Light color influence on obstacle recognition in road lighting

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Influence of light sources in various contrast obstacle recognition is presented in the article. Station of measurement was built and the survey on observers were conducted. Surveys were conducted with two values of adaptive luminance and two values of test luminance. These values corresponds with the road lighting luminance. Tested objects were squares with various contrast luminance placed on the white background. Gained results were analyzed and may be basis to the future laboratory and outdoor surveys.

KEYWORDS: outdoor lighting, lamps, LED, mesopic photometry

1. Introduction

The scopes of the EU energetic policy within the last years focus on limiting the electrical energy consumption. In 2005 [1], there have been accepted and passed the assumptions limiting the production of the energy-consuming light sources.

It is estimated that in Poland 19% of the total electrical energy consumption is used for lighting purposes, and the significant part of it is the outdoor lighting, including the road lighting.

In the designing process ever growing attention is paid to decrease energy-consuming of installations with maintaining at the same time parameters specified in the normatives and standards.

The most important quantitative and qualitative parameters of the road lighting are:

- level of luminance (illuminance),
- uniformity of luminance (illuminance),
- limiting glare.

These factors influence the capacity or faculty of perception and facility of evaluating situation on the road by the traffic participants.

On the roads, destined mainly for the motorized vehicles traffic of medium and high speed, the fundamental requirements base on the luminance criteria.

In the communication zones, where the main users are pedestrians and bicyclists, the basic lighting parameter is the level and uniformity of luminous flux density. These parameters are also applied for the car traffic in cases when the road situation observation is performed from a short distance, i.e. on the local roads and parking places, etc.

The selection of the appropriate photometric parameters of the road lighting depends on a number of factors that usually change in time, i.e. on the car traffic density, brightness of surrounding environment and existing parked vehicles.

The vision conditions, in various lighting situations, can also be influenced by the light color.

The presently operative standard, PN-EN 13201-Road lighting [6], does not contain simple procedures allowing including these factors and selecting the appropriate, rationally justified lighting requirements.

Modifications to this standard are presently the work subject of the Technical Committee 169 "Light and lighting" (CEN/TC169 "Light and lighting"), in the European Normalization Commission [4]. They should consider and include recommendations contained in the Technical Report 191:2010, "System recommended for the mesopic photometry based on the visual efficiency" [5], published by International Lighting Commission. It contains proposals concerning possibility of including the light color influence in the road lighting and selection of the normative parameters, particularly on the roads having the low lighting requirements.

In the road lighting, there are applied mainly the high-pressure sodium lamps. These lamps are characterized by the high durability or long life and luminous efficiency of lamps but low color rendering index. As a result the color differentiation is limited.

The more and more popular light sources in the outdoor lighting become electroluminescent diodes that include all requested operation features of the road lighting lamps and good color rendering. Moreover, the effective obtaining of the white light having higher than sodium lamps color temperature indicates the probability of better adaptation of such lighting to the vision conditions with the relatively low adaptation luminance, occurring in the road lighting.

2. Light color in the road lighting

Presently in Poland there are conducted pioneer projects of the road lighting with use of luminaires with LED lamps. For these light sources the luminous flux, applied in the photometric parameters calculations, corresponds with the vision adaptation to the daily - photopic vision conditions. There exist premises that in case of LED lamps, the real lighting effect, evaluated by drivers, shall correspond with the higher parameters than calculated [3, 4]. It is connected with the change of the eye spectrum sensitivity, adapted to the low lighting levels.

In the road lighting the applied standard luminance levels are contained within the range from approx. 0,1 cd/m^2 to $3cd/m^2$, that corresponds with the mesopic vision conditions. In such conditions the maximum eye spectrum sensitivity of the observers is moved towards shorter wave lengths when comparing with the photopic vision. Moreover, the absolute vision spectrum sensitivity also increases that has been presented on Figure 1.

The application in the exterior lighting of the light sources with the significant share of short-wave radiation causes increase of a stimulus acting on the human eye [3, 4, 5, 8]. This exactly case occurs in the lighting with use of the LED lamps.

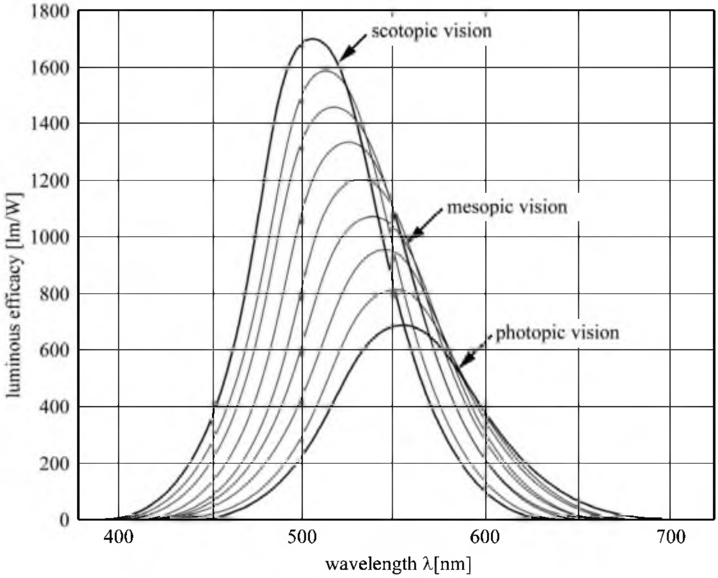

Fig. 1. Eye sensitivity for scotopic, mesopic and photopic vision

In the Report CIE 191:2010 [5] there has been described the simplified method of determining differences between the photopic luminance and mesopic luminance, corresponding with the present level of the vision adaptation. For describing these changes, there has been used parameter S/P – i.e. the ratio of the luminous fluxes of a given lamp calculated for the eye adapted to darkness (S) and to brightness (P). For a given spectrum distribution of the lamp described with use of the S/P parameter and for a given level of the adaptation luminance, determined for the photopic vision, there have been quoted differences between the mesopic luminance and reference photopic luminance – Table 1. Differences exceeding 5%, essential for the designing practice, have been marked in color.

From Table 1 results that essential differences in the luminance perception, depending on the spectrum distribution of the lamps radiation, arise/ occur for the luminance not exceeding 1,0 cd/m^2, i.e. for the levels of the road and street lighting having lower communication significance/ importance. Particularly convenient might be the application of the lamps, having high S/P index on the local roads.

Table 1. Differences between the mesopic and photopic luminance (%) for various S/P values and various photopic luminance levels

Lamp	S/P ratio	Photopic luminance levels [cd/m²]					
		0,3	0,5	1,0	1,5	2,0	3,0
LPS	0,25	-18%	-14%	-9%	-6%	-5%	-2%
HPS	0,65	-8%	-6%	-4%	-3%	-2%	-1%
LRF	1,05	1%	1%	1%	0%	0%	0%
MH ww	1,45	9%	7%	5%	3%	3%	1%
LED cw	2,25	24%	19%	12%	9%	7%	4%

S/P ratios of sample light sources [10]:
LPS – low pressure sodium lamp – 0,25
HPS – high pressure sodium lamp – 0,66
MH – clear metal halide lamp – 1,57
LED – electroluminescent diodes 4300K– 2,04

Applying/ utilizing in practice the "white light" features requires however the precise investigation/ research concerning its influence on the vision conditions on the roads illuminated in this way and in particular on the obstacles recognizing.

3. Obstacles recognizing on stationary illuminated road

To obtain that any object is visible for the observer within the determined lighting conditions, the contrast between the object and its background must be equal or higher that the luminance threshold contrast.

During the night, one of the basic tasks of the driver is to observe the road in front of the vehicle on the distance from 60 up to 160 m [2, 6, 7] and to react to the appearing obstacles. On the roads having the relatively low luminance levels (illuminance/ luminous flux density), colors become hardly differentiable. The obstacle assumed/ considered as the reference one [7], perceiving of which is essential for the safe driving, is the grey object having dimensions 0,2 m x 0,2 m and reflection coefficient 0,2. This object should be visible for a driver as a dark one on a brighter background of the road having the specific luminance value.

The threshold luminance contrast decreases when the background luminance increases. It increases the probability of perceiving the obstacle on the road. It can be assumed that applying the LED light sources, with the low levels of the adaptation luminance, shall influence the improvement of the vision conditions when comparing with the conditions occurring with the sodium lamps lighting. The described research has been conducted for the purpose of confirming this influence and its quantitative evaluation.

4. Measuring position

The measuring position, presented on Figure 2, consisted of the test board and adaptation screen illuminated in alternate way by LED lamps and sodium lamps. The observer positioned before the adaptation screen, has been located 4,8 m distant from the test board on which 30 areas/ fields have been marked, in which at random there have been distributed the square observation objects having various luminance contrast.

The observers task was to determine whether in the indicated area/field they can identify the object. The objects dimensions corresponded with the angular value of the standard obstacle identified on the road. The luminance contrast values between the object and its background were respectively : 6,5%, 3% and 2%. The selection of the contrast values, essential for their detection in the changing lighting conditions, has been made on the basis of the performed preliminary research.

On Figure 3 there has been presented the test board. The research has been performed for four (4) lighting variants:

- L_{ad} = 0,0 cd/m^2 on the adaptation screen and L_{ob}= 0,3 cd/m^2 on the test board
- L_{ad} = 0,3 cd/m^2 on the adaptation screen and L_{ob}= 0,3 cd/m^2 on the test board
- L_{ad} = 0,0 cd/m^2 on the adaptation screen and L_{ob}= 2,0 cd/m^2 on the test board
- L_{ad} = 2,0 cd/m^2 on the adaptation screen and L_{ob}= 2,0 cd/m^2 on the test board

For every of the estimation variants, there have been performed the research for the LED lighting and sodium lamp lighting.

The luminance values, assumed for the vision conditions estimations, correspond with the road luminance for the lighting classes ME1 and ME6.

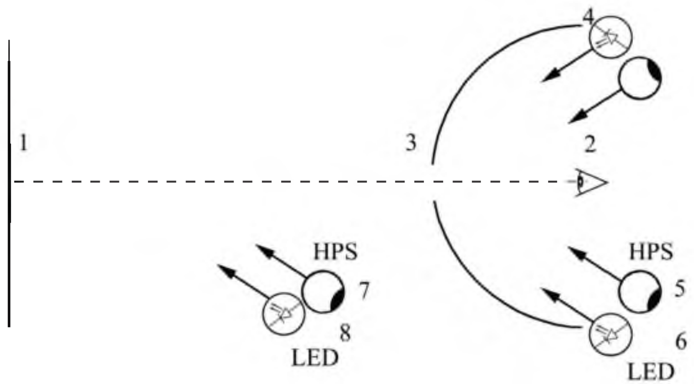

Fig. 2. Measuring position 1. test board, 2. observer, 3. adaptation screen,
4, 5, 6. lighting of the adaptation screen with use of the sodium lamp, lighting of the adaptation screen with use of the diode lamp or LED lamp, 7. lighting of the test board with use of the sodium lamp,
8. lighting of test board with use of the diode lamp or LED lamp

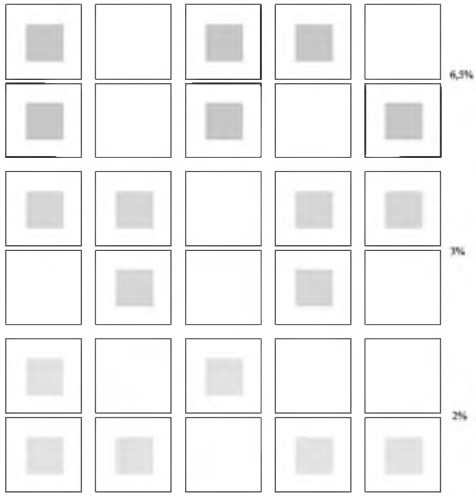

Fig. 3. Test board with observation objects having luminance contrast respectively 2%, 3%, 6,5%

The research has been performed for the LED lamp having the color temperature 6500 K and for the high-pressure sodium lamp SON-T 70W having the color temperature 2200 K.

On Figure 4, there have been presented the spectrum distributions of the light sources used in research, on the background of the curve of the eye spectrum sensitivity for the mesopic and photopic vision.

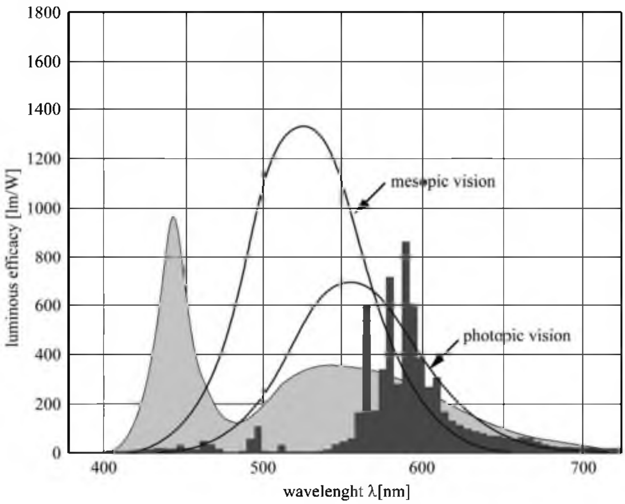

Fig. 4. Spectrum distributions of the light sources used in research, on the background of the spectral sensitivity of the eye for the mesopic and photopic vision

5. Research results

The research has been performed on 14 persons within the age range from 9 to 67 years. The averaging estimation results of the test objects recognizing have been presented in Table 2 and Table 3.

On the basis of the research results, presented graphically on Figure 5, it is possible to assume that for the low luminance of the test board, equal to 0,3cd/m^2, with the diode lighting or LED lighting there has been observed better identification of the obstacles having the low contrast with their background – and therefore potentially more difficult to be perceived in the road traffic. Particularly essential improvement of the obstacles recognizing in the LED lighting, when compared with the sodium lamp lighting, occurs for the situation when the surrounding luminance is high – i.e. when it is comparable with the test luminance. For the obstacles having the high contrast, and therefore easier to be identified, the light color does not have significant effect.

Similar in its tendency, however distinctly lower, influence of the LED lighting on the objects identification conditions, has been obtained in the research conducted for the test luminance of 2 cd/m^2 and adaptation luminance of 0 cd/m^2 and 2 cd/m^2 level.

Table 2. Averaging research results of the objects recognizing in the lighting conditions with use of LED lamp 6500 K

Adaptation luminance [cd/m^2]	**Test board luminance [cd/m^2]**	**Luminance contrast**		
		6,5%	**3%**	**2%**
0	**0,3**	93%	86%	71%
0	**2**	100%	99%	97%
0,3	**0,3**	91%	83%	69%
2	**2**	100%	98%	97%

Table 3. Averaging research results of the objects recognizing in the lighting conditions with use of HPS lamp 2200 K

Adaptation luminance [cd/m^2]	**Test board luminance [cd/m^2]**	**Luminance contrast**		
		6,5%	**3%**	**2%**
0	**0,3**	95%	84%	67%
0	**2**	98%	96%	91%
0,3	**0,3**	88%	76%	56%
2	**2**	100%	98%	93%

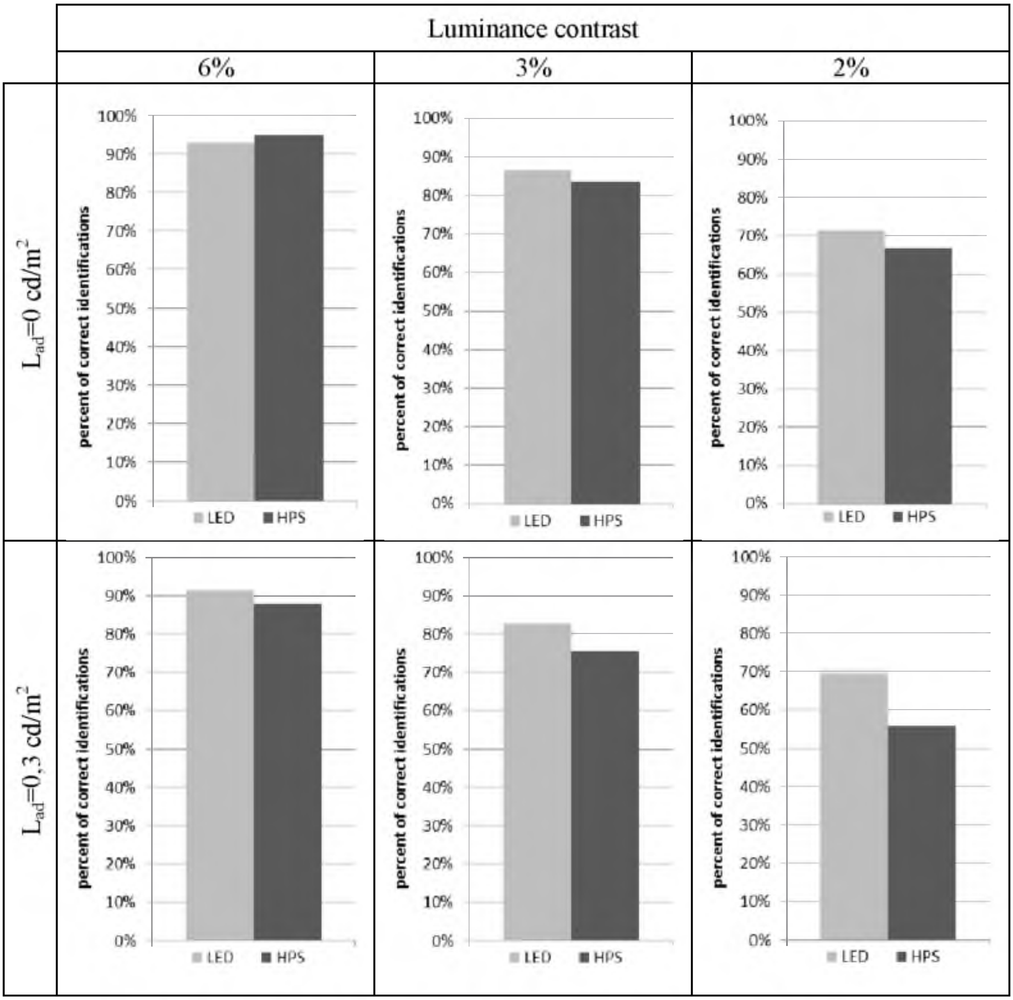

Fig. 5. Recognizing the objects for the test board luminance 0,3 cd/m^2
in the dark surrounding/ environment and with the adaptation luminance 0,3 cd/m^2

6. Conclusions

The presented research results indicate the justification for conducting further research concerning the vision conditions on the roads illuminated with use of LED lamps. It is particularly important for the roads having the low lighting requirements which are in fact in the majority.

In the conditions of the vision adaptation to the low luminance levels, without concerning the surrounding lighting, luminaires with the LED lamps assure the better vision conditions, better obstacles identification and therefore higher safety level. Consequently, they are more effective that luminaires with the sodium lamps, considered until now the most convenient solution.

It is necessary to underline that utilizing in the designing practice features of LED lamps shall be possible after elaborating principles for the lighting requirement selection, allow to replace the photopic luminance level (illuminance level), calculated for the observer adapted to the daily vision conditions, with the mesopic luminance level, the value of which shall be changeable and depending on the spectrum distribution of the applied light source radiation and on the luminance level and distribution in the visual field.

Literature data [9] indicate that in the research it is also necessary to consider the age of the observers.

References

[1] Directive 2005/32/EC on Eco-design requirements for energy-using products.

[2] CIE 031-1976, Glare and uniformity in road lighting installation, ISBN 978-3-901906-67-1.

[3] CIE 115– 1995, Recommendations for the lighting of roads for motor and pedestrian traffic, ISBN 3 900 734 59 3.

[4] CIE 115:2010 Lighting of roads for motor and pedestrian traffic, ISBN 978 3 901906 86 2.

[5] CIE 191:2010 Recommended system for mesopic photometry based on visual performance, ISBN 978 3 901906 88 6.

[6] PN-EN 13 201 – 2007: Road lighting.

[7] Bommel W.J.M., DeBoer J.B., Oświetlenie dróg, WKŁ, Warszawa 1984, ISBN 83-206-0452-4.

[8] Górczewska M., Mroczkowska S., Valuation of road lighting parameters for luminaires with LED, Przegląd Elektrotechniczny Nr 10/2010, ISSN 0033-2097

[9] Sagawa K. Vision of the elderly and visual impared - for accessible design In light and lighting, *CIE Proceedings*, Pekin (2007), D1 62-65.

[10] Outdoor Lighting: Visual Efficacy. Lighting Research Center. http://www.lrc.rpi.edu/ 20.02.2013