"STUDIES OF FOOTBALL FIELD LIGHTING DESIGN AND SIMULATION BASED ANALYSIS"

A thesis submitted towards partial fulfilment

of the requirements for the degree of

Master of Technology in Illumination Technology and Design

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2022

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CERTIFICATE OF RECOMMENDATION

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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 warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

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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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ACKNOWLEDGEMENT

It is a genuine pleasure to express my deep sense of thanks and sincere gratitude to my advisor, Parthasarathi Satvaya Director & Assistant Professor, School of Illumination Science, Engineering and Design, Jadavpur University and Mr. Joy Krishna Pal for providing me with the opportunity to carry out my thesis work and their constant guidance and supervision. I would also like to thank them for providing me their valuable time and helpful suggestions for gathering information, data collections during simulation study on that subject.

I am highly indebted to, Dr. Kamalika Ghosh former Associate professor of School of Illumination Science, Engineering and Design, Jadavpur University and Prof. (Dr.) Biswanath Roy, Department of Electrical Engineering, Jadavpur University and Dr. Suddhasatwa Chakraborty, Assistant Professor of Department of Electrical Engineering, Jadavpur University for their valuable suggestions and encouragements during the thesis work.

Again, I would like to acknowledge my sincere thanks to Prof. (Dr.) Saswati Mazumder, HOD of Electrical Engineering Department, Jadavpur University for providing me the opportunity to carry out my thesis work in Illumination Engineering Laboratory, Jadavpur University.

I am also thankful to Mr. Samir Mandi and Mr. Pradip Pal, Illumination Engineering Laboratory for their warm cooperation during that thesis work.

Last but not the least, my special thanks to all my classmates who helped me directly in completing my thesis successfully.

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Place: Kolkata

[SUNNYMAJUMDER]

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1. Introduction:

1.1 Background:

The lighting of football field plays a vital role in night games. For the audience, their experience depends heavily on the lighting system settings. For players, the lights must provide enough coverage so that they can use their skills to the fullest. Football field lighting is a design with strong functionality, high technology, and a relatively high degree of difficulty. Football stadium lights not only must they meet the standards of various levels of football events, but also pay great attention to the actual effect of the real-time color TV broadcast. The broadcast images are clear and the colors are true, there are corresponding regulations on the vertical illuminance, uniformity of light intensity, spatial three-dimensionality, color temperature, and color rendering

index of the light source, and the lighting standards of different levels of football fields are different.

1.2 Project Scope:

Today football is probably the most popular form of entertainment in the world. Events such as the FIFA World Cup, the Euro Championships, the Champions League and the Copa America capture the attention of almost everyone in the world. Good and proper lighting is essential to the success of any sporting event. The sport is played outdoor or indoor, as a leisure activity or as a professional championship, in daylight or at night, the importance of proper lighting system remains the same. The main objective of football field lighting design is to meet the proper illumination level, uniformity and glare rating of any types of events whether it is televised matches or non-televised matches.

1.3 Objective:

The prime objective of this project is to provide sufficient lighting standards like illumination level, uniformity, glare rating according to the FIFA lighting standards to any of the Indian football stadium which will match the design criteria along with pole arrangement and floodlight arrangement. This project will surely help to develop & established good quality, cost-effective football stadium in India according to the lighting design standard in future.

2. Design parameters of football stadium lighting:

2.1 Field Of Play:

2.1.1 Field surface:

The playing field must be absolutely smooth and level. It should be of natural grass or artificial turf and in perfect condition. With natural grass, it should have an efficient watering system for use in dry weather. In cold climates the primary characteristics of a good playing field should include proper underground and surface drainage to allow play during rain and to rid the surface of water during extremely wet conditions. This is to maintain the quality of the football match

and to avoid spectator frustration which could lead to loss of revenue. The playing surface should be even and level to allow the players the confidence of movement that would not contribute in any way to injury or unexpected falls. The grass should be uniform properly rooted and demonstrate vigorous growth. There should be no patches of water logging. Keeping the field in peak condition at all times requires a proper maintenance plan and resources that include trained personnel, mechanical equipment, fertilizers and testing equipment. Matches may be played on natural or artificial surfaces according to the rules of the competition.

- The color of artificial surfaces must be green.
- Where artificial surfaces are used in either competition matches between representative teams of member associations affiliated to FIFA or international club competition matches the surface must meet the requirements of the FIFA Quality and FIFA standards. [2]

2.1.2 Field markings:

The field of play must be rectangular and marked with lines. These lines refer to the areas of which they are boundaries. The two longer boundary lines are called touch lines. The two shorter lines are called goal lines. The field of play is divided into two halves by a halfway line, which joins the midpoints of the two touch lines. The centre mark is indicated at the midpoint of the halfway line. A circle with a radius of 9.15 m is marked around it. Marks may be made off the field of play 9.15 m from the corner arc and at right angles to the goal lines and the touch lines to ensure that defending players retreat this distance when a corner kick is being taken. All the markings, centre mark, circle radius, goal line, corner arc shown in figure-1. [2]

2.1.3 Dimensions:

The length of the touch line must be greater than the length of the goal line. The length of the touch line should be minimum 90m Maximum 120m &Width of the goal line should be minimum 45m & maximum 90m.All lines must be of the same width, which must be not more than 12 cm. The entire football field dimension shown in figure-2. [2]

2.1.4 International matches:

The length of the football field for international matches should be minimum 100m & maximum 110m & width should be minimum 64m and maximum 75m. Figure-3 shows the length & width dimension of the football field which is required for international football matches. [2]

2.1.5 The goal area:

Two lines are drawn at right angles to the goal line 5.5 m from the inside of each goalpost. These lines extend into the field of play for a distance of 5.5 m and are joined by a line drawn parallel with the goal line. Figure-2 shows the dimension of the goal area. [2]

2.1.6 The penalty area:

Two lines are drawn at right angles to the goal line, 16.5 m from the inside of each goalpost. These lines extend into the field of play for a distance of 16.5 m and are joined by a line drawn parallel with the goal line. The area bounded by these lines and the goal line is the penalty area. Within each penalty area, a penalty mark is made 11 m from the midpoint between the goalposts and equidistant to them. An arc of a circle with a radius of 9.15 m from the centre of each penalty mark is drawn outside the penalty area. Penalty area dimension is shown in figure-2. [2]

2.1.7 Flag posts:

A flag post not less than 1.5 m high with a non-pointed top and a flag must be placed at each corner. Flagposts may also be placed at each end of the halfway line not less than 1 m outside the touch line. Flag post dimension shown in figure-2. [2]

2.1.8 The corner arc:

A quarter circle with a radius of 1 m from each corner flag post is drawn inside the field of play. Corner arc dimension is shown in figure-2. [2]

2.1.9 Goals:

A goal must be placed on the centre of each goal line. A goal consists of two upright posts equidistant from the corner flag posts and joined at the top by a horizontal crossbar. The goalposts and crossbar must be made of wood, metal or other approved material. They must be square, rectangular, round or elliptical in shape and must not be dangerous to players. The distance between the posts is 7.32 m and the distance from the lower edge of the crossbar to the ground is 2.44 m. Figure-2 shows the dimension of the goal area. [2]

2.1.10 Safety:

Goals must be anchored securely to the ground. Portable goals may only be used if they satisfy this requirement.

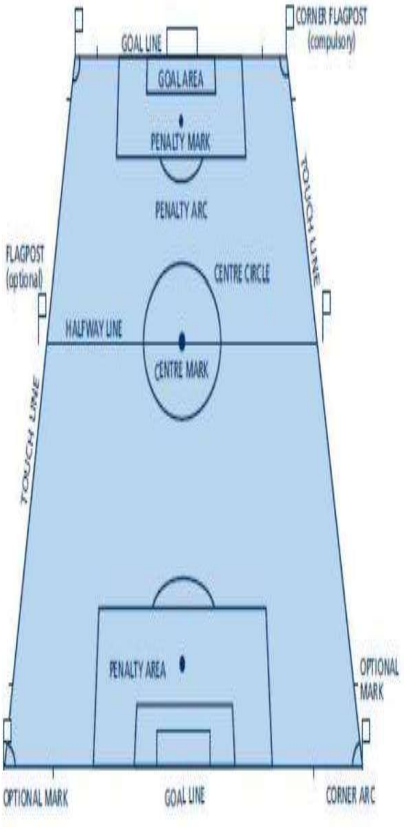

Figure1 Football pitch

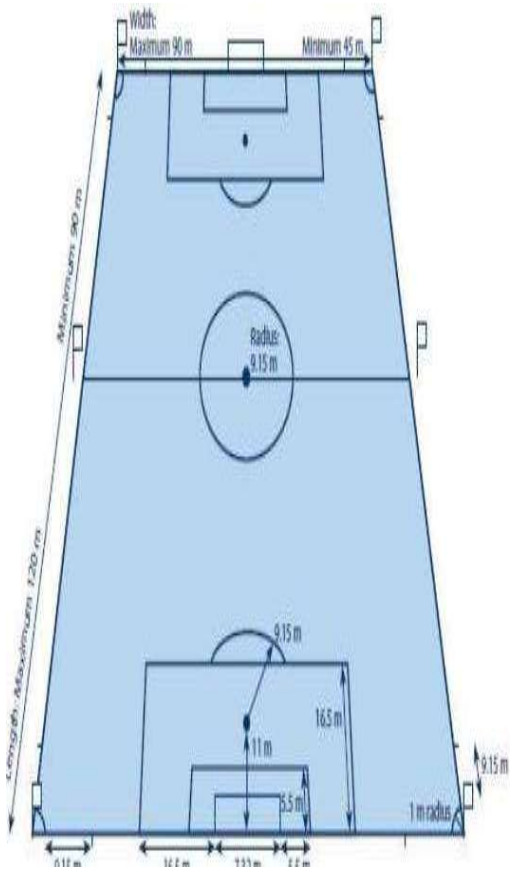

Figure 1 Football pitch dimension

Figure 2 Playing area

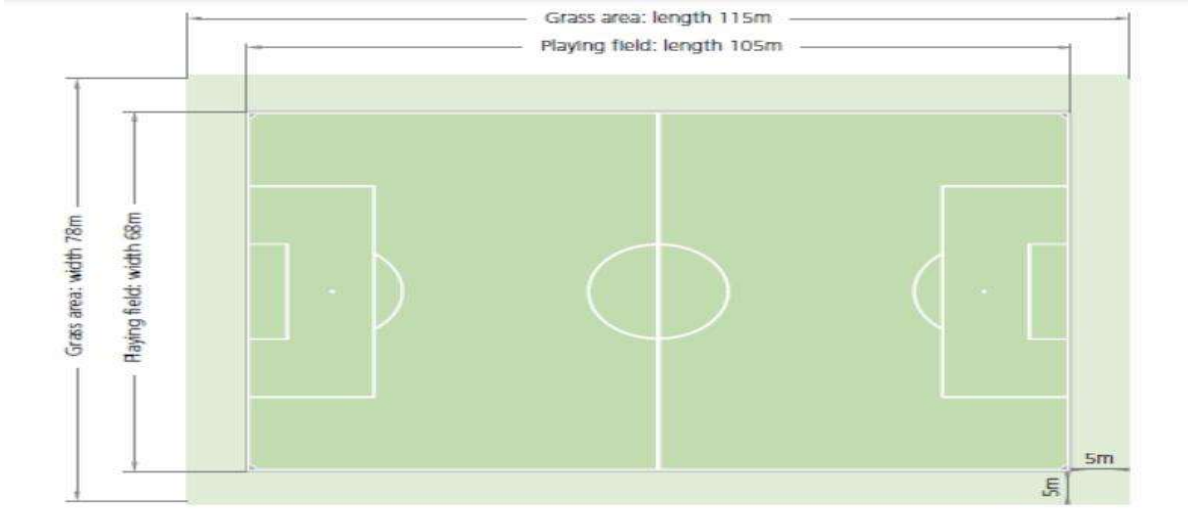

Figure 3 Grass area

2.1.11 Recommended dimensions:

For all matches at the top professional level and where major international and domestic games are played, the playing field should have dimensions of 105m x 68m. These dimensions are obligatory for the FIFA World Cup and the final competitions in the confederations' championships. [2]

2.1.12 Auxiliary area:

Additional flat areas are required beside the playing field, ideally behind each goal line, where players can warm up. This area should also allow for the circulation of assistant referees, ball - boys and girls, medical staff, security staff and the media. It is recommended that this be a minimum of 8.5m on the sides and 10m on the ends. This result in an overall playing field and auxiliary area dimension of length-125m, width-85m. [2]

2.1.13 Grass area:

In this area, a minimum of 5m on the sides or touch lines and 5m behind the goal lines reducing at an angle to 3m near the corner flags. Grass area dimension shown in figure-4. [2]

2.2 Light Arrangement:

2.2.1 Linear roof rim lighting:

Generally the luminaries should be positioned with a sufficient lateral distance from the pitch perimeter to ensure the required vertical illuminance levels and illuminance uniformity be achieved. Usually an angle of greater than 20˚ between the pitch perimeter and the luminaries should be maintained. The general angle is 25°-30° for the majority of stadiums. Linear roof lighting arrangement is shown in figure-5. [1]

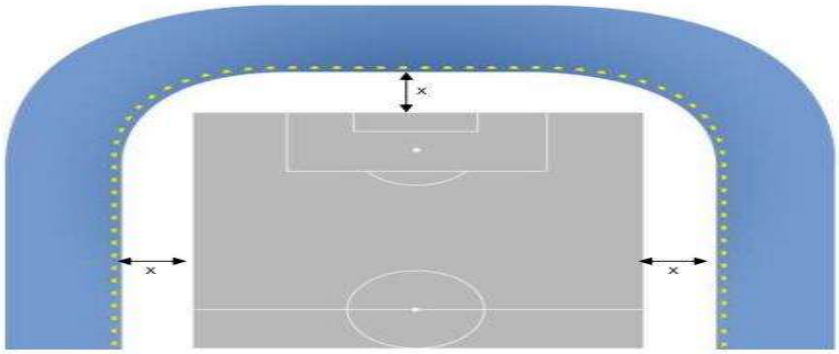

Figure 4 Linear roof rim lighting

2.2.2 Luminaries focus point:

Due to avoid discomfort glare being experienced by players and officials a rule of thumb during the design process is to ensure that luminaries focus-point angle is not more than 70° from the line perpendicular to the pitch. Figure-6 shows the angle and light distribution from the source of floodlight. For the high intensity discharge lamp angle of focal point is maximum 70◦ and for LED angle of focal point maximum 60◦ which is better than HID lamp as shown in figure-6. [1]

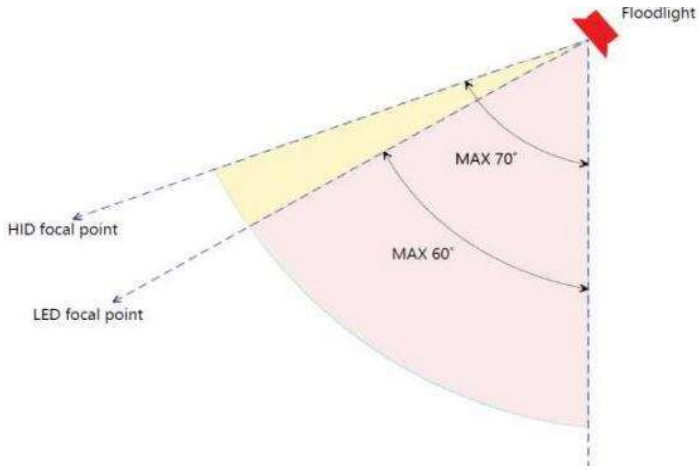

Figure 5 luminaries focus point

2.2.3 Column position:

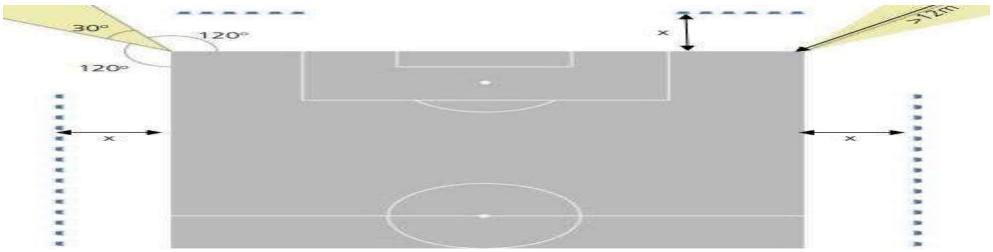

Figure 6 corner column positions

As shown in figure-7 corner column should be located not closer than 12m from the pitch corner. Angle of zone in which the corner column should be located between 120◦ from the goal line and 120◦ from the pitch side. Generally the height of the corner column should be between 40m-45m. [1]

2.2.4 Corners linear floodlight array:

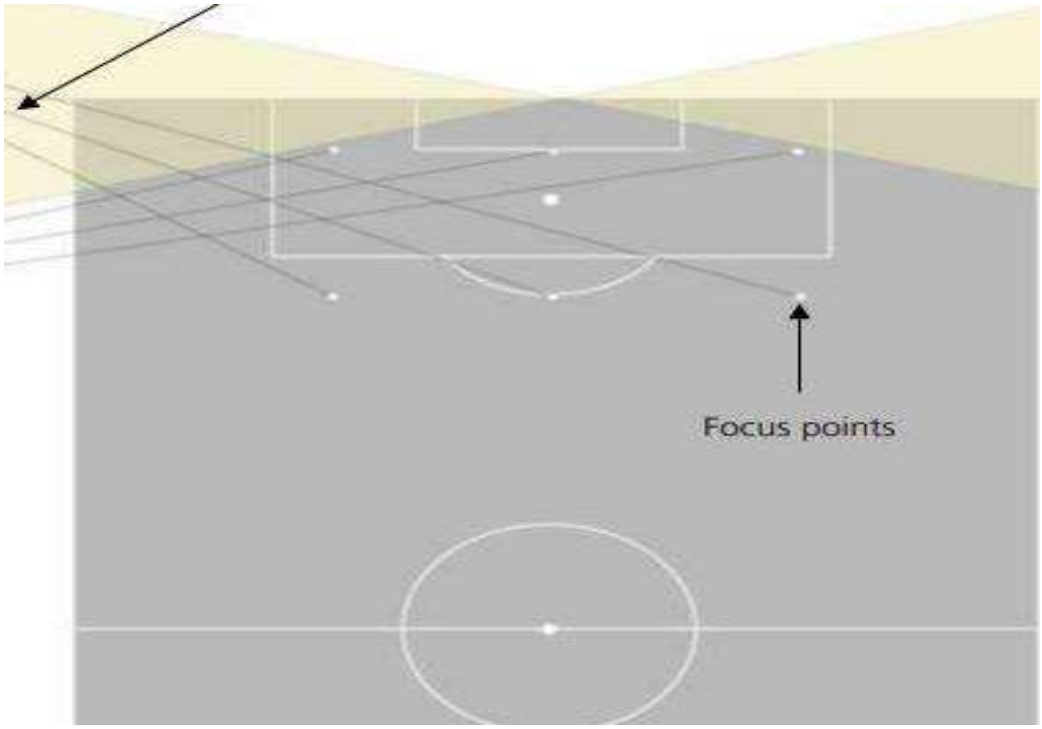

Figure 7 corner linear flood light array

Luminaries mounted within 15° of the goal line should be focused away from the penalty box as shown in figure-8. Multiple arrays of luminaries should not be positioned within 15° of either side of the goal line. A linear array of luminaries used for this purpose should not comprise more than two rows. [1]

2.2.5 Pitch perimeter lateral distance:

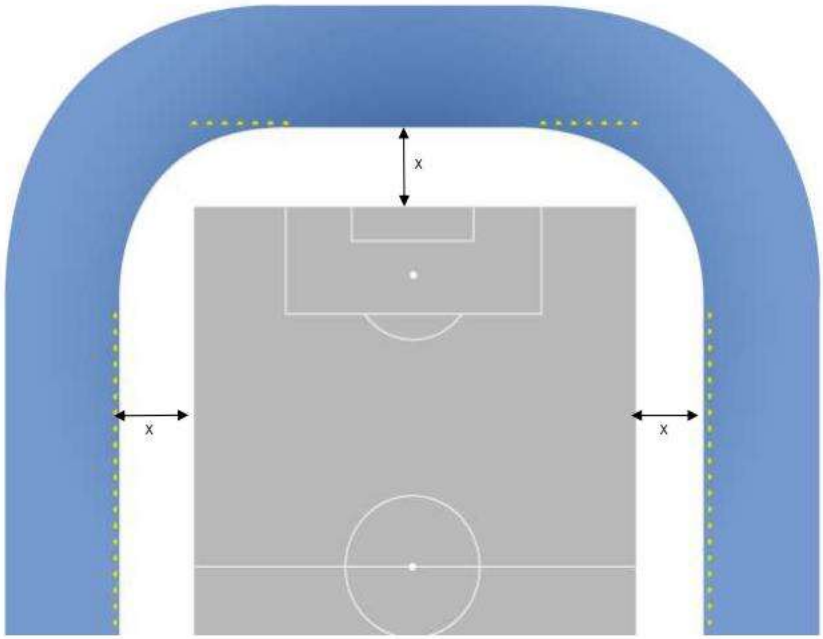

Figure 8 pitch perimeter lateral distance

To achieve the required vertical illuminance around the perimeter of the pitch, the luminaries should have a mounting position with a minimum lateral distance from the pitch perimeter of greater than 12m. Figure-9 shows the pitch perimeter lateral distance from the luminaries. [1]

2.2.6 Pitch perimeter luminaire mounting zone:

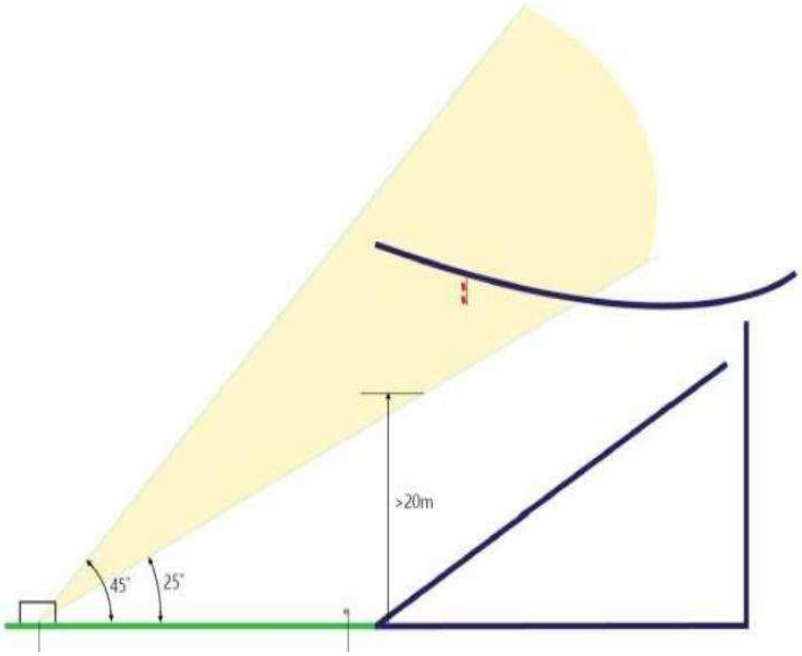

Figure 9 Pitch perimeter luminaire mounting zone

The luminaires should not be mounted less than 25° or more than 45° above the centre of the pitch as shown in figure-10. Luminaires should be mounted at least 20-25m above the surface of the pitch to reduce the glare for the players. [1]

2.2.7 Pitch perimeter second linear row:

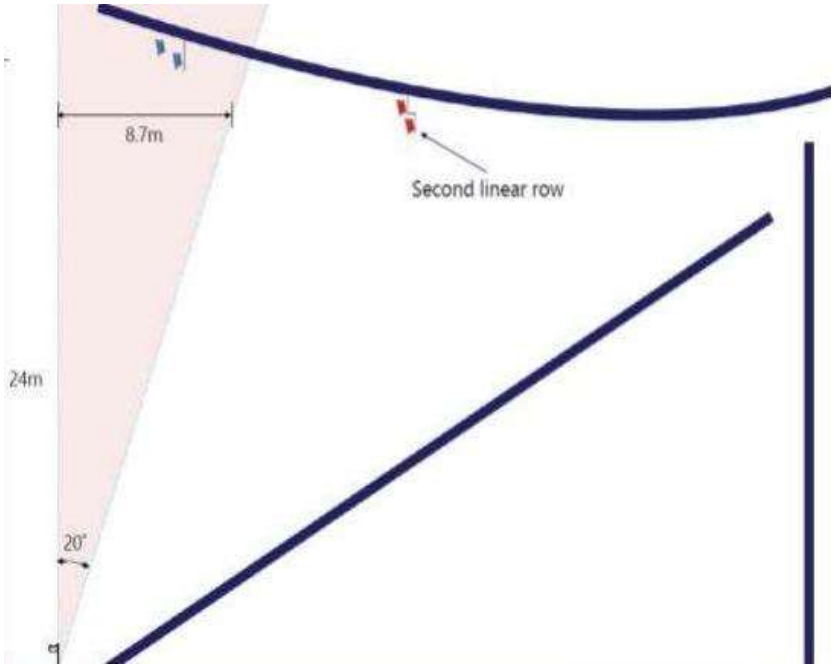

Figure11 Pitch perimeter second linear row

The optimum angle for a second linear row of luminaries is generally 25°-30° for the majority of stadiums. With a luminaire height of 24m it is necessary to have a lateral distance of not less than 8.7m from the pitch perimeter as shown in figure-11. [1]

2.2.8 Pitch sides luminaire mounting position:

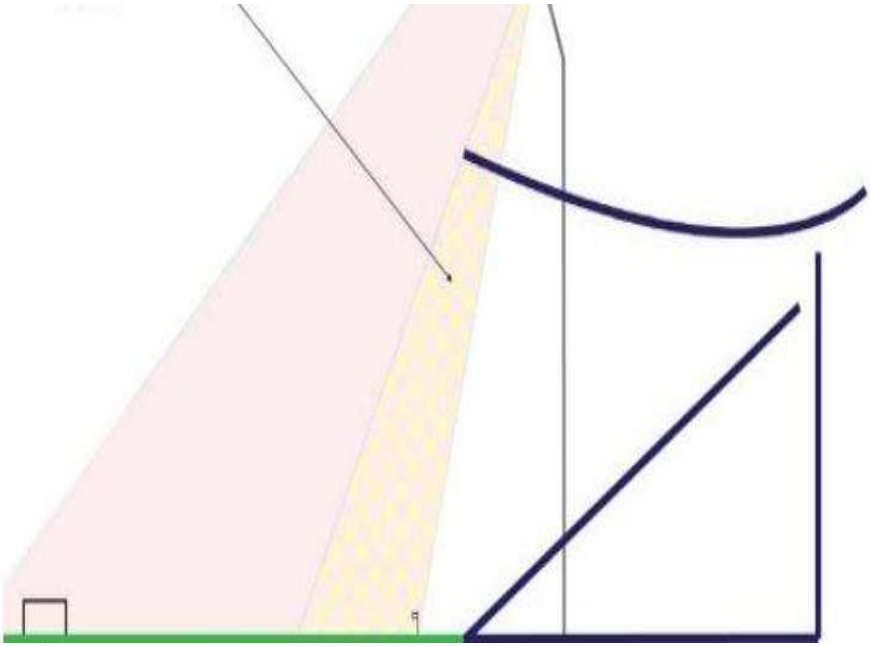

Figure 12 Pitch sides luminaire mounting position

From the above figure it may be seen that the luminous flux of the corner column head frame is obstructed by the stadium roof. In such cases it is necessary to focus the luminaries on the head frame away from the stadium roof structure. It also needs to provide additional illuminance by installing luminaires under the stadium roof structure. [1]

2.2.9 Behind penalty area luminaire mounting zone:

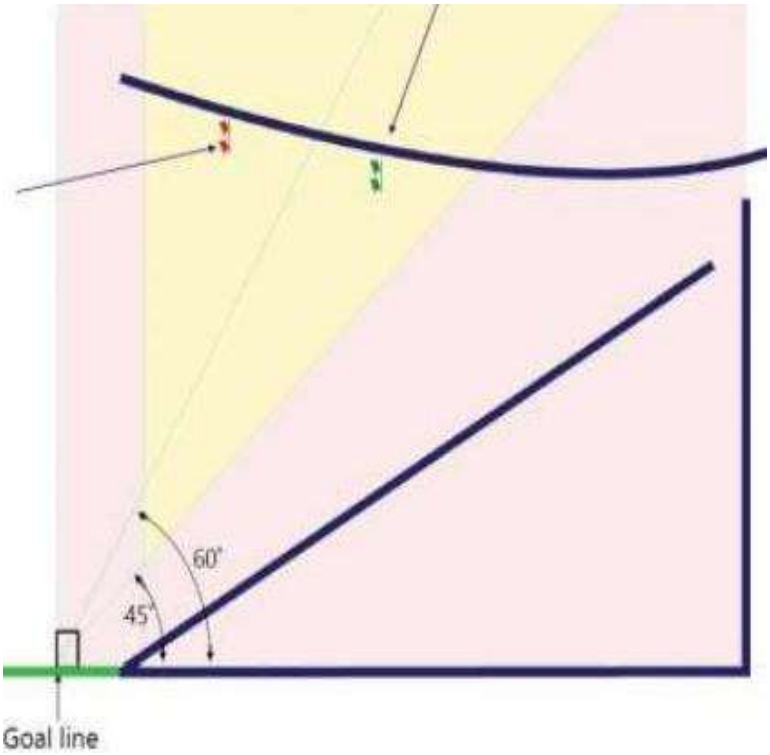

Figure13 behind penalty area luminaire mounting zone

Luminaries positioned directly behind the goal area should not be less than 60˚ above the goal line. Luminaires positioned directly behind the penalty box should not be less than 45◦ above the goal line as shown in figure-13. [1]

2.2.10 Behind goal line luminaire mounting zone:

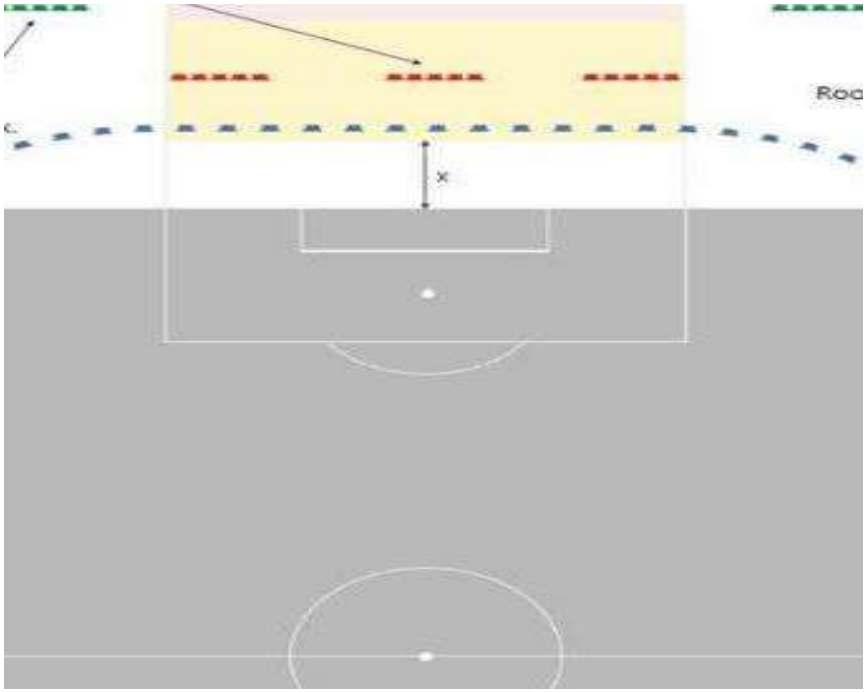

Figure 14 behind goal line luminaire mounting zone

Luminaries positioned directly behind the goal area should not be less than 60˚ above the goal line. Luminaires positioned directly behind the penalty box should not be less than 45◦ above the goal line as shown in figure-14. [1]

2.2.11 Behind goal line second linear row:

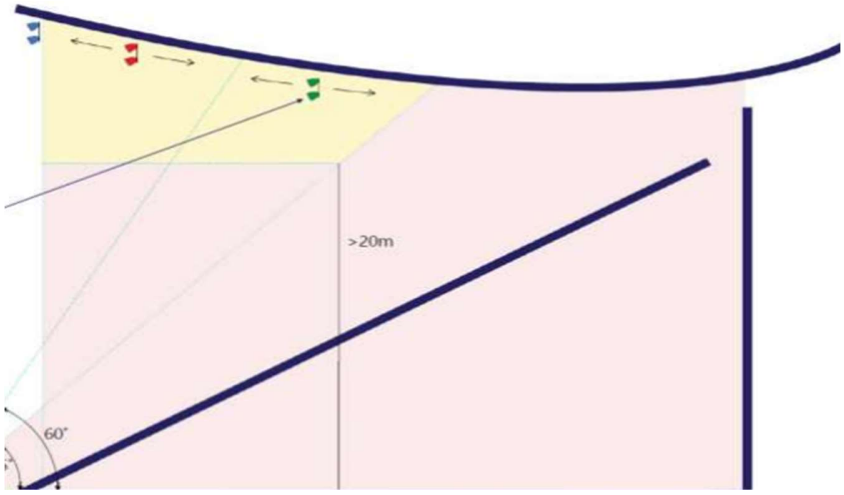

Figure 15 behind goal line second linear row

Luminaries positioned directly behind the penalty area should be mounted at an angle of more than 60°. Outside the area parallel to the penalty area luminaries may be mounted at an angle of more than 45° as shown in figure15. [1]

2.3 Layout and height of poles:

Table 1FIFA training standard & height of poles

FIFA training standard	Number of poles	Luminaries per pole	Pole height	Eh average (Lux)
Grade 1	6	6 x 10	22-25m	> 750 lux
Grade 2	4	4 x 10	22-25m	> 500 lux
Grade 3	4	4 x 7	22-25m	> 300 lux

Table-1 above represents the pole height classification according to the FIFA lighting standard. For grade-2 & grade-3 match practice number of poles is required 4 and luminaires per pole required 10 & 7 respectively. For the entire training standard pole height is required 22m-25m.

For grade -3 training horizontal illuminance required 300lux. For grade -2 training horizontal illuminance required 500lux. For grade -1 training horizontal illuminance required 750lux. [1]

Layout-1:

Figure 16 FIFA World Cup Training Pitch

As shown in figure-16 it is a 6 pole lighting side arrangement layout diagram. Pole to pole distance along the centre of the pitch side is 124m.Mounting height of the pole is 22m. [1]

Layout-2:

Figure 17 Grade 2 Match practice

As shown in figure-17 it is a 4 pole lighting side arrangement layout diagram. Pole to pole distance along the centre of the pitch side is 80m.Mounting height of the pole is 22m.Distance from the centre of the pitch side to the high mast pole is 8m. [1]

Layout-3:

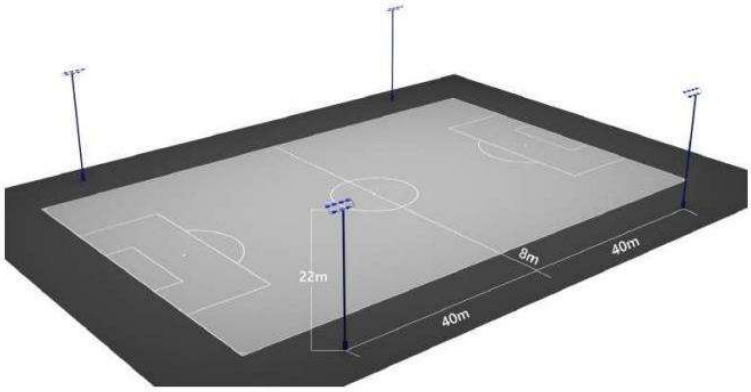

Figure 18 Grade 3 Standard training

As shown in figure-18 it is a 4 pole lighting side arrangement layout diagram. Pole to pole distance along the centre of the pitch side is 80m.Mounting height of the pole is 22m.Distance from the centre of the pitch side to the high mast pole is 8m. [1]

2.4 Uniformity:

A critical element of a pitch illuminance system is the uniformity of illuminance across the whole pitch in all of FIFA's reference planes. The uniformity of illuminance is expressed using two illuminance ratios U1 and U2.U1 means it is 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 means it is 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 means it is the ratio of minimum horizontal illuminance to maximum horizontal illuminance across all the grid points.
- U2h means it is the ratio of minimum horizontal illuminance to average horizontal illuminance across all the grid points.
- **Vertical uniformity of illuminance:**

- U1v it is the ratio of minimum vertical illuminance to maximum vertical illuminance across all the grid points.
- U2v it is the ratio of minimum vertical illuminance to average vertical illuminance across all the grid points. [1]

2.5 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 impaired visibility and visual performance. [1]

2.5.1 Discomfort glare:

Discomfort glare is caused by direct glare from luminaries that are too bright inadequately shielded or too large. It is also caused by reflected glare from specular surfaces lit by other sources. When the eyes have got used to the dark they are particularly susceptible to the impairment and depression of central vision when a bright light enters the field of vision. [1]

2.5.2 Evaluation of glare:

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 (RG) with an assessment scale of 10 to 90. The lower the glare rating, the better the glare situation. [1]

2.6 Color temperature:

Color temperature describes the feeling or appearance of how warm (red) or cools (blue) a certain type of illumination is. It is measured in Kelvin's (K). Digital camera technology allows video-produced media to be altered to 'gain' color and contrast as required to produce the desired color quality. The required color 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. [1]

2.6.1 Color temperature guide:

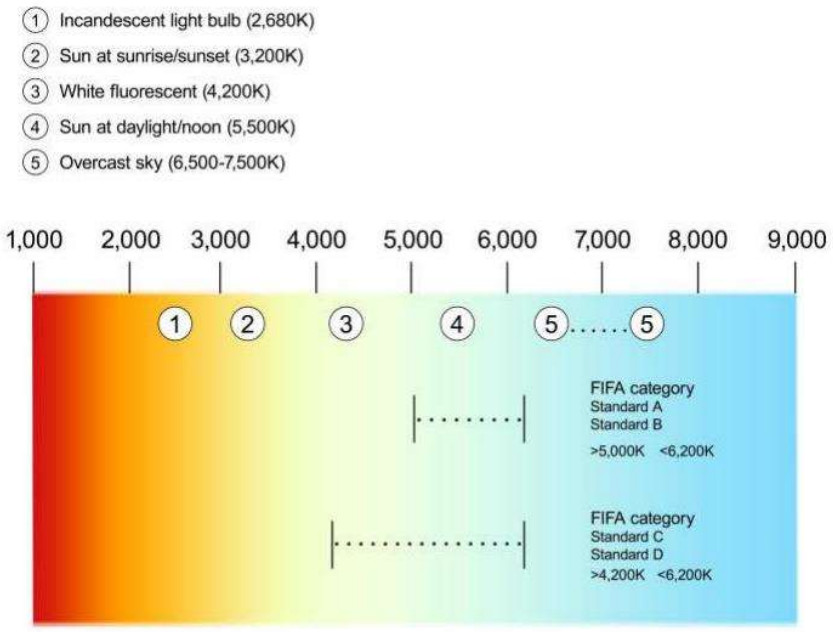

Figure 19 Color temperature guide

Figure-19 shows the color temperature guide at different temperature. For incandescent lamp color temperature is 2700k. For sunrise/ sunset color temperature is 3200k. For white fluorescent tube color temperature is 4200k. For daylight color temperature is 5500k. For overcast sky color temperature is 6500k. [1]

2.7 Color Rendering Index:

Color rendering which is expressed as a score between 0 and 100 Ra on the Color Rendering Index (CRI) describes how a light source makes the color of an object appear to human eyes. The higher the CRI rating the better the ability of a light source to accurately reproduce the colors of the object it illuminates. FIFA's requirements stipulate that illumination systems must produce

good color with CRI rating greater than Ra 80 for FIFA Standard A & B and greater than Ra 70 for FIFA Standard C & D. [1]

2.8 Player 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 achieved by using multiple light sources from various locations for each area of the pitch. This will mean that shadows are reduced and spectators will benefit from good illuminance modeling around their entire bodies. This is essential to provide adequate vertical illuminance and uniformity on all planes. [1]

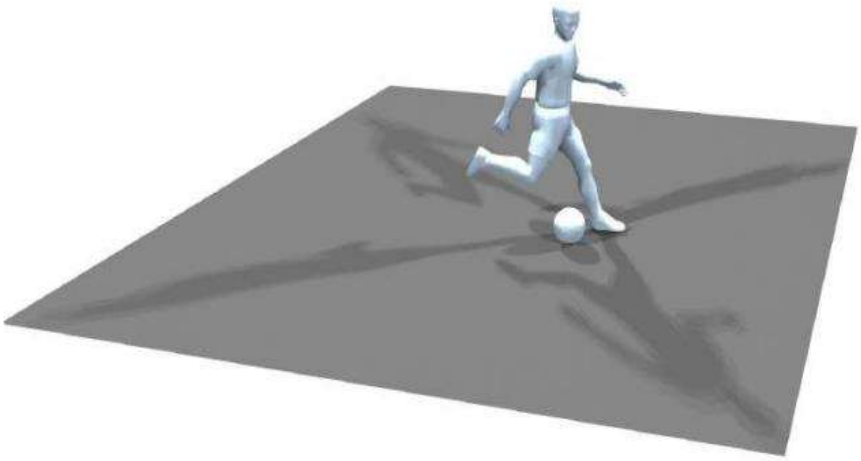

Figure 20 shows the impact of player shadows on a football pitch

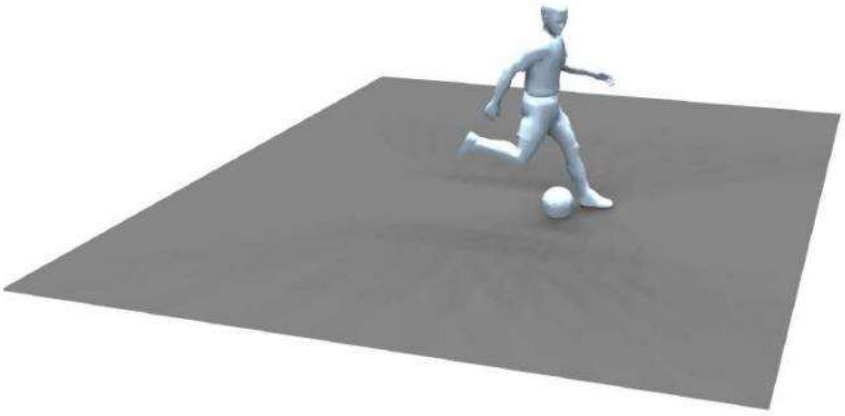

Figure 21 shows soft shadows created by an effective solution involving multiple light sources from different locations.

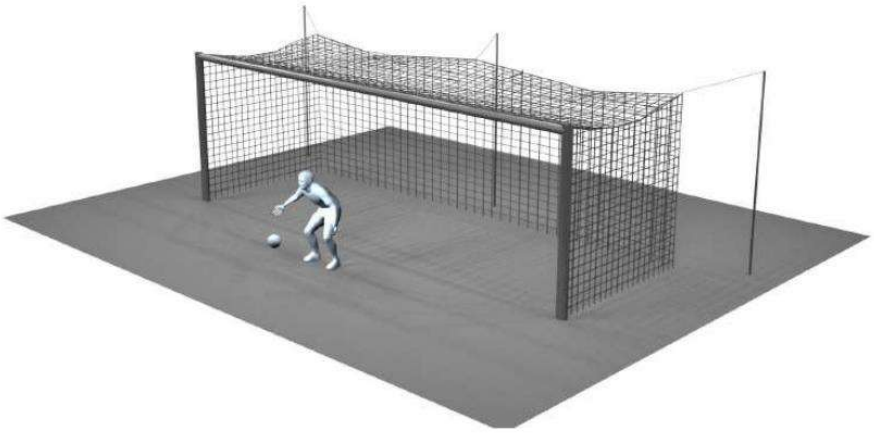

Figure 22 shows the hard shadows in the goal area. Shadows should be reduced where possible while ensuring that players are not hindered by discomfort glare. [1]

2.9 **Maintenance factor:**

If the stadium environment is subject to harsh weather conditions or airborne dirt that could affect the long-term performance of the luminaries, 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 for HID luminaries and 0.8 for LED luminaries.

Luminaries 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 luminaries in normal circumstances. [1]

2.10 Luminaire photometry:

Mainly three types of floodlights generally used based on light distribution in space in outdoor lighting. Symmetric which is circular shaped luminaries, asymmetric which is rectangular shaped luminaries and double asymmetric which is rectangular shaped luminaries.

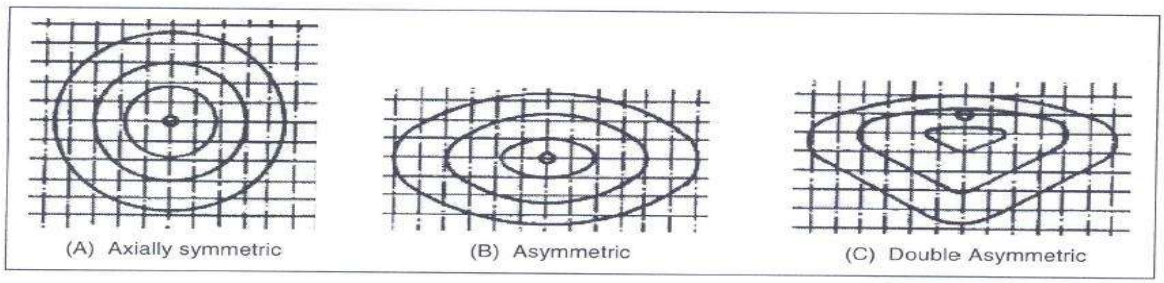

Figure 10 shows the symmetric light distribution different shapes of luminaire photometry of floodlight. To ensure efficient floodlighting with allowable mounting arrangement, the beam shapes plays an important role. A circular beam produces an elliptical light pattern on the field. Whereas rectangular beam produces a trapezoidal light pattern on the field. Circular symmetric beam is more efficient in four corner arrangement whereas rectangular asymmetric beam is used in side arrangement which gives better result. [3]

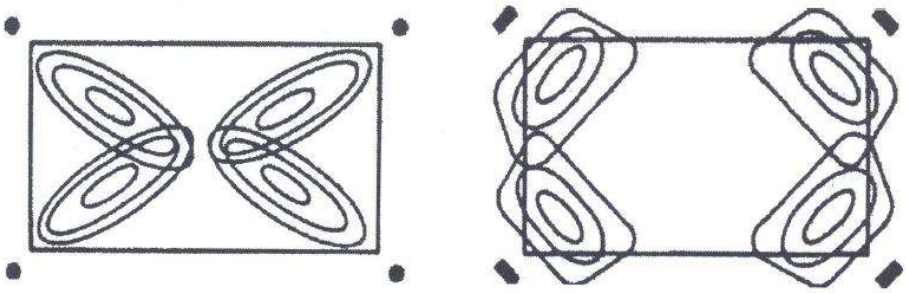

Figure 24 shows the circular shaped light distribution

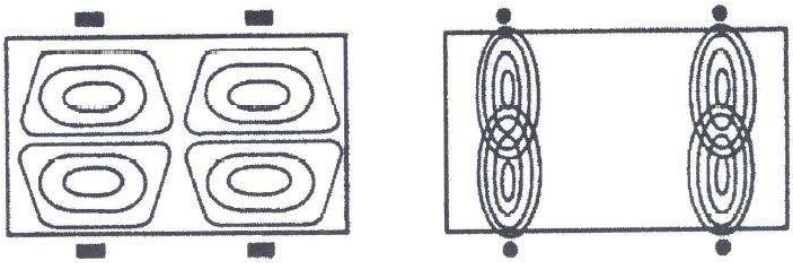

Figure 25 shows rectangular shaped light distribution

2.11 Mounting height of light fittings:

The mounting height of the light fittings is critical to the success of the sports lighting system. The mounting height geometry for sideline head frames and poles is 25 degrees above the horizon, starting from the middle of the pitch and looking back towards the stadium seating bowl. The head frame and light structure may exceed this 25- degree minimum guideline but it may not exceed 45 degrees. To determine the mounting height of floodlight following formula needs to be considered.

$H=D*\tan\theta$, where H is the mounting height (height up to centre point of the head frame from the ground), D is the distance between high mast and centre point of the field, θ is the angle range is taken between 20°-25°. [3]

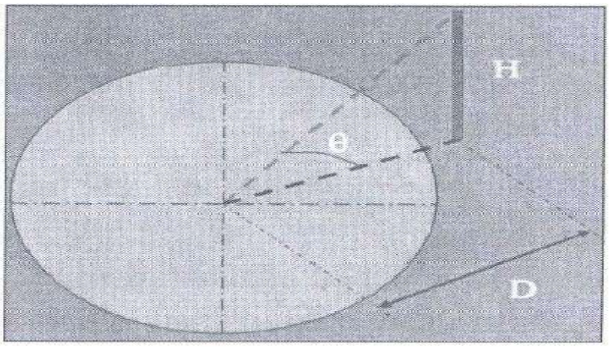

Figure 26 shows the mounting height of high mast

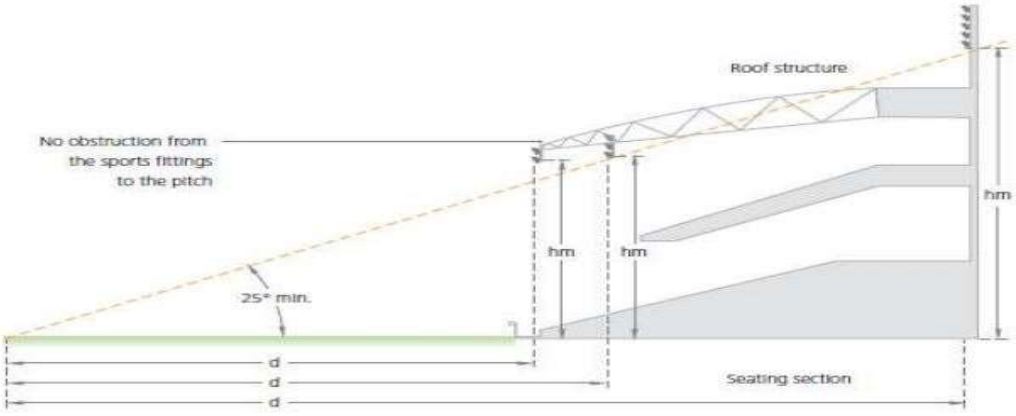

Figure 27 shows the angle coming from the luminaires

2.12 Beam angle:

The beam angle represents the spread of light from the light source. Generally the beam angle is bigger the center intensify will be more weakness but the light will be softer. Such as tennis court lighting, basketball court lighting etc, the height of light pole usually is 6-8m, 60 degree will be used mostly. For another court light pole is high field is big Such as football field lighting, cricket field lighting, softball field lighting, baseball field lighting, track field lighting etc, narrow beam angle of 15 degree to 30 degree will be used mostly. The narrow beam provides concentrated illumination and is suitable for accent lighting. The wide beam makes the light softer. [4]

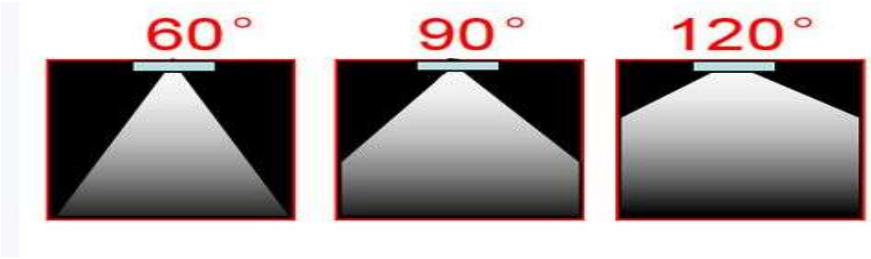

Figure 28 shows the wide beam light distribution

Figure 29 shows the narrow beam light distribution

2.13 Side lighting and corner lighting of football field stadium lighting:

Corner Lighting:

Every sports field has 4 corners that will be idea spots where corner lighting can be placed. The diagonal illumination covers the field from nearly all direction. It also allows players, spectators to see from every direction. [5]

Side Lighting:

Side lighting generally reduce ground shadows. Generally in case of side lighting 4 pole, 6 pole, and 8 pole configuration can be arranged along the edge of the field. To compare the side lighting and corner lighting of the football field following parameters needs to be considered:

- **Glare:**

In case of corner lighting high mast lighting usually has more glare issues because of floodlights with smaller beam angles. This is uncomfortable for both the players and the spectators. In case

of side lighting because its high beam angle with floodlights glares will be more reduced. In case of side lighting pole height will be low as compared to corner lighting. Usually 4, 6, 8 pole arrangement can be done in side lighting. [5]

- **Shadow:**

In case of corner lighting shadow problem generally occurs. In case of side lighting shadow lesser than corner lighting. It will also help visual power, visibility for both the players, spectators and all the spots across the entire field. [5]

- **Heat Generation:**

Corner lighting generates more heat compared to side lighting. In case of side lighting lumens are often lower compared to corner lighting. [5]

Comparative Analysis:

After review and analysis it comes into a conclusion that side lighting will provide better illumination, more users friendly for both the players and the spectators compared to corner lighting. [5]

2.14 Football field stadium lighting standards:

Table 2 FIFA football field lighting standard

Illuminance requirements	FIFA lighting standard A	FIFA lighting standard B	FIFA lighting standard C	FIFA lighting standard D	Grade 1	Grade 2	Grade 3
Competition or training	World cup	Club or U-20 world cup, Olympic	U-20 women's world cup	U-17 world cup	FIFA World Cup training	Match practice	Standard training
Eh (average horizontal Illuminance)	Minimum > 1500 lux Average > 2000 lux	Minimum > 1200 lux Average > 2000 lux	Minimum > 800 lux Average > 1250 lux	Average > 1000 lux	Average > 750 lux	Average > 500 lux	Average > 300 lux
Uniformity (U1h)	> 0.50	> 0.50	> 0.50	> 0.40	> 0.40	> 0.40	> 0.40
Uniformity (U2h)	> 0.70	> 0.70	> 0.70	> 0.60	> 0.60	> 0.60	> 0.60
Color temperature (Tc)	5,000–6,200K	5,000–6,200K	4,200–6,200K	4,200–6,200K	5,000–6,200K	5,000–6,200K	4,200–6,200K
Glare rating	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Vertical Illuminance (0° 90° 180° 270°)	Minimum > 1,000 lux Average > 1,500 lux	Minimum > 650 lux Average > 1,000 lux	Minimum > 350 lux Average > 700 lux	Minimum > 250 lux Average > 400 lux			

Table 2shows the football field stadium lighting standards according to the FIFA guideline and FIFA lighting standard respectively. Average horizontal illuminance (Eavg) required for world cup matches 2000lux, minimum horizontal illuminance required (Emin) for world cup matches 1500lux. Average horizontal illuminance (Eavg) required for U-20 world cup matches 2000lux, minimum horizontal illuminance required (Emin) for U-20world cup matches 1200lux. Average horizontal illuminance (Eavg) required for U-20 women's world cup matches 1250lux, minimum horizontal illuminance required(Emin) for U-20world cup matches 800lux. Average horizontal illuminance (Eavg) required for U-17 world cup matches 1000lux. Overall uniformity required for all types international, national, league competition football matches 0.6-0.7. Color

temperature required for all types of football matches 4200k-6200k. Glare rating always should be maintained less than 50. Average vertical illuminance (Eavg) required for world cup matches 1500lux, minimum vertical illuminance required (Emin) for world cup matches 1000lux. Average vertical illuminance (Eavg) required for U-20 world cup matches 1000lux, minimum vertical illuminance required(Emin) for U-20world cup matches 650lux.Average vertical illuminance (Eavg) required for U-20 women's world cup matches 700lux, minimum vertical illuminance required(Emin) for U-20 women's world cup matches 350lux. Average vertical illuminance (Eavg) required for U-17 world cup matches 400lux, minimum vertical illuminance required (Emin) for U-17 world cup matches 250lux.Verical illuminance should be taken 1.5m above the ground level for televised, broadcasting matches.[1]

3. Football field lighting design for Non-Televised matches:

3.1 Background:

Football field lighting is divided into three categories which according to the EN12193 international standards.

Class III:

As per standards of EN12193 the LED lighting guidelines include 75 lux horizontal lights for recreational and training purpose in field. When it comes to recreational football fields and high school football grounds the range is usually from 75 lux to 200 lux. [4]

Class II:

Class II involves the lighting guidelines for leagues and clubs. The standards for stadium light for professional sports pitches are 200 lux horizontal lightings with uniformity of 0.6. This is specially set for semi-professional stadiums. [4]

Class I:

Class I includes all the stadiums for professional purposes. These stadiums are to be used for televising the events as well for which the lighting needs to be professional as well. These grounds are used for national and international games so the lights installed must be high performance and of excellent quality. For this purpose the ground lux ranges from about 1000lux to 2000lux, the uniformity ranges about U1 at 0.7 and U2 around 0.8. [4]

3.2 Lighting Layout:

3.2.1 Grade 3 Standard training football field lighting layout:

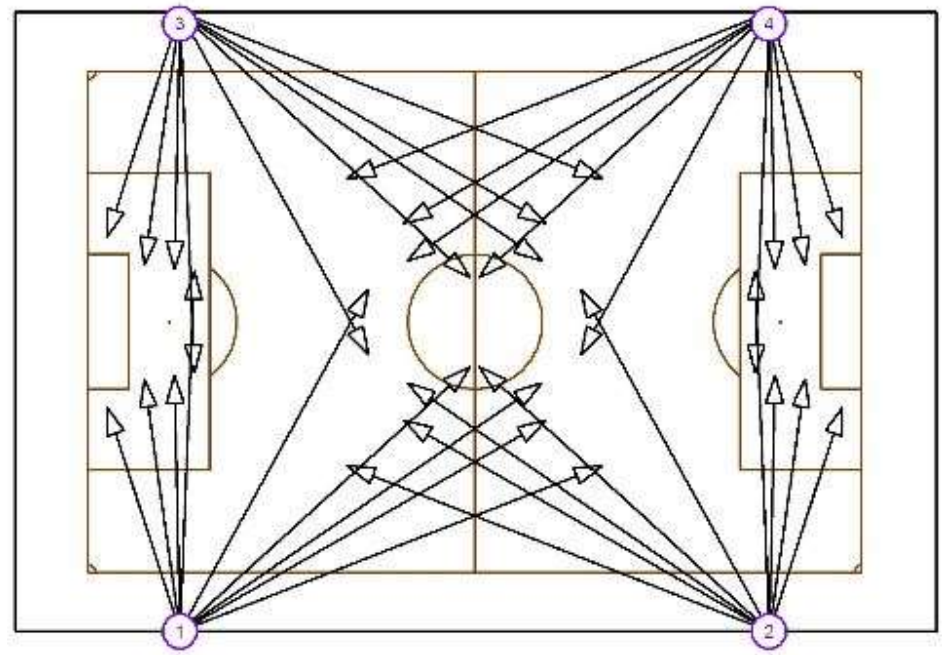

Figure 30 shows the grade 3 standard training football field playing area. To design the above lighting layout number of luminaires considered per pole 12 and luminaire mounting height considered 24m. Pole height considered 25m. Pole to pole horizontal distance considered80m.Distance from the centre of the pitch side to the horizontal line of the pole considered8m.Fourpole placed across four sides of the football field.

3.2.2 Grade 2 Match practice football field lighting layout:

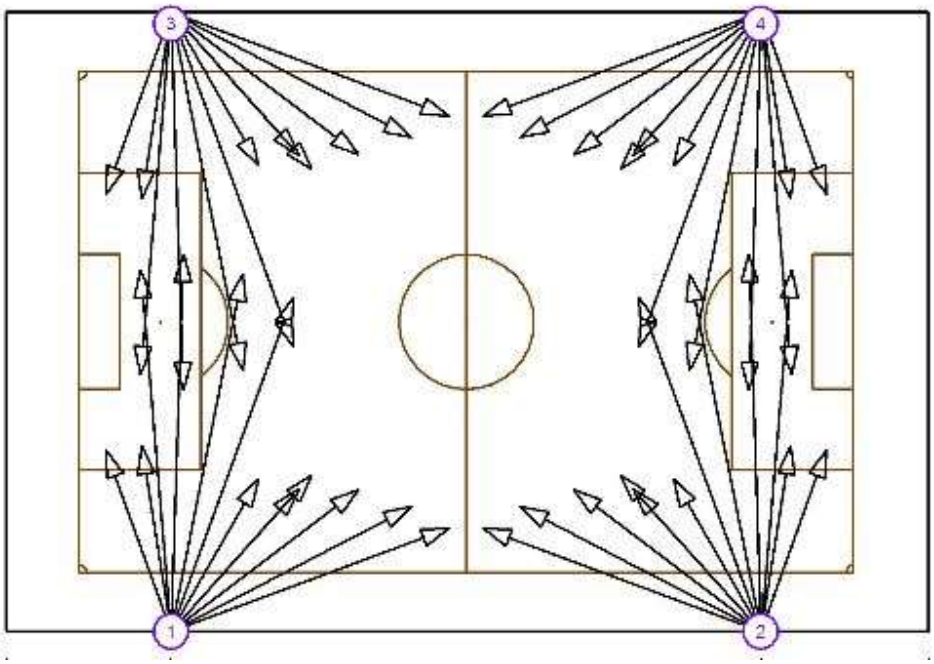

Figure 31 shows the similar lighting layout plan for grade 2 match practice football field playing as per figure-30. In this lighting layout number of luminaires considered per pole 16 and total number of luminaires considered 48.luminaire mounting height considered 25m. Pole height considered 25m. Pole to pole horizontal distance considered 80m. Distance from the centre of the pitch side to the horizontal line of the pole considered 8m. Four pole placed across four sides of the football field.

3.2.3 World cup training pitch football field lighting layout:

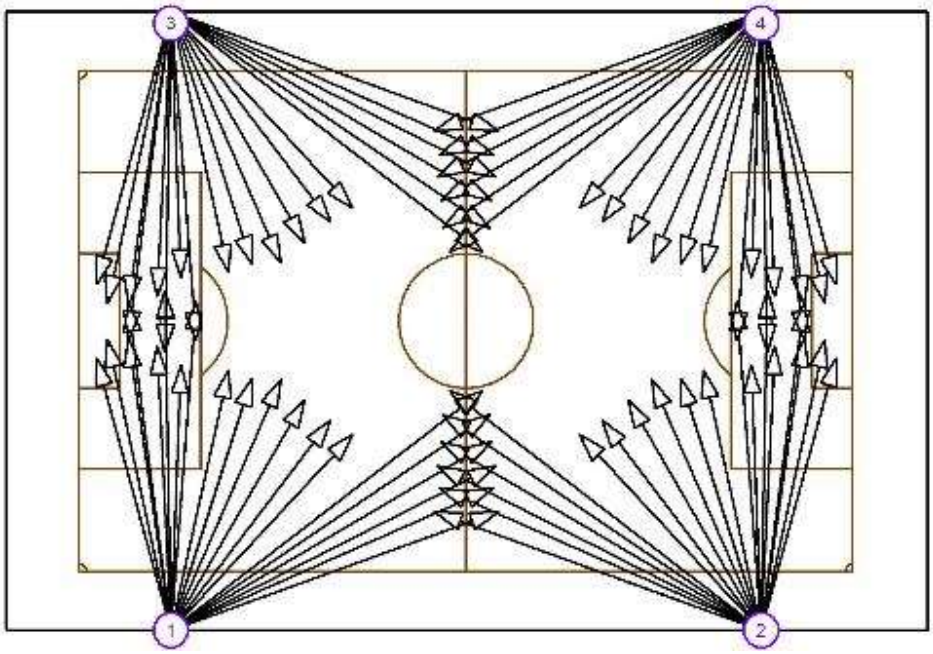

Figure 32 shows the same lighting layout plan for world cup training pitch football field playing area as per figure 30. In this lighting layout number of luminaires considered per pole 40 and total number of luminaires considered 80. luminaire mounting height considered 25m. Pole height considered 25m. Pole to pole horizontal distance considered 80m. Distance from the centre of the pitch side to the horizontal line of the pole considered 8m. Four pole placed across four sides of the football field.

3.3 Lighting design:

3.3.1 Grade 3 Standard training football field lighting design:

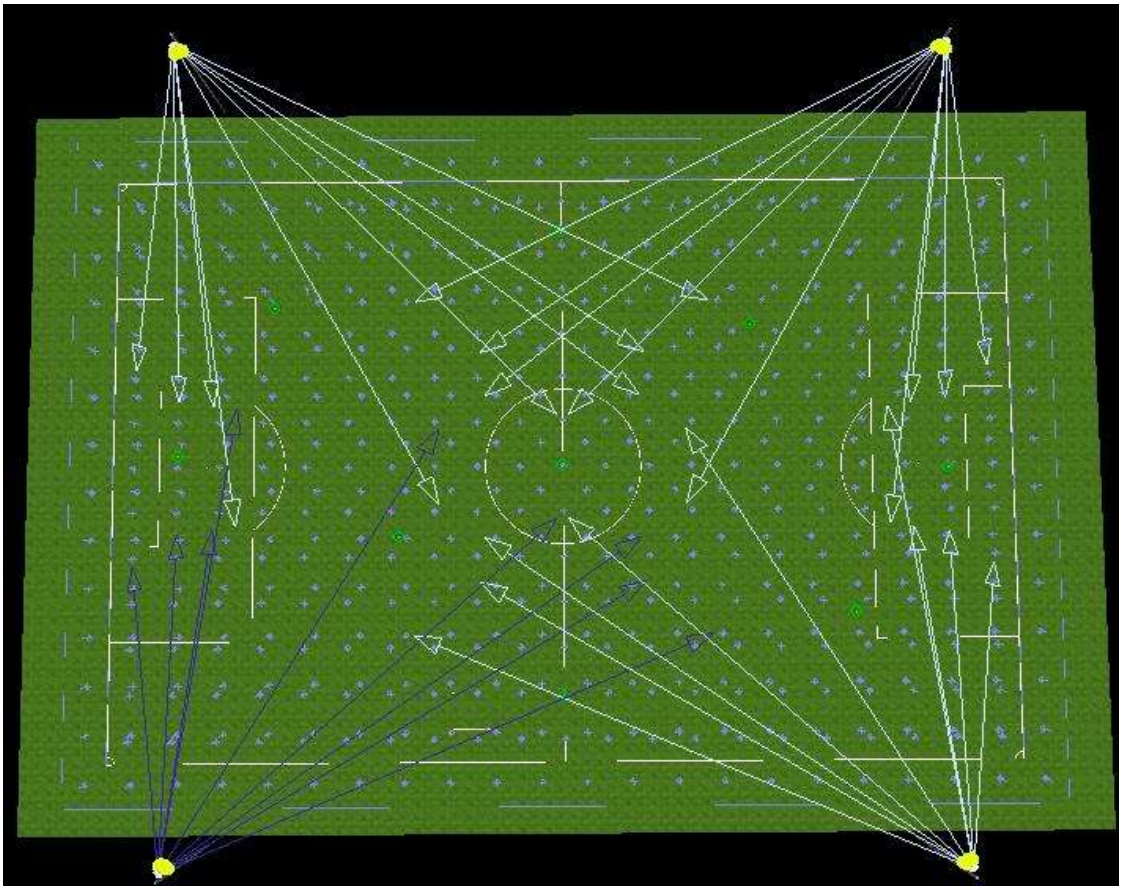

Figure 33 shows the lighting design for grade-3 standard training football field playing area. Generally the football playing field sub divided into two parts. Playing area means it is the actual playing area needed for the performance of a certain sport. Usually this means the actual marked out 'field' area. Total playing area means it is the area includes the principal area (PA) with additional safety area outside the principal area. To construct the football field playing area as shown in figure 35 there are some dimensional criteria needs to be considered. The length of the total area of the football field considered 115m and breadth 78m. Length for playing area considered 105m & breadth 68m. Length of the grid points for playing area considered 21m & width 13. Length of the grid points for total area considered 22m &width 14m. Distance between the grid points are 5m &5m respectively.

3.3.2 Grade 2 match practice football field lighting design:

Similar lighting design approach considered for grade 2 match practice football field playing area as per figure33. There are some dimensional criteria needs to be considered. The length of the total area of the football field considered 115m and breadth 78m.Length for playing area considered 105m & breadth 68m. Length of the grid points for playing area considered 21m & width 13. Length of the grid points for total area considered 22m &width 14m. Distance between the grid points are 5m &5m respectively.

3.3.3 World cup training pitch football field lighting design:

Similar lighting design approach considered for grade 2 match practice football field playing area as per figure33. There are some dimensional criteria needs to be considered. The length of the total area of the football field considered 115m and breadth 78m.Length for playing area considered 105m & breadth 68m. Length of the grid points for playing area considered 21m & width 13. Length of the grid points for total area considered 22m &width 14m. Distance between the grid points are 5m &5m respectively.

3.4 Results and Analysis:

3.4.1 Grade 3 Standard training football field lighting standard value charts:

Table 3 Grade 3 Standard training football field lighting standard & simulation results

Type of match	Required value (Horizontal Illuminance)	Simulated value (Horizontal Illuminance)	Required value (overall uniformity)	Simulated value (overall uniformity)	Required value (Glare)	Simulated value (Glare)
Grade 3 Standard training	>300lux	356lux	0.6	0.62	<50	39,41

Table-3[1] shows the lighting simulation results of grade 3 standard training football field playing area. The lighting simulation has done as per the design criteria mentioned according to the FIFA lighting standard. To fulfill the above lighting design following parameters needs to be considered as mentioned below:

Total luminaries considered 36 pieces. Total luminous flux of the luminaries considered 8100000 lumen and total wattage considered 54000 watt. Light loss factor considered 0.85 as per industry standard. ULR (Upward Light Ratio) considered 11%. Luminous efficacy considered 150lumen/watt.

Analysis:

The total distance between the mast base and the centre point of the football pitch is 58.05m. Horizontal distance between the two pole is 80m. The distance from the center side of the football pitch perimeter to the horizontal edge line between the two pole is 8m.According to the formula ($H=D*\tan\theta$) to determine mounting height for floodlighting, the mounting height of the luminaries is maximum at 27m and minimum at 21m. Where the angle (θ) should be taken between 20◦- 25◦. According to the simulation design, luminaries are placed at a height of 24m which provides sufficient lighting and light output on the ground as well as for both the players and the spectators respectively. According to the simulation design glare level is minimum 39 and maximum 41 which is measured at the different position on the playing area of the football field. All the observer height consider 1.5m from the ground level for checking the glare rating. Since the maximum value of glare is less than the required value as per the FIFA lighting standard which subsequently provides much better illumination on the ground and produce less disturbance of the players during the course of play. Apart from that, the light distribution from the luminaries is circular& symmetrical as per the simulation design which distributes the light all along the ground and corners, as a result provides sufficient illumination and better light output on the field. As per the simulation design four high mast pole of height 25m is placed across the four sides of the football field and because of low height of the mast beam angle of the luminaries is wide kept at 60◦ which also allow much better lighting on the football field playing area.

3.4.2 Grade 2 match practice football field lighting standard value chart:

Table 4 grade 2 match practice football field lighting standard & simulation results

Type of match	Required Value (Horizontal Illuminance)	Simulated value (Horizontal Illuminance)	Required value (overall uniformity)	Simulated value (overall uniformity)	Required Value (Glare)	Simulated value (Glare)
Grade 2 match practice	>500lux	557lux	0.6	0.61	<50	38,40

Table 4[1] shows the lighting simulation results of grade 2 match practice football field playing area. The lighting simulation has done as per the design criteria mentioned according to the FIFA lighting standard. To fulfill the above lighting design following parameters needs to be considered as mentioned below:

Total luminaries considered 48 pieces. Total luminous flux from the luminaries considered 10800000 lumen and total wattage considered 72000 watt. Light loss factor considered 0.85 as per industry standard. ULR (Upward Light Ratio) considered 6%. Luminous efficacy considered 150lumen/watt.

Analysis:

The total distance between the mast base and the centre point of the football pitch is 58.05m. Horizontal distance between the two pole is 80m. The distance from the center side of the football pitch perimeter to the horizontal edge line between the two pole is 8m.According to the formula ($H=D*\tan\theta$) to determine mounting height for floodlighting, the mounting height of the luminaries is maximum at 27m and minimum at 21m. Where the angle (θ) should be taken between 20°- 25°. According to the simulation design, luminaries are placed at a height of 25m which provides sufficient lighting and light output on the ground as well as for both the players and the spectators respectively. According to the simulation design glare level is minimum 38 and maximum 40 which is measured at the different position on the playing area of the football field. All the observer height considers 1.5m from the ground level for checking the glare rating.

Since the maximum value of glare is less than the required value as per the FIFA lighting standard which subsequently provides much better illumination on the ground and produce less disturbance of the players during the course of play. Apart from that, the light distribution from the luminaries is circular& symmetrical as per the simulation design which distributes the light all along the ground and corners, as a result provides sufficient illumination and better light output on the field. As per the simulation design four high mast pole of height 25m is placed across the four sides of the football field and because of low height of the mast beam angle of the luminaries is wide kept at 60◦ which also allow much better lighting on the football field playing area.

3.4.3 World cup training pitch football field lighting standard value chart:

Table 5 world cup training pitch football field lighting standard & simulation results

Type of match	Required Value (Horizontal Illuminance)	Simulated value (Horizontal Illuminance)	Required value (overall uniformity)	Simulated value (overall uniformity)	Required Value (Glare)	Simulated value (Glare)
world cup training	>750lux	899lux	0.6	0.62	<50	40,41

Table 5[1] shows the lighting simulation results for world cup training football field playing area. The lighting simulation has done as per the design criteria mentioned according to the FIFA lighting standard. To fulfill the above lighting design following parameters needs to be considered as mentioned below:

Total luminaries considered 80 pieces. Total luminous flux from the luminaries considered 18000000 lumen and total wattage considered 120000 watt while light loss factor considered 0.85 as per industry standard. ULR (Upward Light Ratio) considered 8%. Luminous efficacy considered 150lumen/watt.

Analysis:

The total distance between the mast base and the centre point of the football pitch is 58.05m. Horizontal distance between the two pole is 80m. The distance from the center side of the football pitch perimeter to the horizontal edge line between the two pole is 8m.According to the formula ($H=D*\tan\theta$) to determine mounting height for floodlighting, the mounting height of the luminaries is maximum at 27m and minimum at 21m. Where the angle (θ) should be taken between 20°- 25°. According to the simulation design, luminaries are placed at a height of 25m which provides sufficient lighting and light output on the ground as well as for both the players and the spectators respectively. According to the simulation design glare level is minimum 38 and maximum 40 which is measured at the different position on the playing area of the football field. All the observer height considers 1.5m from the ground level for checking the glare rating. Since the maximum value of glare is less than the required value as per the FIFA lighting standard which subsequently provides much better illumination on the ground and produce less disturbance of the players during the course of play. Apart from that, the light distribution from the luminaries is circular& symmetrical as per the simulation design which distributes the light all along the ground and corners, as a result provides sufficient illumination and better light output on the field. As per the simulation design four high mast pole of height 25m is placed across the four sides of the football field and because of low height of the mast beam angle of the luminaries is wide kept at 60° which also allow much better lighting on the football field playing area.

4. Football field lighting design for Televised matches:

4.1 Background:

For television- broadcasting matches vertical illuminance needs to be done. Vertical illuminance required for both the players and the spectators. Vertical illumination required to be measured at 1.5metre from the ground level.

4.2 Lighting layout:

4.2.1 U-17 world cup football field lighting layout:

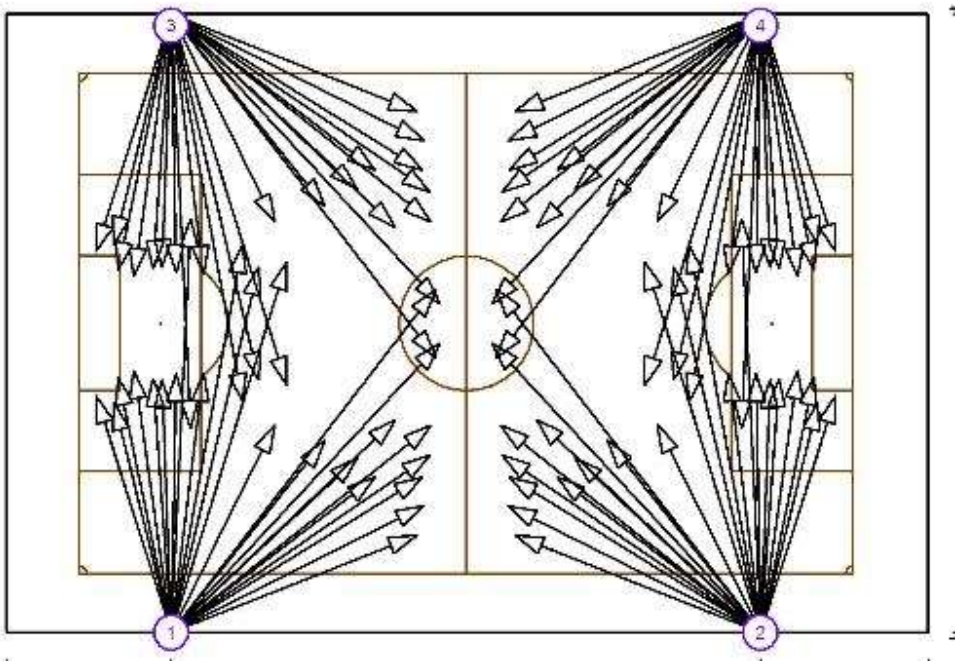

Figure 34 shows the same lighting layout plan for U-17 world cup football field playing area as per figure 30. In this lighting layout number of luminaires considered per pole 24 and total number of luminaires considered 96. luminaire mounting height considered 25m. Pole height considered 25m. Pole to pole horizontal distance considered 80m. Distance from the centre of the pitch side to the horizontal line of the pole considered 8m. Four pole placed across four sides of the football field.

4.2.2 U-20 world cup football field lighting layout:

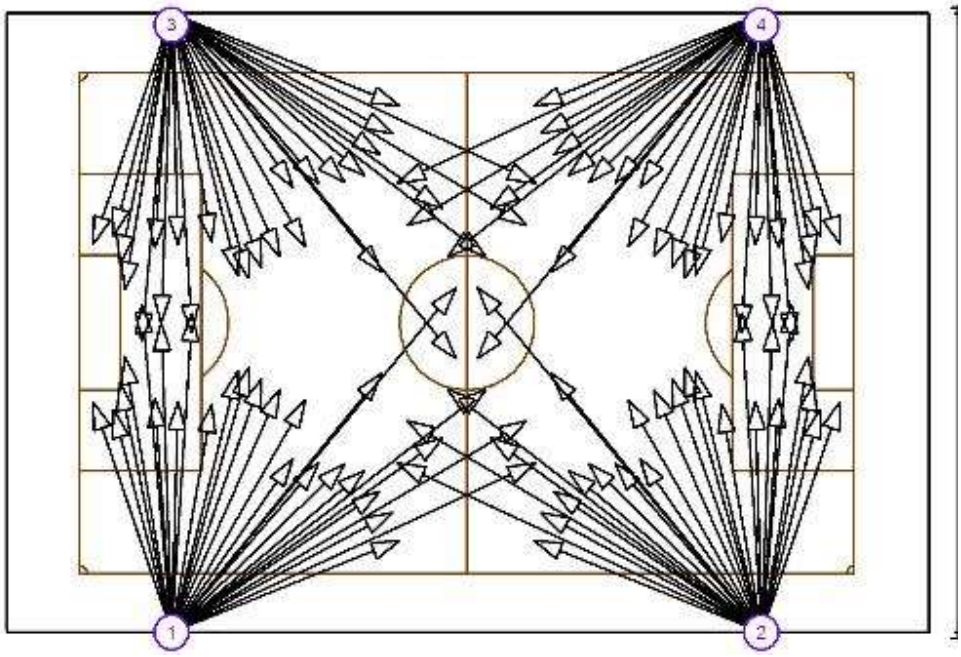

Figure 35 shows the same lighting layout plan for U-17 world cup football field playing area as per figure 30. In this lighting layout number of luminaires considered per pole 28 and total number of luminaires considered 112. luminaire mounting height considered 25m. Pole height considered 25m. Pole to pole horizontal distance considered 80m. Distance from the centre of the pitch side to the horizontal line of the pole considered 8m. Four pole placed across four sides of the football field.

4.3**Lighting design:**

4.3.1 U-17 world cup football field lighting design:

Similar lighting design approach considered for U-17 world cup football field playing area as per figure-33. There are some dimensional criteria needs to be considered. The length of the total area of the football field considered 115m and breadth 78m.Length for playing area considered 105m & breadth 68m. Length of the grid points for playing area considered 21m & width 13. Length of the grid points for total area considered 22m &width 14m. Distance between the grid points are 5m &5m respectively.

4.3.2 U-20 world cup football field lighting design:

Same lighting design approach considered for U-20 world cup football field playing area as per figure-33. There are some dimensional criteria needs to be considered. The length of the total area of the football field considered 115m and breadth 78m.Length for playing area considered 105m & breadth 68m. Length of the grid points for playing area considered 21m & width 13. Length of the grid points for total area considered 22m &width 14m. Distance between the grid points are 5m &5m respectively.

4.4 Results and analysis:

4.4.1 U-17 world cup football field lighting standard value chart:

Table 6 U-17 world cup football field lighting standard & simulation results

Type of match	Required Value (Horizontal Illuminance)	Simulated value (Horizontal Illuminance)	Required Value (vertical Illuminance)	Simulated value (vertical Illuminance)	Required value (overall uniformity)	Simulated value (overall uniformity)	Required Value (Glare)	Simulated value (Glare)
U-17 world cup	>1000lux	1105lux	>400lux	594lux	0.6	0.63	<50	39,42

Table 6 [1] shows the lighting simulation results for U-17 world cup football field playing area. The lighting simulation has done as per the design criteria mentioned according to the FIFA lighting standard. To fulfill the above lighting design following parameters needs to be considered as mentioned below:

Total luminaries considered 96 pieces. Total luminous flux from the luminaries considered 21600000 lumen and total wattage considered 144000 watt while the light loss factor considered 0.85 as per industry standard. ULR (Upward Light Ratio) considered 7.5%. Luminous efficacy considered 150lumen/watt.

Analysis:

The total distance between the mast base and the centre point of the football pitch is 58.05m. Horizontal distance between the two pole is 80m. The distance from the center side of the

football pitch perimeter to the horizontal edge line between the two pole is 8m.According to the formula (H=D*tanθ) to determine mounting height for floodlighting, the mounting height of the luminaries is maximum at 27m and minimum at 21m. Where the angle (θ) should be taken between 20◦- 25◦. According to the simulation design, luminaries are placed at a height of 25m which provides sufficient lighting and light output on the ground as well as for both the players and the spectators respectively. According to the simulation design glare level is minimum 39 and maximum 42 which is measured at the different position on the playing area of the football field. All the observer height considers 1.5m from the ground level for checking the glare rating. Since the maximum value of glare is less than the required value as per the FIFA lighting standard which subsequently provides much better illumination on the ground and produce less disturbance of the players during the course of play. Apart from that, the light distribution from the luminaries is circular& symmetrical as per the simulation design which distributes the light all along the ground and corners, as a result provides sufficient illumination and better light output on the field. As per the simulation design four high mast pole of height 25m is placed across the four sides of the football field and because of low height of the mast beam angle of the luminaries is wide kept at 60◦ which also allow much better lighting on the football field playing area. For measure the vertical illuminance height is taken 1.5m from the ground level.

4.4.2 U-20 world cup football field lighting standard value chart:

Table 7 U-20 world cup football field lighting standard & simulation results

Type of match	Required Value (Horizontal Illuminance)	Simulated value (Horizontal Illuminance)	Required Value (vertical Illuminance)	Simulated value (vertical Illuminance)	Required value (overall uniformity)	Simulated value (overall uniformity)	Required Value (Glare)	Simulated value (Glare)
U-20 world cup	>1250lux	1313lux	>700lux	706lux	0.6	0.6	<50	39,42

Table 7[1] shows the lighting simulation results for U-20 world cup football field playing area. The lighting simulation has done as per the design criteria mentioned according to the FIFA lighting standard. To fulfill the above lighting design following parameters needs to be considered as mentioned below:

Total luminaries considered 112 pieces. Total luminous flux from the luminaries considered 25200000 lumen and total wattage considered 168000 watt while the light loss factor considered 0.85 as per industry standard. ULR (Upward Light Ratio) considered 6.5%. Luminous efficacy considered 150lumen/watt.

Analysis:

The total distance between the mast base and the centre point of the football pitch is 58.05m. Horizontal distance between the two pole is 80m. The distance from the center side of the football pitch perimeter to the horizontal edge line between the two pole is 8m.According to the formula ($H=D*\tan\theta$) to determine mounting height for floodlighting, the mounting height of the luminaries is maximum at 27m and minimum at 21m. Where the angle (θ) should be taken between 20◦- 25◦. According to the simulation design, luminaries are placed at a height of 25m which provides sufficient lighting and light output on the ground as well as for both the players and the spectators respectively. According to the simulation design glare level is minimum 39 and maximum 42 which is measured at the different position on the playing area of the football field. All the observer height considers 1.5m from the ground level for checking the glare rating. Since the maximum value of glare is less than the required value as per the FIFA lighting standard which subsequently provides much better illumination on the ground and produce less disturbance of the players during the course of play. Apart from that, the light distribution from the luminaries is circular& symmetrical as per the simulation design which distributes the light all along the ground and corners, as a result provides sufficient illumination and better light output on the field. As per the simulation design four high mast pole of height 25m is placed across the four sides of the football field and because of low height of the mast beam angle of the luminaries is wide kept at 60◦ which also allow much better lighting on the football field playing area. For measure the vertical illuminance height is taken 1.5m from the ground level.

4. Conclusion:

After done the football field lighting simulation design of different class & categories for non-televised and televised matches following design criteria needs to be considered for making a good and efficient football field lighting design:

Less number of luminaires per pole, low luminaires mounting height, right selection of beam angle of the luminaires, right selection of luminaires based on light distribution, selection of pole height according to the football field dimension. These are the parameters which need to be considered for making a successful football field light design which provide sufficient illumination, reduce glare, maintained overall uniformity on the playing area of the football field. Apart from that in football field lighting design LED floodlight should be used in place of conventional floodlight because of its certain features like high energy consumption, less maintenance, longer life span, higher luminous efficacy, easy replaceable, dimmable.

5.1 Future scope:

For football field lighting design following design criteria needs to be maintained which will certainly produce a cost effective well maintained football field stadium lighting in future. These are less number of luminaires per pole, low mounting height of high mast, wide beam angle and should use LED floodlight over the conventional floodlight because of its high luminous efficacy.

Reference:

1. FIFA lighting design guide handbook

2. Handbook on field of play and specifications for sports infrastructure at sports authority of India centres

3. National lighting code 2010

4. Lighting design guide 4 Sports Lighting handbook

5. https://sportlightsupply.com/side-lighting-vs-corner-lighting-of-sports-field/