

MODELING AND SIMULATION OF LIGHTING OF A ROAD WITH 2 STRIPS PER DIRECTION TO EN 13201: 2015 STANDARD

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Abstract: When providing solutions for lighting of streets, the parameters must comply with some predefined standards. One of these standards is the standard for EN 13201:2015. Performance requirements - This part of this European Standard that defines performance requirements which are specified as lighting classes for road lighting aiming at the visual needs of road users, and it considers environmental aspects of road lighting.

Keywords: lighting, street, photometric distribution, poles, simulation.

1. INTRODUCTION

In the case of outdoor lighting, there are no side surfaces that limit the analyzed space and therefore the calculation can be performed by the point-by-point method, starting from the photometric curves of the lighting sources used [2], [4], [11], [15].

The lighting system must be sized separately for the roadway and the sidewalk.

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It is necessary to know the data on the density of vehicles, the type of road cover, the width, both for the road and for the sidewalk, the type of sources used, clamping height, etc. [1], [5], [9].

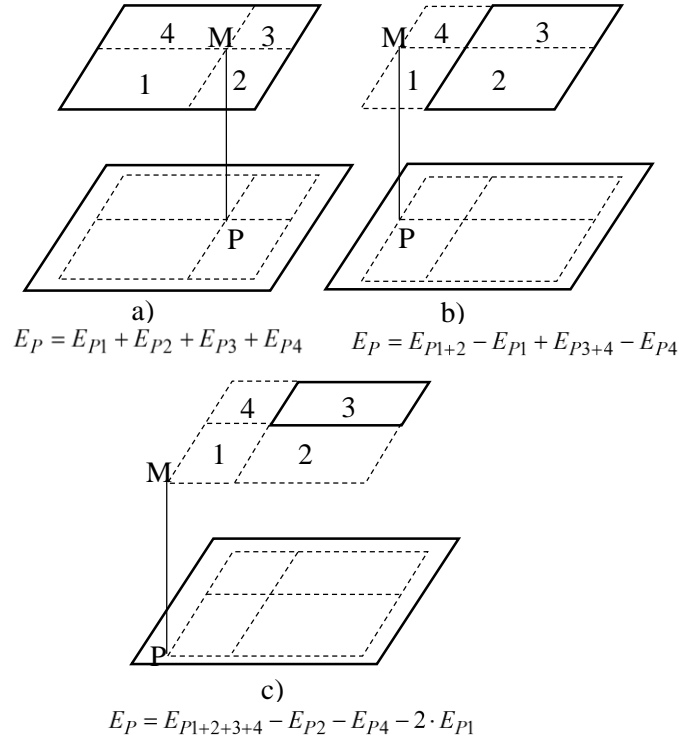


Fig.1. Calculation of rectangular lighting sources.

Narrow streets are lit with light sources placed on one side (Fig. 2) or in the middle of the street. For wider streets, lighting is usually used on both sides (2a and 2b). The dimensioning of the lighting installation for sidewalks is done based on the imposed values of the lighting level, indicated according to the circulated area and the importance of the artery. Light sources can be considered point-like and the calculation is done by the point-by-point method [3], [8], [12].

The sizing of the lighting installations on the road is made on the basis of the imposed values of the lights and taking into account the overlapping of the contributions of the different sources [2], [4], [12].

For the simple case of a light source the luminance at point P_i results from the relation:

$$L_{P_i} = p_t \cdot q_{P_i} \cdot E_{P_i} \quad (1)$$

where:

$p_t = p_l \cdot p_a$ is the holding factor of the light source (the product of the holding factor of the lamps p_l and the holding factor of the luminaire p_a),
 q_{Pi} – luminance coefficient (known size, depending on source type and angles α and β),
 E_{Pi} – lighting level in point P_i .

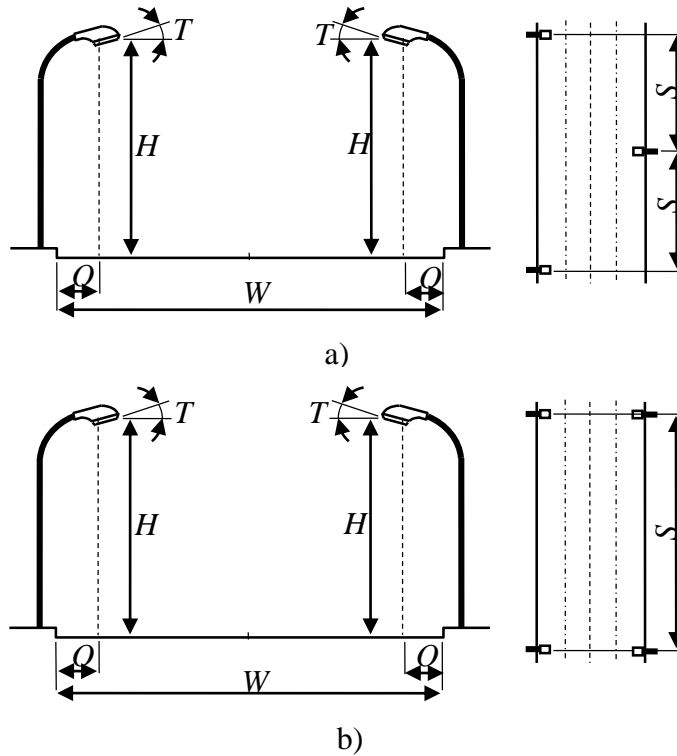


Fig.2. Bilateral street lighting:
a) alternate arrangement; b) face-to-face arrangement.

Equation (1) can also be written in the form:

$$L_{Pi} = p_t \cdot q_{Pi} \cdot \frac{I_{c\gamma} \cdot \cos^3 \gamma}{H^2} \quad (2)$$

The light intensity $I_{c\gamma}$ of the light source, in the direction is known from the photometric curve indicated by the luminaire manufacturer for the standard 1000 lm source [6], [16].

$$I_{c\gamma} = (I_{c\gamma})_{1000} \cdot \frac{\phi}{1000} \quad (3)$$

where ϕ is the luminous flux of the source used, and $(I_{c\gamma})_{1000}$ is read from the curve indicated by the manufacturer.

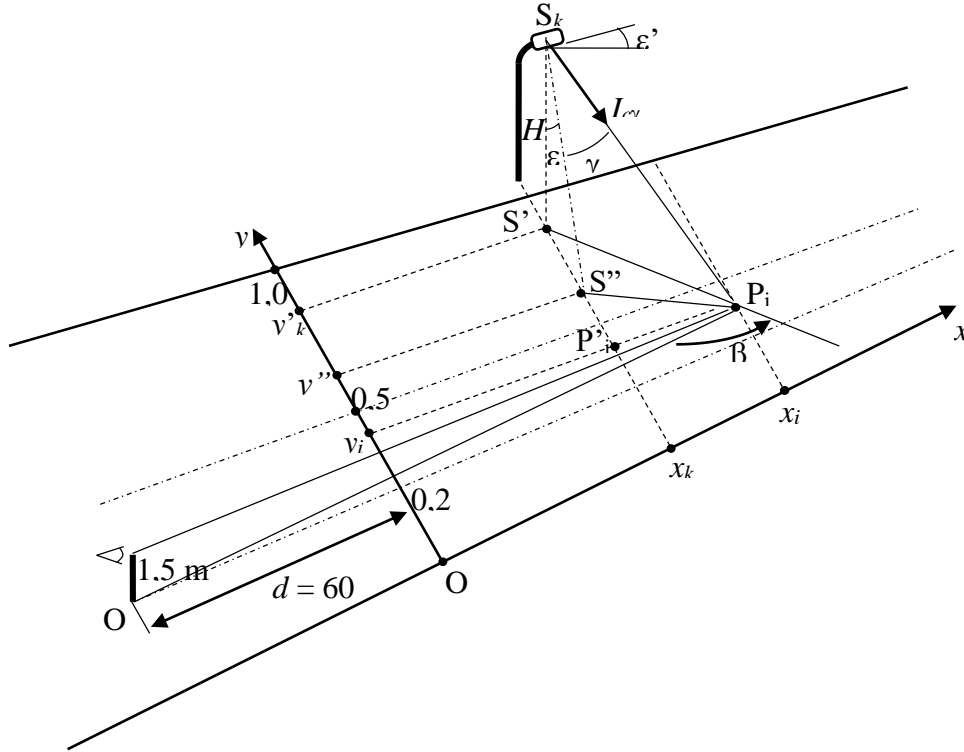


Fig.3. Calculation of outdoor lighting installations

In the general case, where there are multiple light sources, the total light $(L_{Pi})_{total}$ it results by summing up the contributions of the n light sources:

$$(L_{Pi})_{total} = p_t \cdot \sum_{k=1}^n r_k \cdot I_{c\gamma k} \cdot \frac{1}{H_k^2} \quad (4)$$

In relation (4) it was considered that all sources have the same maintenance coefficient p_t and the expression of the reduced luminance factor was noted with r_k :

$$r_k = q_{Pi} \cdot \cos^3 \gamma \quad (5)$$

Low luminance factor values are tabulated for each source and different angle values α , β și γ .

The choice of light sources is made on the basis of relation (4), by an iterative calculation. The obtained solution is verified from the point of view of the longitudinal

MODELING AND SIMULATION OF LIGHTING OF A ROAD WITH 2 STRIPS PER
DIRECTION TO EN 13201: 2015 STANDARD

non-uniformity factor, of the transversal non-uniformity factor and of the global non-uniformity factor, for an interval between two successive pillars, on the same side [7].

2. METHODOLOGY

For the existing in site situation, was used a certain Phillips luminaire with the following technical data:

Article No.	S466 LEDXION K09129
P	218.0 W
Φ_{Lamp}	31200 lm
$\Phi_{Luminaire}$	25238 lm
η	80.89 %
Luminous efficacy	115.8 lm/W
CCT	4000 K
CRI	99

Fig.4. Nikkon luminaire technical data

The luminaire has the following photometric distribution:

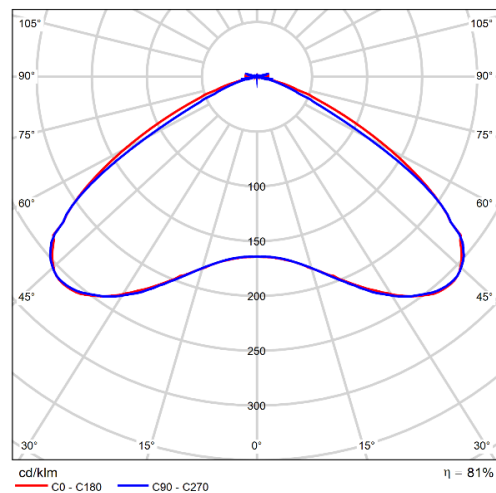


Fig.5. Nikkon luminaire photometric distribution

The image shows that the luminaire is well suited for this kind of application, street lighting requiring a special lens or LED distribution inside the luminaire body that can provide a light spread like in the picture above [13].

As shown in the figure, at an angle of around 45 degrees, the maximum intensity. Using Dialux Evo, a simulation was made with the following settings:

Pole distance	15.000 m
(1) Light spot height	8.000 m
(2) Light point overhang	0.000 m
(3) Boom inclination	0.0°
(4) Boom length	0.600 m
Annual operating hours	4000 h: 100.0 %, 218.0 W
Consumption	29213.3 W/km
ULR / ULOR	0.00 / 0.00
Max. luminous intensities Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.	≥ 70°: 68.3 cd/klm ≥ 80°: 10.5 cd/klm ≥ 90°: 1.67 cd/klm
Luminous intensity class The luminous intensity values in [cd/klm] for calculation of the luminous intensity class refer to the luminaire luminous flux according to EN 13201:2015.	G*3
Glare index class	D.5

Fig.6. Lamp and pole setting – LED street lantern (4000K) Both sides opposite

As the data in the figure presents, the pole distance of real site is 15m with a pole height of 8m. No inclination of the luminaire was used, but the boom length (the arm of the pole) was 0.6m.

Designation for the color rendering index of a luminaire or a lamp acc. The general color rendering index R_a (or CRI) is a dimensionless figure that describes the quality of a white light source in regards to its similarity with the remission spectra of defined 8 test colors to a reference light source – usually the Sun. The higher the CRI factor, the better for the eyes [4], [10].

The light output ratio describes what percentage of the luminous flux of a free radiating lamp (or LED module) is emitted by the luminaire when installed. Unit: %

Body temperature of a thermal radiator that serves to describe its light color. The unit is Kelvin [K]. The lesser the numerical value the redder; the greater the numerical value the bluer the light color. The color temperature of gas discharge lamps and semi-conductors are termed "correlated color temperature" in contrast to the color temperature of thermal radiators [14].

Allocation of the light colors to the color temperature ranges according to EN 12464-1: Light color - color temperature [K] warm white (ww) 4000 K.

3. THE 3D SITE CREATION

Using a special set of tools in Dialux Evo, one particular part of the program allows the user to create an editable street site, having the possibility to add median

MODELING AND SIMULATION OF LIGHTING OF A ROAD WITH 2 STRIPS PER DIRECTION TO EN 13201: 2015 STANDARD

space, bicycle lanes, green spaces, sidewalks, emergency lanes [17]. The setting was recreated according to the real site of an expressway with a median space between the two ways.

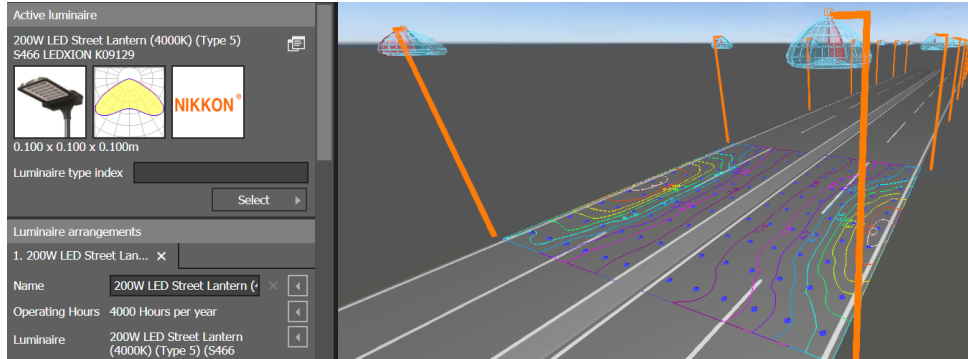


Fig.7. 3D rendering of the 4 lane street, valuation site and colour map

	Symbol	Calculated	Target	Check
Roadway 2 (M4)	L_{av}	3.31 cd/m ²	≥ 0.75 cd/m ²	✓
	U_0	0.78	≥ 0.40	✓
	U_l	0.77	≥ 0.60	✓
	TI	2 %	≤ 15 %	✓
	R_{ei}	0.92	≥ 0.30	✓
Roadway 1 (M4)	L_{av}	3.31 cd/m ²	≥ 0.75 cd/m ²	✓
	U_0	0.78	≥ 0.40	✓
	U_l	0.77	≥ 0.60	✓
	TI	0 %	≤ 15 %	✓
	R_{ei}	0.92	≥ 0.30	✓

A maintenance factor of 0.67 was used for calculating for the installation.

Fig. 8. The results for energy efficiency indicators

	Symbol	Calculated	Consumption
Street 1	D_p	0.029 W/lx*m ²	-
200W LED Street Lantern (4000K) (Type 5) (both sides opposite)	D_e	8.3 kWh/m ² yr,	1744.1 kWh/yr

Fig.9. Energy consumption automatic calculation

With an average annual working time of 4000 hours, the annual consumption calculated for this luminaire is averaged to 1750 kWh.

	Symbol	Calculated	Target	Check
Roadway 1 (M4)	L_{av}	3.31 cd/m ²	≥ 0.75 cd/m ²	✓
	U_D	0.78	≥ 0.40	✓
	U_l	0.77	≥ 0.60	✓
	TI	0 %	≤ 15 %	✓
	R_{El}	0.92	≥ 0.30	✓

Fig.10. Results for valuation field

The illuminance is not tied to an object surface. Surface ($lm/m^2 = lx$). It can be determined anywhere in space (inside or outside). The illuminance is not a product feature because it is a recipient value. Luxometers are used for measuring illuminance.

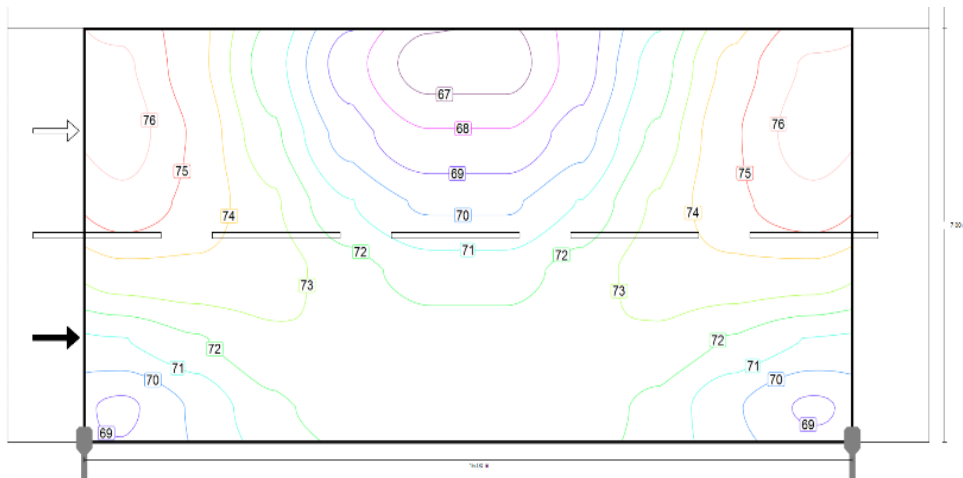


Fig.11. The light distribution of the luminaire

As seen in this color map, the illuminance at the surface of the road, has very little fluctuations, the deviation from the average being insignificant. This is due to the fact that the light distribution of the luminaire is specifically created for this kind of applications.

4. CONCLUSIONS

To implement a luminaire swap from old sodium type to LED type is a much more easily task to simulate beforehand and draw a conclusion. AS the software has shown, all the parameters were met successfully (green checked) with this kind of LED luminaire, making it a good solution for that particular setting of the road and poles.

The design procedure of a lighting installation also requires the knowledge of the parameters involved in the described model, their tolerances and variability. The

annual energy consumption indicator determines the power consumption during the year, even if the relevant lighting requirements change during the night or seasons.

These indicators may be used to compare the energy performance of different road lighting solutions and technologies for the same road lighting project. The energy performance of road lighting systems with different road geometries or different lighting requirements cannot be compared to each other directly, as the energy performance is influenced by, amongst others, the geometry of the area to be lit, as well as the lighting requirements.

This paper specifies the lighting classes set out in EN 13201 and gives guidelines on the selection of the most appropriate class for a given situation. To do this, it includes a system to define appropriate lighting classes for different outdoor public areas in terms of parameters relevant to guarantee the aims presented in introductions. The decision on whether a road should be lit is defined in the national road lighting policy. This varies by country or municipality.

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