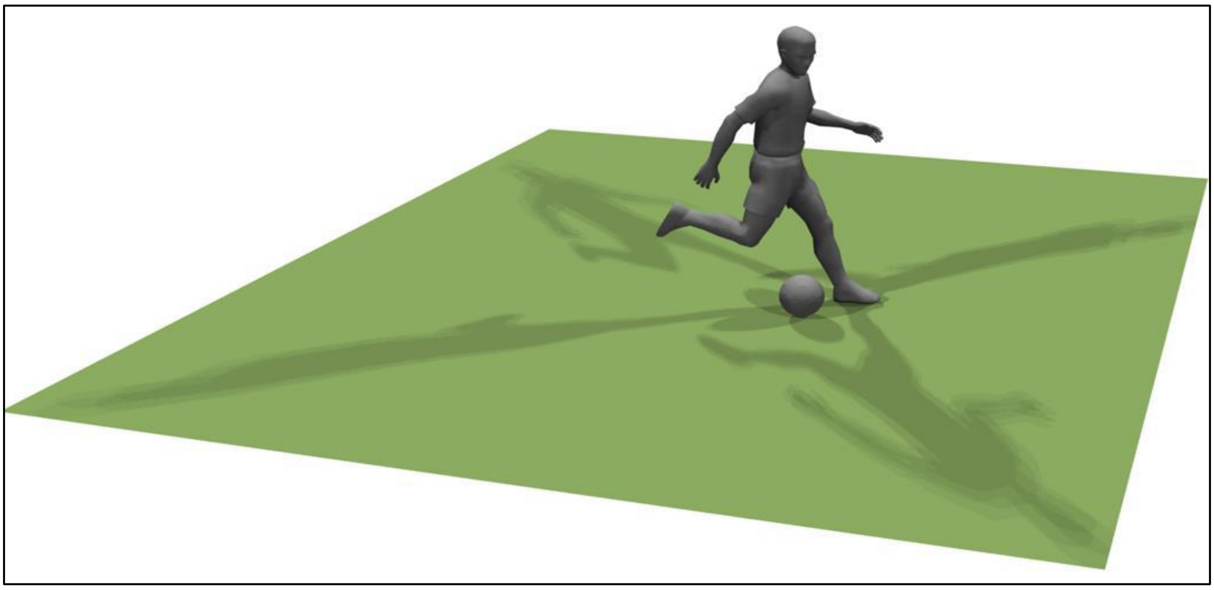


Fig-4.21: Shadow image

The image above demonstrates the impact of player shadows on a football pitch.

In some stadiums, the existing infrastructure will mean that a four-corner tower/column floodlighting system is the only viable option in terms of the pitch lighting design. Corner tower illuminance systems will generally produce hard shadows, which will vary in different areas of the pitch. With this type of installation, it is not possible to produce consistently soft shadows.

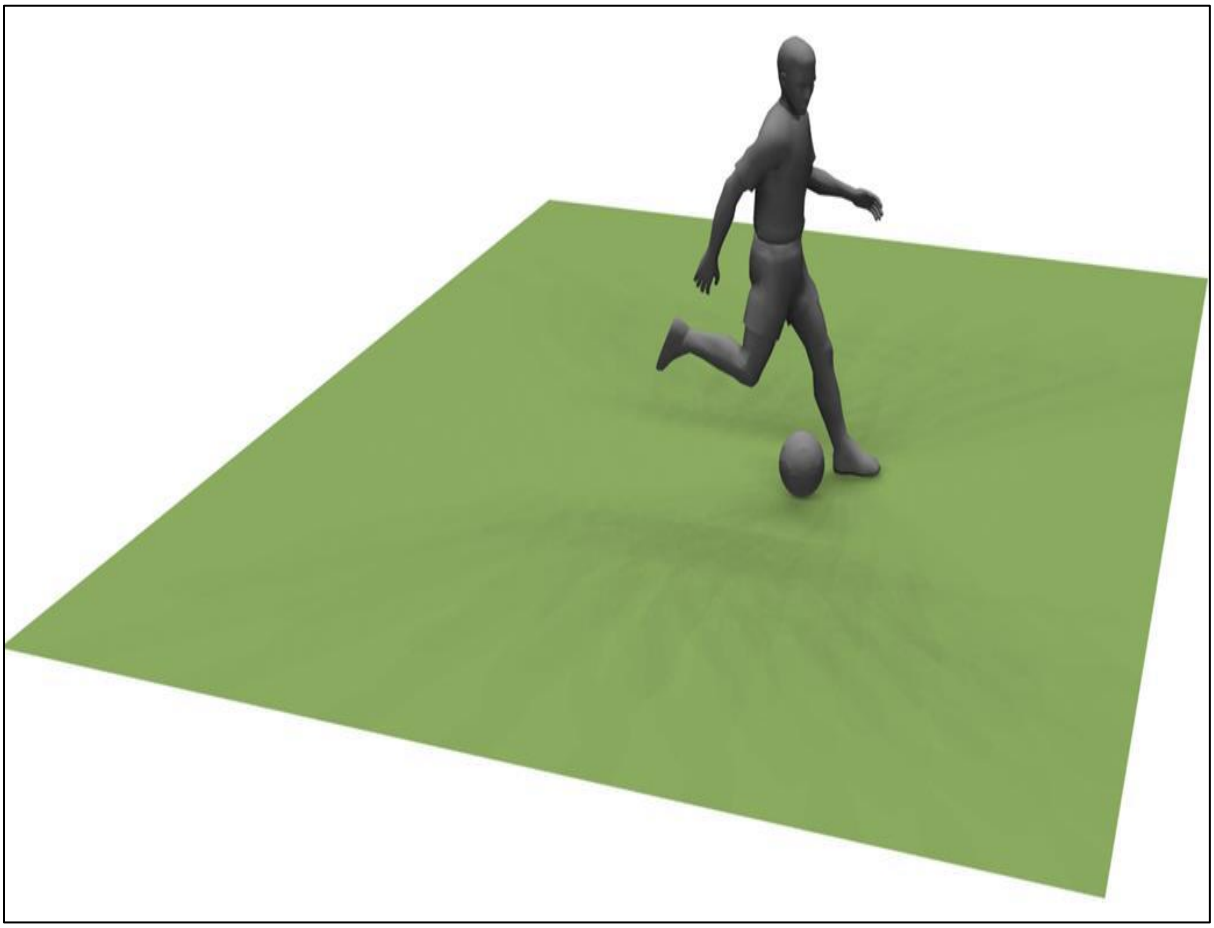


Fig-4.22 Shadow less image

The image above is an example of the soft shadows created by an effective solution involving multiple light sources from different locations.

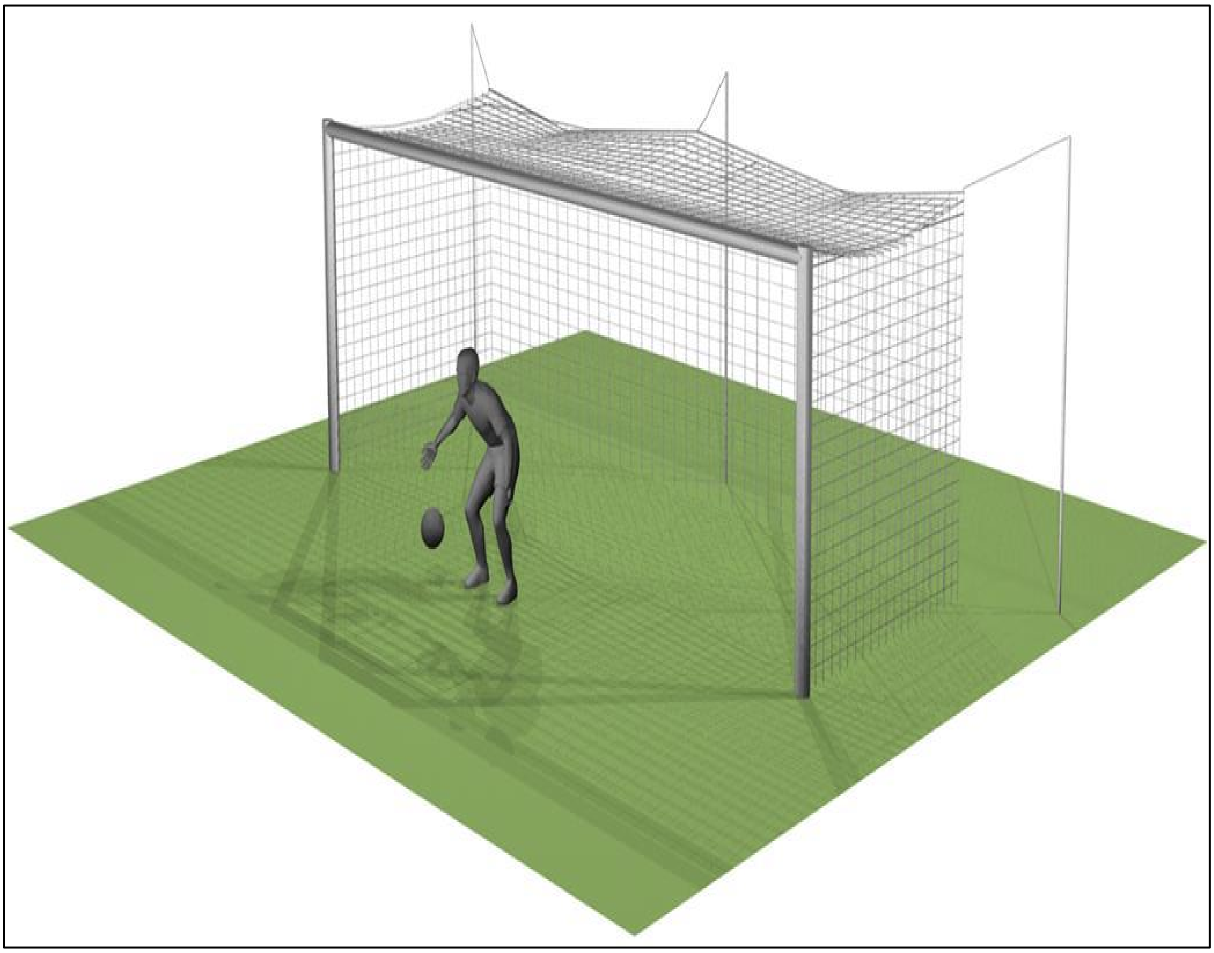


Fig-4.23: Shadow less effects

The image above is an example of hard shadows in the goal area. Shadows should be reduced where possible, while ensuring that players are not hindered by discomfort glare.

4.2.10 Maintenance factor

The average illuminance values required by the tables in Section 4 should be achieved during matches. However, a maintenance factor is used to take account the depreciation of luminous flux caused by the ageing and soiling of the light sources, reflectors and front glasses. In the absence of any other information, the maintenance factor indicated in the relevant table in Section 4 should be used.

However, it is possible to modify that maintenance factor if relevant information is available and systems are in place that facilitate a calculated alteration to that value for a given project.

Reasons to alter the maintenance factor are provided below:

– A proactive and frequent maintenance programme. This would require the implementation of a comprehensive and documented schedule of lamp replacement, luminaire cleaning, voltage regulation and illuminance testing. Most stadium pitch illuminance systems would not be suitable for this kind of very proactive maintenance.

– Luminaires that use LED technology. The rate of lumen depreciation is very low with this technology. In order to alter the maintenance factor, a documented schedule of work including luminaire cleaning, voltage regulation and illuminance testing should be implemented. It is not recommended to increase the maintenance factor beyond a value of 0.90 when using LED luminaires in normal circumstances.

– Lumen depreciation may be compensated for by the use of 'constant illumination lamp technology'. This system would need to be available and supported by the luminaire manufacturer, with documented analysis of the pitch illuminance system's performance with voltage regulation. It would also be necessary to provide a schedule of lamp replacement, luminaire cleaning, voltage regulation and illuminance testing.

– If the stadium environment is subject to harsh weather conditions or airborne dirt that could affect the long-term performance of the luminaires, it will be necessary to lower the maintenance factor to an appropriate level. In such circumstances, a study should be carried out to evaluate the conditions. A typical maintenance factor in the above circumstances might be 0.70 or 0.75.

4.2.11 TV broadcast camera plan

It is important that people designing lighting systems for football stadiums understand the requirements of television cameras and the positions that they operate from. Below is a typical camera plan for a high-specification TV broadcast of a football match:

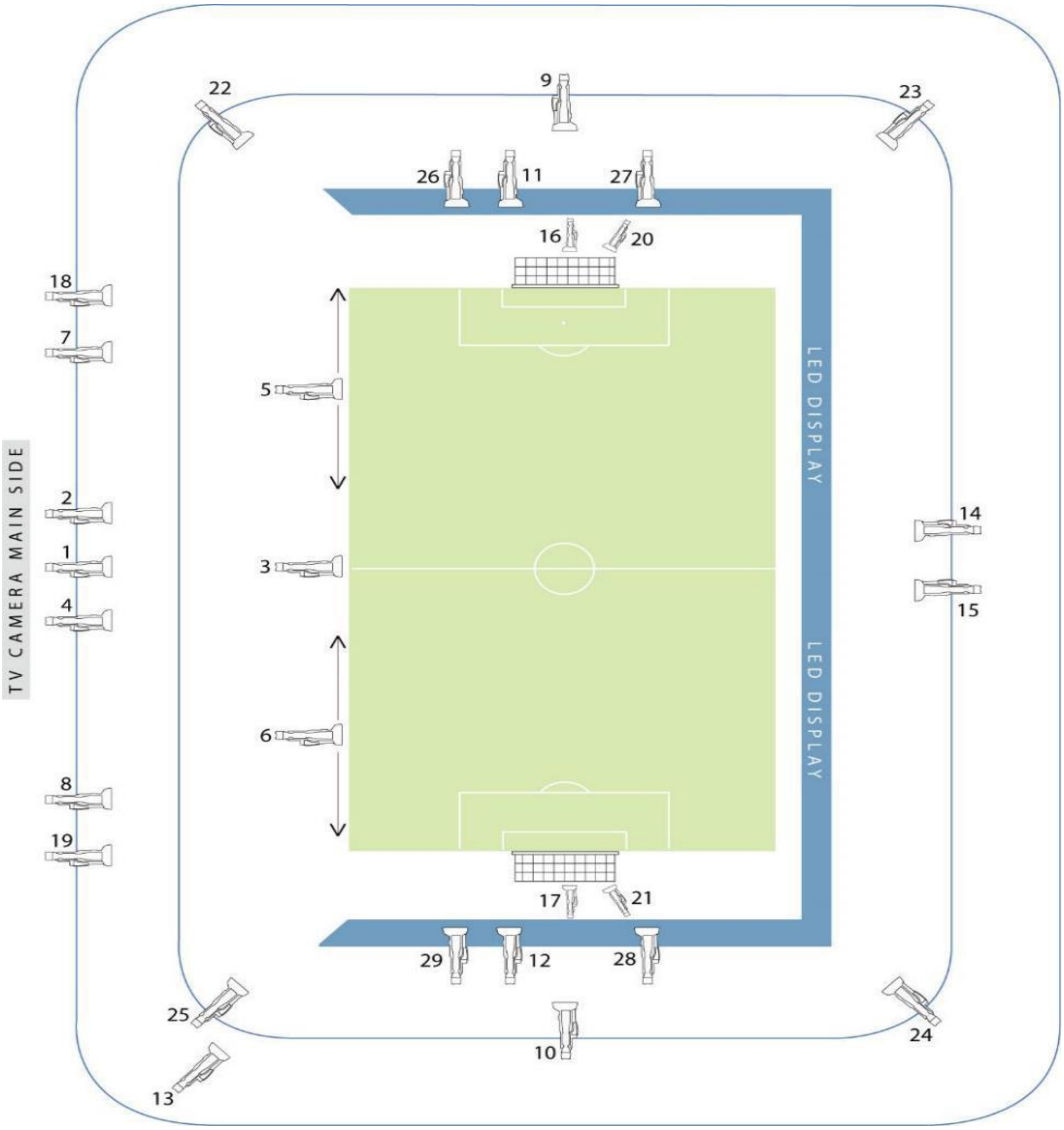


Fig-4.24: TV broadcast camera plan

4.2.12 Key to camera plan

That camera plan is fairly typical, but some broadcasters and TV directors will deviate from it slightly. The purpose of the plan is to help you understand how the different elements of the lighting design should be used to ensure the correct illuminance conditions in all areas of the pitch.
Key to camera plan:

Fig-4.25: Horizontal test

1 MAIN CAMERA
2 CLOSE-UP CAMERA
3 PITCHSIDE HALFWAY CAMERA
4 CLOSE-UP CAMERA
5-6 STEADICAMS
7-8 22-YARD CAMERAS
9-10 HIGH-BEHIND-GOAL CAMERAS
11-12 LOW-BEHIND-GOAL CAMERAS
13 BEAUTY SHOT CAMERA
14-15 REVERSE ANGLE CAMERAS
16-17 MINI-CAMERAS
18-19 GOAL LINE CAMERAS
20-21 HOT HEAD CAMERAS
22-25 CORNER CAMERAS
26-29 HI-MOTION OR BIG LENS CLOSE-UP CAMERAS

4.2.13 Pitch Illuminance Test Report

UEFA requires that all venues which could potentially host a televised match undergo assessments of their pitch illuminance systems.

Such illuminance tests must be conducted in accordance with UEFA's guidelines to ensure a consistent and objective analysis of the illuminance conditions at all relevant stadiums.
The illuminance test procedure and requirements are detailed below.

- **Inspection equipment**

The illuminance meter used for the illuminance test should be suitable for a floodlighting environment, with a wide angle receptive light sensor. The meter must be recalibrated on an annual basis.

- **Test procedure**

A football pitch measures 68m by 105m. This area is divided up into a grid containing 96 points. At each point, an illuminance test is carried out to measure both the horizontal illuminance and the vertical illuminance at four different angles. Thus, the test will require 480 illuminance tests in total. Please ensure that the correct grid orientation is used when marking out the grid positions. The orientation can be seen in the pitch orientation plan.

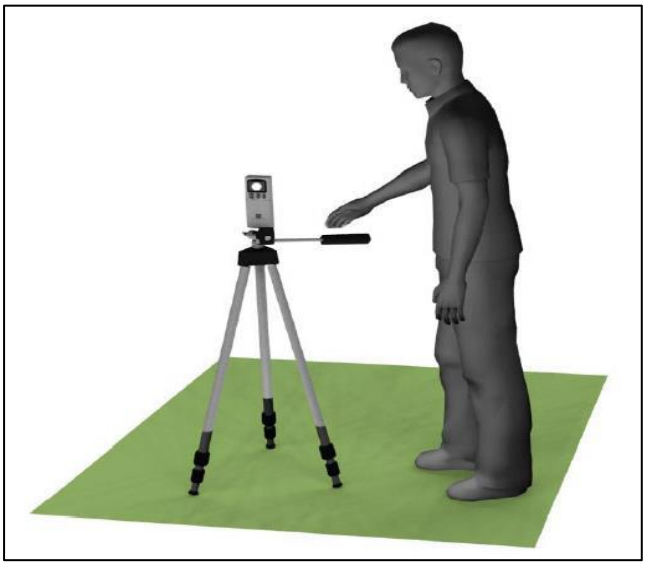


Fig-4.26: Vertical test

Care should be taken when recording illuminance readings. The illuminance meter should always be positioned at the correct angle for the intended measurement. Personnel carrying out the test must not create any shadows that could impinge upon the illuminance meter. The meter should be 1m above the playing surface

The illuminance reading for each grid point should be recorded on the relevant illuminance grid plan.

- **Horizontal test**: The meter is positioned facing upwards, 1m above the playing surface, and parallel to the pitch, at every grid point.

- **Vertical test**: The meter is positioned perpendicular to the pitch, 1m above the playing surface, at every grid point. The meter should then be adjusted for each of the four test positions. The test positions are indicated on the vertical illuminance grid plan and are at 0°, 90°, 180° and 270°. This procedure should be repeated at all 96 grid points.

4.3 Tennis Court Lighting Standard

Tennis was conceived in France and originated in England in the 19th century. It began to develop rapidly around the world in the 20th century. It is a beautiful and full of competitive sport. and its unique charm has been loved by the world. Tennis and golf enjoy the title of "Noble Sports" together. With the widespread development of tennis and the increasing frequency of competitions. it is of course impossible without uniform rules. So in 1876, some famous tennis clubs in some regions sent representatives to meet together to study and discuss the formulation of a unified national tennis rule. After many consultations. the representatives of all parties finally reached a consensus on the tennis venue. equipment. play style and competition, and formed a unified rule. After about 1878. most of the British tennis clubs gradually carried out activities. training and competitions in accordance with the new style of play.

Fig-4.27: ATP Citi Open 500, Washington

A high-level tennis match is inseparable from a good lighting environment. high-quality LED lamps. reasonable arrangement. scientific light-emitting angles and appropriate brightness. etc., to ensure that athletes play a good competitive level on the court. and at the same time. Ensure that referees clearly see the game on the court and make accurate judgments. For spectators, good lighting conditions can greatly improve the viewing of the game.

To enjoy any sport to the fullest, you must meet its lighting requirements. Fortunately, there are various types of field lighting systems for you to choose from. Tennis is a hugely popular sport that is played on a court. It can also be played in a variety of places including indoors, outdoors, and underground.

Whether your court is located in a high school, college, university, or college, you must ensure that the tennis court lighting is well designed. If not, you will find the time you spend on the court less enjoyable. You will also find yourself paying high energy bills. Hence, the importance of having proper court lighting can't be over-emphasized.

Tennis is a ball game, usually played between two singles players or two pairs of combinations. The player hits the tennis ball with a racket across the net on the tennis court. Tennis has high requirements for strength and speed. In the sport of tennis, some professional athletes can serve at a speed of 200+km/h. Because the speed of tennis is too fast, it is very difficult to judge the impact of tennis! This also greatly improves the difficulty of tennis competition, and also has stricter and more professional requirements for tennis lighting.

4.3.1 Types of Tennis Court

Tennis courts can be divided into outdoor and indoor, and there are various court surfaces. It will be determined by economic factors. For example, lawn tennis is the most basic outdoor court, but its establishment and maintenance costs are too expensive, so it is now replaced by artificial courts, which are cheaper and easier to maintain. There is another kind of clay court that is popular in Europe, the French Open is such a court.

- Grass field

The grass court is the oldest and most traditional venue. Its characteristic is that the friction between the ball and the ground is small when the ball lands, the ball rebounds fast. and the player's reaction. agility. running speed and skills are very high. Therefore, grass is often regarded as the world of "offensive tennis." Various aggressive tactics such as serving and surfing the Internet are almost regarded as a magic weapon for winning on grass tennis courts. while bottom-line players are difficult on grass tennis courts. achieved.

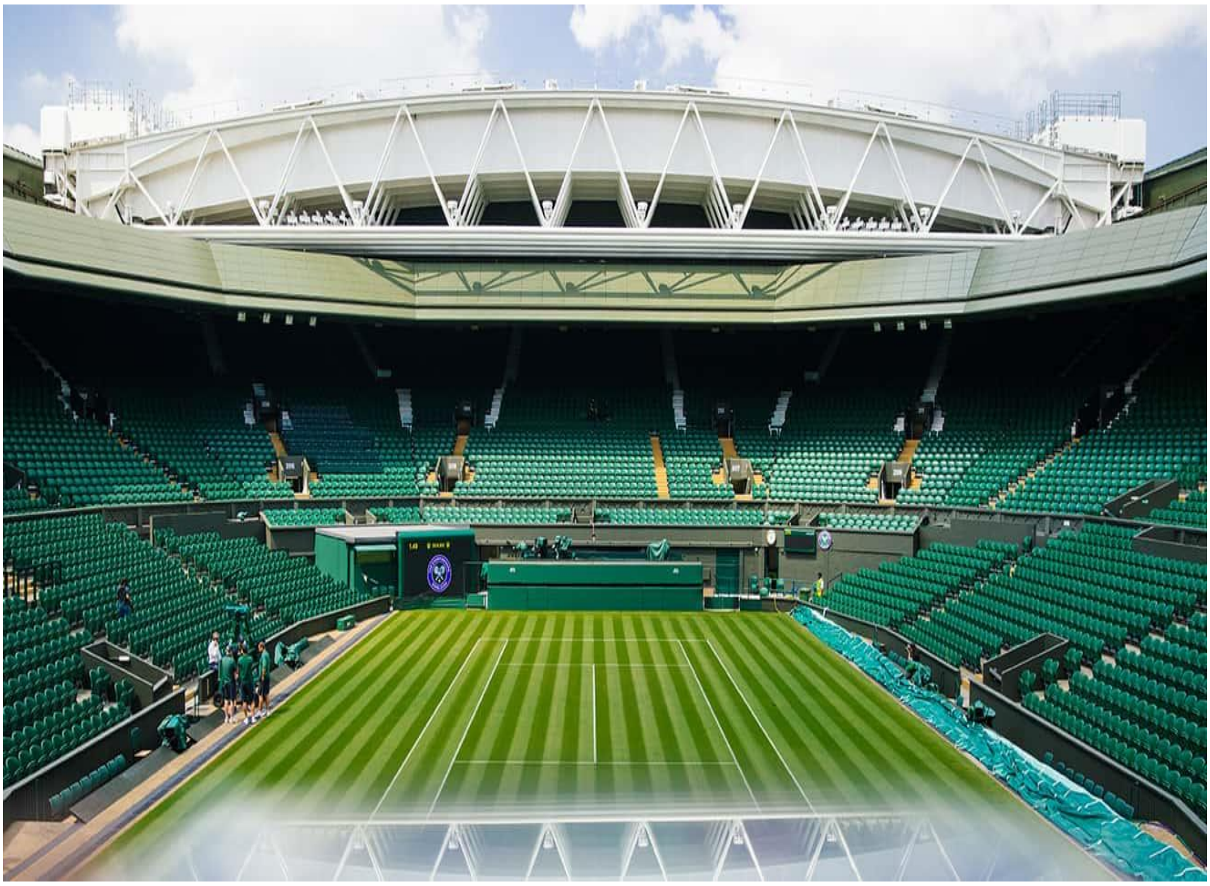


Fig-4.28: Lawn Tennis" on the Grass Courts

However, due to the extremely high requirements for grass characteristics and specifications of grass courts. coupled with climate restrictions and high maintenance and maintenance costs. it is difficult to be popularized all over the world. At present. the few lawn professional tennis tournaments each year are almost all held on the British Isles. and the time is concentrated in June and July. The Wimbledon Championship is one of the oldest and most prestigious

- Clay Field

To be more precise. it is a "soft court". the most typical representative of which is the French Open on clay courts. In addition, all kinds of common sand. mud. etc. can be called soft grounds.
The characteristic of this kind of court is that there is greater friction between the ball and the ground when it Lands, and the ball speed is slow. Players will have a lot of room for sliding when running. especially when they stop and return. This determines that the players must have better physical fitness, running and movement abilities. and more tenacious will quality on other fields.

A match on this kind of venue is a great test for players' bottom-line stubbornness. Players generally have to pay several times the sweat and patience to deal with opponents on the bottom line. The winners are often not fierce serve net players. but fierce serve net players. The side struggling hard on the bottom line.

Fig-4.29: Clay tennis court and stadium

- Hard court

Most modern games are played on hard courts. which is also the most common and common kind of venue. Hard court tennis courts are generally pavement made of cement and asphalt. They are coated with red and green plastic surfaces. The surface is flat and hard. The ball bounces very regularly. but the ball rebounds quickly.

Fig- 4.30: Hard court ground

Many excellent tennis players believe that hard court tennis is more "explosive" and that hard courts dominate in tennis matches and must be paid special attention to. It should be noted that hard courts are not as flexible as other courts. The reaction of the ground is strong and rigid. so it is easy to cause damage to players, and this damage has caused many excellent tennis players to pay a great price.

- Carpet field

As the name suggests, this is a "portable" roll-up tennis court. Its surface is a plastic surface layer. nylon woven surface layer. etc. It is usually bonded to a certain strength and hardness of asphalt. cement. and concrete bases with special glue. On the ground.

Some can even be directly spread or glued on any supporting ground. They are easy to roll. suitable for

Fig-4.31: Carpet field ground

transportation and very adaptable. and can be used indoors, outdoors. and even on the roof.

The speed of the ball depends on the flatness of the field surface and the roughness of the carpet surface. The maintenance of this kind of site is also very simple, as long as the ground is kept clean, free from damage and no accumulation of water.

4.3.2 The Size of Tennis court

The tennis court is a rectangular field. There are two standard sizes of tennis courts. One is a singles tennis court. Its standard size is 23.77 meters in length and 8.23 meters in width. The other is a doubles tennis court. Its standard size is 23.77 meters in length and 10.97 meters in width.

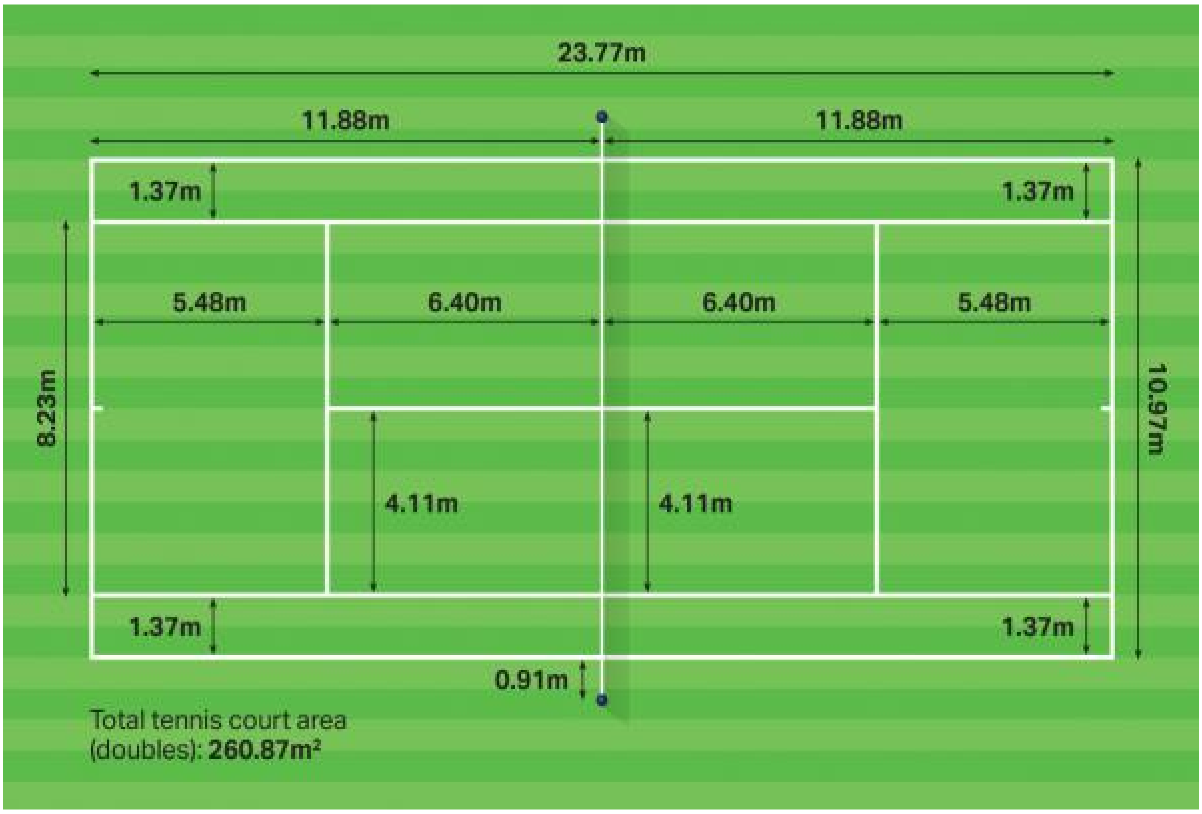


Fig-4.32 Tennis Court Dimensions & Size

And leave room behind each end line and side line, the end line free space is not less than 6.40 meters, the side line free space is not less than 3.66 meters. The middle is separated by a ball net hung on a rope or wire rope with a maximum diameter of 0.8 cm.

4.3.3 Standard of Play

Illuminating a tennis court is determined by different organizations based on the level of competition being played on the court. These levels are often referred to as Class I, Class II, Class III.

Table-4.3: Standred Classification

Sports field standard		
Class I	Top-level national and international competitions (non-television broadcast)	Big-sized numbers of spectators. Require long viewing distances for spectators.
Class II	Mid-level competition, regional or local club competitions	Medium-sized numbers of spectators. Sports field is smaller than the Class I field. Viewing distances is shorter than Class I stadium, medium distance. High-level training may also be included in this class.
Classic	Low-level competition, local or small club competitions	Meet the private recreation demand. Few spectators. General training, school sports and recreational activities.

Class I: International & National

- High level for international/professional grade – 500 lux.

- Top level of competitive playing for a large amount of spectators.
- Facilities generally include broadcasted tennis matches such as U.S. Open, Wimbledon, etc.

Class II: Club Competition & Commercial

- Medium level for club standard – 300 lux
- Mid-level competition, high level training, average viewing distances
- May include collegiate facilities primarily used for intercollegiate or recreational play

Class III: Recreational & Residential

- Lower level of play or recreational play – 200 lux
- Low- level competition, local, general training, school teams or recreational activities

Table-4.4: Lighting parameters for outdoor tennis courts

Lighting parameters for outdoor courts					
	Horizontal illuminance	Uniformity of illuminance	Glare	Light colour temperature	Light colour rendering
	Eh average (lux)	Emin/Eh ave	GR	(K)	Ra
Class I	> 500*	> 0.7	< 50	> 4000	> 80
Class II	> 300*	> 0.7	< 50	> 4000	> 65
Class III	> 200*	> 0.6	< 55	> 2000	> 20

Table-4.5: Lighting parameters for indoor tennis courts

Lighting parameters for indoor courts					
	Horizontal illuminance	Uniformity of Illuminance	Glare	Lamp Colour Temperature	Lamp Colour Rendering
	Eh average (lux)	Emin/Eh ave	GR	(K)	Ra
Class I	> 750*	> 0.7	< 50	> 4000	> 80
Class II	> 500*	> 0.7	< 50	> 4000	> 65
Class III	> 300*	> 0.5	< 55	> 2000	> 20

4.3.4 Some Requirements of Tennis Court Lighting

Tennis court lighting is the lights that are used to provide good illumination levels and distribute the light across the tennis court. The tennis court has lamp side lateral lighting on both sides of the court. In addition, in the long axis direction, two to three light poles are installed on both sides.

Irrespective of the event and crowd, the tennis court must have the right type of lighting. This is to make sure everyone gets a chance to clearly view what is happening. The ball should be clearly visible, no matter how fast or where it is.

The tennis field lighting will improve the experience of the fans and offers better safety. It enhances the vision of the players, ensuring they perform well.

Good outdoor/underground parking lot and architectural lighting design are also for pedestrians to have a better lighting experience.

When the tennis court lighting solution is being designed, the requirements of tennis court lighting must be concentrated on. Here are some of the requirements you need to pay attention to.

A. Brightness of tennis court lighting

The first requirement of the tennis court lighting is the brightness. The court needs to be well-lit to ensure the proper vision for the players and spectators. There are many courts using HID lights to light up the whole space. They might be cheap but extra lights need to be installed.
The LED tennis lights are a better option as they provide more brightness levels in comparison to HID lights. In the technical aspect, the maximum power of the LED tennis lights in 10,000 watts while the power of metal halide can reach only up to 1,500 to 2,000 watts.

B. Efficiency of tennis court lighting

Another requirement for the tennis court lighting is its efficiency. Since the light will be turned on for most of the day, it costs a lot on the energy bills. This is where led tennis court lighting comes in handy; they are known for their energy efficiency.
For determining the efficiency of the light, luminous efficacy is used. The unit used to measure the efficacy is lm/W, where lm stands for lumen. Keep in mind, higher the lumen, higher is the brightness.
Led tennis court lighting have 120 to 150 lm/W, metal halide has 75 to 100 lm/W, HPS has 90 to 100 lm/W, and halogen has 10 to 20 lm/W. This shows for 1 wattage of power consumption, led tennis court lighting will emit 150 lumens. So, LED tennis lights will save more electricity than any other lighting solution.

C. Life Span

One of the most important requirements you should pay attention to is the life span of the light. Since the courts are open late till night, the lights must have a long service life. If the light has a short life span, it will lead to frequently replacing the lights. This not only increases the cost of maintenance and replacement but also increases operation costs as well. The installation cost of the field lighting is high.
LED tennis lights have a long service life as they can last for up to 80,000-100,000 hours. On the other hand, the halogen light will only last for 2000 hours while metal halide can last up to 10,000 hours. Hence, LED tennis lights provide the best performance.

D. Wide Range of Color Temperature

In order to buy the right led tennis court lighting, you have to consider the color temperature of the tennis lights. It is recommended to use cool white like that has 5000 to 6000K. Some tennis courts require warm light with a color temperature of 2800 to 3500K.

Fig-4.33: Color Temperature

E. Anti-glare Feature

One of the most important features of the LED tennis court lighting is the anti-glare function. The glare is the strong light that causes irritation or discomfort. Our LED tennis lights have an anti-glare lens that reduces the dazzling effect and makes it easy to see things.

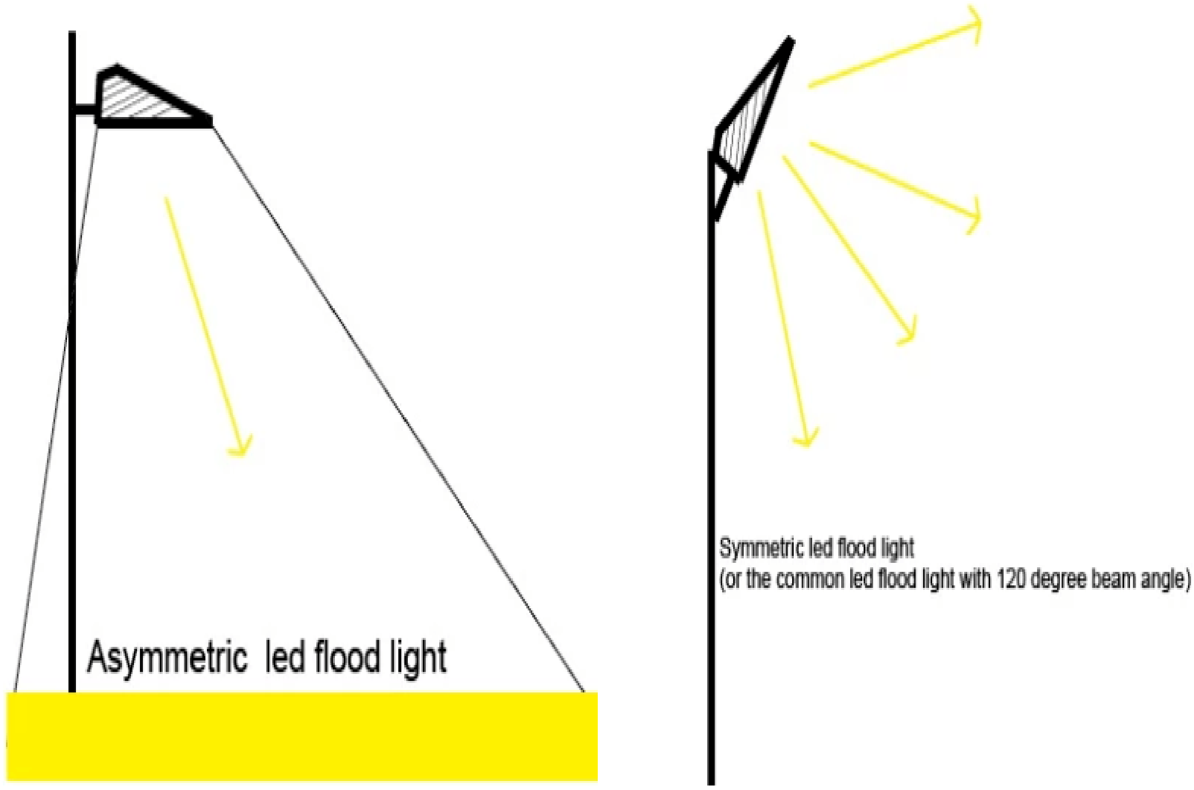


Fig-4.34: Good light for player and audience eyes & Dizzy light for player and audience eyes

F. Pole Arrangements

According to our years of lighting design experience, usually, for tennis courts, most of the light poles will be 6-8m (20ft-26.7ft). According to the lighting requirements of the stadium, the wattage of court lights is usually 300-500W. The solution below is for reference.

- 8 poles (6m/20ft)

Standard tennis court (36*18m/120*60ft), installed 8PCS MECREE LED 400W to up average lux 783lux.

- 6 poles (8.7m/29ft)

Standard tennis court, installed 6PCS MECREE LED 300W to up average lux 500lux.
Standard tennis court, installed 6PCS MECREE LED 200W to up average lux 300lux.

- 4 poles (12m/40ft)

Standard tennis court, installed 4PCS MECREE LED 500W to up average lux m 419lux.
Standard tennis court, installed 8PCS MECREE LED 300W to up average lux 489lux.

4.3.5 Some Main Points to Follow the Tennis Court Design

A. Tennis court lighting and competition-related requirements (1) The installation position of the tennis court lighting is generally not allowed to be directly above the venue:(2) Tennis courts have areas where lamps are not allowed to be installed, mainly for locations where lighting will adversely affect the main line of sight during the game;(3) The installation position and projection angle of the tennis court lighting fixtures should avoid glare to tennis payers;(4) Prevent direct light from tennis court lighting fixtures from affecting tennis players and 5pectators.

B. Requirements related to lighting and broadcasting (1) The vertical illuminance and its uniformity in the direction of the tennis court camera must meet the requirements of camera and relay;(2) The color temperature of the tennis court will affect the adjustment of the white balance of the camera. For the tennis court of broadcast level, T cp >4000 K {general broadcast) or SS00K (high-definition broadcast) is required;(3) The color rendering index will affect the degree of color reproduction of broadcast and video. For broadcast tennis courts, Ra >80 {general broadcast) or Ra >90 {high-definition broadcast) ;(4) The installation position and projection angle of the tennis court lamps sometimes cause glare to the camera.

CHAPTER 5

5.Challenges in outdoor sports lighting design

Outdoor sports lighting provides an important way of extending the use and the overall value of outdoor sports facilities. Lighting design can have many different challenges. Ideally, these challenges are determined by the client and the designer in collaboration and cover both outcomes and costs (Figure 5.0). The most common challenges for a lighting installation is to allow the users of a space to carry out their work quickly and accurately, without discomfort. However, this is a rather limited view of what a lighting installation can achieve. For traffic routes, the objective of lighting is to facilitate the safe and rapid movement of vehicles after dark. For urban areas where people and traffic may come into conflict, safety is the primary concern although the appearance of people and buildings is also important. Sport facilities are lit at night to encourage their use. Businesses use lighting to promote their brand and attract customers. Most lighting installations have to serve multiple functions. When designing lighting it is always desirable to identify all the functions that the lighting is expected to fulfil.

As for constraints, an important aspect of lighting design is the need to minimise the amount of electricity consumed, for both financial and environmental reasons. It is also necessary to consider the sustainability of the lighting equipment.

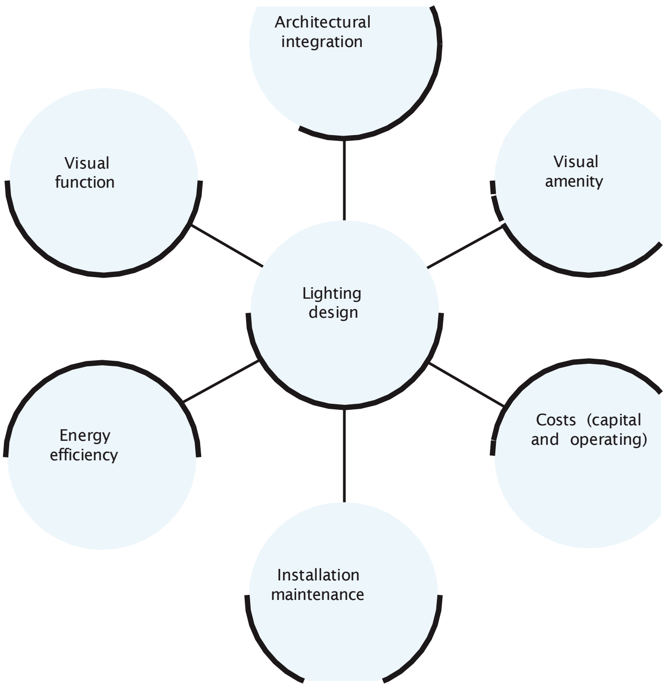


Fig-5.1: Objectives, outcomes and costs

This means using materials that can be easily replaced and considering to what extent the equipment can be recycled at the end of its life. The financial costs, particularly the capital cost, are always an important constraint. No one wants to pay more for something than is absolutely necessary so the designer needs to be able to justify the proposal in terms of value for money.

A holistic strategy for lighting design is necessary because without it important benefits will be lost and money and human resources will be wasted. The starting point is an in-depth conversation with the client and other members of the design team to formulate a design brief. At such a discussion, it will be necessary to address such fundamental questions as what do you want to see and what do you not want to see, what is the function of the space, what is the proposed architectural style and what is the budget?

More formally, nine distinct aspects of lighting need to be considered.
They are:

- Planning Permits
- Visual Function
- Visual Amenity
- Obtrusive light
- Energy efficiency and sustainability
- Operation and Maintenance
- Costs/ Budget
- Photopic or mesopic vision
- Equipment
- Aiming floodlights and commissioning sports floodlighting installations
- Planning Power and Electrical Supply

5.1 Planning Permits

A planning permit is a statement that a particular use or development (subdivision, buildings, and works) may proceed on a specified parcel of land. Sometimes a permit is specific to a nominated person or operator. It is always subject to a time limit and will expire under specified circumstances. The responsible authority (usually local council) is entitled to impose conditions when granting a permit. If you propose to use or develop land, first discuss the proposal in detail with your local council planning and recreation departments. Early discussion will confirm whether a planning permit is necessary and highlight likely conditions. Typically, sports lighting upgrades do not require a permit. The planning permit process may require consultation with surrounding residents and other stakeholders. Organisations should consider undertaking community consultation prior to seeking a planning permit to help address any community concerns. It is important not to confuse planning permits with building permits. Building permits relate to the method of construction of a building or development to ensure it complies with relevant standards. A planning permit does not remove the need to obtain a building permit. When applying for a planning permit, applicants should use their local council's *Planning Permit Application* form and include the prescribed permit application fee (refer to the *Planning and Environment (Fees) Regulations 2000*), and all necessary supporting information, such as accurate plans, reports and photographs.

Many light pole installations will require a building permit, irrespective of whether a planning permit is also required. In many instances local council is the landowner and needs to grant permission for any works to be carried out on its land. The *Building Regulations 2006* indicate that for poles not attached to a building, a permit is required when they are over eight metres in height. Further information about the building permit process can be obtained from the building department of your local council.

If planning permits require verification of Obtrusive Lighting Provisions (i.e. calculation of spill light to nearby residences or other sensitive locations), include this into your project design brief and be aware that additional design time may be required. Establish the proximity and orientation of any nearby residential areas at the time of planning the site design layout. Simple matters like field/court orientation and set out can help limit spill light to residential areas. Typically, greater than 20m distance from a property boundary will likely see less light spill. Identify any particularly sensitive locations that may be impacted by proposed sports lighting e.g. main roads and/or intersections. Consider proximity to airports and ensure civil aviation requirements for screening of sports lights are addressed. Restrictions typically exist up to 6kms away from airport runways.

5.2 Visual function

This aspect is related to the lighting required for doing tasks without discomfort. The values apply to the task area and do not necessarily need to apply to the whole working plane. For this approach, a minimum task illuminance uniformity (minimum/average task illuminance 0.7) is recommended. This approach has the benefit that the tasks can be carried out on the horizontal plane anywhere in the work place. In some cases, the task will have a colour recognition element. In sports area will be necessary to use lamps with a general colour rendering index (CRI). For such tasks it will be appropriate to use lamps with a CRI 70 but for main playing area with a requirement for very good colour discrimination, lamps with a CRI 80 will be necessary. The human visual system can adapt to a wide range of luminances but it can only cope with a limited luminance range at any single adaptation state. When this range is exceeded, glare will occur. If a field of view contains bright elements that cause glare it is likely that they will affect performance or at least cause stress and fatigue which in turn will cause problems.

5.3 Visual amenity

There is no doubt that lighting can add visual amenity to a space which can give pleasure to the occupants but whether this provides a more tangible performance benefit is uncertain (Boyce, 2003). Studies have shown that people respond to the lit appearance of an area on two independent dimensions: visual lightness and visual interest (Hawkes et al, 1979, Loe et al, 1994, 2000). Visual lightness describes the overall lightness of the space, which is related to the average luminance of vertical surfaces. Visual interest

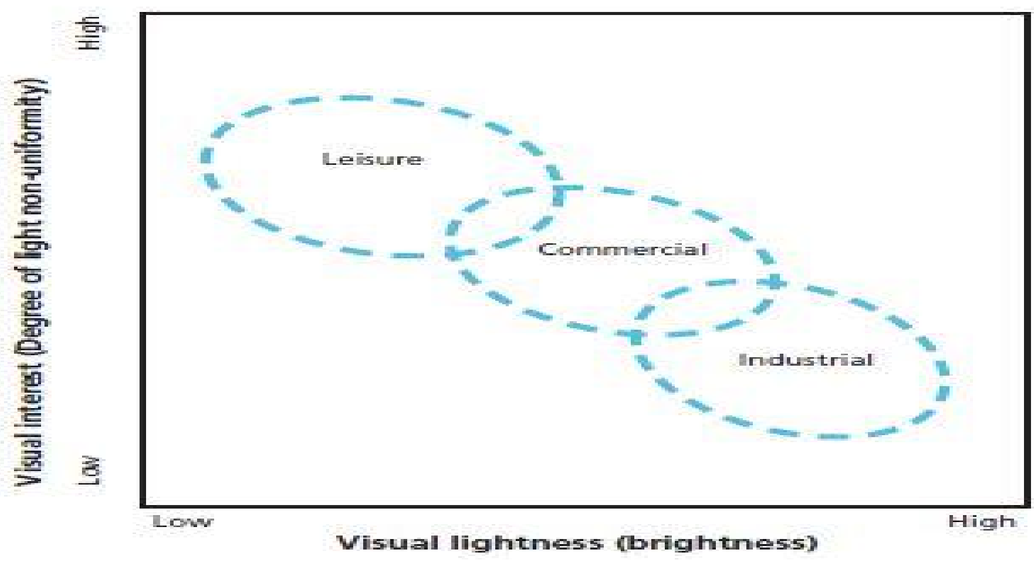


Fig- 5.2: Map showing the possible locations of three application areas on a schematic diagram linking subjective impressions of visual interest and visual lightness.

refers to the non-uniformity of the illumination pattern or the degree of 'light and shade'. People prefer some modulation in the light pattern rather than an even pattern of illumination, the magnitude of the modulation depending on the application. There is some evidence that visual lightness and visual interest are inversely correlated (Fig- 5.2)

Although variation in the light pattern is desirable, it has to be seen as meaningful in terms of the application and the architecture. To provide random patches of light in an uncoordinated way for no reason other than to provide light variation would be a poor design solution. Acceptable examples could be highlighting displays within a retail outlet, or a floral display in a hotel lobby. There are two further areas of visual amenity that need to be considered and these are in the colour rendering and colour appearance of the lighting. The required colour rendering will depend on the functions the lighting is designed to fulfil. Where fine colour discrimination is required, light sources with a CIE general colour rendering index of at least 80 should be used. Where a natural appearance is required for people and objects, light sources with a CIE general colour rendering index of at least 60 and preferably higher should be used. Where such functions are not important poorer colour rendering light sources can be used. As for colour appearance, a light source with a correlated colour temperature (CCT) ^{2} 3000 K will appear warm and if it has a CCT 5300 K it will appear cool. Where on this scale from warm to cool the colour appearance should be will depend on the nature of the space. The designer should be wary of the names applied to light sources as these can be misleading and differ between manufacturers. The best way to choose colour appearance is through practical trials

5.4 Obtrusive light

In exterior applications the obtrusive light from floodlighting should be considered with respect to:

– sky glow (direct upward waste light);
– overspill (intrusive light and light into windows); and
– glare (source intensity).

These potential problems should be given consideration at the design stage as part of an overall environmental impact
Light pollution is a recognised statutory nuisance in the UK under the

Clean Neighbourhoods and Environment Act 2005. Recommended limitations on obtrusive light are shown in Table 5.1.

Table 5.1: Recommended obtrusive light limitations.

Environmental zone	Sky glow ULR inst (max %)	Light trespass. (into windows) *Ev* (lux) max	Source intensity *I* (kcd) max
E1 Dark landscapes	0	2	2.5
E2 Rural, village, dark urban locations	2.5	5	7.5
E3 Urban locations and small town centres	5	10	10
E4 Town and city centres	15	25	25

Note 1: Lower values may apply in relation to light trespass and source intensity where curfews are implemented by a local planning authority.

Note 2: ULR inst. relates to the upward light ratio for the full lighting installation.

Note 3: Where sports lighting overspills onto public highways, a limiting value of threshold increment should apply (TI = 15% max). To calculate TI see EN 13201-3.

5.4.1 Light trespass and sky glow

Light can be considered a form of pollution. This is implied by the inclusion of light as a statutory nuisance in the Clean Neighbourhoods and Environment Act: 2005. Exterior lighting is the major source of light pollution. Complaints about light pollution from exterior lighting can be divided into two categories, light trespass and sky glow. Light trespass is local in that it is associated with complaints from individuals in a specific location. The classic case of light trespass is a complaint about light from a road lighting luminaire entering a bedroom window and keeping the occupant awake. Light trespass can be avoided by the careful selection, positioning, aiming and shielding of luminaires and by operating a curfew system where lighting is only available during specified times. The Institution of Lighting Engineers (ILE) has produced general guidance on the vertical illuminance that should be allowed to fall on windows, the maximum luminous intensity of any obtrusive light source and a maximum building luminance for floodlighting. These limits are different for different environmental zones. The idea behind environmental zones is that some locations are more sensitive to light pollution than others. Table 5.1 shows the four environmental zones identified by the CIE. The limits recommended by the ILE for limiting light trespass are given in Table 5.2.

Table 5.2 The environmental zoning system of the CIE
Table 5.3 Maximum vertical illuminance on windows, maximum luminous intensity for obtrusive luminaires and maximum building luminance produced by floodlighting, for four environmental zones

Table 5.2: The environmental zoning system of the CIE

Environmental zone	Zone description and examples of sub-zones
E1	Areas with intrinsically dark landscapes: National Parks, areas of outstanding natural beauty (where roads are usually unlit)
E2	Areas of ‘low district brightness’: outer urban and rural residential areas (where roads are lit to residential road standard)
E3	Areas of ‘middle district brightness’: generally urban residential areas (where roads are lit to traffic route standard)
E4	Areas of ‘high district brightness’: generally, urban areas having mixed recreational and commercial land use with high night-time activity

Table 5.3: Maximum vertical illuminance on windows, maximum luminous intensity for obtrusive luminaires and maximum building luminance produced by floodlighting, for four environmental zones.

Environmental zone	Maximum vertical illuminance on windows (lx)		Maximum luminous intensity (cd)		Maximum building luminance (cd/m2)
	Before curfew	After curfew	Before curfew	After curfew	
E1	2	1	0	0	0
E2	5	1	50	.5	5
E3	10	5	100	1	10
E4	25	10	100	2.5	25

The values in Table 5.3 are for general guidance only and may need to be adjusted for specific circumstances. For example, the criteria given under zone E1 would not preclude the installation of lighting to meet health and safety requirements. As for the maximum building luminance, this is given to avoid over lighting but should be adjusted according to the general district brightness. An alternative approach based on limiting light crossing a property's boundary is the outdoor site-lighting performance (OSP) method (Brons et al, 2008). This method has the advantage that it deals with the site the designer is responsible for and does not require detailed knowledge of areas outside the site. Sky glow is more diffuse than light trespass in that it can affect people over great distances.

Fig-5.3: Light trespass, sky glow & glare

Sky glow is caused by the multiple scattering of light in the atmosphere, resulting in a diffuse distribution of luminance. The problem this causes is that it reduces the luminance contrast of all the features of the night sky thereby reducing the number of stars and other astronomical phenomena that can be seen. Sky glow has two components, one natural and one due to human activity. Natural sky glow is light from the moon, planets and stars that is scattered by interplanetary dust, and by air molecules, dust particles, water vapour and aerosols in the
Earth's atmosphere, and light produced by a chemical reaction of the upper atmosphere with ultra-violet radiation from the sun. The luminance of the natural sky glow at zenith is of the order of 0.0002 cd/m2. The contribution of human activity is produced by light traversing the atmosphere and being scattered by dust and aerosols in the atmosphere. The magnitude of the contribution of city lights to sky glow at a specific remote location can be crudely estimated by Walker's Law. This can be stated as

$I = 0.01\ P\ d–2.5$

where: I = the proportional increase in sky luminance relative to the natural sky luminance, for viewing 45° above the horizon in the direction of the city (e.g. I = 0.1 = 10 percent increase)
P = the population of the city

d = distance to the city (km)

This empirical formula assumes a certain use of light per head of population. Experience suggests the predictions are reasonable for cities where the number of lumens per person is between 500 and 1000 lumens. Sky glow can be reduced by limiting the amount of light used for exterior lighting, by using full-cut-off luminaires that have no upward component and by adopting a curfew in which the exterior lighting is either extinguished or reduced to a lower level when there are few people using it. For each environmental zone the maximum installed upward light output ratio of the luminaires used should be limited as shown in Table 5.3. Again, this is general guidance only and may need to be overturned in specific circumstances. The OSP method (Brons et al, 2008) again provides an alternative and more comprehensive approach in that it takes the whole installation and covers reflected light as well as direct upward light.

Table 5.4 Maximum installed upward light output ratio; luminous flux emitted above the horizontal plane as a percentage of the total luminous flux emitted by the luminaire

Environmental zone	Maximum upward light output ratio (%)
E1	0
E2	5
E3	15
E4	25

5.4.2 Glare

Glare may either impair vision (disability glare) or cause discomfort (discomfort glare). As both forms can occur simultaneously or separately, the control of glare is therefore a major factor to be considered in defining lighting.

In sports applications, direct discomfort glare is generally caused by high brightness light sources coming into a participant’s field of view. Minimising this may require special attention to the selection, positioning and screening of light sources and the use of diffusers, reflectors, refractors and similar devices on the luminaires. As the viewing direction of the participants constantly changes, it is difficult to provide definitive advice. However, some sports have frequently recurring viewing directions, so there is a need to limit discomfort glare as far as possible in principal viewing directions.

Some glare from light sources is unavoidable and may cause a certain amount of discomfort to players, officials and spectators. In exterior applications glare may also produce obtrusive light to the surrounding locality if not adequately controlled.

The degree of glare should always be restricted to a level where vision is not seriously affected. The levels of brightness of both the light source and adjacent background are important factors in the cause of glare. If the contrast between these is reduced, so will the effect of the glare.
This can be achieved in several ways.

– Lamps can be screened from view by an internal baffle and/or external louvre or cowl fitted to the luminaire.
– Luminaires may utilise a deep reflector to recess the lamp from view.
– Luminaires may incorporate a variable reflector to emit the beam forward from the nadir to the front glass, allowing shallower luminaire elevations in use.
– Luminaires may incorporate precise beam control to restrict stray light and focus the beam within the lit area.
– Luminaires can be positioned so that the observer’s line of sight is avoided.
– Background brightness can be controlled by utilising suitable room surface reflectance’s to reduce contrast in indoor sports applications.

The need to limit glare may conflict with other requirements. For instance, players and spectators are likely to be troubled most by glare when light reaches them at angles near the horizontal. However, it is this light which contributes to vertical plane illumination, enabling shuttles to be clearly seen in flight during badminton. The problem usually occurs where mounting heights are too low.

Glare associated with exterior sports may be evaluated by calculating the glare rating for the lighting installation. Control of discomfort glare in indoor applications may be evaluated using the unified glare rating (UGR) method. Disability glare in interior lighting is controlled by limiting the shielding of bare lamps.

5.4.2.1 Glare rating

Glare rating is calculated at a regular array of observer positions and viewing directions, specified to allow determination of the highest degree of glare over the playing surface. The maximum GR value achieved over the sports surface is taken as the glare rating for the sports installation. In this glare assessment the lower the value of GR, the better the glare restriction.

Glare rating is expressed for practical purposes as a number between 10 and 90, with interpretation as shown in Table 5.5

Table -5.5: Glare rating

Glare rating	Interpretation
10	Unnoticeable
30	Noticeable
50	Just admissible
70	Disturbing
90	Unbearable

5.4.2.2 Unified glare rating

In interior applications the likelihood of glare being experienced can be estimated by calculating the unified glare rating. The calculated index for a particular interior and lighting system can then be compared with a limiting value given in the recommendations of the SLL *Code for Lighting*. If the calculated value is greater than the recommended limit, modifications to the lighting system or the interior may be required.

5.5 Energy efficiency and sustainability

It is the responsibility of the lighting profession to use energy as efficiently as possible but at the same time to provide lit environments that enable people to operate effectively and comfortably. The current estimate for the

India is that approximately 18% of the electricity generated is consumed by lighting.
Energy use involves two components: the power demand of the equipment and its hours of use. The lighting industry has worked hard to develop equipment that has reduced the demand for electricity for lighting by producing more efficient light sources and their related control circuits, as well as more efficient luminaires. Good energy efficient lighting design is not just about equipment; it is also about the use of lighting. There are many examples where lighting is left on when it is not required. This may be because there is inadequate lighting through daylighting or because people are not present and therefore the lighting is unnecessary. This aspect of lighting design needs a dramatic change in attitude to improve the energy efficiency of all lighting installations. This requires changes to how the lighting is controlled both manually and automatically as well as how lighting is provided in terms of the distribution of light, particularly with respect to the daylighting. It is also necessary for the lighting industry and its customers to use equipment that is sustainable.

Sports lights are usually operated manually. Curfew timers can, however, offer a simple inexpensive energy saving measure to ensure sports lights do not burn excessively if they are accidentally left on. Curfew timers can also ensure that sports lights are not run past a set 'curfew' time that have been set in agreement with local residents or council policy. N.B. Curfew timers are not appropriate if the lighting could be used by emergency services.

5.6 Operation and Maintenance

Manuals Operation and maintenance manuals provide guidance on the correct operation and maintenance of floodlights. Developing an operation and maintenance manual at the time of the sports lighting installation will assist with the longevity and performance of lights.

The operation and maintenance manual should identify a policy for lamp replacement and should specify how regularly lights are cleaned. Manufacturer's advice should be sought regarding cleaning procedures and any other maintenance recommendations. Labelling each light with a unique reference and cross referencing this in the operation and maintenance manual assists with future maintenance and record keeping. Information from hours-run indicators and curfew timers (devices that automatically record the hours of lighting usage) should be recorded in the operation and maintenance manual to assist with further maintenance scheduling.

5.7 Cost or Budget

The budget tables included in this guide provide a breakdown of indicative costs for a new sports lighting installation consistent with the sample layouts highlighted. This is current at the time of writing (2011) and annual cost escalations should be taken into account. There are a number of factors that will have a bearing on probable costs to establish new or upgraded sports lighting. It is recommended that the budget be used as a guide only as site specific factors and implementation aspects will vary between projects (e.g. power supply requirements). Existing installations give rise to different cost considerations. Questions regarding suitability of the existing equipment to be used as part of an upgraded design need to be carefully considered to ensure they comply with the current Australian Standards (AS). Be particularly mindful of the pole height as many older poles do not meet current Australian Standards. For new sports lighting, soil conditions should be considered as this may impact on the placement of poles and overall costs. For example, many recreational reserves are constructed over landfill sites with poor soil conditions. Alternatively, facilities may be constructed on sites where rock is commonly encountered. Therefore, it is critical to obtain a geotechnical report of soil conditions at the proposed pole locations in conjunction with a structural engineer advising on the pole foundation designs. A geotechnical report typically costs $2,000 and should be included in your budget.

Costs are always a major concern for any project and it is important to consider these before any work is undertaken. Both the capital cost and the running, or operational, costs must be considered at the outset. If the two cost elements are not considered together in terms of life cycle costing, then a solution which has a low capital cost but a high operational cost could be costlier overall than an installation with a more expensive capital cost but a low operating cost. A conflict of interests may arise if the two cost elements are paid for from different budgets or organisations. This can happen with local authority projects. Here the designer needs to present a balanced view of the options to enable the clients to decide on the best approach.

The capital costs include the cost of the design process, the equipment and the installation process, both physical and electrical. It also includes the commissioning and testing of the installation. Allowance must also be made for any builders' work that forms part of the lighting installation. Any other costs that are particular to the lighting design need to be included. It is important that the capital cost is agreed at an early stage if a lot of time is not to be wasted. The capital cost should be challenged if the client's expectations seem to be unrealistic. The operational costs include the cost of the electricity consumed, which comprises items such as standing charges, maximum demand charges and electricity unit costs. They will also include the cost of maintenance, which includes cleaning and relamping throughout the life of the installation. In some cases, charges may have to be budgeted for the disposal of redundant equipment although this may be borne by the supplier.

5.8 Photopic or mesopic vision

The photometric quantities used to characterise lighting are all based on photopic vision. This makes sense for interior lighting where the luminances are usually high enough to ensure the visual system is operating in the photopic state but there may be problems for exterior lighting. This is because for adaptation luminance's below about 3 cd/m2 peripheral vision is operating in the mesopic state (see Section 2.2.2) and exterior lighting often produces luminances below this level. This is a problem because the spectral sensitivity of the peripheral retina changes continually during mesopic vision depending on the adaptation luminance, the peak sensitivity moving from the 555 nm to 507 nm as the adaptation luminance decreases to the scotopic state. There is no CIE mesopic observer so no system of mesopic photometry. In this situation, the simplest approach to ensuring good mesopic vision in exterior lighting is to use a light source with a scotopic/photopic (S/P) ratio greater than 1.5. Such light sources provide stimulation to both the cone and rod photoreceptors of the retina.

5.9 Equipment

Sports lighting should be designed and installed so that the sport being conducted can be comfortably performed by the participants and officials and viewed by spectators. Before installation, consideration should be given to determine what the intended purpose of play is; training, club-competition or semi-professional play. Making provision for upgrades (e.g. pole size and cabling) can significantly reduce the cost of upgrades in the future. The decision to install sports lighting should be made following consultation between the user groups, council and peak sporting bodies. Visiting sites with different levels of lighting also provides project proponents with a practical understanding of what various lux levels actually mean. The sports lighting installations can also serve to intentionally illuminate the areas where spectators gather. Poles can be used to mount other lights to illuminate perimeter areas. This needs to be considered when specifying poles and allowing the provision to mount such lighting (usually at lower levels on the poles), using separate electrical cabling infrastructure. This will allow operation of the lights for different times and requirements, such as public lighting Contact your local electricity company early in the process to organise power to the facility. Consider who is paying for the power use. Options include providing a separate metered account, installing a check meter which logs hours of use or payments based on typical usage patterns. Power supply requirements should be discussed early in the planning process to ensure supply requirements can be met for both immediate and future lux levels.

A field of play will vary in its power demand requirements depending on the illumination level. Competition level lighting power demands are often greater than the rest of the facility's demand combined. In addition, many sports lights have a higher demand during start up and this demand needs to be carefully considered when selecting the electrical supply and cable reticulation. Power supply to each pole can come from either the clubroom main switchboard (for training level) or a dedicated floodlighting switchboard and sub main supply system for each pole (for competitive level). Ensure existing switchboards have the capacity to cope with additional requirements.

5.10 Aiming floodlights and commissioning sports floodlighting installations

5.10.1 Checking Equipment

After erection of masts and fixing of floodlights, the lighting scheme enters its final stage prior to commissioning. It is advisable to re-check that all equipment (masts and floodlights) is located correctly since any installation errors will be difficult to determine at commissioning.

5.10.2 Floodlight Aiming

There are two principal methods used for aiming floodlights:

– floodlights are adjusted to stated

Fig-5.4: Floodlight aiming

angles of horizontal (azimuth) and vertical alignment; and – floodlights are sighted to predetermined aiming points on the playing surface.

The decision over which method is deployed will be influenced greatly by the degree of accessibility to floodlights and masts. When a floodlighting scheme is being prepared, the design calculations will probably be based upon grouping floodlights at a single point at each masthead. In large floodlight

arrays this may result in aiming errors unless position corrections are applied. For small floodlight arrays, collective floodlight grouping should produce insignificant aiming errors. Azimuth angles are a measure of the floodlight's rotation about its fixing point on the mast relative to a horizontal reference plane. Elevation angles relate to the angle between the floodlight's peak intensity and the downward vertical. Most floodlights are fitted with a side protractor scale to enable simple setting of the elevation angle. Where a lighting scheme does not provide details of the individual aiming adjustments, it may be necessary to derive angles of azimuth and vertical settings from basic trigonometry. Where floodlights are aimed via direct sighting, either a telescopic sight or a special aiming device will be required to aim each floodlight to a precise point on the playing surface.

5.10.3 Large floodlight Arrays

In a floodlighting installation in a large stadium, consideration should be given to provision of lighting switching steps for various levels of stadium use. The arrangement of floodlight groups should be in such a way that logical visual appearance is achieved. The impression that some floodlights may have failed should not be conveyed when switching from one arrangement to the next.

Large floodlight head frames may be tilted forward to a fixed inclination (typically 15º) to reduce the possibility of floodlights on upper rows from shining onto those floodlights directly below. An inclined head frame may also provide a more aesthetically pleasing appearance.

5.10.4 Commissioning the installation

The commissioning of lighting involves a visual assessment at night, the measurement of illuminances and validation against design objectives and calculations. During the assessment, good climatic conditions are required and any extraneous light from surroundings should be kept to a minimum and recorded. Before measurements are taken, all lamps should be run-up sufficiently to ensure stable operation and full output. It is advisable to conduct a visual assessment of the lit sports surface prior to undertaking illuminance measurements. A visual assessment should determine:

– the acceptability of the brightness and contrast over the playing surface for the appropriate sports;

and

– the acceptability of the visual impression of glare while viewing the sports surface.

5.10.5 Measurement of Illuminance

All measurements of illuminance should be recorded using a suitable portable light meter with a valid certificate of calibration (see BS 667). The instrument should use an appropriate means of aligning the photocell to the plane of measurement. Large reading errors may result if the photocell is out of alignment from the reference plane by only a few degrees. Measurements of horizontal plane illuminance are taken at ground level.

Measurements of vertical plane illuminance are taken at 1 m above ground level in the appropriate reference direction. Care should be taken not to cast shadows or reflect light from clothing onto the photocell during measurement. To avoid this, it is advisable to use a remote photocell sensing unit connected to the light meter by a long extension cable.

The measurement record should include the following:

- Date and time of measurement/commissioning;
- Nomenclature of the sports ground;
- Full installation details (the sport's surface dimensions, mast locations, floodlight quantities, aiming discrepancies);
- Lighting equipment information (lamp type, control gear settings, dimming and switching provision, number of lamps operating);
- Installation age, condition and hours of use since last cleaning;
- The number of hours the lamps have been burning;
- Apparent differences in lamp colour temperature;
- Operating voltage at control gear terminals taken during illuminance measurements;
- Weather conditions; and
- Light meter type, serial number and date of last calibration.

Correction factors may need to be applied to the measured illuminance values depending upon the installation details appertaining to the measurement record. In the final comparison between the measured and designed average values, a variation of not more than 10% may result (excluding illuminance meter uncertainties) due to:

- Manufacturing tolerances (luminaires, lamps, mast heights etc.);
- Installation tolerances (reference area size, mast locations, floodlight positioning and aiming); and
- Tolerances in photometric measurements.

Additional tolerances can be caused by voltage variation relative to nominal control gear settings. Lamp manufacturers generally provide graphical information per lamp type and wattage, relating variation in Supply Voltage

(Vs) against Lamp Lumen Output (Lm) to enable applicable corrections to be applied where appropriate.

5.11 Power and Electrical Supply

Contact your local electricity company early in the process to organise power to the facility. Consider who is paying for the power use. Options include providing a separate metered account, installing a check meter which logs hours of use or payments based on typical usage patterns. Power supply requirements should be discussed early in the planning process to ensure supply requirements can be met for both immediate and future lux levels. A field of *play* will

.

requirements depending on the illumination level. Competition level lighting power demands are often greater than the rest of the facility's demand combined. In addition, many sports lights have a higher demand during start up and this demand needs to be carefully considered when selecting the electrical supply and cable reticulation. Power supply to each pole can come from either the clubroom main switchboard (for training level) or a dedicated floodlighting switchboard and sub main supply system for each pole (for competitive level). Ensure existing switchboards have the capacity to cope with additional requirements.

Fig-5.4: The pole is permanently wired from the club switchboard. A key switch at the base of the pole provides lighting control of a playing surface

5.11.1 Safety & Suggestions

The power supply to each pole can come from the clubroom main switchboard. While not mandatory, control via a suitable Residual Current Device is recommended. The Residual Current Device is designed to disconnect the power supply to prevent an 'electrical leak' which can cause fatal injury through an 'electric shock'.

- Establish what method will be used to meter/record lighting use, particularly for the purposes of attributing power bill payments and maintenance.
- Determine the power supply required to meet immediate and future levels of play. Ascertain whether the supply required is readily available and any potential costs.

5.11.2 Control Supply – How should lights be controlled?

Training level lighting is often controlled directly through manual switches. Club competition level lighting can also be controlled in a similar way on a pole-by-pole basis. Pole switches can be located at a central location or at the base of each pole. Switches should be either operated by key, in a lockable enclosure or locked in a controlled area accessible to authorized persons only. Accessibility should be considered when locating lighting controls. A useful and inexpensive additional measure is to fit an hours-run indicator to log operating hours. This allows clubs to keep track of energy use (= hours x total rated wattage of lights) and provides a log for repair and maintenance purposes.

CHAPTER 6

6. Lighting design & Result analysis

A. General

The lighting design of the football pitch shall be complied with Class I (Training and Recreation). The design shall conform to the BS EN 12193 (Latest version) and FIFA Standards (Lighting Design Specifications and Technology) on lighting for football stadiums. The work covered by this section of specifications covers the sports lighting for football pitch and all related works including light luminaire, light pole, panel boards, cabling, lightning protection access systems, standby power supply etc. and this shall be read in conjunctively with drawings provided.

B. Lighting design

1. Performance Requirements: Lighting calculations shall be developed and field measurements taken on the grid spacing with the minimum number of grid points specified in the FIFA & ITF document. Measured average illumination level shall be predicted mean in accordance with IESNA RP-6-01, and measured at the first 100 hours of operation.

2. Lumen maintenance: Light system shall use adjustments to achieve a lumen maintenance. Lumen maintenance control strategy calls for reducing the initial illumination of a new system to the designed minimum level.

3. Independent Test Report: Manufacturers bidding light system must provide an independent test report verifying the field performance of the system for the duration of the life of the lamp, signed by a licensed professional engineer with outdoor lighting experience.

4. Project References: Manufacturers bidding any form of a light system must provide a minimum of five (5) sports project references that have been completed within the last calendar year utilizing this exact technology that have a minimum of 500 hours of operation and field testing to verify light levels. Manufacturer will include project name, project city with country, contact name, and contact phone number for each reference.
Strictly follow the specifications attached for electrical installation

According to the FIFA Standards & ITF standards on lighting for football & tennis court stadiums and BS EN 12193 following conditions must be satisfied for Class III – Training and Recreation & Class –II for national non televised. Following shall be available at the pitch when the installation is finished

Table-6.1: Standards

Index	Horizontal illuminance1	Eh ave (lux)	≥200- Class III ≥500-Class II
1	Uniformity	U1(min./average illumination)	≥0.7
2	Lamp colour temperature	T (k)	> 4,000
3	Lamp colour rendering		≥ 70
4	Recommended maintenance factor		0.75
5	Initial values will therefore be approximately 1.4 times those indicated above.		
6	Illuminance uniformity shall not exceed than 30% every 10 metres.		
7	Primary player view angles must be free of direct glare. This glare rating is satisfied when the player view angles are satisfied.		

Horizontal illuminance is a measure of light reaching a horizontal plane, one metre above the playing surface. A 5m x 5m grid across the playing field is used as a basis for collecting these measurements and calculating maximum/minimum/average illumination on the playing field.

Contractor shall adjust the luminaries using an aiming device as per the DIALux design and prove the above light levels are satisfied by using Lux meter. The necessary testing instruments shall be supplied and testing shall be done by the bidder at the presence of the Engineer. Testing format shall comply with the FIFA & ITF standard.

C. Luminaire

Energy efficient LED floodlight system used for sports applications shall be used. The proposed system shall be innovative LED lighting solution that supports the latest sports requirements standards and features a control platform. Proposed system shall be with outstanding lighting quality, effective thermal management and long lifetime. It shall ensure effective thermal management system to optimize the lifetime cost and deliver high performance.

Table-6.2: LED luminaire specification

1	Ingress protection	IP65
2	Housing Material	Extruded aluminium and die cast aluminium
3	Adjustable bracket	Stainless steel galvanized
4	comply with requirements of IEC 60598-2-3 in conjunction with IEC 60598-1, such that adequate resistance to dust and moisture, impact/vibrations and corrosion is achieved	
5	Power Consumption (Maximum)	1000W
6	Lamp colour rendering	≥ 70
7	Efficacy	≥108 lm/W.
8	Power factor	≥ 0.9
9	Surge protection of luminaire	15kV/kA.
10	IK protection	IK08
11	colour temperature	> 4,000K
12	lifetime	50000 hours at Ta 35 outdoor
13	Shall be high resistance to temperature and UV (heat sink fins with proper thermal management system). Aluminium	
14	LM - 79 and LM - 80 test reports shall be attached	
15	Lumen depreciation - more than 70% available at the end of 50000hrs	
16	Shall be compatible for mounting in high masts more than 18m height with wind force protection, Anti-dust, UV resistance	
17	Provision for future upgrading with Remote operating facility and dimming shall be included	

a. Support Housing shall be shielded with protective coating(s) and shall comply with requirements of IEC 60598-2-3 in conjunction with IEC 60598-1, such that adequate resistance to dust and moisture, impact/vibrations and corrosion is achieved.
b. Lens (clear front cover): Flat optic cover made from injected melded high impact acrylic plastic or tempered glass and shall be impact resistant, dust proof
c. Color of the body: Gary/Black
d. Shall match with the light pole
e. The pole, cross arms shall be designed to cater to the proposed luminaire

In this chapter we will discuss the design and results of two types of sports ground in IIM Calicut.

i) Football Ground

a) Class III (Training & Recreation Level)

b) Class II (National Level Non televised)

ii)Tennis Court

a) Class III (Training & Recreation Level)

b) Class II (National Level Non televised)

6.1 Football Ground

The lighting design of the football pitch shall be complied with Class III (Training and Recreation) & Class II (National Level Non televised).

The design shall conform to the BS EN 12193 (Latest version) and FIFA Standards (Lighting Design Specifications and Technology) on lighting for football stadiums.

6.1.1 Planning data

Construction of sport complex, playgrounds, sport school, sport grounds and fields assumes creation clear plans, layouts, or sketches. In many cases we need represent on the plan multitude of details, including dimensions, placement of bleachers, lighting, considering important sport aspects and other special things. In this chapter we will discuss two types of football ground lighting design. First we will discuss the education sports ground lighting then we will discuss the lighting of the national level sports ground, this will continue in succession. In the case of two types of field lighting, the planning data will be the same because we are doing two types of lighting in the same field. Fig-6.1 shows the area dimension of football ground and their surrounding area.

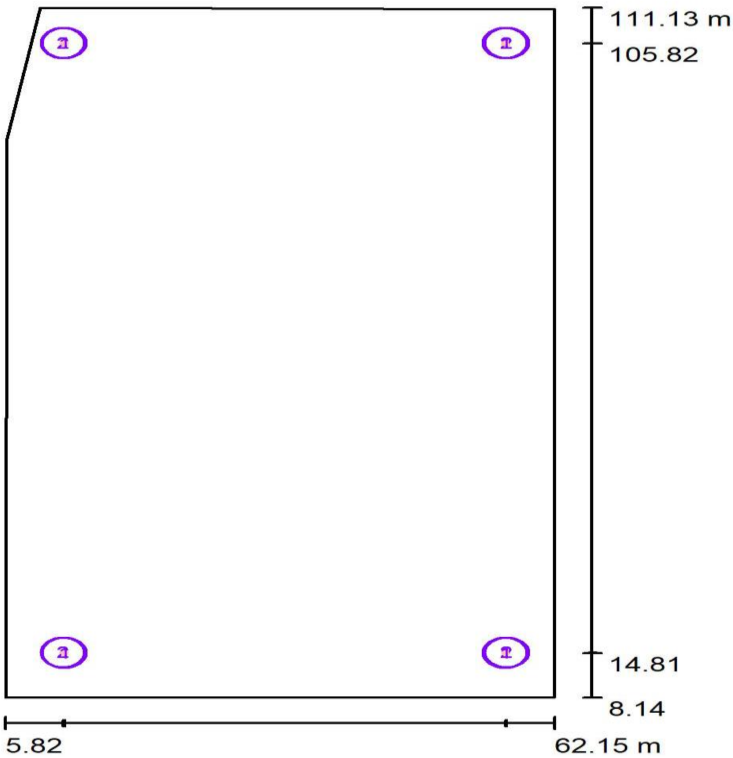


Fig-6.1: Planning diagram

6.1.2 Luminaire parts list

In this section we have soon in tabular form, in which area what type of luminaire is used. Table-6.3 & 6.4 shows the data of luminaire.

Note- a. UHLUNB-Ultra high lumen output & ultra-narrow beam
b. HLNB- High lumen output & narrow beam

- **Luminaire parts list for education level sports lighting design**

Table-6.3: Luminaire parts list

No.	Pieces	Designation (Correction Factor)	(Luminaire) [lm]	(Lamps) [lm]	P [W]
1	16	ORIENT ELECTRIC LFSMP-500-C-UHLUNB	44000	44000	400
2	20	ORIENT ELECTRIC LFSMP-400-C-HLNB	60000	60000	600
		Total:	1904001	1904000	16400.0

- **Luminaire parts list for national level sports lighting design**

Table-6.4: Luminaire parts list

No.	Pieces	Designation (Correction Factor)	(Luminaire) [lm]	(Lamps) [lm]	P [W]
1	16	ORIENT ELECTRIC LFNG1-1000-C-UNB (1.000)	120000	120000	1000
2	32	ORIENT ELECTRIC LFSMP-500-C-UHLNB(1.000)	60000	60000	500
		Total:	3840001	3840000	32000.0

6.1.3 Sport Sites (layout plan) of education level sports lighting design & national level sports lighting design

Construction of sport complex, playgrounds, sport school, sport grounds and fields assumes creation clear plans, layouts, or sketches. In many cases you need represent on the plan multitude of details, including dimensions, placement of bleachers, lighting, considering important sport aspects and other special things.
Design standard football field class III & II football pitches and a stadium capacity and the capacity audience to the location and the importance of play and the percentage of the population are dependent on pro football. This number varies between 5 and 120 thousand. Suitable for audiences on both sides of the longitudinal view of soccer. At district level, towns and places where there is a large audience and in the fields of training usually consists of a length of the pitch side spectator's alternative platforms. We have designed the education football ground here. It is designed to seat 100 to 200 people to watch the game.

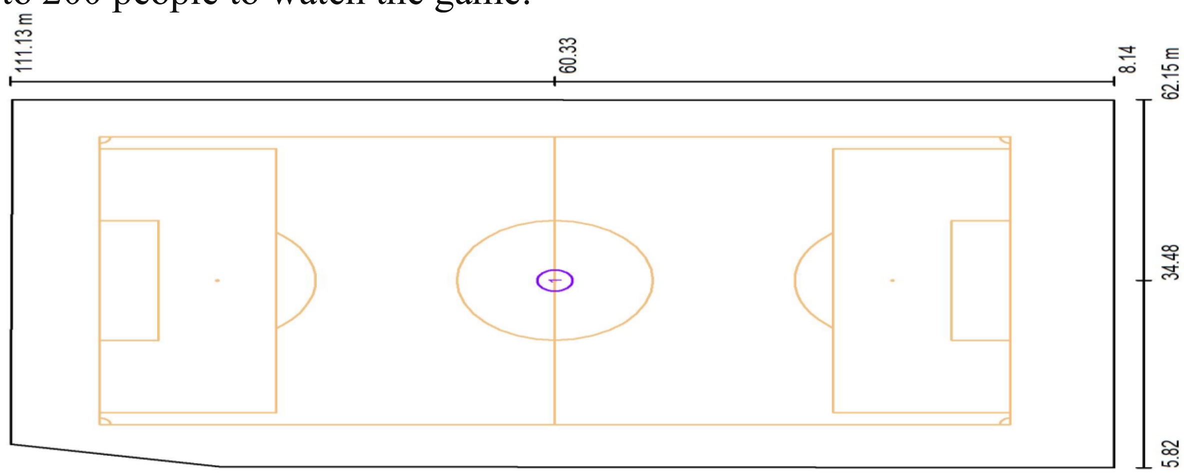


Fig-6.2: Sport Sites (layout plan)

Sport Sites (Coordinates List)

Table-6.5: Sport Sites (Coordinates List)

Size Playing Area [m]		Size Total Area [m]	
L	W	L	W
85	44	95	48

6.1.4 Sport Luminaires (Coordinates List) of education level sports lighting design & national level sports lighting design

Here we will discuss about the position of light. How high are the lights mounted? What is the aiming point point of each light? How many degrees is a light turned? All types of information are discussed here. If we do not mount each light according to this date, we will not get the correct results. So this information becomes very necessary for us. All the information is discussed in the table below.

In Fig-6.5 & Fig-6.6 each of the arrow symbols shown here represents a light. In table-6.6 & 6.7 shows each luminaire position (X,Y), mounting height(Z), aiming angle, tilt angle(o).

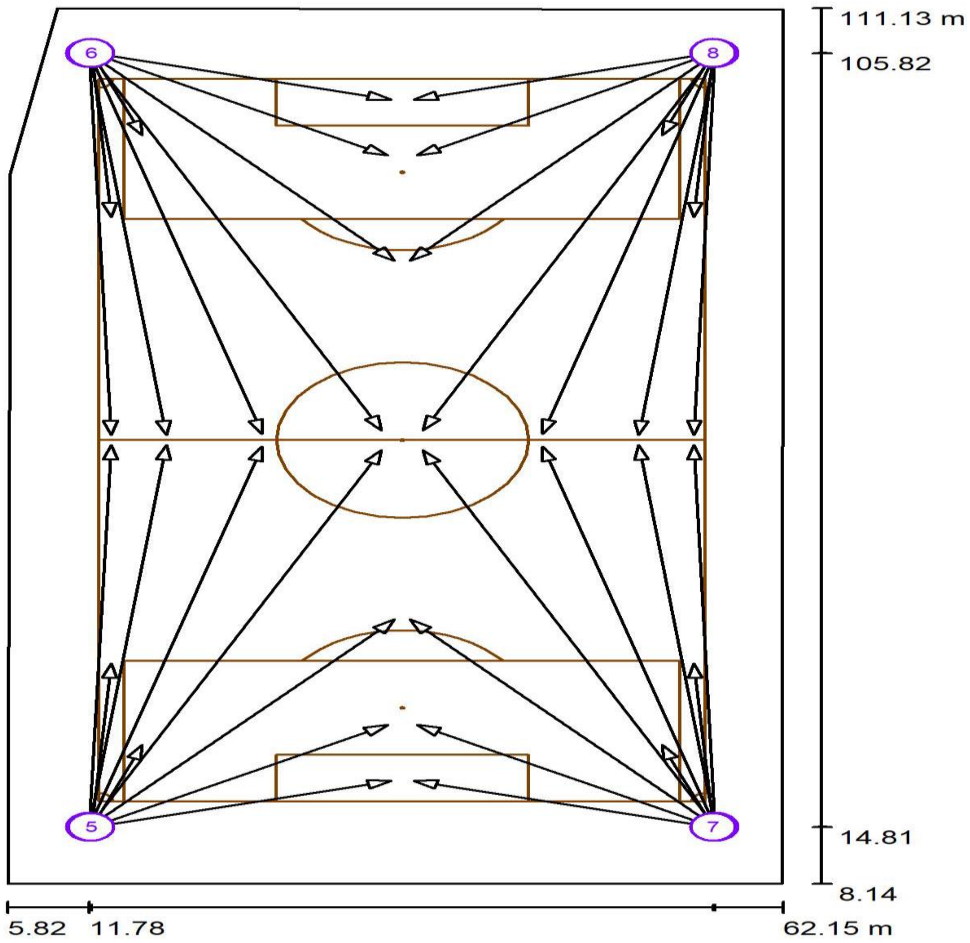


Fig-6.3: Class III education level luminaire Coordinates List

Table-6.6 List of the Sport Luminaires of Class III education level

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]
		X	Y	Z	X	Y	Z	
ORIENT ELECTRIC LFSMP-500-C-UHLUNB	1	11.779	14.832	20	33.912	39.223	0	31.3
	1	11.779	14.832	20	17.344	59.721	0	23.9
	1	11.779	14.832	20	24.294	59.596	0	23.3
	1	11.779	14.832	20	32.969	59.168	0	22.1
	1	11.779	14.832	20	13.361	59.721	0	24.0
	2	11.779	105.820	20	33.912	81.429	0	31.3
	2	11.779	105.820	20	17.344	60.931	0	23.9
	2	11.779	105.820	20	24.294	61.056	0	23.3
	2	11.779	105.820	20	32.969	61.484	0	22.1
	2	11.779	105.820	20	13.361	60.931	0	24.0
	3	57.181	14.832	20	35.048	39.223	0	31.3
	3	57.181	14.832	20	51.616	59.721	0	23.9
	3	57.181	14.832	20	44.666	59.596	0	23.3
	3	57.181	14.832	20	35.991	59.168	0	22.1
	3	57.181	14.832	20	55.599	59.721	0	24.0
	4	57.181	105.820	20	35.048	81.429	0	31.3
	4	57.181	105.820	20	51.616	60.931	0	23.9
	4	57.181	105.820	20	44.666	61.056	0	23.3
	4	57.181	105.820	20	35.991	61.484	0	22.1
	4	57.181	105.820	20	55.599	60.931	0	24.0
ORIENT ELECTRIC LFSMP-400-C-HLNB	5	11.916	14.807	20	15.618	24.466	0	62.7
	5	11.916	14.807	20	33.403	26.856	0	39.1
	5	11.916	14.807	20	13.361	34.077	0	46.0
	5	11.916	14.807	20	33.652	20.258	0	41.7
	6	11.916	105.845	20	15.618	96.186	0	62.7
	6	11.916	105.845	20	33.403	93.796	0	39.1
	6	11.916	105.845	20	13.361	86.575	0	46.0
	6	11.916	105.845	20	33.652	100.394	0	41.7
	7	57.044	14.807	20	53.342	24.466	0	62.7
	7	57.044	14.807	20	35.557	26.856	0	39.1
	7	57.044	14.807	20	55.599	34.077	0	46.0
	7	57.044	14.807	20	35.308	20.258	0	41.7
	8	57.044	105.845	20	53.342	96.186	0	62.7
	8	57.044	105.845	20	35.557	93.796	0	39.1
	8	57.044	105.845	20	55.599	86.575	0	46.0
	8	57.044	105.845	20	35.308	100.394	0	41.7

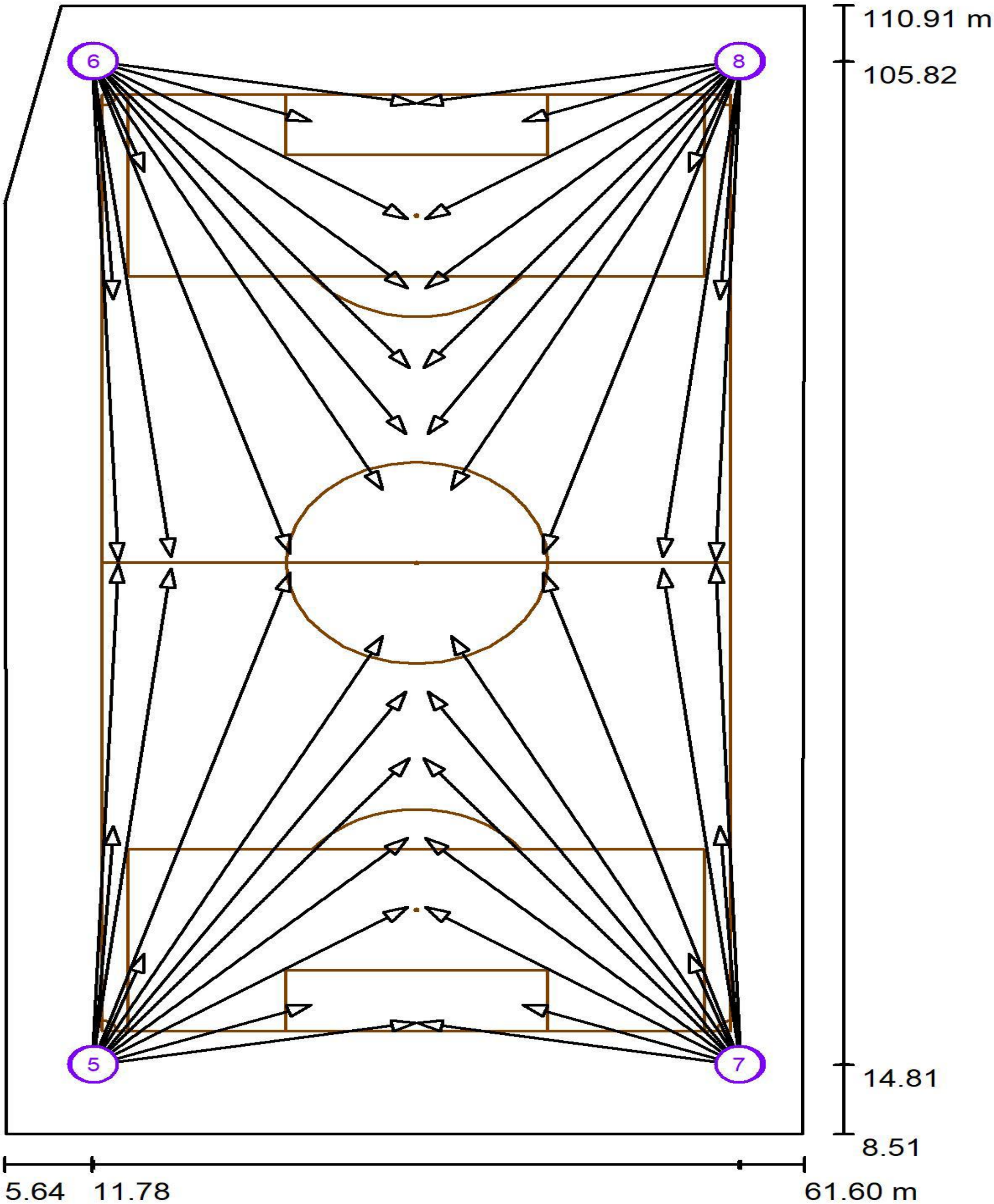


Fig-6.4 -Class II national level luminaire arrangement

Table-6.7: List of the Sport Luminaires Class II (National Level Non televised)

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]
		X	Y	Z	X	Y	Z	
ORIENT ELECTRIC LFNG1-1000-CUNB	1	11.779	14.832	20	13.584	60.200	0	23.8
	1	11.779	14.832	20	17.284	59.787	0	23.8
	1	11.779	14.832	20	25.610	59.473	0	23.2
	1	11.779	14.832	20	32.076	53.690	0	24.5
	2	11.779	105.820	20	13.584	60.452	0	23.8
	2	11.779	105.820	20	17.284	60.865	0	23.8
	2	11.779	105.820	20	25.610	61.179	0	23.2
	2	11.779	105.820	20	32.076	66.962	0	24.5
	3	57.181	14.832	20	55.376	60.200	0	23.8
	3	57.181	14.832	20	51.676	59.787	0	23.8
	3	57.181	14.832	20	43.350	59.473	0	23.2
	3	57.181	14.832	20	36.884	53.690	0	24.5
	4	57.181	105.820	20	55.376	60.452	0	23.8
	4	57.181	105.820	20	51.676	60.865	0	23.8
	4	57.181	105.820	20	43.350	61.179	0	23.2
	4	57.181	105.820	20	36.884	66.962	0	24.5
ORIENT ELECTRIC LFSMP-500-C-UHLNB	5	11.916	14.807	20	33.987	42.631	0	29.4
	5	11.916	14.807	20	27.073	20.243	0	51.2
	5	11.916	14.807	20	13.279	36.427	0	42.7
	5	11.916	14.807	20	34.395	18.625	0	41.3
	5	11.916	14.807	20	15.437	24.867	0	61.9
	5	11.916	14.807	20	33.851	29.115	0	37.4
	5	11.916	14.807	20	33.851	35.395	0	33.6
	5	11.916	14.807	20	33.714	48.638	0	26.4
	6	11.916	105.845	20	33.987	78.021	0	29.4
	6	11.916	105.845	20	27.073	100.409	0	51.2
	6	11.916	105.845	20	13.279	84.225	0	42.7
	6	11.916	105.845	20	34.395	102.027	0	41.3
	6	11.916	105.845	20	15.437	95.785	0	61.9
	6	11.916	105.845	20	33.851	91.537	0	37.4
	6	11.916	105.845	20	33.851	85.257	0	33.6
	6	11.916	105.845	20	33.714	72.014	0	26.4

ORIENT ELECTRIC LFSMP-500-C-UHLNB	7	57.044	14.807	20	34.973	42.631	0	62.7
	7	57.044	14.807	20	41.887	20.243	0	39.1
	7	57.044	14.807	20	55.681	36.427	0	46.0
	7	57.044	14.807	20	34.565	18.625	0	41.7
	7	57.044	14.807	20	53.523	24.867	0	62.7
	7	57.044	14.807	20	35.109	29.115	0	39.1
	7	57.044	14.807	20	35.109	35.395	0	46.0
	7	57.044	14.807	20	35.246	48.638	0	46.0
	8	57.044	105.845	20	34.973	78.021	0	29.4
	8	57.044	105.845	20	41.887	100.409	0	51.2
	8	57.044	105.845	20	55.681	84.225	0	42.7
	8	57.044	105.845	20	34.565	102.027	0	41.3
	8	57.044	105.845	20	53.523	95.785	0	61.9
	8	57.044	105.845	20	35.109	91.537	0	37.4
	8	57.044	105.845	20	35.109	85.257	0	33.6
	8	57.044	105.845	20	35.246	72.014	0	26.4

6.1.5 GR Observer (Results Overview)

In 1994, the CIE developed a glare evaluation method for outdoor sports lighting and area lighting applications (CIE document 112-1994). This system is available for checking the Glare Rating situation of existing installations and for predicting glare rating at the design stage in new installations.

The Glare Rating calculation grid provides an indication of glare experienced by the observer for each point in the grid based on the veiling illuminance produced by the luminaires and the environment (ground plane only) on an observer's eye. It is measured as the observer looks at each point on a horizontal illuminance grid. Glare Rating is restricted to horizontal grids of points below eye level and is used in outdoor area and sports lighting applications. A lower Glare Rating value (GR) indicates better glare restriction.

Each glare rating grid is tied to one observer position. Glare rating is calculated for each point on grid based on the veiling luminance produced on the eye by the luminaires and the environment.

When Glare Rating is specified, grids are created for each observer position that duplicate the specified horizontal illuminance grid. Each GR grid is identified by its correlated observer position, which are labelled sequentially, Object_1, Object_2, etc.

In this design, a horizontal grid labelled "GR Observer" with one observer position would have a Glare Rating grid associated with it called "GR Observer 1." The Glare Rating calculation does not take reflective or obstructive entities around or within the GR grid into account.

To prevent both the uncomfortable effects of direct and indirect glares, and the unnecessary amount of light pollution to the individuals and settlements near to the stadium premises, glare rating is to be considered, with upper limit fixed at 50. As displayed in Fig-6.5 and Fig-6.6, a total of eighteen GR observer points with 0 to 360º field-of-view have been taken at random, each situated at a height of 1.5m above the ground level to depict position of observer's eye level, and each one with a slope angle of -2° is below the horizontal level, so the observer looks towards the ground. The resultant level of GR has been found to be in a range of 31 to 48. i.e. within the acceptable limits. Table 6.8 & 6.9 shows the tabular data of GR observer.

Education level sports lighting design / GR Observer (Results Overview)

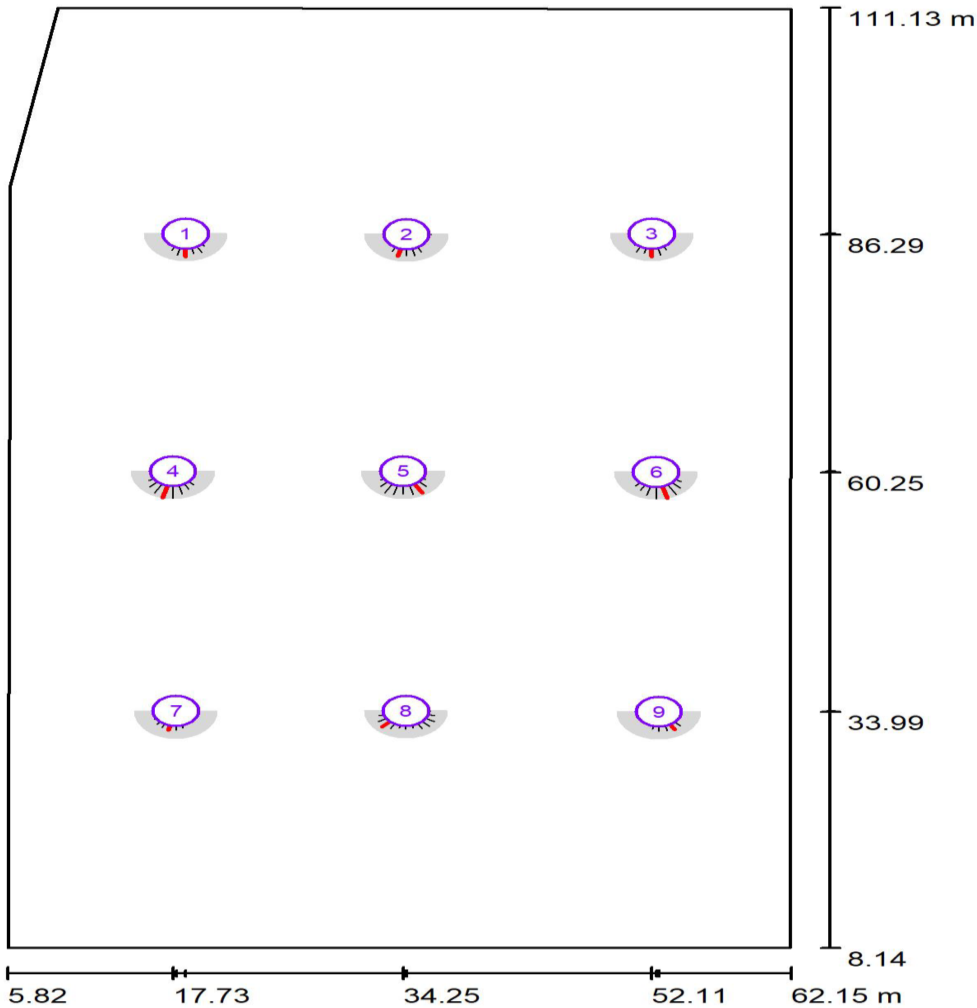


Fig-6.5: GR Observer

- ## GR Observer list

Table-6.8: GR Observer list

1	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
1	GR Observer 1	18.640	86.357	1.500	180	360	15	-2	41
2	GR Observer 2	34.482	86.287	1.500	180	360	15	-2	39
3	GR Observer 3	52.113	86.376	1.500	180	360	15	-2	41
4	GR Observer 4	17.730	60.331	1.500	180	360	15	-2	48
5	GR Observer 5	34.253	60.349	1.500	180	360	15	-2	44
6	GR Observer 6	52.416	60.249	1.500	180	360	15	-2	48
7	GR Observer 7	17.940	34.073	1.500	180	360	15	-2	34
8	GR Observer 8	34.463	34.091	1.500	180	360	15	-2	40
9	GR Observer 9	52.626	33.991	1.500	180	360	15	-2	36

National level sports lighting design / GR Observer (Results Overview)

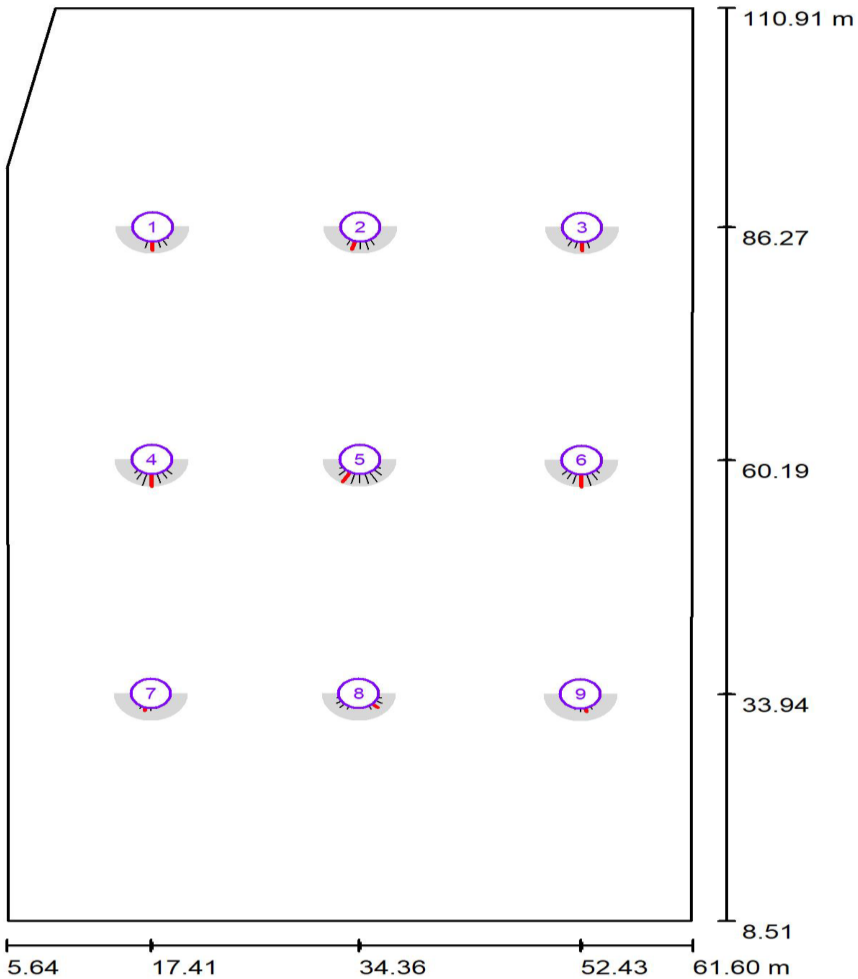


Fig-6.6: GR Observer

GR Observer list

Table-6.9: GR Observer list

No.	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
1	GR Observer 1	17.547	86.340	1.500	180	360	15	-2	41
2	GR Observer 2	34.492	86.340	1.500	180	360	15	-2	41
3	GR Observer 3	52.569	86.270	1.500	180	360	15	-2	41
4	GR Observer 4	17.506	60.256	1.500	180	360	15	-2	47
5	GR Observer 5	34.451	60.256	1.500	180	360	15	-2	45
6	GR Observer 6	52.416	60.186	1.500	180	360	15	-2	47
7	GR Observer 7	17.412	34.009	1.500	180	360	15	-2	31
8	GR Observer 8	34.357	34.009	1.500	180	360	15	-2	35
9	GR Observer 9	52.434	33.939	1.500	180	360	15	-2	32

6.1.6 3D Rendering

3D rendering is the process of turning information from a 3D model into a 2D image. 3D rendering can be used to create a variety of images, from the intentionally non-realistic (see Figure 1) to what's called photorealistic. Fig-6.7 shows our design 3D model of football ground. Fig-6.8 & 6.9 shows the 3D rendering image of two types football ground.

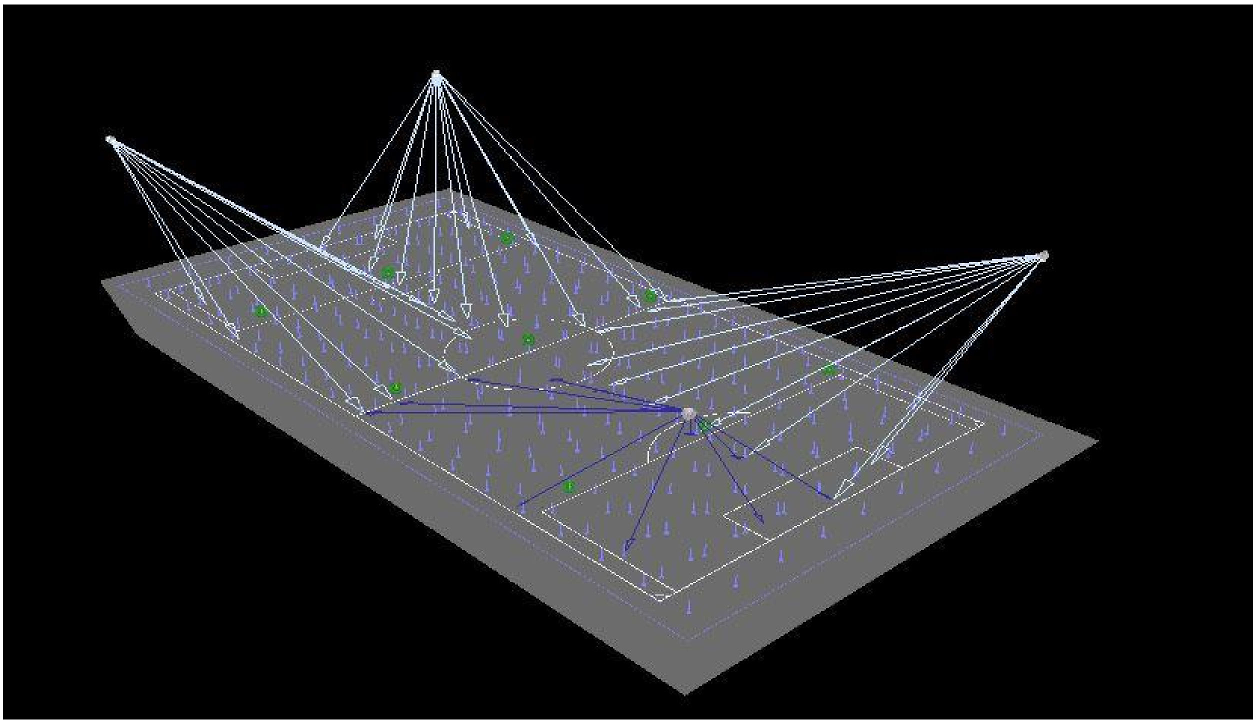


Fig-6.7: 3D Rendering

Education level sports lighting design / 3D Rendering

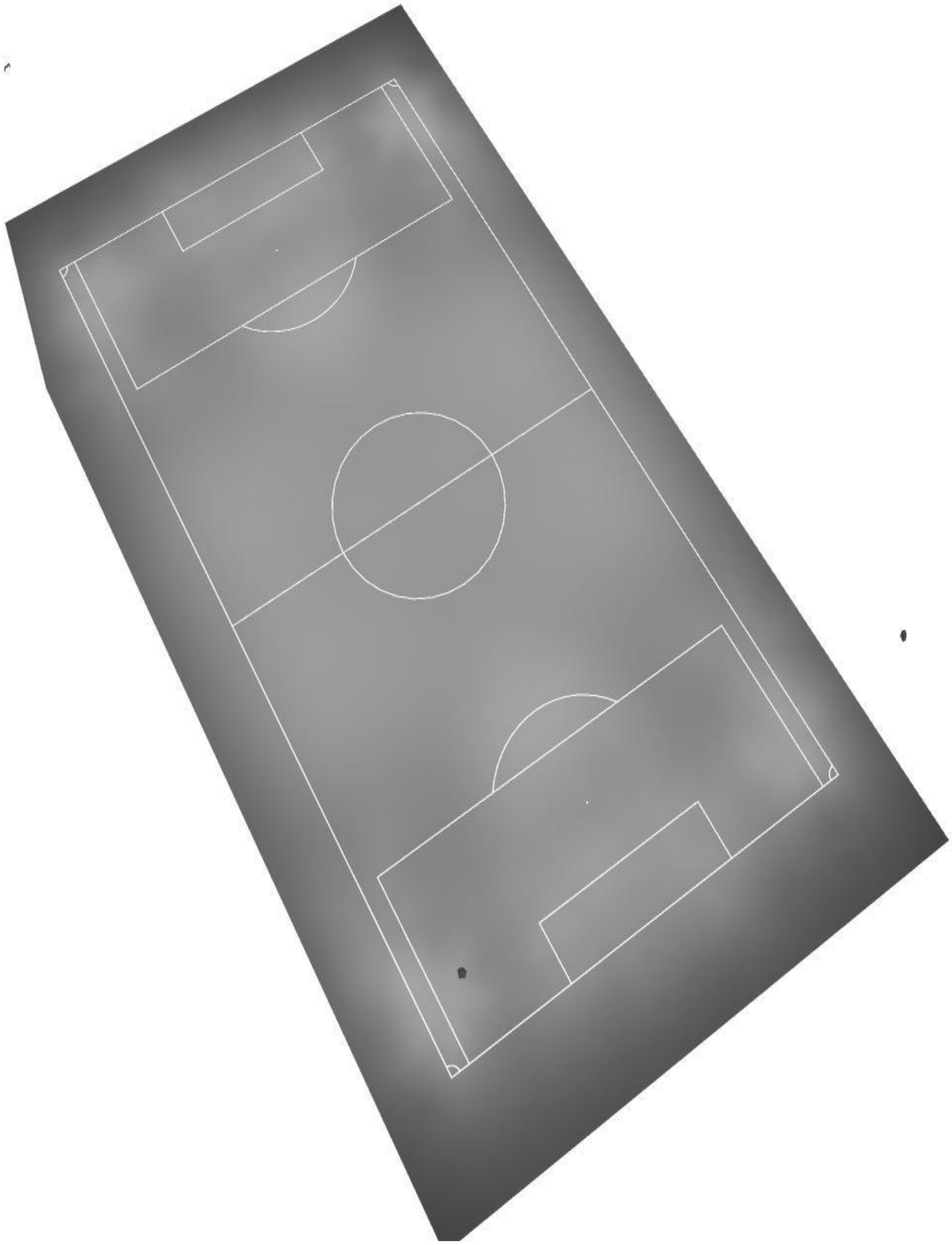


Fig-6.8: Education level sports lighting design / 3D Rendering

National level sports lighting design / 3D Rendering

Fig-6.9: National level sports lighting design / 3D Rendering

False Color Rendering

False color or pseudo-color renderings help in evaluating rendered spaces. These renderings given a quick idea of the lighting distribution within the space by graduating them on an illuminance or luminance scale and representing them in different colors or grey tones. With the help of the color code below, we can easily understand how many lux level there are in any place. Fig-6.10 & 6.11 shows the false color rendering image of two types football ground. From the color bar code, we can easily understand how much light there is in any place.

Education level sports lighting design / False Color Rendering

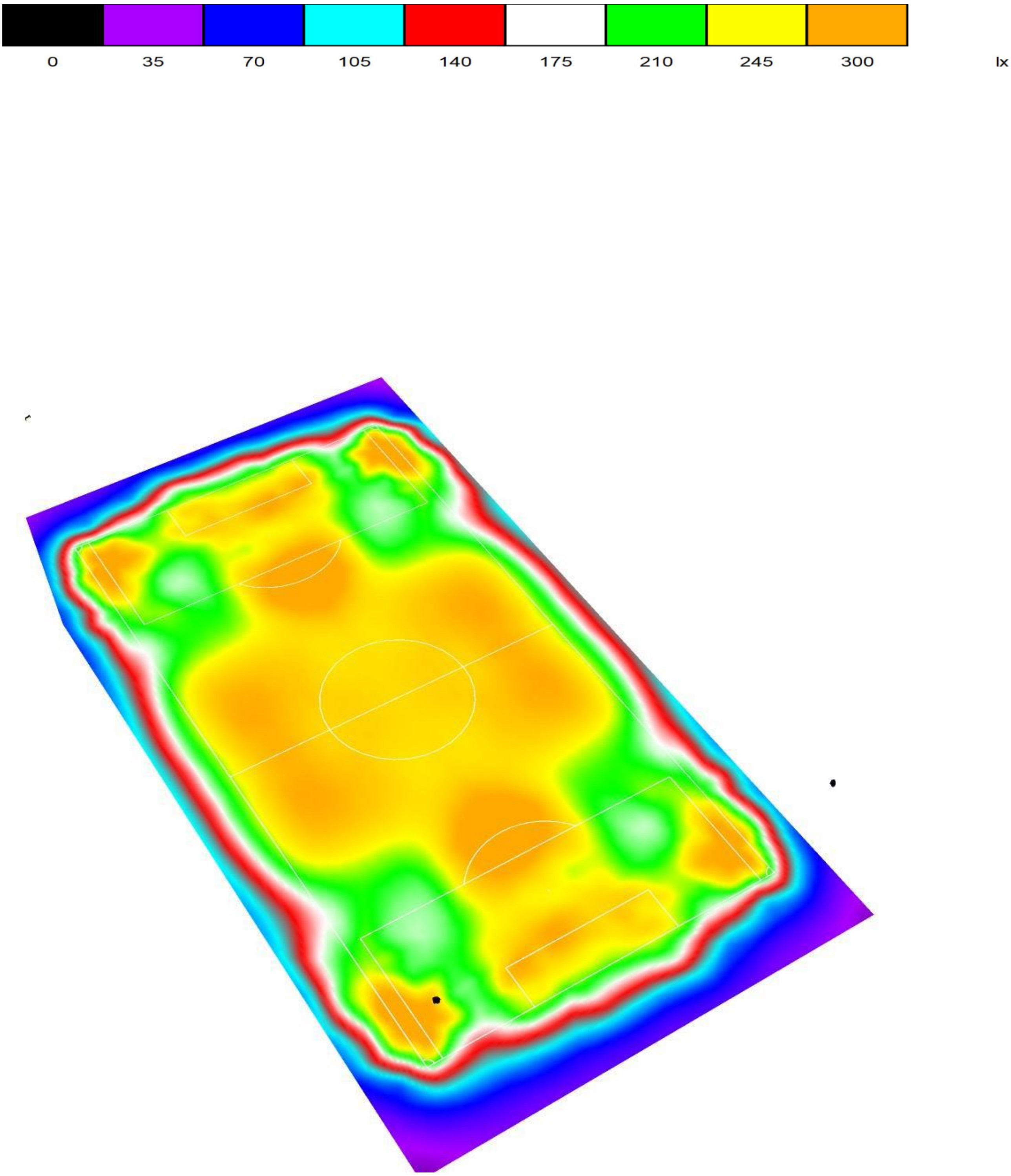


Fig-6.10: Education level sports lighting design / False Color Rendering

National level sports lighting design / False Color Rendering

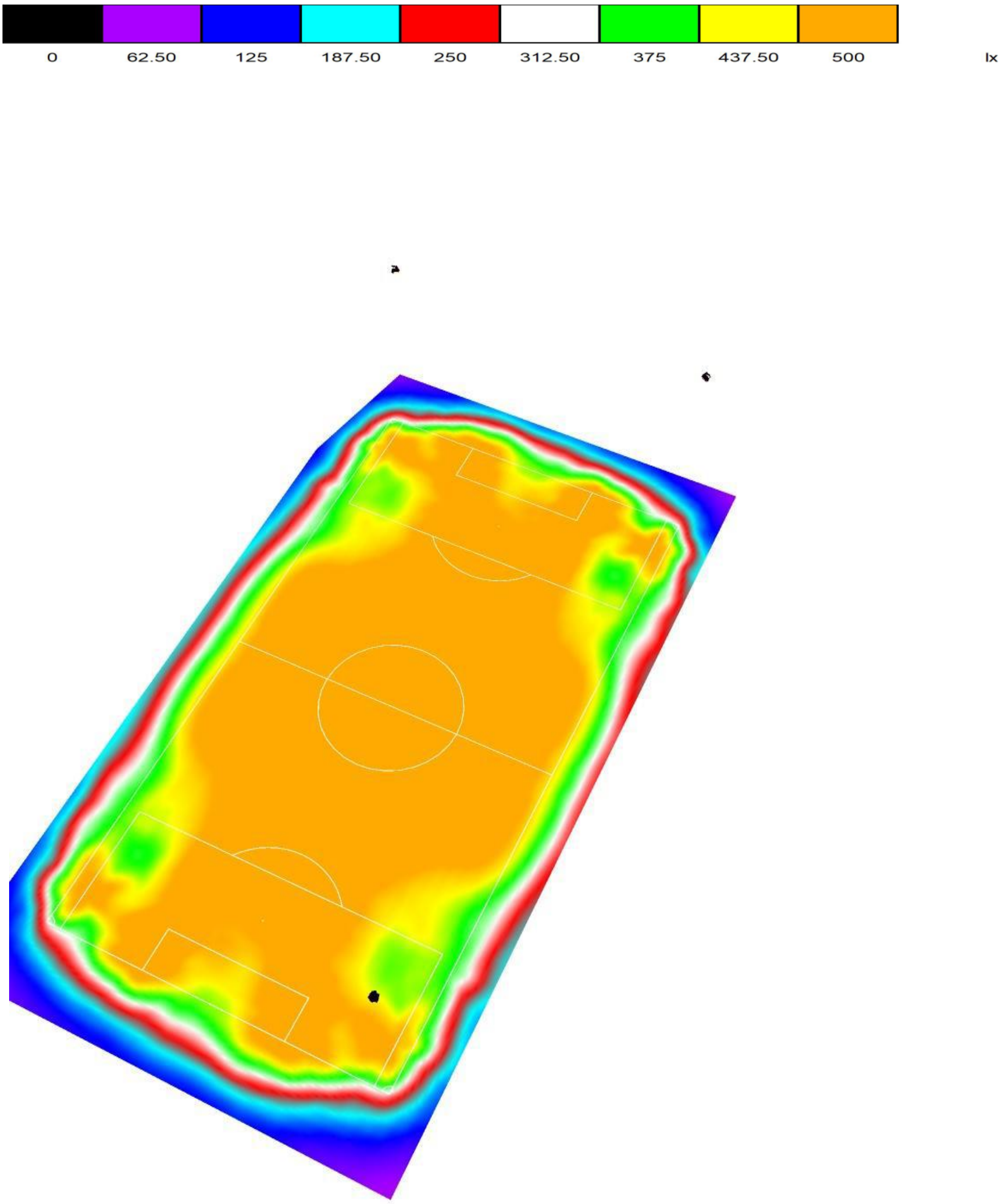


Fig-6.11: National level sports lighting design / False Color Rendering

6.1.7 Isolines (E) Greyscale (E) & Value Chart(E)

With this point we can understand how many lumens there are around the football ground. The football ground should have adequate lux level as other functions also take place there. All isoline diagram, ray scale value, value chart is shown below. From the diagram 6.11 to 6.16 we can easily compare and understand those isolines, grayscale and value chart. We can also compare the data of two design in tabular form which shows in table 6.10.

Education level sports lighting design / Ground Element 1 / Surface 1 / Isolines, Greyscale, Value Chart

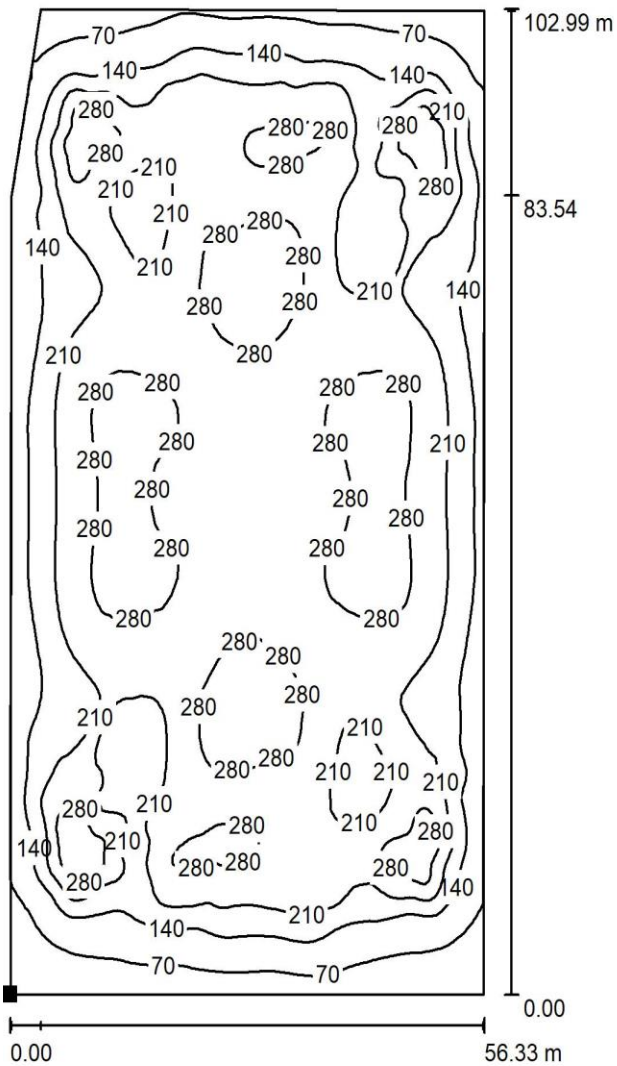


Fig-6.11: Isoline diagram

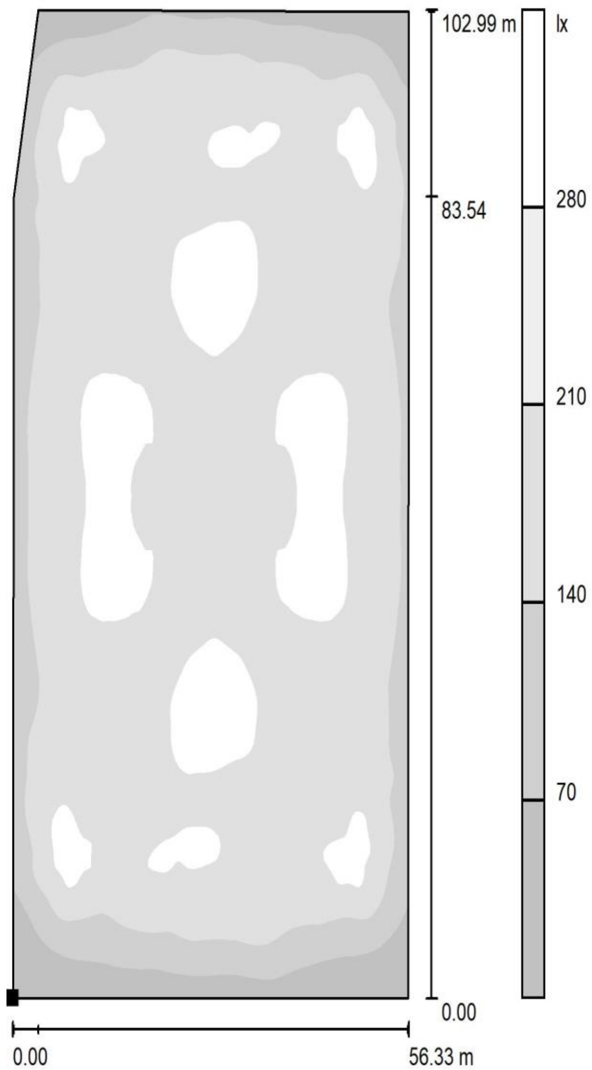


Fig-6.12: Grey scale diagram

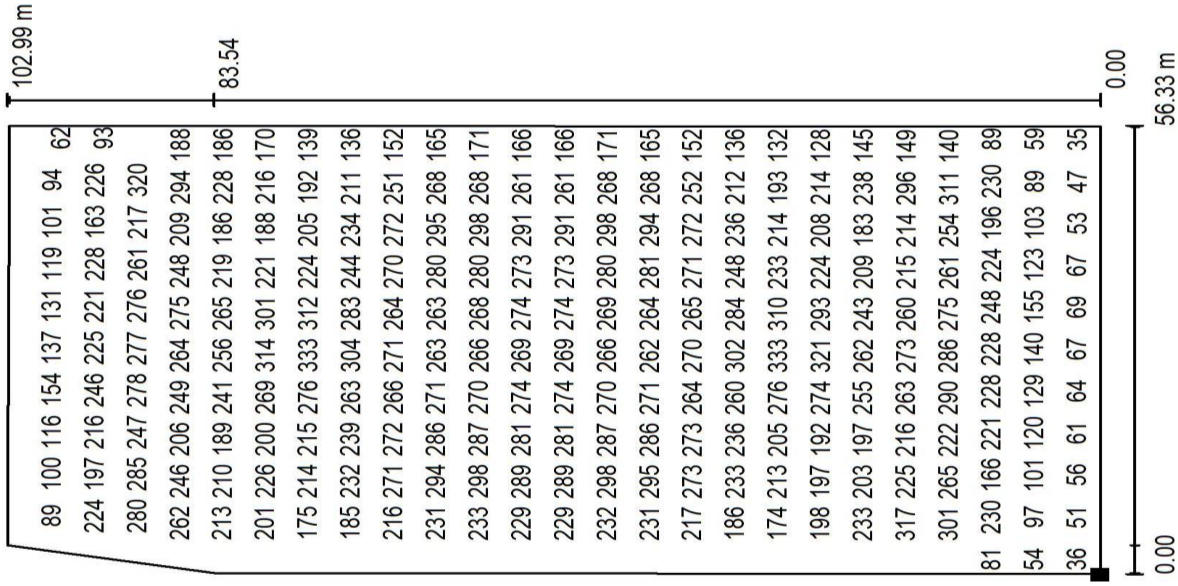


Fig-6.13: Value chart diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
212	26	345	0.123	0.057

National level sports lighting design / Ground Element 1 / Surface 1 / Isolines , Greyscale. Value Chart

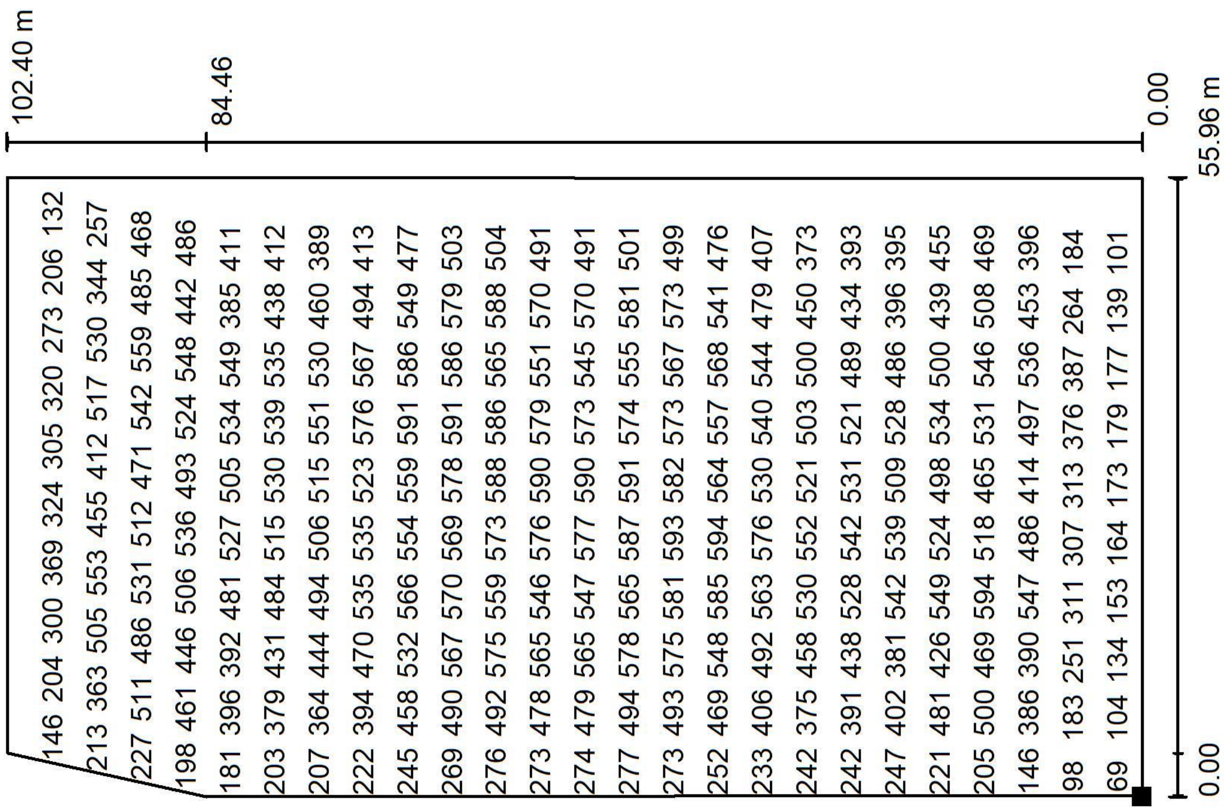


Fig-6.14: Value chart diagram

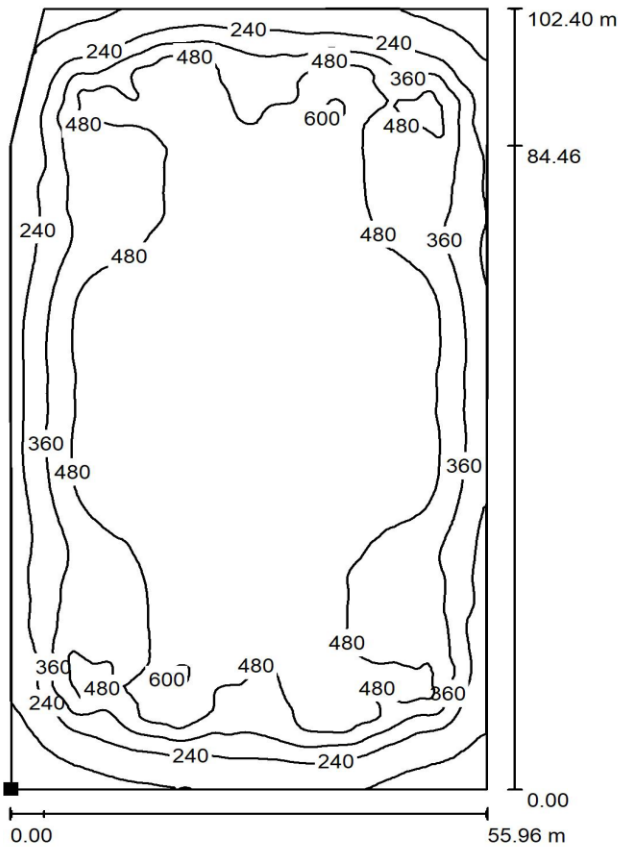


Fig-6.15 Isoline diagram

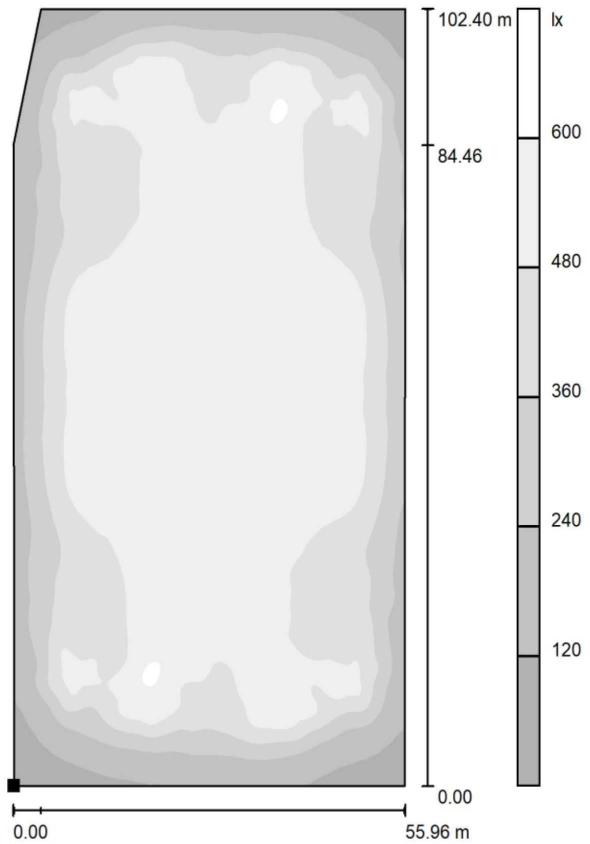


Fig-6.16: Grey scale diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
429	52	627	0.121	0.083

Tabular comparison table

Table-6.10

Area	Eav [lx]	Emin [lx]	Emax [lx]	u0
Education level football sports field	212	26	345	0.123
National level football sports field	429	52	627	0.121

6.1.8 Education level/National level sports lighting design / Soccer Field 1 Calculation Grid (PA)

There are two types of area is being considered in design. One is playing area and other one is total area. Playing area(PA) means the area where the actual task is being done. Total area(TA) means some existing area around the playing area where other necessary work to be done. Diagram 6.18 shows the main playing of the football field.

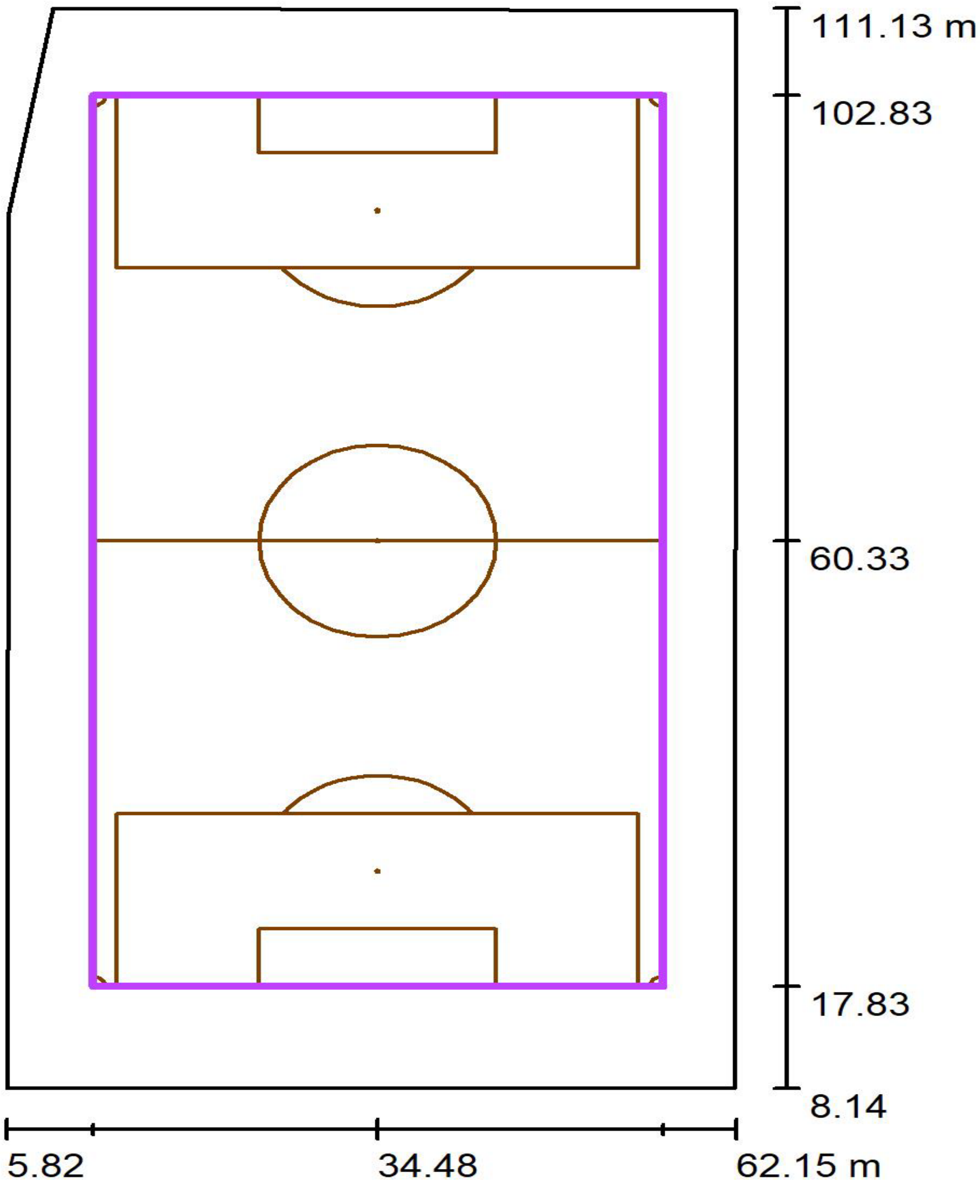


Fig-6.17: Field diagram

Position: (34.480 m, 60.326 m, 0.000 m)
Size: (85.000 m, 44.000 m)
Rotation: (0.0°, 0.0°, -90.0°)
Type: Normal, Grid: 19 x 9 Points
Belongs to the following sport arena: Soccer Field 1

6.1.9 Soccer Field 1 Calculation Grid (PA)

Calculation grids are used to quantify Illuminance values within a rectangular boundary using regularly spaced light meter positions. Two versions of the Calculation Grid are available - 2 Point and 3 Point specification.

Calculation grids are used when you have to include point by points in a large rectangular area. With the help of the calculation grid, we can easily measure the adequate lux level and uniformity of an area. We have taken the 5/5 calculation grid here.

The football ground is designed in such a way that education level and national level games can be played here. Lighting levels are maintained during games at the recreation level and education level and at the national level as per FIFA standards. Average 250 lux for education level and 500 lux for national level non televised are maintained and uniformity is maintained at 0.7 in both designs.

The data obtained through DIALux 4.13 have been tabulated and displayed as in Tables 6.10 while the pictorial data are displayed in Fig-6.18, Fig-6.19, Fig-6.20, Fig-6.21, Fig-6.22, Fig-6.23.

Education level sports lighting design / Soccer Field 1 Calculation Grid (PA) / Isolines (E, Perpendicular)

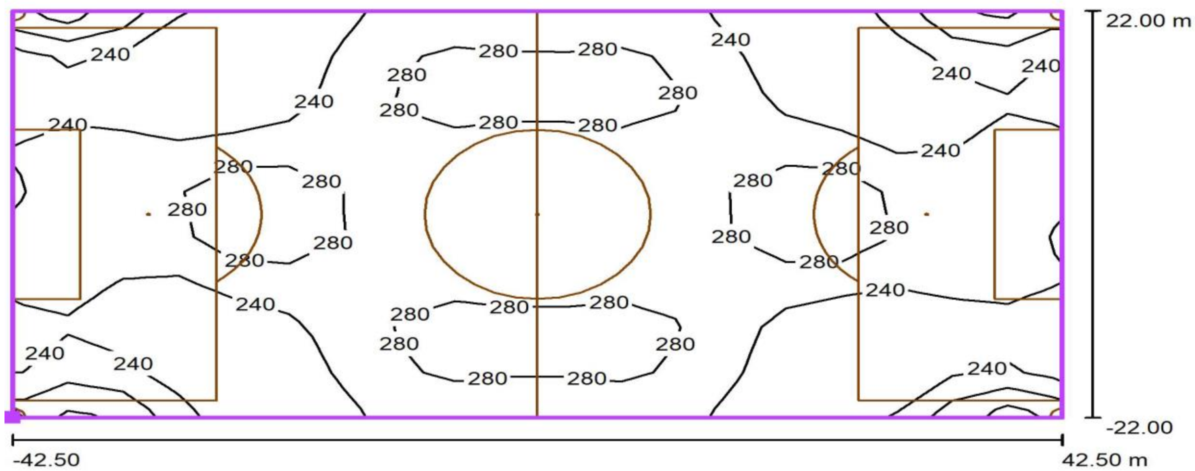


Fig-6.18: Isoline diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
257	187	339	0.73	0.55

National level sports lighting design / Soccer Field 2 Calculation Grid (PA) / Isolines(E, Perpendicular)

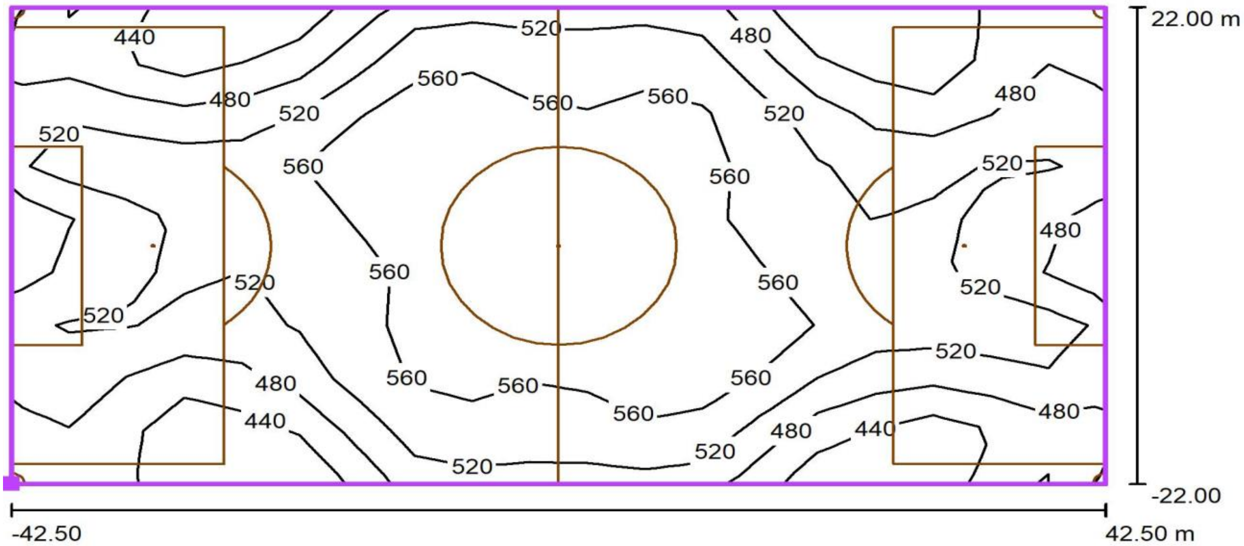


Fig-6.19: Isoline diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
517	401	592	0.78	0.68

Education level sports lighting design / Soccer Field 1 Calculation Grid (PA) /Greyscale (E, Perpendicular)

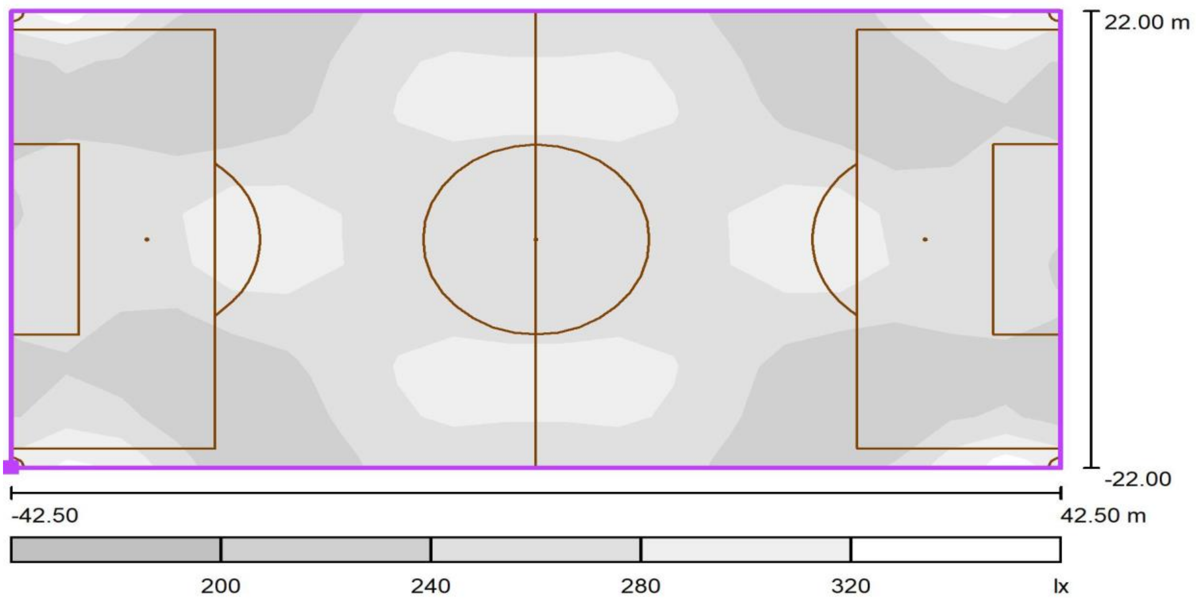


Fig-6.20: Gray scale diagram

National level sports lighting design / Soccer Field 2 Calculation Grid (PA) /Greyscale (E, Perpendicular)

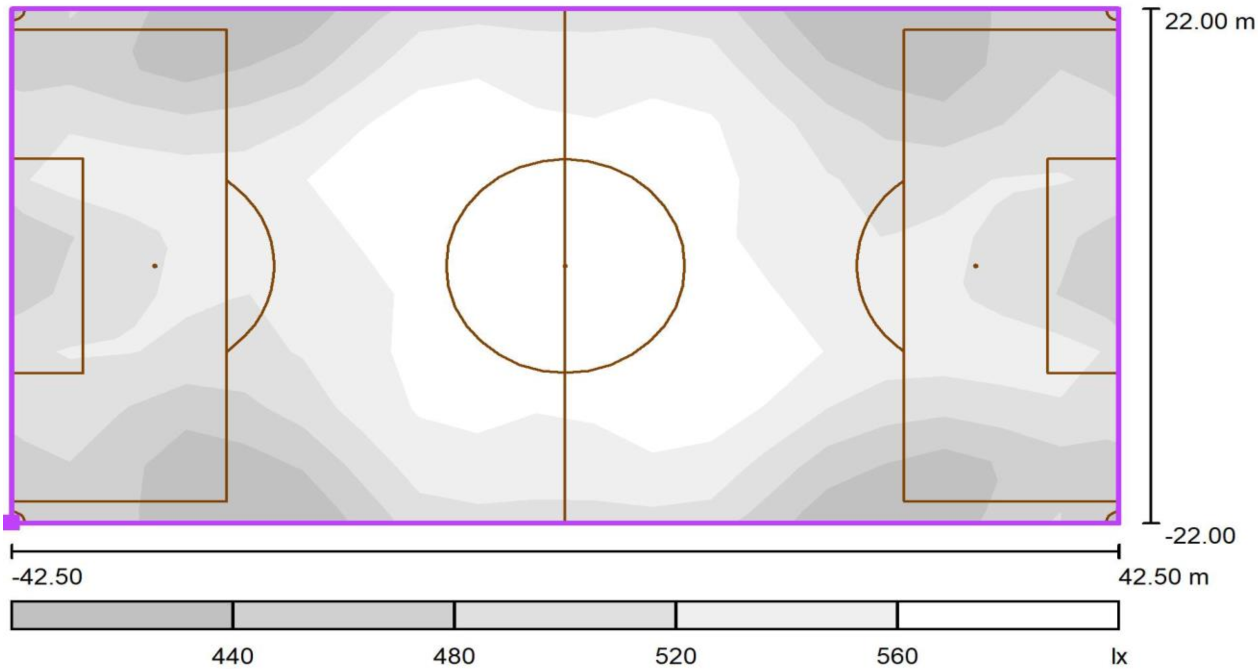


Fig-6.21: Grey scale diagram

Education level sports lighting design / Soccer Field 1 Calculation Grid (PA) / Value Chart (E, Perpendicular)

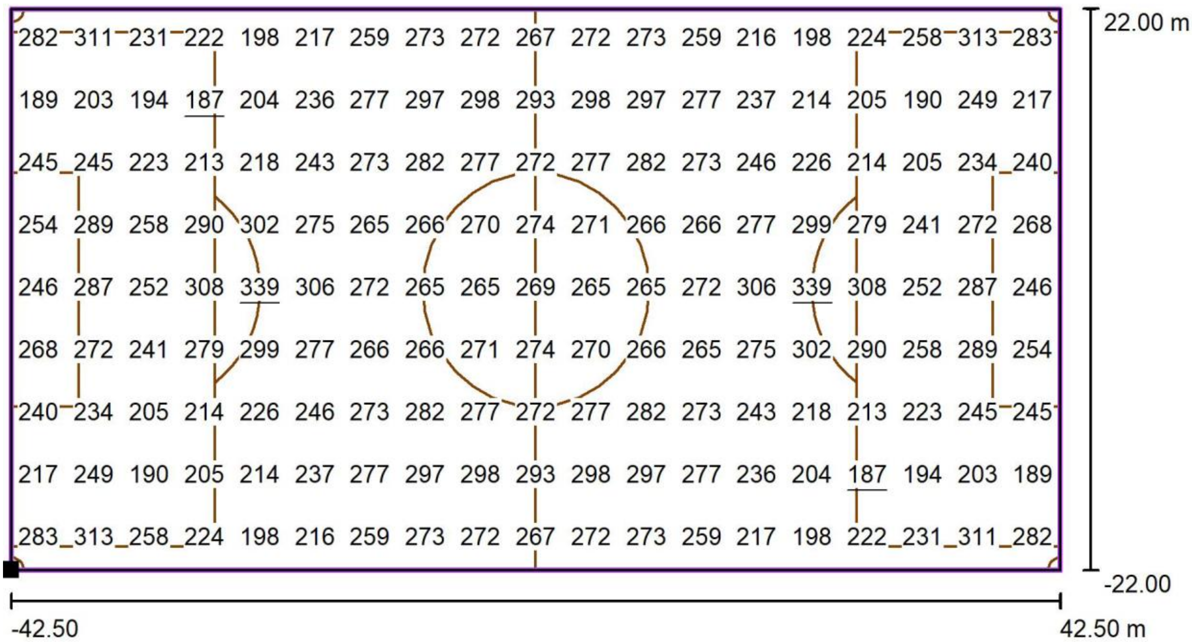


Fig-6.22: Value chart diagram

National level sports lighting design / Soccer Field 2 Calculation Grid (PA) / Value Chart (E, Perpendicular)

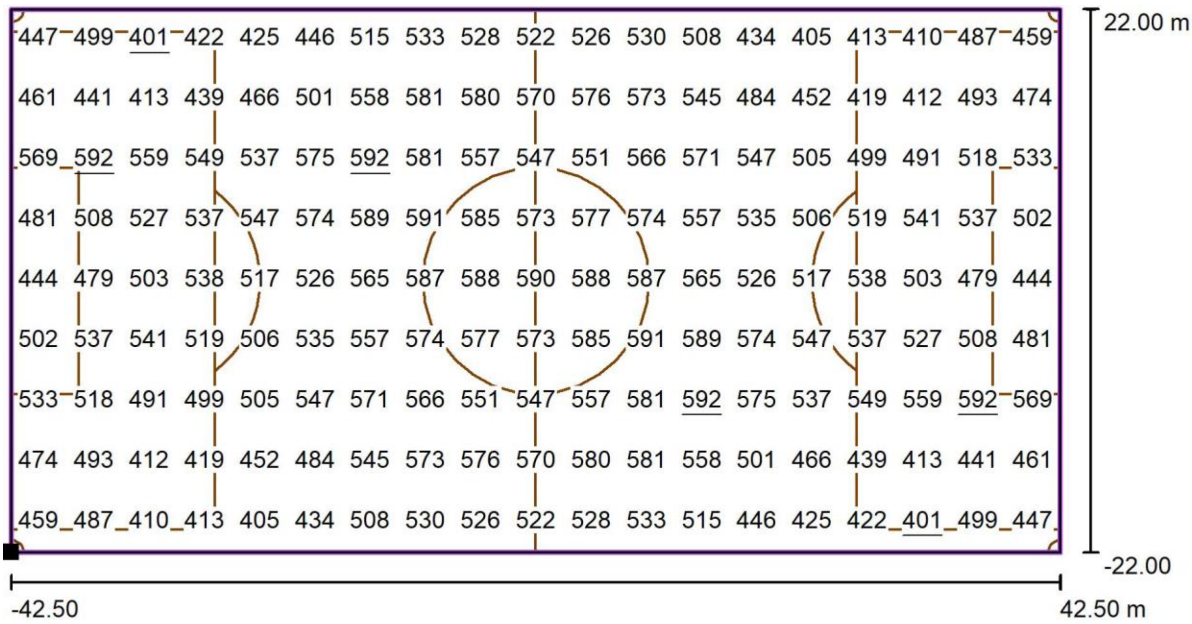


Fig-6.23: Value chart diagram

6.1.10 Comparison with standard values

Till now the values that have been seen were from the proposed design. However, no matter how much hard work was done, they are needed to be on par with the standard values given in the necessary lighting codes and guides which govern the football field lighting.

Therefore, the proposed values are to be compared against the established standards in order for their validation. It is to be noted that there are plenty of quantities that are produced from the standard DIALux 4.13 output, however in the light of keeping our analysis as compact and simple as possible, only the following quantities are to be compared

i. **Average Horizontal Illuminance (Ehavg):** The average final value of all illuminance values contained on the horizontal plane of a surface

ii. **Average Vertical Illuminance (Evavg):** The average final value of all illuminance values contained on any one of the considered vertical planes. Only required for televised events.

iii. Uniformity (U0): The ratio of the minimum available illuminance value to the average illuminance. The uniformity under consideration is done only for the horizontal planes

iv. Glare rating (GR) ranges: Glare value compared to the standard limit prescribed

Tabular comparison

The parameters spoken of in previous sections are summed up in the Table 6.11 in order to facilitate a side-by-side comparison

Table-6.11: Comparison

Level of competition	Parameters	Standard	Proposed	Remarks
Class III(Training & recreation level or education level)	Average Horizontal Illuminance (Eh avg)	200-250	257	Achive beyond standard
	Uniformity (U0)	0.7	0.73	
	Glare rating (GR) Max	50	Min-34,Max-48	
Class II(National Level Non televised)	Average Horizontal Illuminance (Eh avg)	500	517	Achieve beyond standard
	Uniformity (U0)	0.7	0.78	
	Glare rating (GR) ranges	50	Min-31,Max-47	

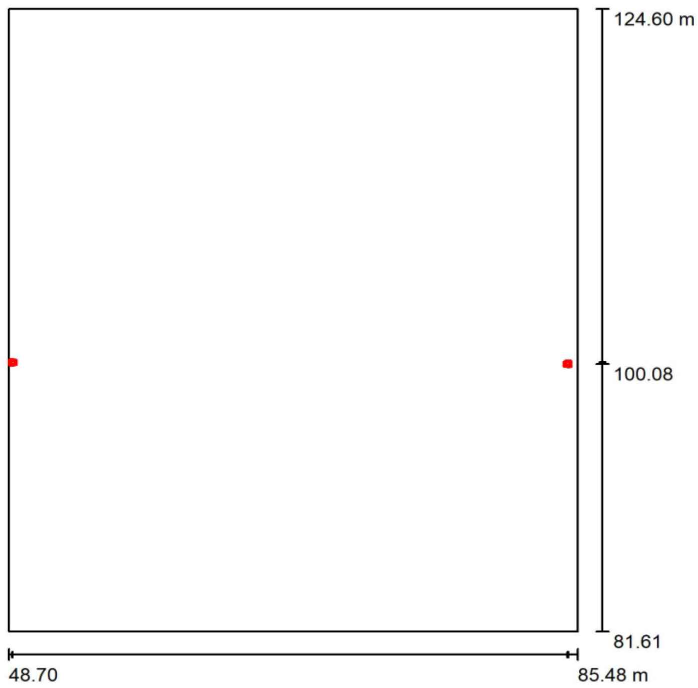
6.2 Tennis court

The lighting design of the football pitch shall be complied with Class III (Training and Recreation) & Class II (National Level Non televised).

The design shall conform to the BS EN 12193 (Latest version) and ITF Standards (Lighting Design Specifications and Technology) on lighting for Tennis court stadiums.

6.2.1 Planning data

Construction of sport complex, playgrounds, sport school, sport grounds and fields assumes creation clear plans, layouts, or sketches. In many cases we need represent on the plan multitude of details, including dimensions, placement of bleachers, lighting, considering important sport aspects and other special things. In this chapter we will discuss two types of tennis court complex lighting design. Tennis court complex contained two tennis court ground. First we will discuss the education sports ground lighting then we



will discuss the lighting of the national level sports ground, this will continue in succession. In the case of two types of field lighting, the planning data will be the same because we are doing two types of lighting in the same field. Fig-6.24 shows the area dimension of tennis court and their surrounding area.

Fig-6.24: Planning data

6.2.2 Luminaire parts list

In this section we have soon in tabular form, in which area what type of luminaire are used. Table-6.12 & 6.13 shows the data of luminaire.

Note- a. UHLUNB-Ultra high lumen output & ultra-narrow beam
b. HLNB- High lumen output & narrow beam

- **Luminaire parts list for education level sports lighting design**

Table-6.12: Luminaire parts list

No.	Pieces	Designation (Correction Factor)	(Luminaire) [lm]	(Lamps) [lm]	P [W]
1	2	ORIENT ELECTRIC LFSMP-300-C (1.000)	30000	30000	300
2	18	ORIENT ELECTRIC LFSMP-300-C-UHLNB (1.000)	36000	36000	300
		Total:	708000	708000	6000

- **Luminaire parts list for national level sports lighting design**

Table-6.13: Luminaire parts list

No.	Pieces	Designation (Correction Factor)	(Luminaire) [lm]	(Lamps) [lm]	P [W]
1	2	ORIENT ELECTRIC LFSMP-500-C-UHL (1.000)	60000	60000	500
2	22	ORIENT ELECTRIC LFSMP-500-C-UHLNB (1.000)	60000	60000	500
		Total:	1440000	1440000	12000.

6.2.3 Sport Sites (layout plan) of education level sports lighting design & national level sports lighting design

Construction of sport complex, playgrounds, sport school, sport grounds and fields assumes creation clear plans, layouts, or sketches. In many cases you need represent on the plan multitude of details, including dimensions, placement of bleachers, lighting, considering important sport aspects and other special things.
Design standard football field class III & II tennis court and a stadium capacity and the capacity audience to the location and the importance of play and the percentage of the population are dependent on pro football. This number varies between 3 and 10 thousand. Suitable for audiences on both sides of the longitudinal view of tennis. At district level, towns and places where there is a large audience and in the fields of training usually consists of a length of the pitch side spectator's alternative platforms. We have designed the education tennis court here. It is designed to seat 80 to 100 people to watch the game.

Sport Sites (Coordinates List)

Table-6.14: Dimenssion

Size Playing Area [m]		Size Total Area [m]	
L	W	L	W
36	18	36	18

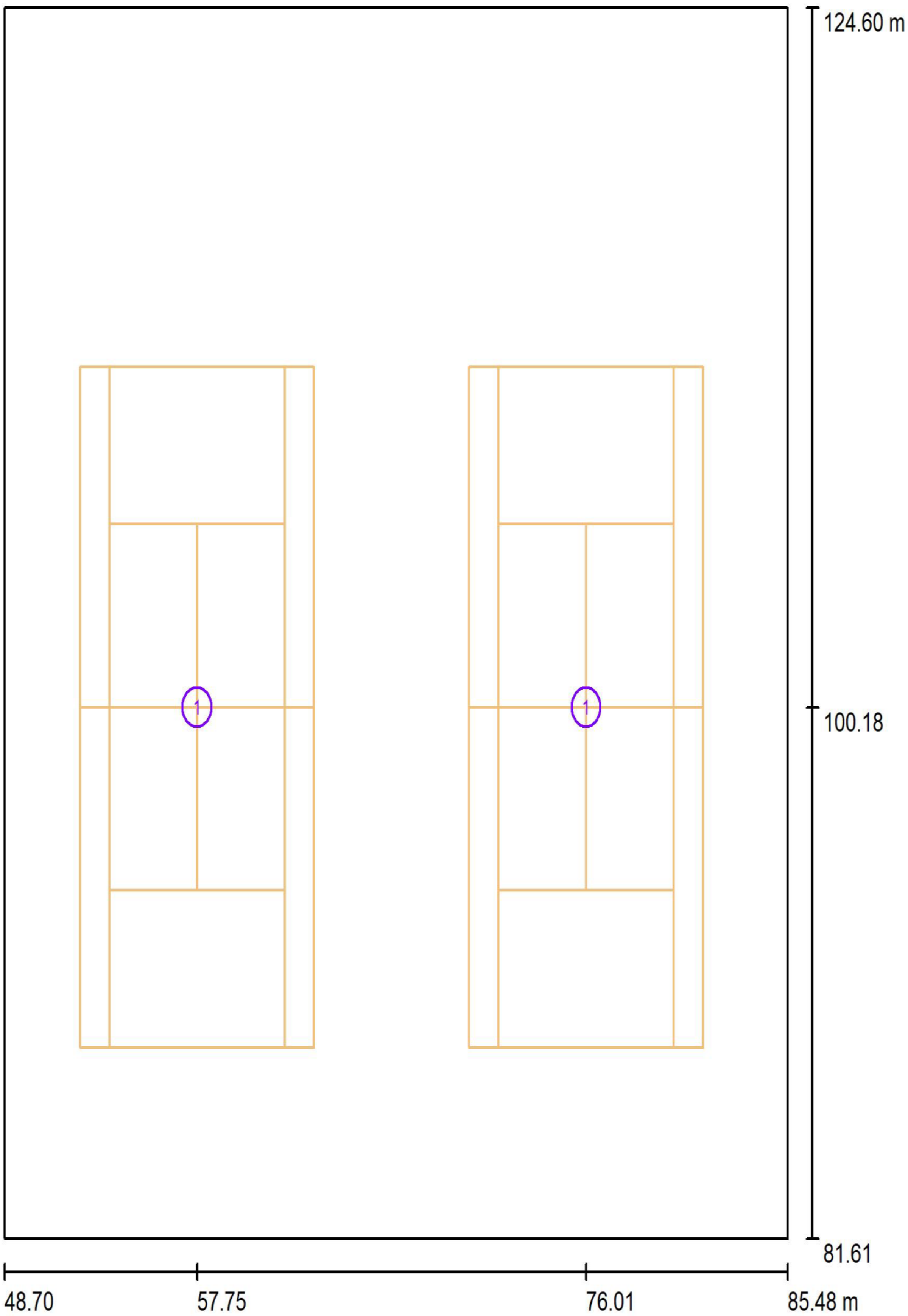


Fig-6.25: Sport Sites (layout plan)

6.2.4 Sport Luminaires (Coordinates List) of education level sports lighting design & national level sports lighting design

Here we will discuss about the position of light. How high are the lights mounted? What is the aiming point point of each light? How many degrees is a light turned? All types of information are discussed here. If we do not mount each light according to this date, we will not get the correct results. So this information becomes very necessary for us. All the information is discussed in the table below.

In Fig-6.26 & Fig-6.27 each of the arrow symbols shown here represents a light. In table-6.15 & 6.16 shows each luminaire position (X,Y), mounting height(Z), aiming angle, tilt angle(o).

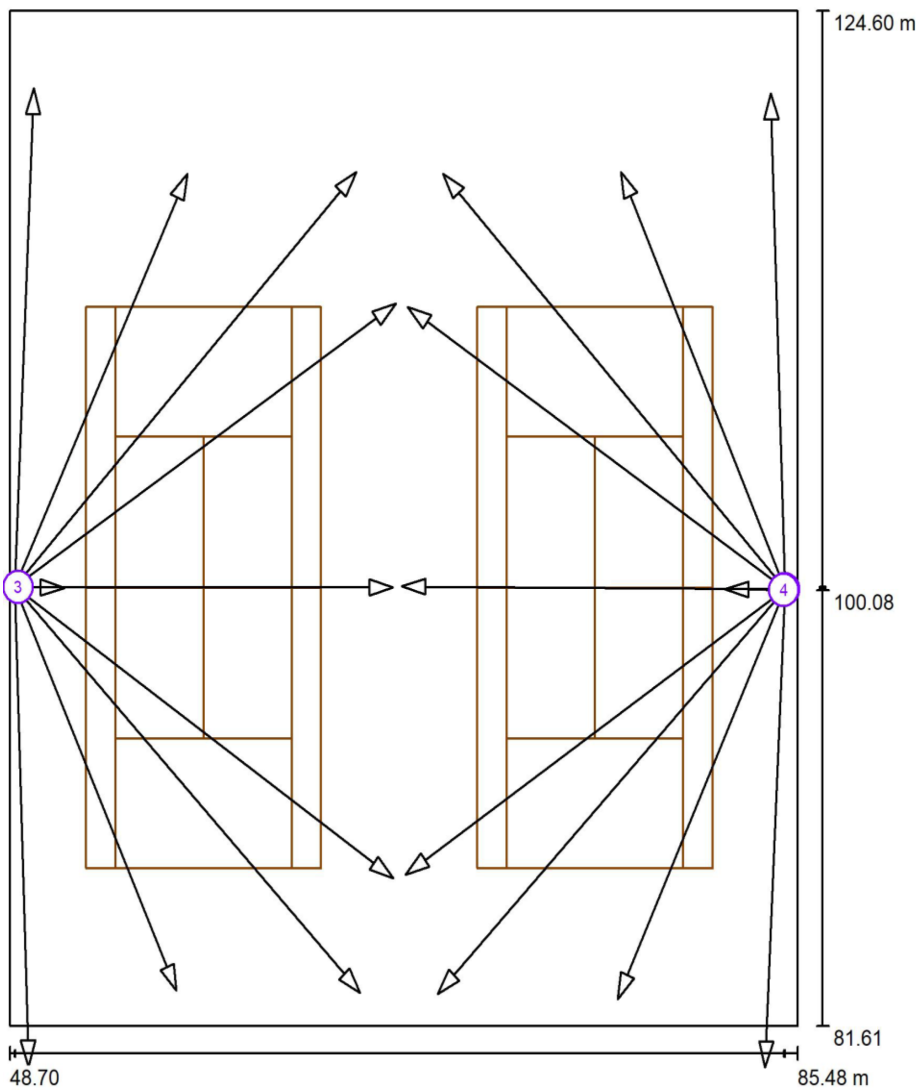


Fig-6.26

Class III education level luminaire Coordinates List

List of the Sport Luminaires of Class III education level

Table-6.15:

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]
		X	Y	Z	X	Y	Z	
ORIENT ELECTRIC LFSMP-300-C (1.000)	1	48.933	100.208	12	49.588	79.886	0	30.5
	1	48.933	100.208	12	56.984	117.717	0	31.9
	1	48.933	100.208	12	64.884	117.790	0	26.8
	1	48.933	100.208	12	66.586	100.185	0	34.2
	1	48.933	100.208	12	66.734	112.207	0	29.2
	1	48.933	100.208	12	66.592	87.875	0	29.1
	1	48.933	100.208	12	65.064	83.012	0	27.0
	1	48.933	100.208	12	56.485	83.107	0	32.7
	1	48.933	100.208	12	49.830	121.338	0	29.6
	2	84.879	100.113	12	67.169	88.020	0	29.2
	2	84.879	100.113	12	68.906	117.717	0	26.8
	2	84.879	100.113	12	84.208	121.115	0	29.7
	2	84.879	100.113	12	66.990	100.230	0	33.9
	2	84.879	100.113	12	77.233	117.794	0	31.9
	2	84.879	100.113	12	77.067	82.753	0	32.2
	2	84.879	100.113	12	83.959	79.847	0	30.6
	2	84.879	100.113	12	68.666	82.964	0	27.0
	2	84.879	100.113	12	67.269	112.064	0	29.4
ORIENT ELECTRIC LFSMP-300-C-UHLNB (1.000)	3	48.953	100.204	12	51.256	100.174	0	79.1
	4	84.829	100.077	12	82.067	100.120	0	77.0

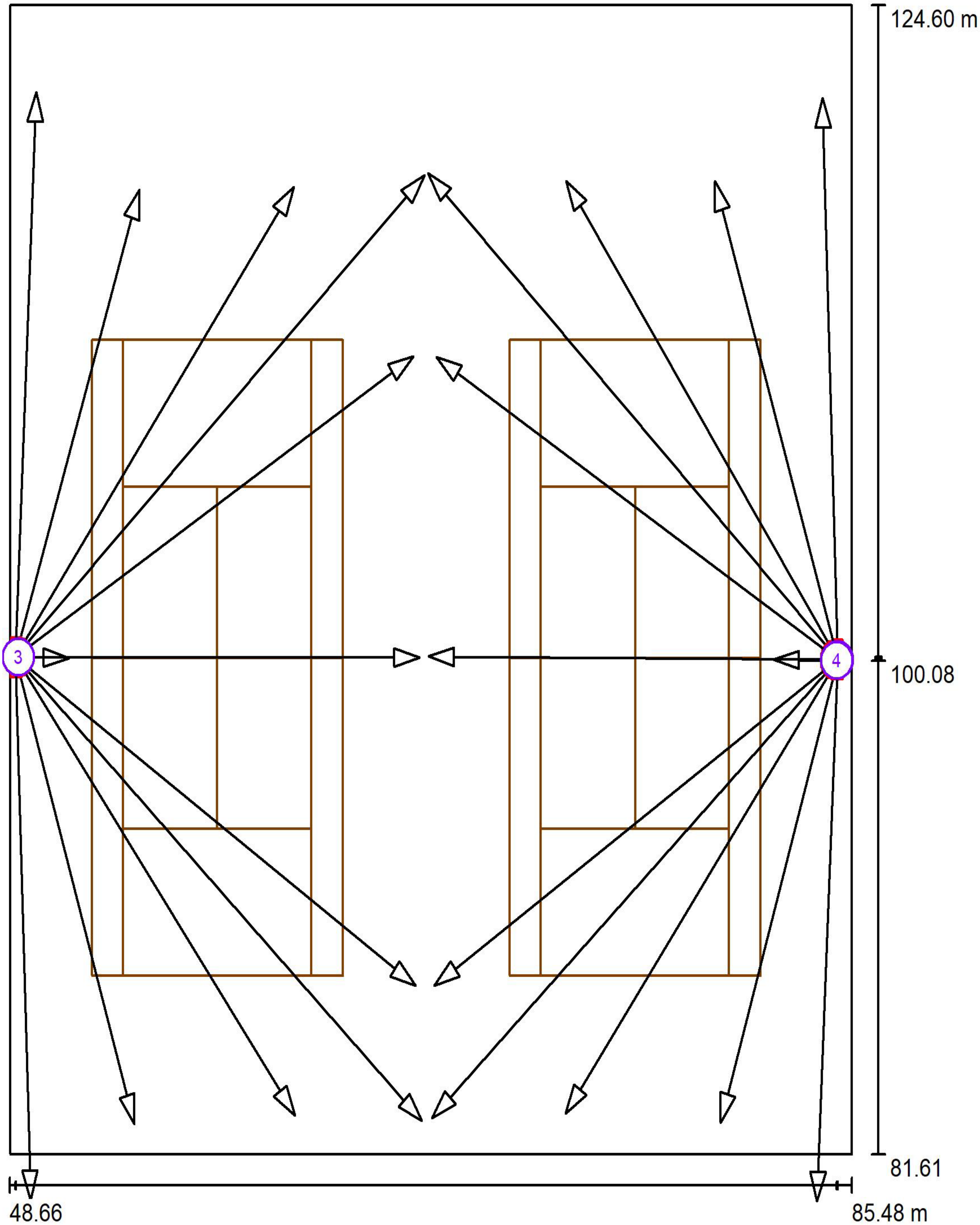


Fig-6.27 -Class II national level luminaire arrangement

List of the Sport Luminaires Class II (National Level Non televised)

Table 6.16

Luminaire	Index	Position [m]			Aiming Point [m]			Angle [°]
		X	Y	Z	X	Y	Z	
ORIENT ELECTRIC LFSMP-500-C-UHLNB)	1	48.933	100.208	12	66.701	82.854	0	25.8
	1	48.933	100.208	12	54.333	117.699	0	33.2
	1	48.933	100.208	12	61.090	117.804	0	29.3
	1	48.933	100.208	12	66.586	100.185	0	34.2
	1	48.933	100.208	12	66.328	111.466	0	30.1
	1	48.933	100.208	12	66.406	87.914	0	29.3
	1	48.933	100.208	12	61.136	83.077	0	29.7
	1	48.933	100.208	12	54.124	82.743	0	33.4
	1	48.933	100.208	12	49.830	121.338	0	29.6
	1	48.933	100.208	12	66.800	118.223	0	25.3
	1	48.933	100.208	12	49.588	79.886	0	30.5
	2	84.879	100.113	12	66.963	118.298	0	25.2
	2	84.879	100.113	12	73.003	118.019	0	25.8
	2	84.879	100.113	12	84.208	121.115	0	33.2
	2	84.879	100.113	12	66.990	100.230	0	29.3
	2	84.879	100.113	12	79.507	118.019	0	34.2
	2	84.879	100.113	12	79.758	82.789	0	30.1
	2	84.879	100.113	12	83.959	79.847	0	29.3
	2	84.879	100.113	12	72.985	83.124	0	29.7
	2	84.879	100.113	12	67.335	111.422	0	33.4
	2	84.879	100.113	12	67.131	82.957	0	29.6
	2	84.879	100.113	12	67.242	87.914	0	25.3
ORIENT ELECTRIC LFSMP-500-C-UHL	3	48.953	100.204	12	51.256	100.174	0	79.1
	4	84.829	100.077	12	82.067	100.120	0	77.0

6.2.5 GR Observer (Results Overview)

To prevent both the uncomfortable effects of direct and indirect glares, and the unnecessary amount of light pollution to the individuals and settlements near to the stadium premises, glare rating is to be considered, with upper a slope angle of -2° is below the horizontal level, so the observer looks towards the ground. The resultant level of GR has been found to be in a range of 31 to 48. i.e. within the acceptable limits. Table 6.17 & 6.18 shows the tabular data of GR observer.

Education level sports lighting design / GR Observer (Results Overview)

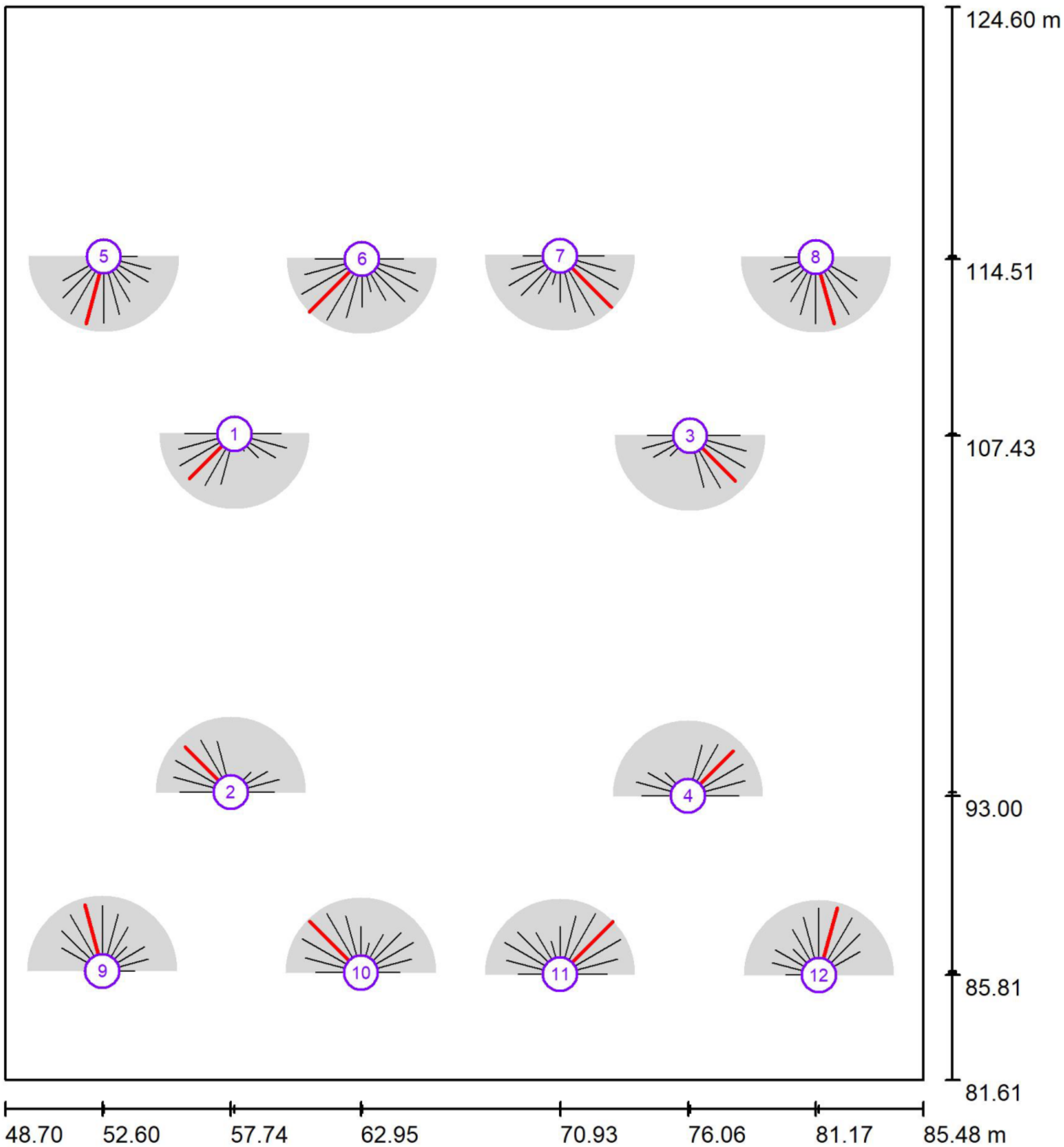


Fig-6.28: GR Observer

National level sports lighting design / GR Observer (Results Overview)

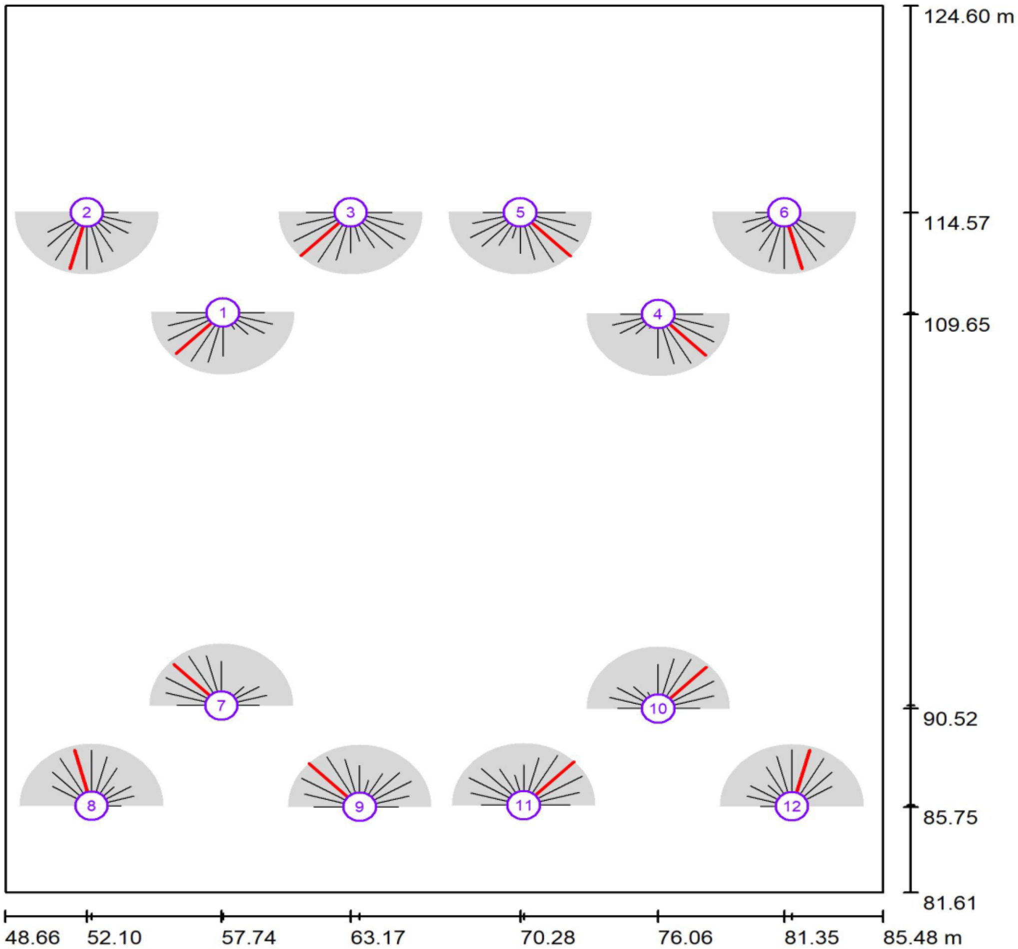


Fig-6.29 :GR Observer

- ## GR Observer list

Table-17: GR Observer Education level

1	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
1	GR Observer 1	57.887	107.50	1.500	180	360	15	-2	37
2	GR Observer 2	57.741	93.142	1.500	0	180	15	-2	37
3	GR Observer 3	52.113	107.43	1.500	180	360	15	-2	37
4	GR Observer 4	76.058	92.996	1.500	0	180	15	-2	37
5	GR Observer 5	52.662	114.61	1.500	180	360	15	-2	40
6	GR Observer 6	63.000	114.51	1.500	180	360	15	-2	43
7	GR Observer 7	70.933	114.63	1.500	180	360	15	-2	42
8	GR Observer 8	81.174	114.58	1.500	180	360	15	-2	40
9	GR Observer 9	52.601	85.973	1.500	0	180	15	-2	39
10	GR Observer 10	62.952	85.913	1.500	0	180	15	-2	42
11	GR Observer 11	70.930	85.846	1.500	0	180	15	-2	43
12	GR Observer 12	81.291	85.808	1.500	0	180	15	-2	40

Table-18: GR Observer National level

1	Designation	Position [m]			Viewing sector [°]				Max
		X	Y	Z	Start	End	Increment	Slope angle	
1	GR Observer 1	57.887	107.50	1.500	180	360	15	-2	41
2	GR Observer 2	57.741	93.142	1.500	0	180	15	-2	41
3	GR Observer 3	52.113	107.43	1.500	180	360	15	-2	44
4	GR Observer 4	76.058	92.996	1.500	0	180	15	-2	41
5	GR Observer 5	52.662	114.61	1.500	180	360	15	-2	44
6	GR Observer 6	63.000	114.51	1.500	180	360	15	-2	41
7	GR Observer 7	70.933	114.63	1.500	180	360	15	-2	42
8	GR Observer 8	81.174	114.58	1.500	180	360	15	-2	41
9	GR Observer 9	52.601	85.973	1.500	0	180	15	-2	44
10	GR Observer 10	62.952	85.913	1.500	0	180	15	-2	42
11	GR Observer 11	70.930	85.846	1.500	0	180	15	-2	44
12	GR Observer 12	81.291	85.808	1.500	0	180	15	-2	42

6.2.6 3D Rendering

3D rendering is the process of turning information from a 3D model into a 2D image. 3D rendering can be used to create a variety of images, from the intentionally non-realistic to what's called photorealistic. Fig-6.30 shows our design 3D model of football ground. Fig-6.31 & 6.32 shows the 3D rendering image of two types football ground.

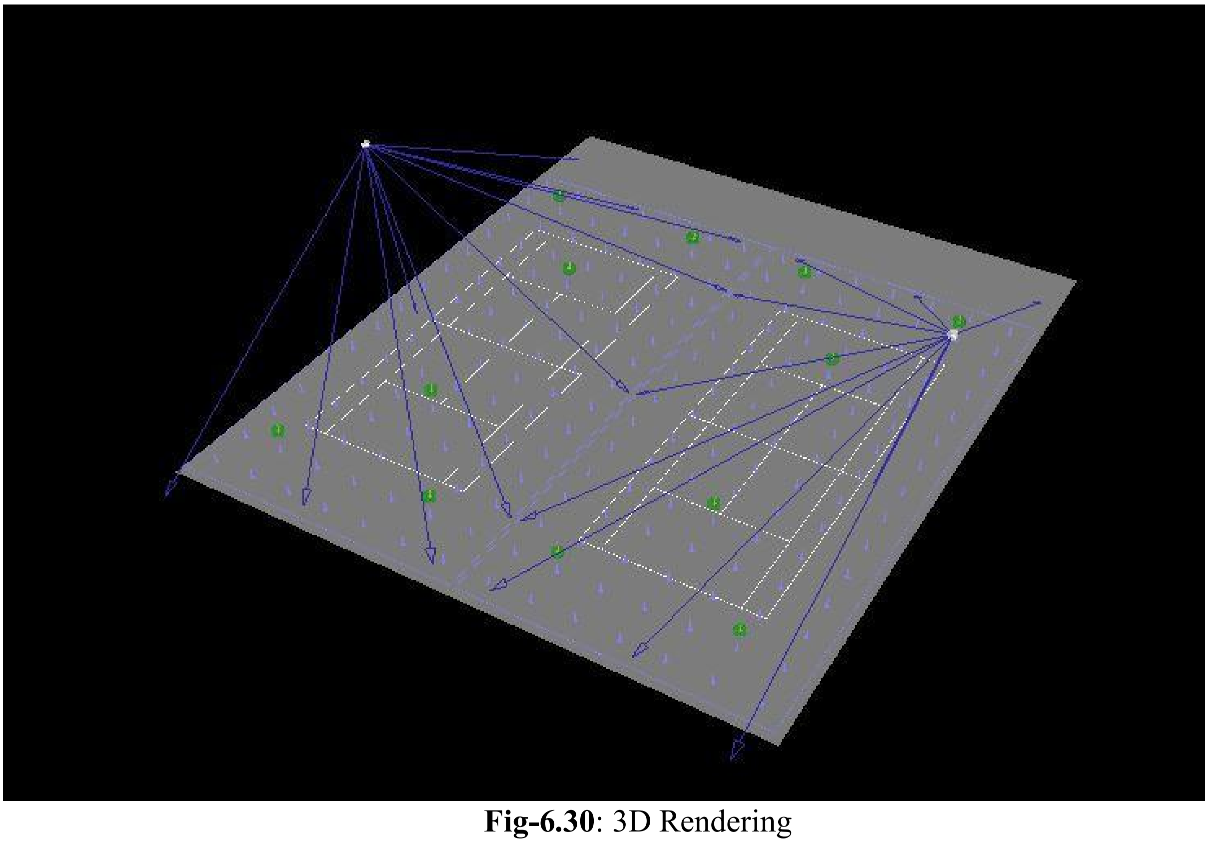


Fig-6.30: 3D Rendering

Education level sports lighting design / 3D Rendering

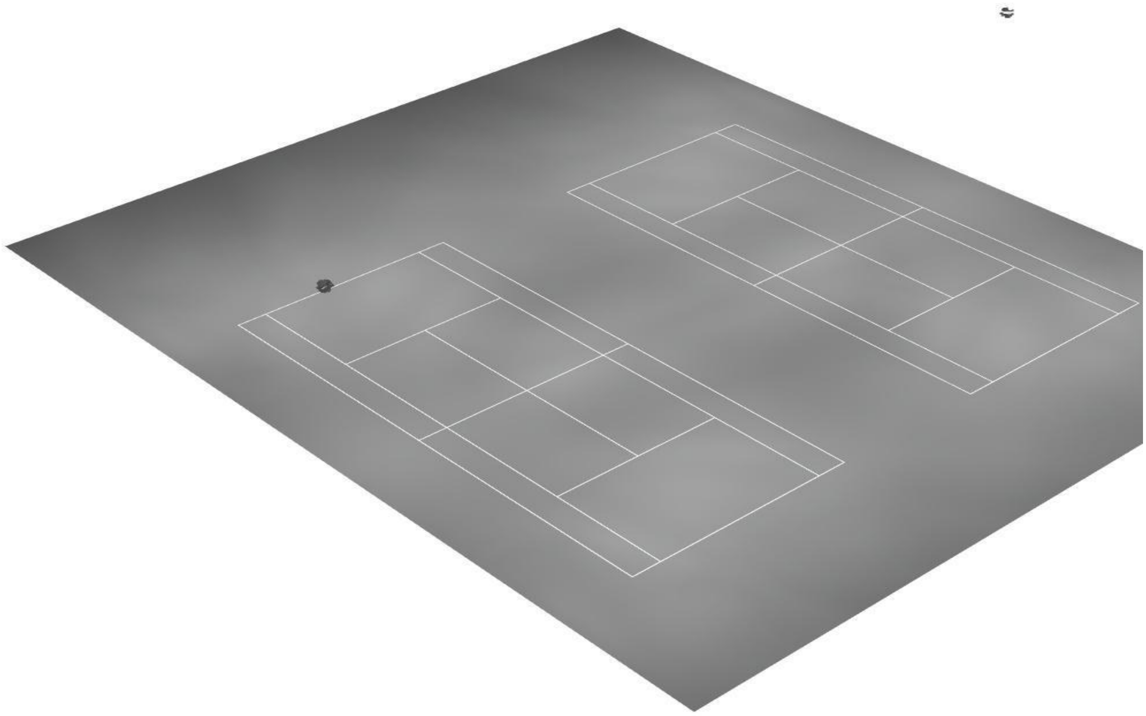


Fig-6.31: 3D Rendering Education level

National level sports lighting design / 3D Rendering

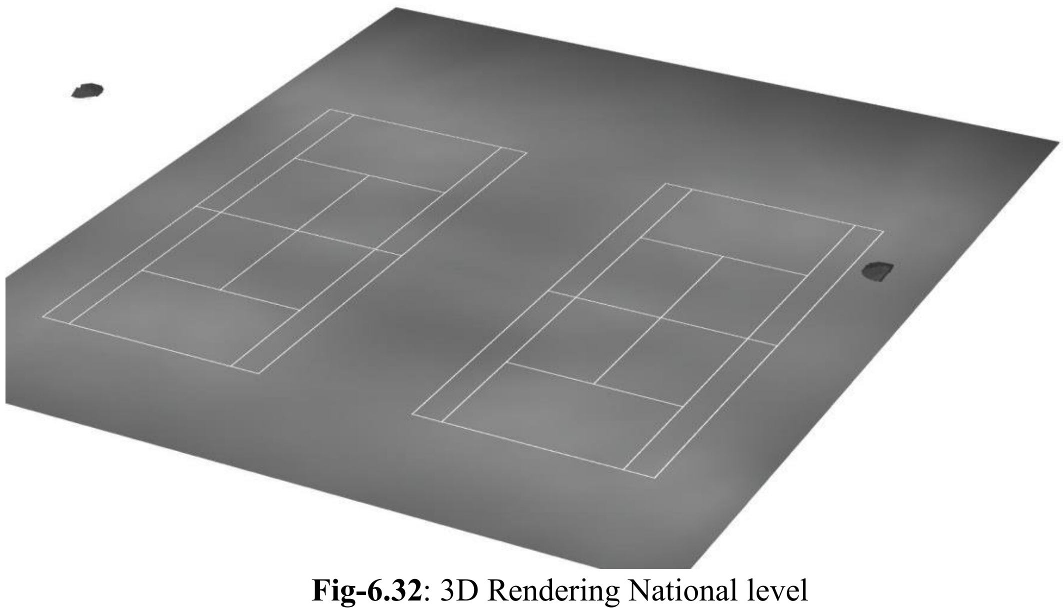


Fig-6.32: 3D Rendering National level

Education level sports lighting design / False Color Rendering

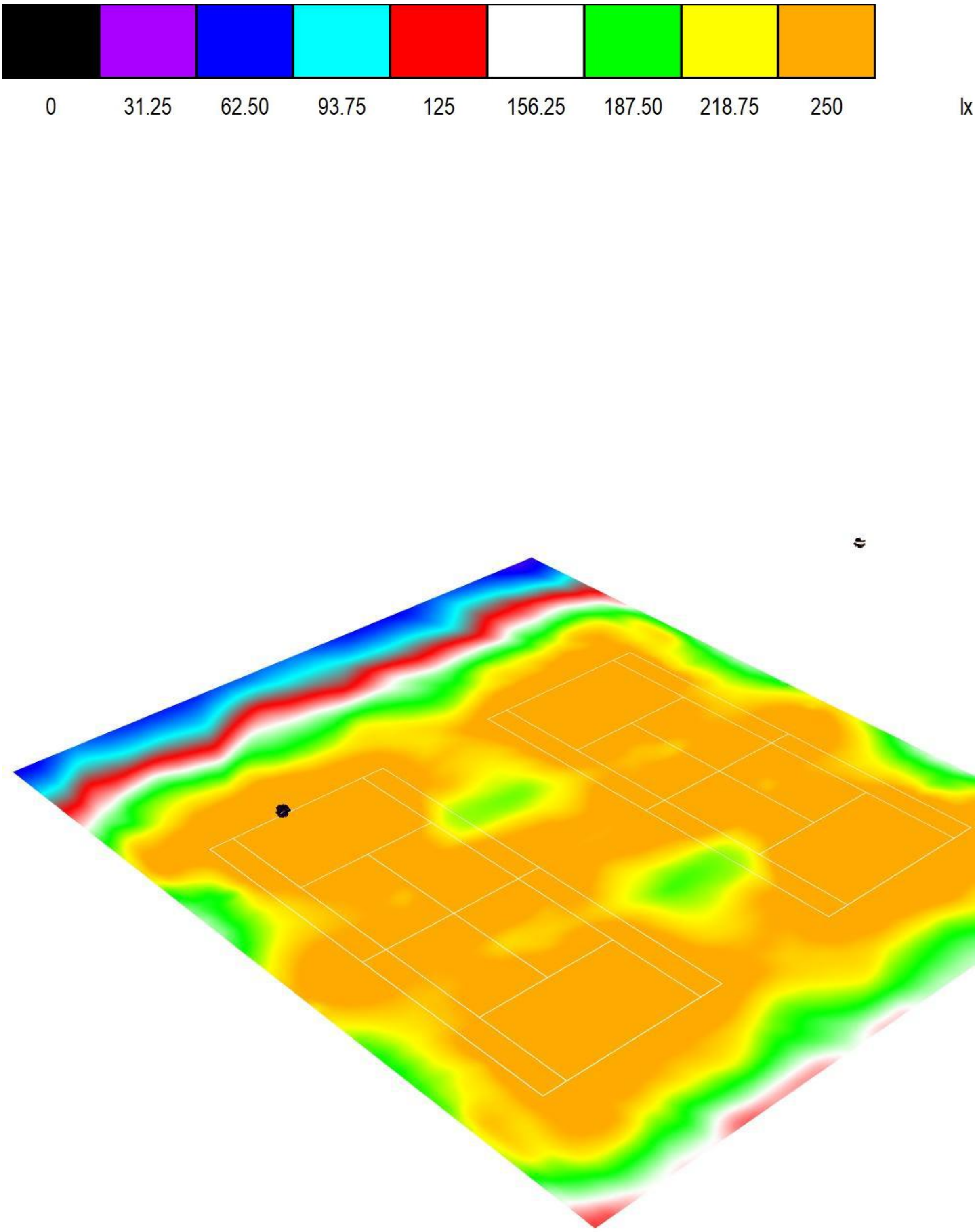


Fig-6.33: False Color Rendering

\National level sports lighting design / False Color Rendering

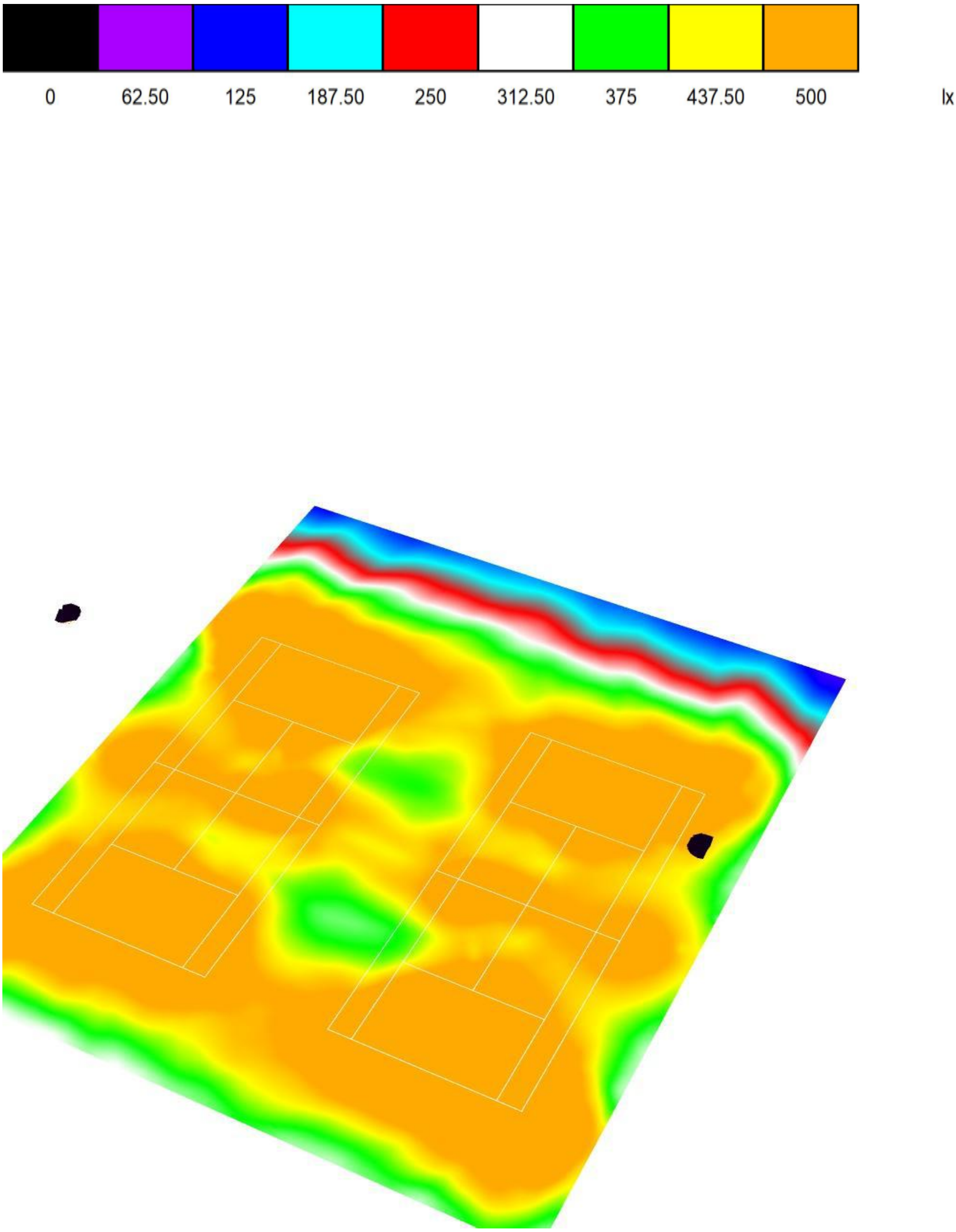


Fig-6.34: False Color Rendering

6.2.7 Isolines (E) Greyscale (E) & Value Chart(E)

With this point we can understand how many lumens there are around the football ground. The football ground should have adequate lux level as other functions also take place there. All isoline diagram, ray scale value, value chart is shown below. From the diagram 6.35 to 6.40 we can easily compare and understand those isolines, grayscale and value chart. We can also compare the data of two design in tabular form which shows in table 6.19

Education level sports lighting design / Ground Element 1 / Surface 1 / Isolines, Greyscale , Value Chart

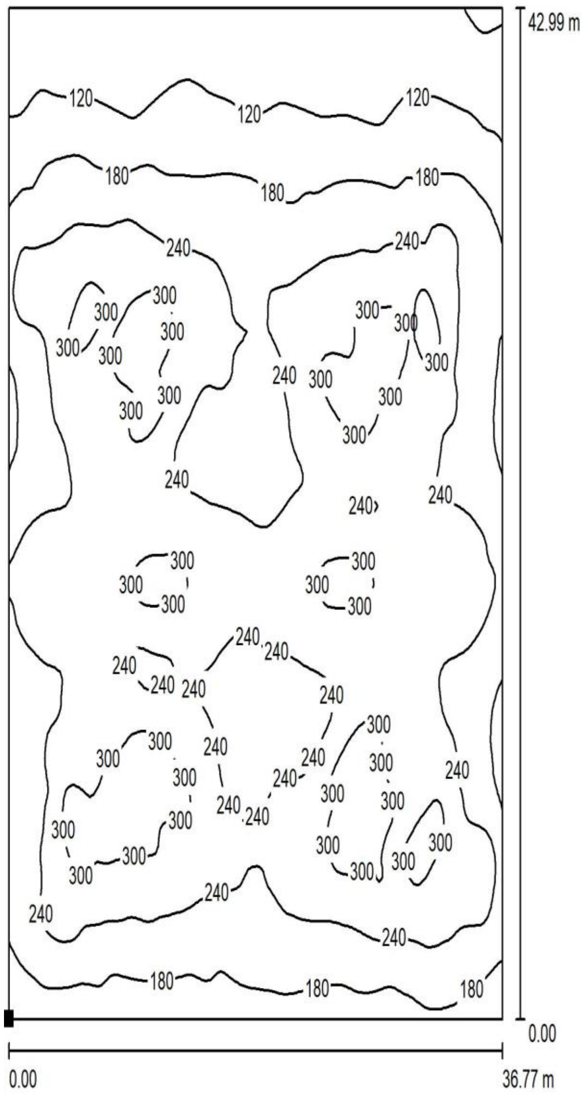


Fig-6.35:Isoline diagram

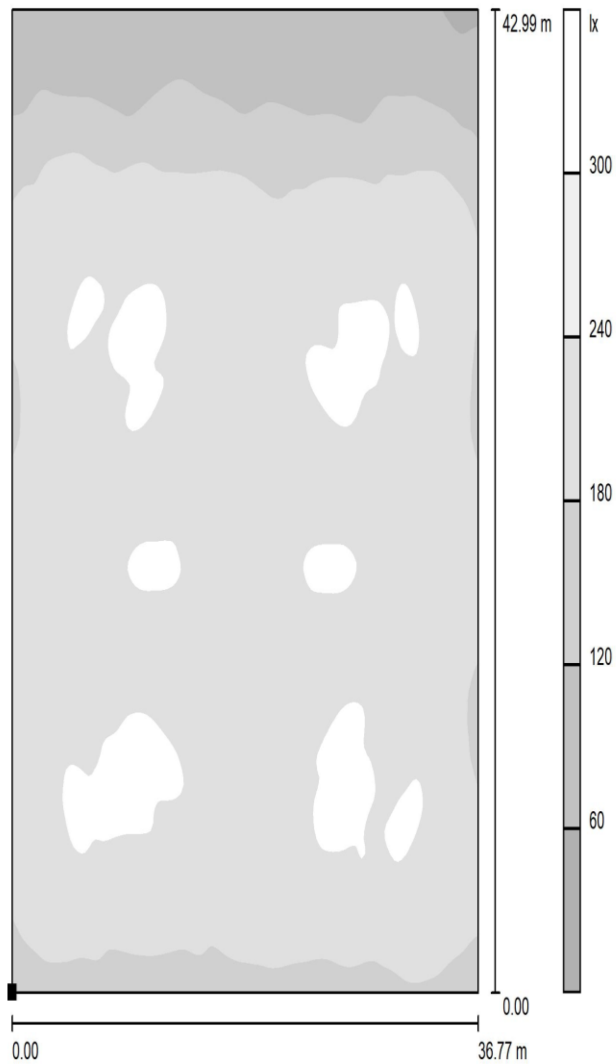


Fig-6.36: Grey scale diagram

80	98	89	86	81	93	97	92	91	83	81	77	88	93	84	69
104	118	114	107	104	126	119	110	108	106	104	98	109	117	109	94
131	145	152	135	142	155	147	136	134	139	130	129	133	141	141	120
164	190	193	174	184	177	176	174	167	170	165	169	163	172	176	156
201	214	227	222	215	203	206	214	192	184	199	212	205	214	222	187
242	248	265	276	263	242	234	227	217	211	229	239	245	242	247	220
261	275	302	292	293	279	259	232	239	251	268	279	284	302	247	230
233	261	316	298	339	294	262	243	242	270	289	311	317	314	253	221
193	253	286	303	316	284	251	237	231	265	313	313	315	294	238	201
187	243	261	282	313	279	224	220	220	261	299	313	291	263	247	196
187	227	255	284	290	237	206	203	211	250	268	285	273	249	230	195
205	229	247	265	267	243	223	215	220	238	245	242	257	246	233	209
231	248	248	238	267	290	263	251	239	263	252	250	255	250	252	232
260	273	263	271	312	305	274	258	259	267	308	308	271	266	274	255
260	273	263	270	303	299	271	261	259	278	299	302	264	264	272	253
234	249	248	250	244	243	258	232	244	256	283	259	243	248	248	226
214	236	249	255	236	239	231	214	208	216	239	246	269	253	229	202
207	238	251	278	286	268	246	206	199	205	242	299	287	260	232	192
208	260	274	307	324	301	258	219	220	227	287	322	289	266	252	195
211	259	306	328	324	319	267	231	241	259	293	333	301	286	263	206
237	262	322	319	310	292	272	249	249	271	307	337	293	319	272	260
235	256	295	279	274	275	257	243	242	268	286	294	293	300	285	274
219	254	245	241	241	233	214	221	233	239	242	256	264	264	252	245
184	213	204	195	204	198	188	197	217	204	199	208	212	228	224	198
150	169	166	155	159	158	168	165	169	174	171	175	167	187	186	161

42.99 m

0.00

0.00

36.77 m

Fig-6.37: Value chart diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
226	51	349	0.227	0.147

National level sports lighting design / Ground Element 1 / Surface 1 / Isolines , Greyscale , Value Chart

169	196	173	177	195	197	195	208	197	177	191	178	173	191	184	139
229	252	223	236	255	250	246	259	247	219	239	232	222	244	242	190
293	325	291	318	309	310	317	311	300	285	293	296	286	302	308	247
374	430	382	397	378	379	399	367	361	358	356	382	376	379	380	327
454	496	492	466	467	464	445	434	409	414	427	443	480	467	492	412
554	569	591	585	564	527	491	474	437	453	487	496	525	542	549	475
601	626	612	635	601	607	514	474	465	503	590	592	632	625	605	492
516	651	591	672	669	614	511	463	483	545	600	663	671	649	617	471
422	561	571	623	661	574	488	455	458	531	590	645	641	599	540	430
382	500	540	568	611	554	452	421	422	503	591	603	564	527	487	403
380	452	505	551	576	468	400	386	400	476	510	553	521	496	451	388
410	457	480	512	506	455	412	398	402	444	470	464	492	474	459	417
457	492	480	462	491	533	483	458	434	481	468	465	484	483	495	457
508	539	509	506	573	559	501	466	468	489	566	563	509	514	541	504
511	540	510	504	553	544	490	467	465	503	546	549	495	510	537	496
464	492	474	473	454	443	463	414	437	461	511	473	464	482	491	447
425	463	481	486	443	444	417	380	369	383	433	454	515	490	461	406
409	469	519	532	543	509	452	372	357	373	454	561	562	524	469	388
430	515	572	619	664	593	498	413	408	428	550	641	596	568	523	400
461	575	625	693	720	637	543	460	469	499	599	697	648	590	596	457
512	642	657	685	678	646	559	508	506	539	667	687	697	610	678	579
503	621	613	594	586	615	551	500	509	550	627	629	645	631	645	637
484	563	528	523	503	515	484	476	488	513	548	563	573	588	574	565
404	469	440	457	430	425	417	432	447	457	459	452	451	485	512	454
315	375	353	348	350	345	351	367	380	397	364	358	383	368	416	371

42.99 m

0.00

0.00

36.77 m

Fig-6.37: Value chart diagram

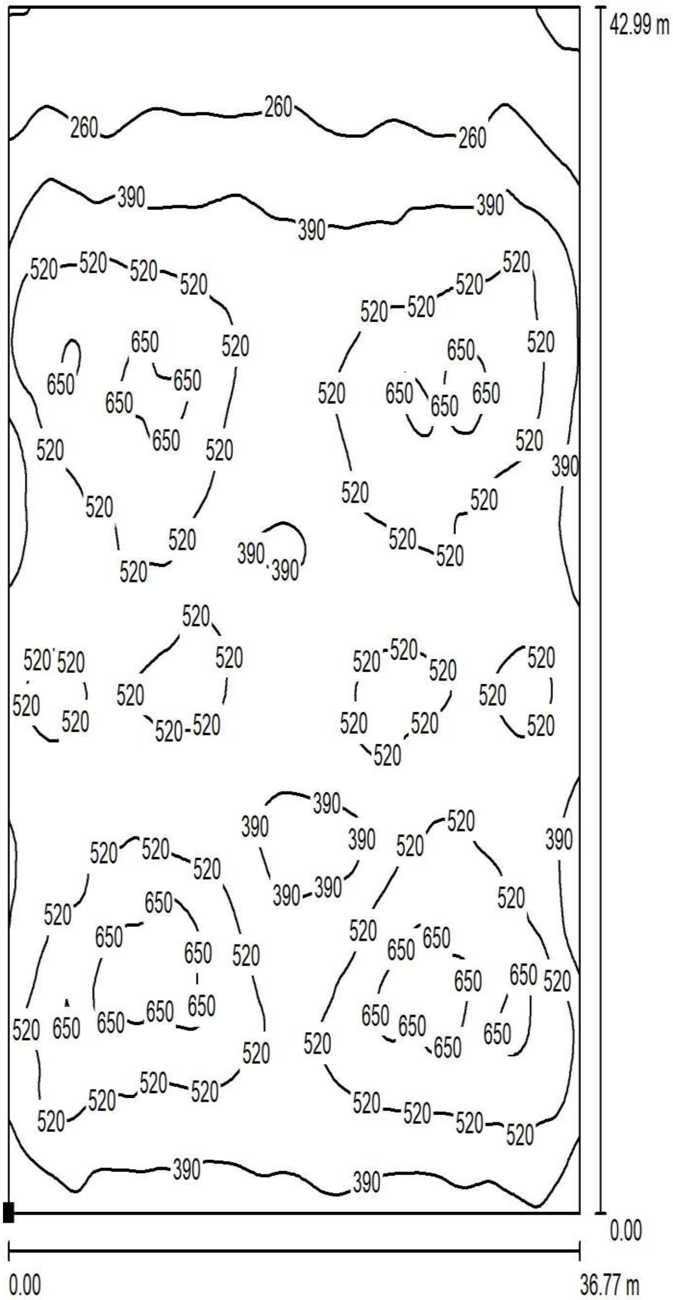


Fig-6.39: Isoline diagram

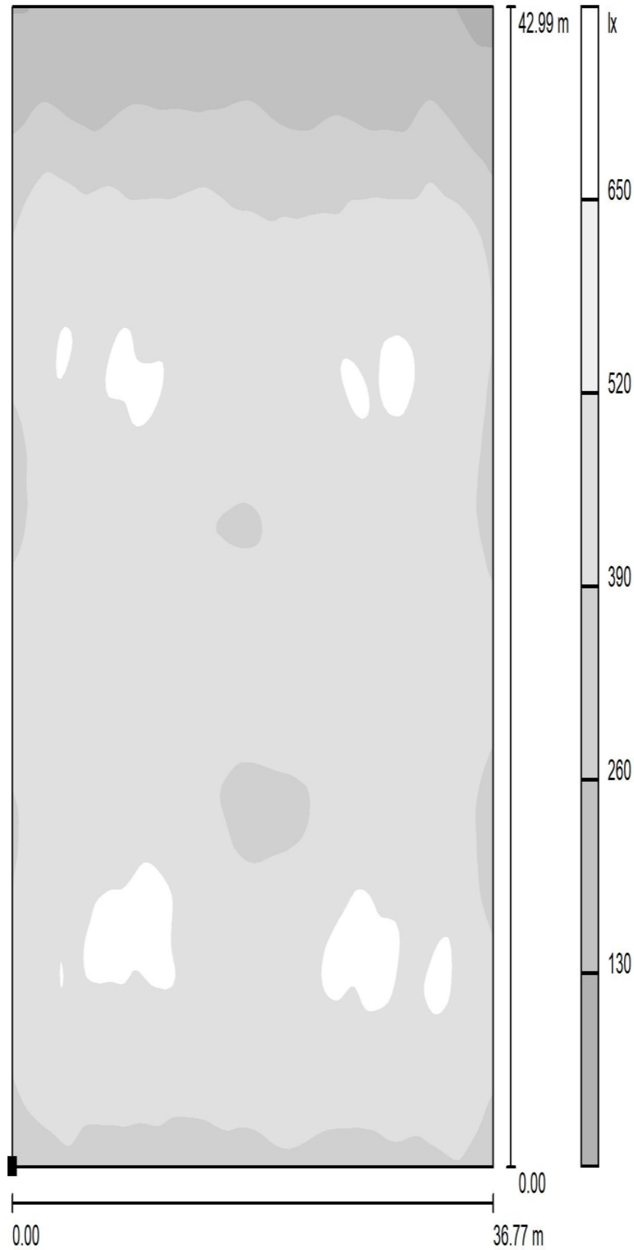


Fig-6.40: Grey scale diagram

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
461	104	732	0.226	0.143

Tabular comparison table

Table-6.19: Comparison

Area	Eav [lx]	Emin [lx]	Emax [lx]	u0
Education level football sports field	226	51	349	0.147
National level football sports field	461	104	732	0.226

6.2.8 Education level/National level sports lighting design / Soccer Field 1 Calculation Grid (PA)

There are two types of area is being considered in design. One is playing area and other one is total area. Playing area(PA) means the area where the actual task is being done. Total area(TA) means some existing area around the playing area where other necessary work to be done. Diagram 6.41 & 6.42 tennis court 1 & court 2 respectively shows the main playing of the football field.

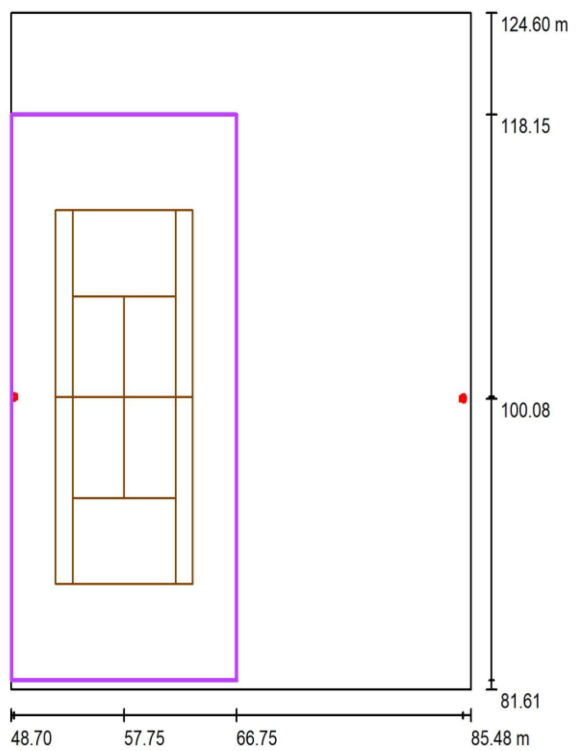


Fig-6.41:Layout

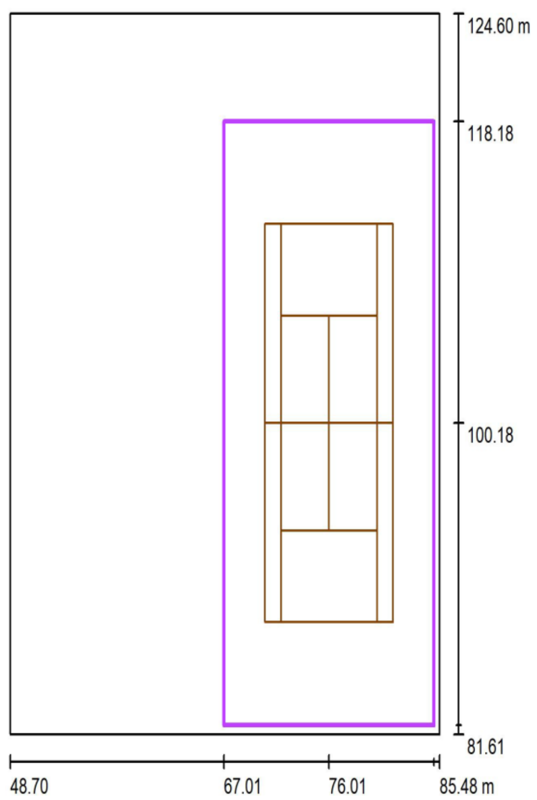


Fig-6.42:Layout

6.2.9 Tennis court 1 Calculation Grid (PA)

The tennis ground is designed in such a way that education level and national level games can be played here. Lighting levels are maintained during games at the recreation level and education level and at the national level as per ITF standards. Average 250 lux for education level and 500 lux for national level non televised are maintained and uniformity is maintained at 0.60 for training & recreation level and 0.70 for national level designs.

The data obtained through DIALux 4.13 have been tabulated and displayed as in Tables 6.18 while the pictorial data are displayed in Fig-6.43 to Fig-54

Educational level sports lighting design / Tennis 1 Calculation Grid (PA) / Isolines (Perpendicular)

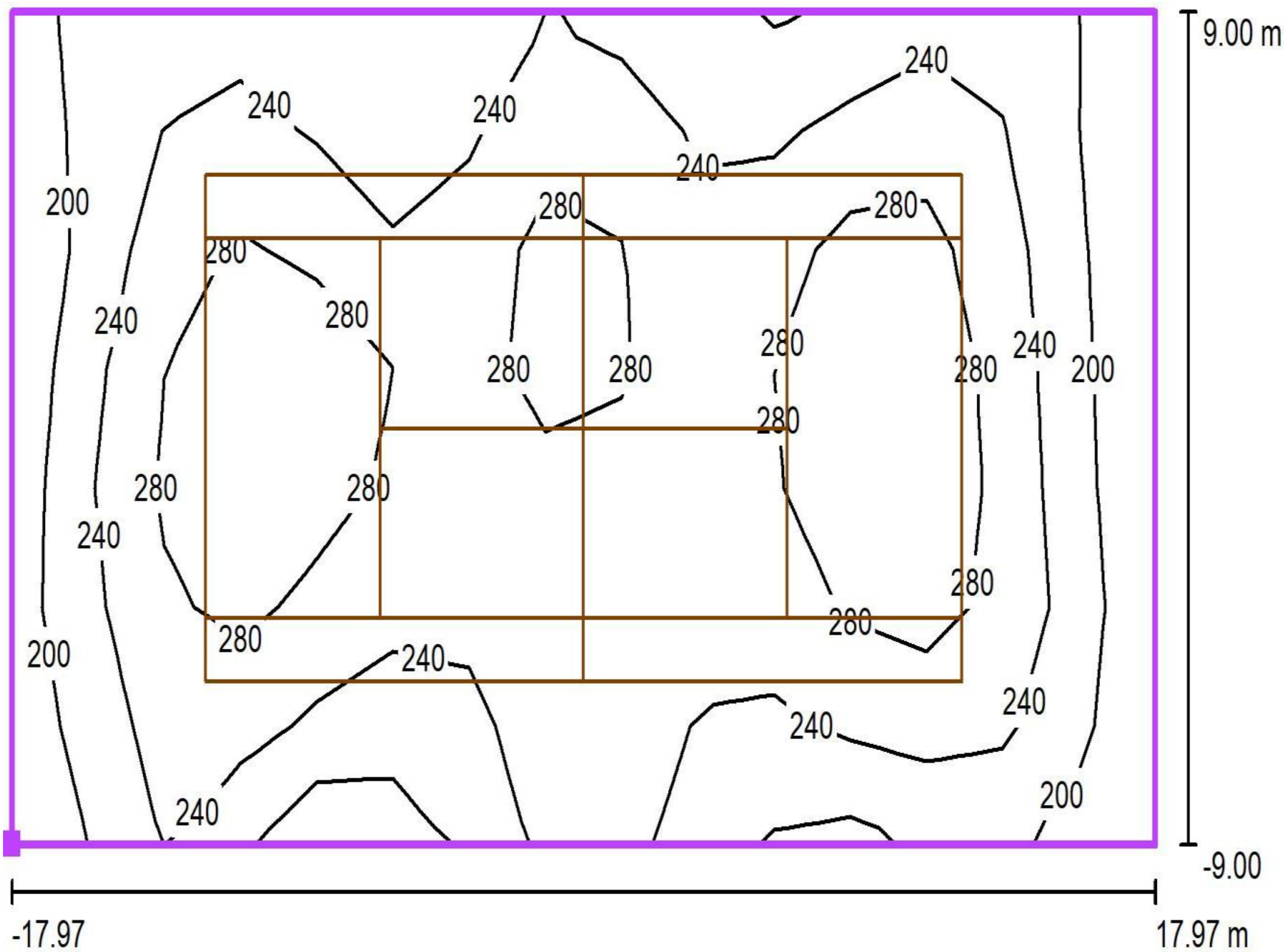


Fig-6.43: Isoline

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
250	175	341	0.70	0.51

Educational level sports lighting design / Tennis 2 Calculation Grid (PA) / Isolines (E,Perpendicular)

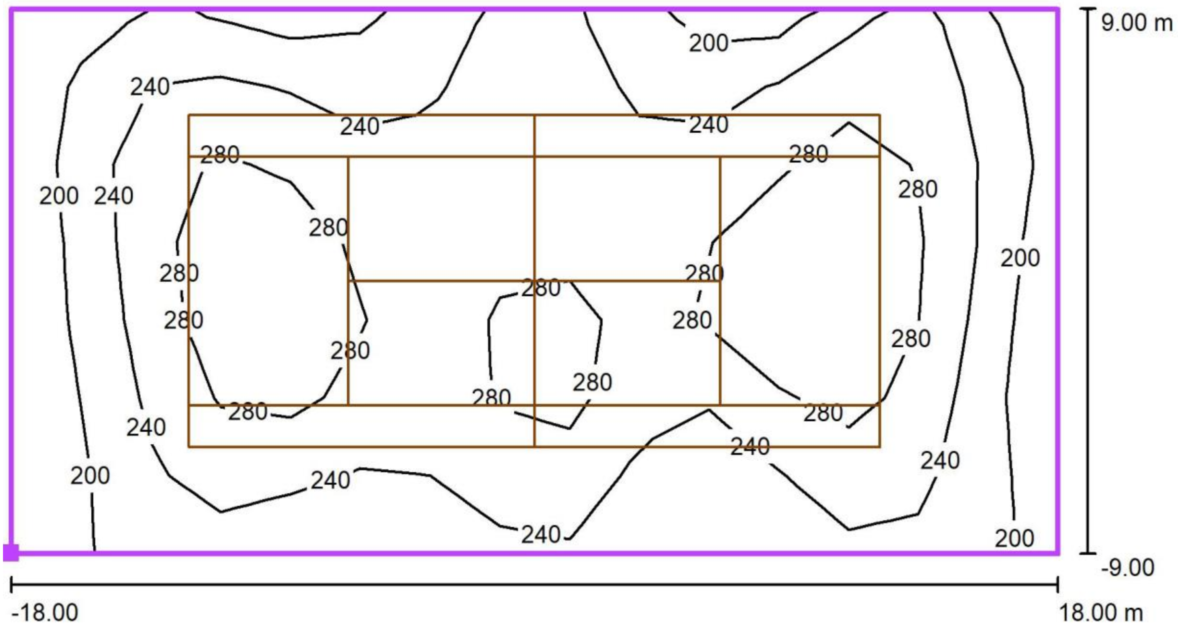


Fig-6.44: Isoline

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
250	175	337	0.70	0.52

National level sports lighting design / Tennis 1 Calculation Grid (PA) / Isolines (Perpendicular)

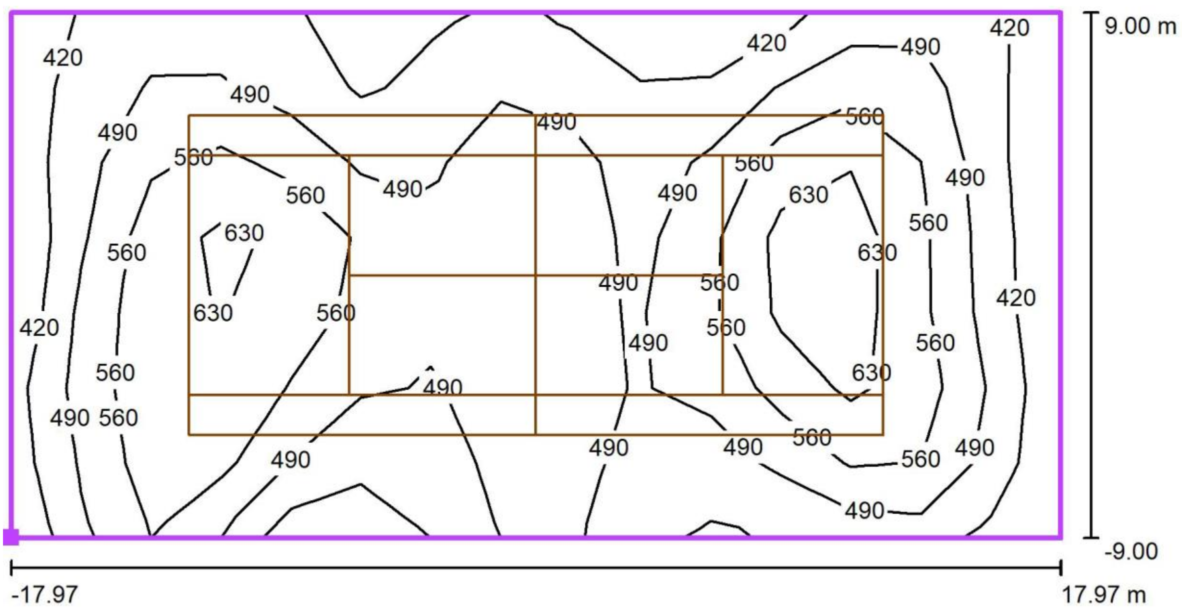


Fig-6.45: Isoline

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
509	375	692	0.74	0.54

National level sports lighting design / Tennis 2 Calculation Grid (PA) / Isolines (E,Perpendicular)

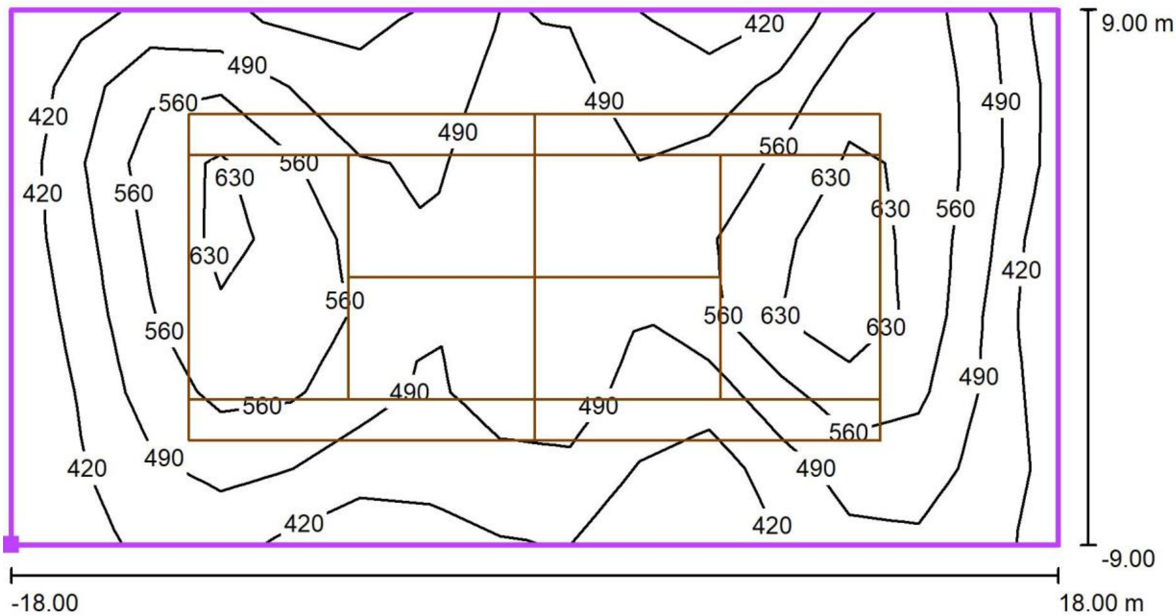


Fig-6.46: Isoline

Eav [lx]	Emin [lx]	Emax [lx]	u0	Emin / Emax
508	355	692	0.70	0.51

Educational level sports lighting design / Tennis 1 Calculation Grid (PA) / Greyscale(E, Perpendicular)

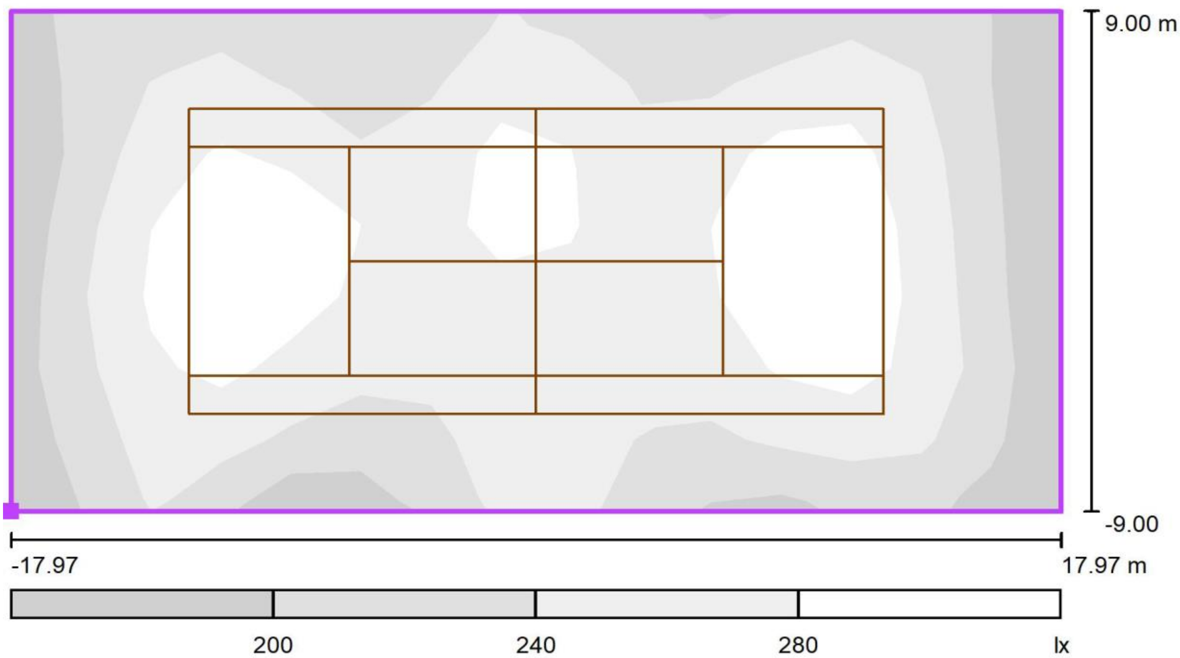


Fig-6.47: Gray scale value

Educational level sports lighting design / Tennis 2 Calculation Grid (PA) / Greyscale(E, Perpendicular)

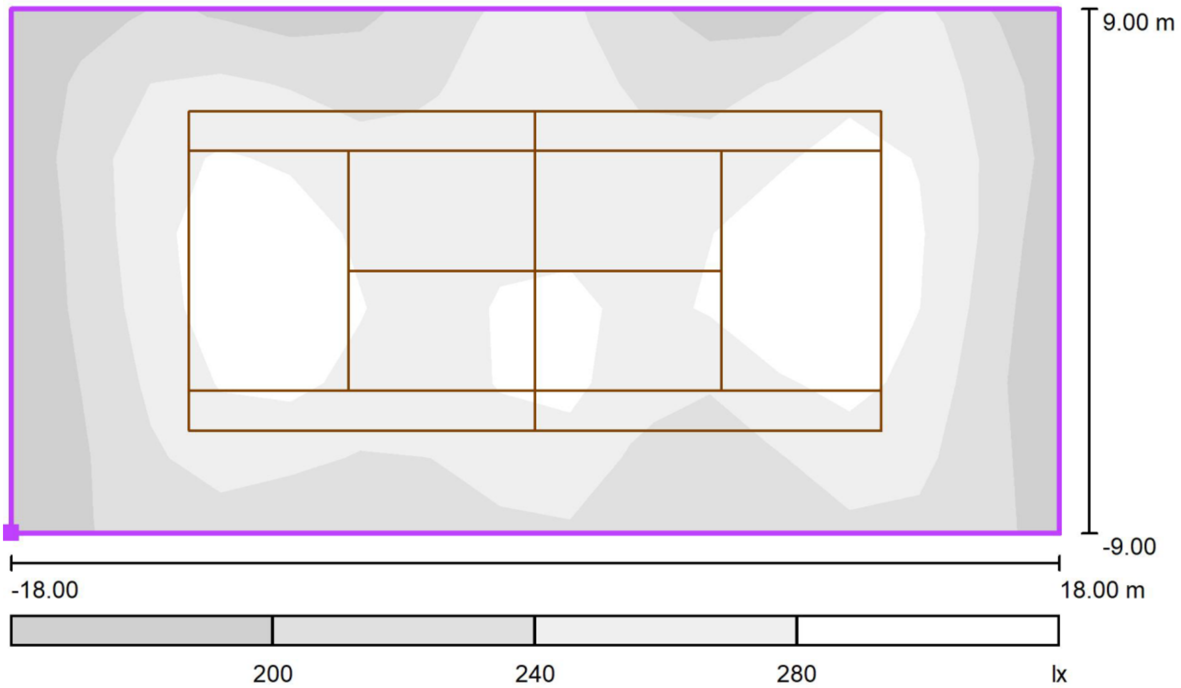


Fig-6.48: Grey scale value

National level sports lighting design / Tennis 1 Calculation Grid (PA) / Greyscale (E,Perpendicular)

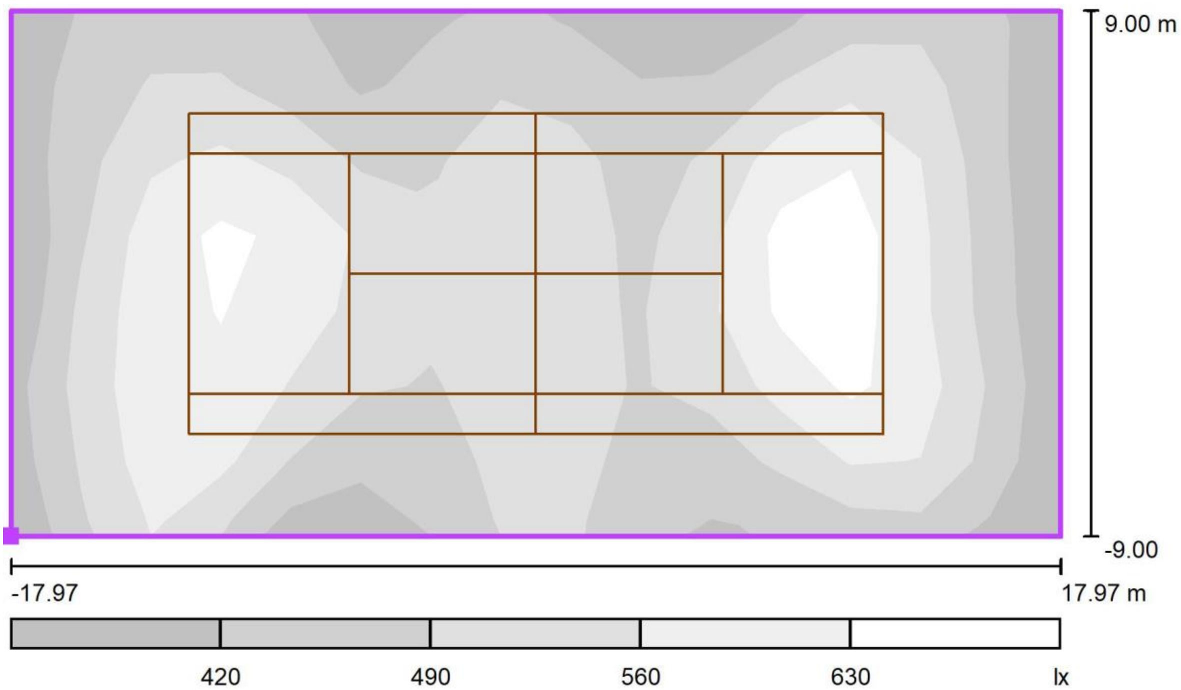


Fig-6.49: Grey scale value

National level sports lighting design / Tennis 2 Calculation Grid (PA) / Greyscale (E,Perpendicular)

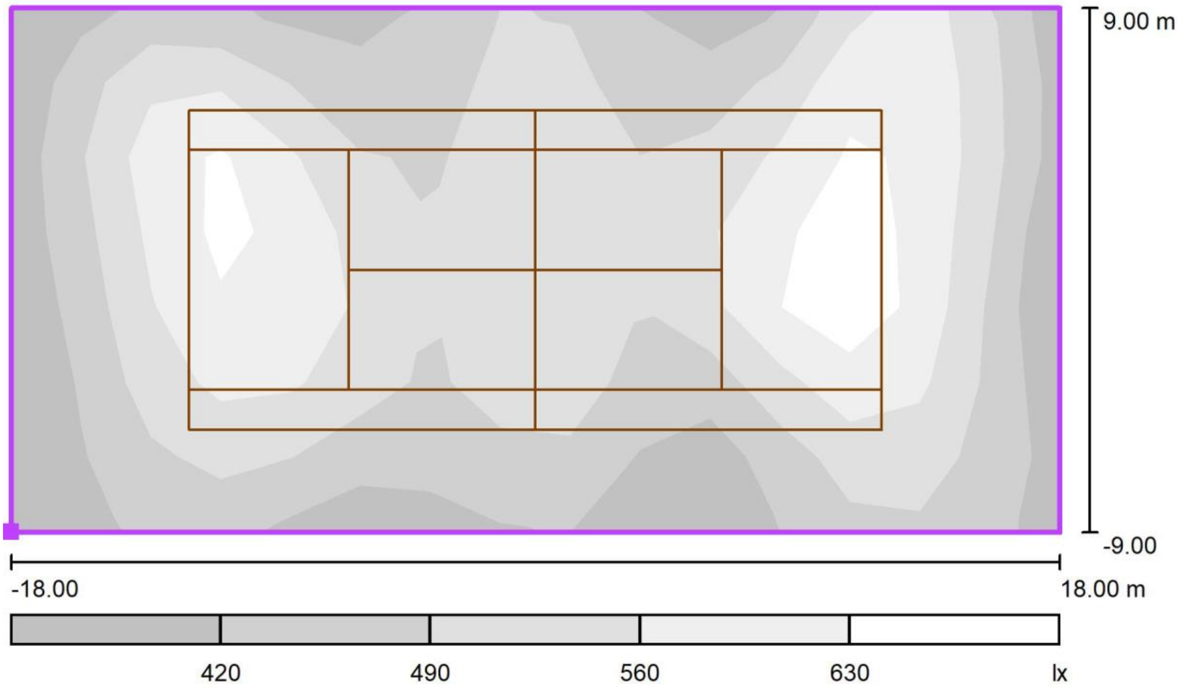


Fig-6.50: Grey scale value

Educational level sports lighting design / Tennis 1 Calculation Grid (PA) / Value Chart (E, Perpendicular)

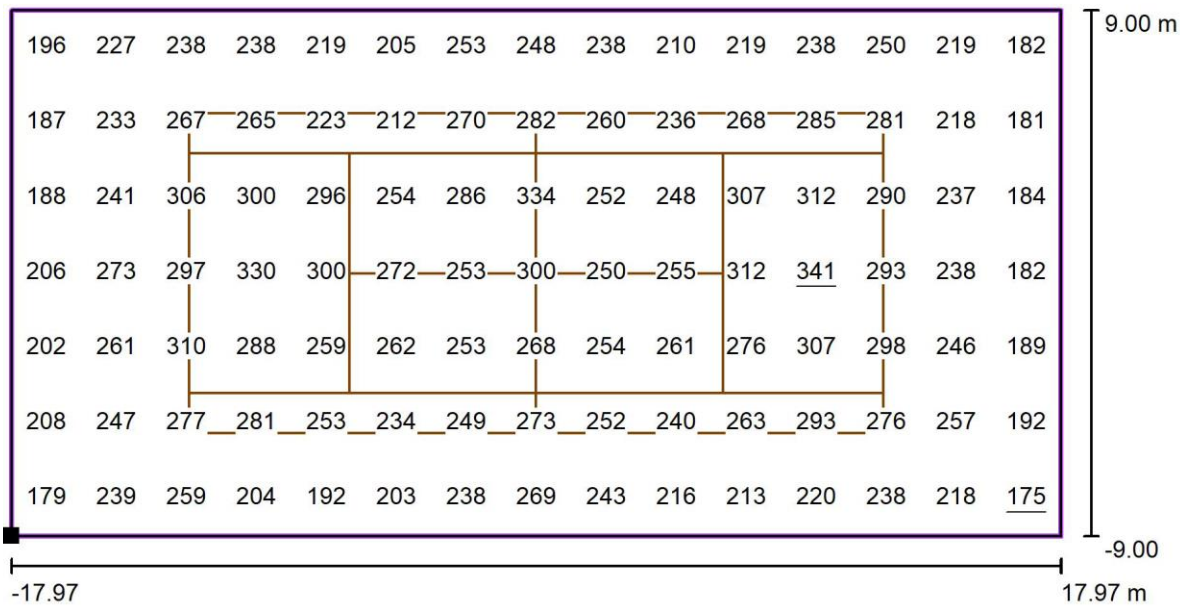


Fig-6.51: Isoline value diagram

Educational level sports lighting design / Tennis 2 Calculation Grid (PA) / Value Chart (E, Perpendicular)

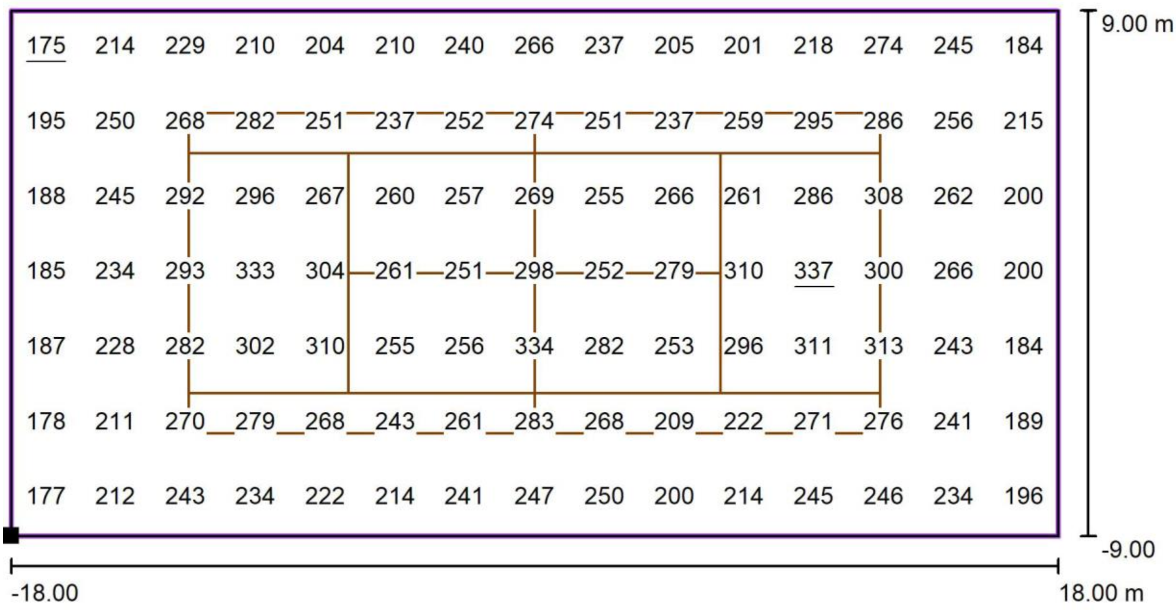


Fig-6.52: Isoline value diagram

National level sports lighting design / Tennis 1 Calculation Grid (PA) / Value Chart (E, Perpendicular)

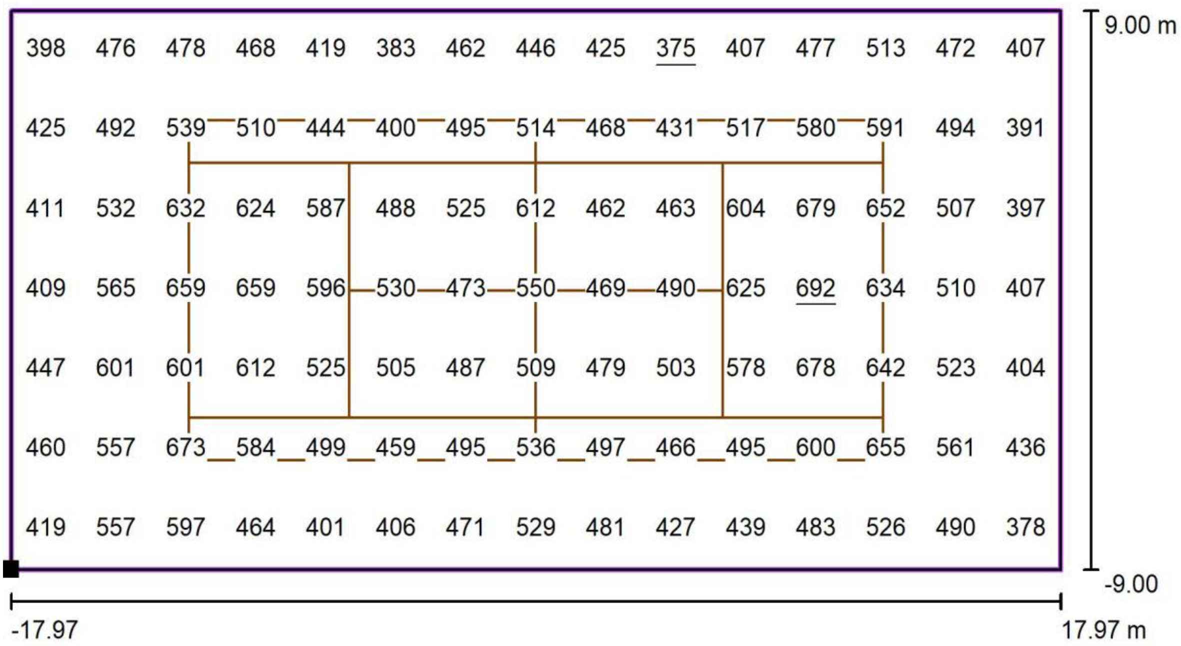


Fig-6.53: Isoline value diagram

National level sports lighting design / Tennis 2 Calculation Grid (PA) / Value Chart (E, Perpendicular)

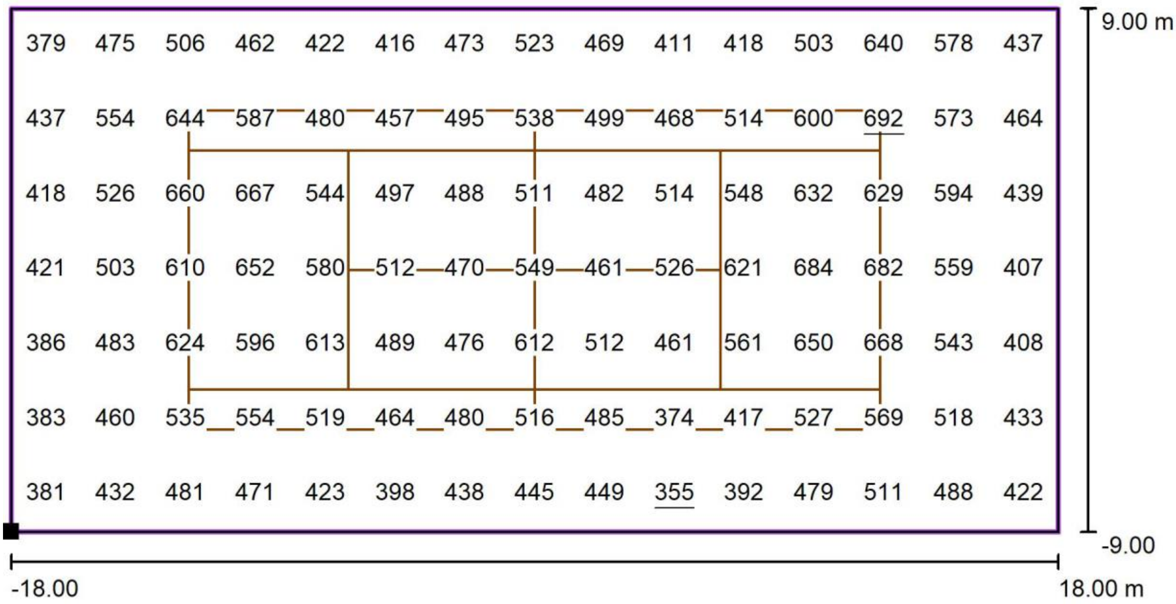


Fig-6.54: Isoline value diagram

6.2.10 Comparison with standard values

Till now the values that have been seen were from the proposed design. However, no matter how much hard work was done, they are needed to be on par with the standard values given in the necessary lighting codes and guides which govern the football field lighting.
Therefore, the proposed values are to be compared against the established standards in order for their validation. It is to be noted that there are plenty of quantities that are produced from the standard DIALux 4.13 output, however in the light of keeping our analysis as compact and simple as possible, only the following quantities are to be compared

i. **Average Horizontal Illuminance (Ehavg):** The average final value of all illuminance values contained on the horizontal plane of a surface

ii. **Average Vertical Illuminance (Evavg):** The average final value of all illuminance values contained on any one of the considered vertical planes. Only required for televised events.

iii. Uniformity (U0): The ratio of the minimum available illuminance value to the average illuminance. The uniformity under consideration is done only for the horizontal planes

iv. Glare rating (GR) ranges: Glare value compared to the standard limit prescribed

Tabular comparison

The parameters spoken of in previous sections are summed up in the Table 6.20 in order to facilitate a side-by-side comparison

Table-6.20:Comparison

Level of competition	Parameters	Standard	Proposed		Remarks
Class III (Training & recreation level or education level)	Average Horizontal Illuminance (Eh avg)	200-250	Court 1-250 Court 2-250		Achieve beyond standard
	Uniformity (U0)	0.6	Court 1 -0.70 Court 2 -0.70		
	Glare rating (GR) Max	50	Court - 1	Min-37 Max-40	
			Court 2	Min-37 Max-43	
Class II (National Level Non televised)	Average Horizontal Illuminance (Eh avg)	500	Court 1-509 Court 2-508		Achieve beyond standard
	Uniformity (U0)	0.7	Court 1- 0.74 Court 2- 0.70		
	Glare rating (GR) ranges	50	Court -1	Min-41 Max-44	
			Court 2	Min-41 Max-44	

CHAPTER 7

7. Summary and Conclusion

The incumbent design involved creating a stadium which can hold primarily from inter-college to recreational matches, which has been upgraded now to a stadium where all kinds of matches could be held with considerable ease of players and spectators alike. The stadium has now become a more versatile and practical playing ground in terms of lighting.

The methodology for design has been extensively discussed in this thesis and stress has been given for optimization. By optimization, we refer the design using the minimum possible number of luminaires to achieve the desired lighting levels meant for the occasion and alongside making the design's initial & operational costs significantly lower. Any design at end of the day if it is optimized to its best extent (irrespective of whether it's interior or exterior lighting) would be eligible for a higher preference from the client side than an unoptimized design.

Optimization could be done by various means; one such technique uses a mathematical methodology called "Rough Set Theory". This theory could also be applied here for a more optimized design. However, this was something that could not be achieved in this work, owing to the limited timeframe of the thesis.

India has no standard data for sports lighting. This work has been carried out on the strength of international standard however the guidelines for sports lighting has been prepared by our **Dr Kamalika Ghosh** mam and under the process of publications by Bureau of Indian standards. In future sports lighting design will be carried out in various field of sports and games. Considering various environmental aspect to suit Indian conditions. However, depending upon the technology development same also need to be upgraded time to time.

The standards for installation of Sport lighting is important considering present popularity of sports. The goal of lighting of sport ground / stadium is to offer an adequate environment to enjoy sport events both by spectators and players. Adequate horizontal luminescence from the house lighting is also required to ensure safety of movement for the spectators when entering and leaving the strands or surrounds. The arrangement of the luminaries determines the possible length and hardness of the shadow caused by the players. Floodlights are used for sport ground and stadium lighting floodlights. Modern sport ground and stadiums increasingly have the light positioned within the stand.

This research began with an analysis of the new lighting design in education -level sport competitions, particularly with respect to the current lighting requirements. Our observations and recommendations related to illuminance can be summarized as follows:

It was concluded that it is unfeasible to illuminate high-level stadiums using only luminaires in the corners. The location of the luminaires in the stadium is a determining factor. With a symmetrical design, the same point can be illuminated from multiple locations, reaching maximum horizontal and vertical uniformity.

We have achieved lux level of class III and class II sports ground as per FIFA & ITF standards.

Spreading light in the sports complex of IIM, Calicut was even due to distribution of the amount of light that produced by the light bulbs on the main poles.

Design of the lighting intensity of sports complex of IIM, Calicut reached an average of 257 lux & 517 lux for football ground and 250 lux & 509 lux for tennis court that can be used for non-televised league games.

We have achieved uniformity level of class III and class II sports ground as per FIFA & ITF standards which is 0.73 & 0.78 (for football ground), 0.70 & 0.74 (tennis court).

The type of lamp used at sports complex of IIM, Calicut is LED which is the modern types of lights from high intensity, these lamps have a higher efficacy of 120 to 130 lumens per watt.

Power consumption of sports complex of IIM, Calicut amounted to 16400 W (education level design) 32000 W (national level design) for football ground & 6000 W (education level design) 12000 W (national level design) for tennis court.

The Brand of the lamps used in the sports complex of IIM, Calicut was of M/s. Orient Electric.

In addition to Illumination level and optimization of electric power consumption, the selection of luminaires as well as their installation have been made to avoid light pollution to spectators, outsiders and glare to the eyes of the players.

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