LED TECHNOLOGIES IN ROAD LIGHTING

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Like all over the world, efficient use of electrical energy has gained utmost importance in Turkey where its production is mostly realized by fossils fuels which are exported around 60% from foreign sources. Among important subjects of energy efficiency projects, evaluation of energy saving potentials in the road lighting installations can be regarded as a priority area due to ease of implementation and monitoring. Certainly, there is a need for sufficient and qualified lighting for the sake of a city, considering security and good quality visual conditions at nights. It is obviously stated that, the improvement of efficiency on road lighting installations is related to not only replacing the old lamps and luminaires with efficient ones but also performing design calculations for these installations accurately. By this way, it is aimed to implement sustainable installations providing sufficient lighting criteria with low energy consumption.

In this scope, high pressure mercury lamps are forbidden to be used in urban road lighting since 2006 in Turkey. Instead, it is forced to use tubular high pressure sodium lamps which have higher efficacy factor. Besides, the luminaire manufacturers are also obliged to state the light intensity tables of their luminaires for road lighting. Additionally, an uncommercial road lighting computer software has been developed for the authorities responsible for the calculations and installations who may practically check the design, conformity and economical availability of the lighting criteria.

In recent years, parallel to the development on the LED technology, usage of LED products in road lighting became an important subject in the scope of energy efficiency studies. On the other hand, sufficient visual conditions should be provided in road lighting installations where the security of vehicle and pedestrian has the first priority and the required lighting quality criteria for these conditions are defined in the international recommendations. For this reason, usage of LED luminaires in such road lighting installations can be considered only if supplying the required lighting quality criteria.

In this study, the photometric data of the recent LED luminaires, which are not easily accessible so far, are tried to be obtained from the manufacturers. Obviously, the luminaires to be used in road lighting installations should have the suitable light distribution curves with sufficient luminous flux in order to achieve the road lighting criteria according to international recommendations (Table 1). Thus, some photometric data of the LED luminaires for road lighting installations could be obtained from the manufacturers around the world. Those data are used in the related computer software for calculating the lighting criteria achieved in different road lighting classes with different geometries. The suitable lighting criteria under international recommendations could be achieved by only three luminaires, two of which are from same manufacturer and one from another. The design calculations could be done for M3, M4 and M5 road lighting classes, not for M1 and M2, because those luminaires could not achieve the suitable lighting criteria in “geometrical acceptable” installations.

Table 1. The suitable lighting criteria under international recommendations

Lighting Class	L_{avg} (cd/m²)	U_o	U_l	TI (%)	SR
M1	≥2,0	≥0,4	≥0,7	≤10	≥0,5
M2	≥1,5	≥0,4	≥0,7	≤10	≥0,5
M3	≥1,0	≥0,4	≥0,5	≤10	≥0,5
M4	≥0,75	≥0,4	≥0,5	≤15	≥0,5
M5	≥0,50	≥0,35	≥0,4	≤15	≥0,5
M6	≥0,30	≥0,35	≥0,4	≤15	-

L_{avg}: Average road luminance; U_o: Overall luminance uniformity ($U_o=L_{min}/L_{avg}$); U_l: Longitudinal luminance uniformity ($U_l=L_{min}/L_{max}$); TI: Threshold Increment; SR: Surrounding Ratio

The results obtained with LED luminaires are compared with the results of the calculations with high pressure sodium lamps which are accepted as energy efficient solutions for road lighting installations. The technical characteristics like power, ballast losses, luminous flux and efficacy factors of the LED and high pressure sodium lamps that are used for comparison are given in Table 2.

Table 2. Technical properties of the luminaires used in the calculations

Lamp Type	Lamp Power [W]	Ballast Loss [W]	Luminous Flux [lm]	Efficacy Factor * [lm/W]
LED	150	0	8006,54	53,4
LED	103,2	0	6716	65,1
LED	100	0	5345,65	53,5
HPS-T	150	20	17000	100
HPS-T	100	15	10000	87,0
HPS-T	70	13	6500	78,3
HPS-T	50	11	4000	65,6

* Ballast losses are included.

Calculations were performed for M3 lighting class which has two-lanes in both sides with twin-bracket central arrangement on the reservation of one meter. On the other hand, left single sided lighting arrangement of two-lane road with 7.0 meters wide by considering M4 and M5 road lighting classes were done and all results were tabulated as follows:

Table 3. Calculation Results for M3 Road Lighting Class

Luminaires	s [m]	h [m]	k [m]	θ [°]	Θ_{lum} [°]	E [lx]	L_{avg} (cd/m²)	U_o	U_l	TI [%]	SR	kW/km
150W LED	35	13	1	5	5	17,65	1,0	0,50	0,51	1,6	0,63	**8,70**
100W HPS-T	39	11	1	0	0	14,03	1,03	0,58	0,77	9,8	0,62	**5,98**
150 W HPS-T	66	15	1	5	5	13,43	1,03	0,44	0,53	9,8	0,67	**5,10**

Table 4. Calculation Results for M4 Road Lighting Class

Luminaires	s [m]	h [m]	k [m]	θ [°]	Θ_{lum} [°]	E [lx]	L_{avg} (cd/m²)	U_o	U_l	TI [%]	SR	kW/km
103.2W LED	31	7	0	0	0	12,58	0,75	0,61	0,56	14,8	0,63	**3,30**
100W LED	23	9	1	5	5	12,8	0,75	0,54	0,59	1,9	0,81	**4,30**
100W HPS-T	41	10	1	0	0	9,98	0,75	0,58	0,67	9,3	0,58	**2,76**
70 W HPS-T	31	7	1,5	5	5	10,66	0,76	0,55	0,66	11,6	0,50	**2,66**

Table 5. Calculation Results for M5 Road Lighting Class

Luminaires	s [m]	h [m]	k [m]	θ [°]	Θ_{lum} [°]	E [lx]	L_{avg} (cd/m²)	U_o	U_l	TI [%]	SR	kW/km
103,2W LED	41	8	0	0	0	8,31	0,51	0,5	0,44	12,8	0,71	**2,48**
100W LED	32	10	1	5	5	8,39	0,5	0,55	0,42	1,9	0,87	**3,10**
70W HPS-T	42	9	1	0	0	6,89	0,51	0,47	0,58	10,7	0,53	**1,99**
50W HPS-T	28	8	1,5	0	0	6,92	0,51	0,53	0,74	8,6	0,50	**2,20**

s: spacing; h: montage height; k: overhang; θ: tilt angle; E: average illuminance; U_o: Overall luminance uniformity ($U_o = L_{min}/L_{avg}$); U_l: Longitudinal luminance uniformity ($U_l = L_{min}/L_{max}$);

TI: Threshold Increment; SR: Surrounding Ratio

These tables represent the geometries of the road lighting installations, which can fulfill the required lighting criteria (Table 1) for stated lighting classes. In addition, in the last column of the tables, the required electrical installed capacity was calculated per 1 km of installation. This value can characterize the energy consumption, which constitute a big share in the operating cost of the installation. It can be easily understood from the tables that in every case, road lighting installations with LED consume more electrical energy than that with high pressure sodium lamps. When it is considered that as the power of LED light sources increases, their economical life becomes approximately equal to the high pressure sodium lamps, usage of LED light sources in road lighting installations cannot be evaluated as an optimum solution regarding current available technology.