International Journal of Research in Engineering, Science and Management
Volume-2, Issue-1, January-2019
www.ijresm.com | ISSN (Online): 2581-5792

Constructional Design of Energy Efficient Street Lighting System

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***Abstract*: Today, energy shortage and carbon emission are the major challenges to many countries. There are many ways to save energy in every sector for reducing the carbon emission and global warming. The lighting is used in many applications and it is one of the areas that offer many opportunities for improving the energy efficiency thereby reducing the energy consumption. This seminar presents a case study on energy efficient street lighting system design for the roadways in energy city Qatar. The different types of lamps and highlights how the concepts can be visually compared its cost effectiveness can be studied during the design phase in order for the decisions to be made prior to its implementation. The seminar has concluded that forty percent reduction in the energy consumption can be achieved with the proposed street lighting system design.**

***Keywords*: Energy Efficiency, High Pressure Sodium, LDR, Light Emitting Diode, Low Pressure Sodium, Photoelectric Sensor, Relay.**

1. Introduction

The design of street lighting has many objectives and considerations night-time safety of the community members and the road users, the reduction of crime and fear of crime, minimizing its effect on the environment whilst enhancing the night-time ambience, provide public lighting that is cost effective, taking into account energy conservation and sustainability. A well designed street lighting shall reduce crime rates by twenty percent in the public places due to the fact that improved street lighting will lead to increase social surveillance and decrease criminal opportunities. Work has been reported by many authors concerning the effect of improved street lighting on crime levels However, their findings focus only on the role of street lighting in the reduction of crime rates through improving visibility and by increasing the number of people on the street in the public area while the energy saving and illumination level is not reviewed. This Seminar highlights the energy efficient street lighting system design. There are many ways to save energy. The energy saving will lead to drop off the need for the establishment of new power plants thereby minimizing carbon emission and hence global warming. Qatar, in the Middle East is mainly depending on natural gas and petroleum products for energy consumption. Due to its rapidly growing economy Qatar has shown a growing demand for electricity consumption and the energy consumption has doubled over the past ten years and forecasted to double over the next ten years also. This focuses on providing the design and presents to reduce power consumption by designing an efficient street lighting system that can be adopted and considered by local authorities for the development of roadways in other parts of Qatar. The performance of different types of lighting technologies used for street lighting applications and saving in energy consumptions in such applications are discussed.

2. Street lighting system design considerations

Table 1
Lamp Efficiency and Service Life

Types of lamp	Lumens per watt	Average lamp life in hours
Incandescent	8-25	1000-2000
Fluroscent	60-600	10000-24000
High pressure sodium	45-110	12000-24000
Low pressure sodium	80-180	10000-18000
Metal halide	60-100	10000-15000
LED	28-79	25000-100000

Road lighting can be categorized according to the installation area, performance and their use as lighting for traffic routes, lighting for subsidiary roads and lighting for urban centers and public amenity areas. Street lighting can be classified according to the type of lamp used such as Low Pressure Sodium (LPS) which produce monochromatic orange yellow light, High Intensity Discharge (HID) lamps, High Pressure Sodium (SON) lamps that can give golden white light, Metal Halide, Mercury Vapor and Light Emitting Diode (LED) Street lights. Low pressure sodium lighting causes the lowest environmental impacts of any currently available outdoor lighting source. Due to its rapidly growing economy Qatar has shown a growing demand for electricity consumption and the energy consumption has doubled over the past ten years and forecasted to double over the next ten years also. Adjustable lamp reflectors and holders are usually provided along with the road lighting in order to optimize the distribution of the light according to road layout. Different types of lamps used in lighting design with their luminous efficiency and lamp service life is given in Table1.

A. *Lighting Scenarios*

The street lighting system design for energy city project in Qatar which is located in lusail city, north of doha is presented. Energy city Qatar project is one of many cities that Qatar is aiming to develop in the coming years. The total length of the road in this city is 6 km. The parameters are, the width of the carriageway is 7.3 m, and number of lanes is two. Three lighting scenarios were applied to know the power consumption of the street lighting. This has been done by designing the road with three types of light fixtures and lamps like Metal halide, High Pressure Sodium and LED lamps. In the design, the working hours of the lighting is assumed to be 12 hours a day from 6 P.M till 6 A.M, seven days a week. The price of the light pole is considered the same for all three scenarios and it is not included in the calculation.

B. *Scenario-I*

The strategic route in scenario I is illuminated through the use of Philips with LED lamps. Street lights are arranged in single row placed on one side of the road. Fig. 1, shows the luminaire arrangement. 3-D color rendering is shown in Fig. 2, and Fig. 3, show the lighting distribution values and Table 2, shows the contents and specification of luminaire arrangements. Table 3, shows maximum luminous intensities.

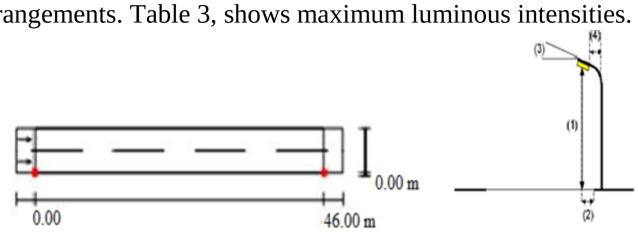

Fig. 1. Luminaire Arrangements

Table 2
Contents and Specification of Luminaire Arrangements

Contents of luminaire arrangements	Specifications
Luminaire	Philips BGP323 160×GRN-1S/740 DC
Luminaire luminous flux	16800 m
Luminaire wattage	192.0 W
Arrangement	Single row, bottom
Pole distance	48.00 m
Mounting height (1)	11.370 m
Overhang (2)	0.000 m
Boom angle (3)	0.0˚
Boom length (4)	0.500 m

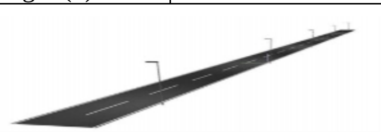

Fig. 2. 3-D Renderings

Table 3
Maximum Luminous Intensities

Maximum Luminous Intensities	
At 70˚	428cd/km
At 80˚	16 cd/km
At 90˚	0.00 cd/km

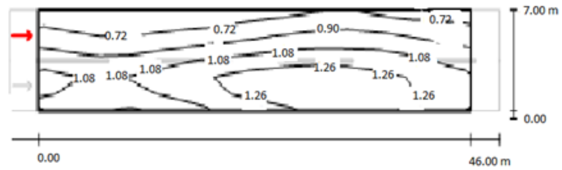

Fig. 3. Lighting Distribution Values

All the values shown in Fig. 3, are in candela per meter square. And scale is 1: 372.

C. *Scenario-II*

The strategic route is illuminated through the use of philips equipped with ceramic metal halide outdoor lamp with clear tubular outer bulb. Fig. 4, shows the luminaire arrangement and Fig. 5, shows the lighting distribution values and Table 4, shows the contents and specification of luminaire arrangements. Table 5, shows maximum luminous intensities.

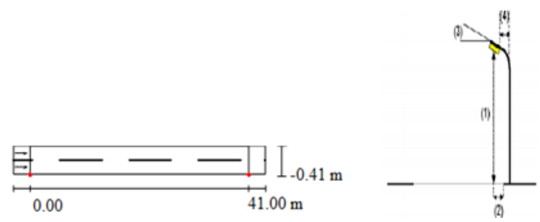

Fig. 4. Luminaire Arrangements

Table 4
Contents and Specification of Luminaire Arrangements

Contents of luminaire arrangements	Specifications
Luminaire	Philips CGP431 PC 1xCDO-TT250W
Luminaire luminous flux	22500 m
Luminaire wattage	276.0 W
Arrangement	Single row, bottom
Pole distance	41.00 m
Mounting height (1)	15.590m
Overhang (2)	0.000 m
Boom angle (3)	0.0˚
Boom length (4)	0.093 m

Table 5
Maximum Luminous Intensities

Maximum Luminous Intensities	
At 70˚	346 cd/km
At 80˚	10 cd/km
At 90˚	1.16 cd/km

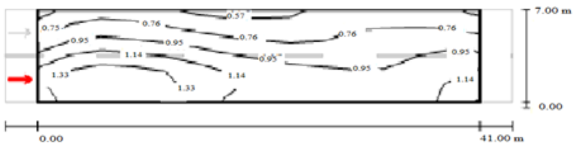

Fig. 5. Lighting Distribution Value

All the Values shown in Fig. 5, are in candela per meter square, and scale is 1:337.

D. Scenario-III

The strategic route is illuminated through the use of Philips equipped with high pressure sodium lamp. Fig. 6, shows the luminaire arrangement. And lighting distribution values are shown in Fig. 7. And Table 6, shows the contents and specification of luminaire arrangements. Table 7, shows maximum luminous intensities.

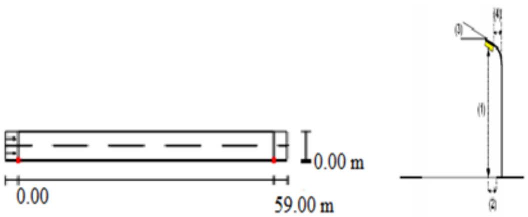

Fig. 6. Luminaire Arrangements

Table 6
Contents and Specification of Luminaire Arrangements

Contents of luminaire arrangements	Specifications
Luminaire	Philips SGS254 GB 1xSON-TPP250W
Luminaire luminous flux	33200 m
Luminaire wattage	276.0 W
Arrangement	Single row, bottom
Pole distance	59.00 m
Mounting height (1)	14.590 m
Overhang (2)	0.000 m
Boom angle (3)	0.0˚
Boom length (4)	0.500 m

Table 7
Maximum Luminous Intensities

Maximum Luminous Intensities	
At 70˚	452 cd/km
At 80˚	81 cd/km
At 90˚	1.60 cd/km

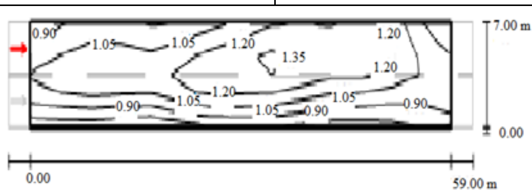

Fig. 7. Lighting Distribution Values

All the values shown in Fig. 7, are in candela per meter square. And scale is 1: 372. The measurement of required illumination was taken at different locations in the street under consideration and a grid. Professional lighting simulation programs presented in this seminar provide accurate results with option to optimize and visualize the impact of different lighting design scenarios. Manual verification of the results shows that the accuracy of the proposed design is high. In Scenario I LED lamps are utilized and the design is requiring 130 light fittings to provide illumination of 1 cd/m^2. There is approximately 40% power saving compared to the design with metal halide lamps and 9% compared to high pressure sodium lamps. Lighting distribution values illustrate very good illumination level of lighting on different areas in the street. In Scenario II metal halide lamps are used. Although the power consumption is 40296 W. In Scenario III, High Pressure Sodium (SON) lamps are introduced and it is observed that there is approximately 31% power saving compared to the design using metal halide lamps. Hence it is well within the maximum limit. Life cycle cost analysis is carried out assuming that the only part of the light fittings which requires replacement is the lamps. It is observed that over twenty years of operation, the design using LED lamps will have lesser lamp replacement cost despite its high initial cost. It is observed that payback period is around thirty five years with the design using LED lamps over metal halide lamps and few hundreds of years over high pressure sodium lamps. However, payback period is around eight years with the design using SON lamps over metal halide lamps. This shows that the design using LED is a bad choice as far as the financial judgment is concerned despite its high energy saving. A high pressure sodium (SON) lamp is the best choice due to short return of investment and cost effectiveness.

3. Conclusion

This paper presented constructional design of energy efficient street lighting system.

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