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Assessment model of luminance contrast of pedestrian figure against background on pedestrian crossing

***Abstract**. Realization of existing normative recommendations concerning lighting of pedestrian crossings gives the designer some freedom in the choice of lighting standards. Determining the actual state of lighting conditions is connected with conducting field research of as-built lighting. The article will present formal requirements of the currently applied standard concerning lighting of pedestrian crossings. Preliminary proposal shall be presented of the way of conducting lighting assessment on pedestrian crossings taking into consideration luminance and contrast parameters.*

***Streszczenie.** Realizacja istniejących zaleceń normatywnych dotyczących oświetlenia przejść dla pieszych pozostawia projektantowi pewną swobodę dotyczącą doboru standardu oświetlenia. Ustalenie stanu faktycznego warunków oświetleniowych wiąże się z powykonawczym przeprowadzeniem badań w terenie. W artykule zostaną zaprezentowane wymogi formalne obecnie stosowanej normy, dotyczące oświetlenia przejść dla pieszych. Przedstawiona zostanie wstępna propozycja sposobu przeprowadzenia badań oświetlenia na przejściu dla pieszych z uwzględnieniem parametrów luminancji i kontrastu. (**Model do oceny kontrastu luminancji sylwetki pieszego z tłem na przejściu dla pieszych**).*

Keywords: pedestrian, luminance, contrast, lighting of pedestrian crossings, street lighting.
Słowa kluczowe: pieszy, luminancja, kontrast, oświetlenie przejść dla pieszych, oświetlenie uliczne.

Introduction

Ensuring appropriate observation conditions of the pedestrian crossing area by drivers allows for noticing a pedestrian from such a distance that makes it possible to react properly in a hazardous situation. Monitoring the state of pedestrian crossing lighting is a key factor in maintaining high standards of lighting and traffic safety of both drivers and pedestrians. Currently conducted measurements of street lighting including pedestrian crossing lighting mainly take place at the reception of newly designed installations. What is also indispensable is the monitoring of the state of lighting of currently exploited installations from the point of view of complex lighting parameters maintenance.

Formal requirements exist both in Poland [1, 2], Europe [3, 4] and in the USA [5, 6], which might constitute the basis for creating lighting assessment criteria for pedestrian crossings. The subject of lighting and safety on pedestrian crossings among others was discussed in the researches conducted in the USA [7] and in Europe [8, 9].

Current requirements concerning pedestrian crossing lighting in Poland

Between the years 1997 - 2004 the standard EN 13201 „Road lighting" [1] was drawn up and implemented. Full membership of Poland in the European Union resulted in the fact that the National Standards Body being a member of CEN/CENELEC was obliged to introduce European regulations to the collection of Polish Standards. Introduction of the new European standard PN-EN 13201 [1] by virtue of the Act of 12 September 2002 „concerning standardization" results in the change of attitude towards the manner of road lighting design including pedestrian crossing areas. Application of the standard is voluntary on the territory of Poland, and the standard itself remains a normative document, which is not the act of law. The same Act stipulates that the standards (among others, PN-EN 13201) may be created through the provisions of law after their publication in the Polish language with simultaneous change of status into a legal decision. Full text of the standard PN-EN 13201 [1] has not been published in the Polish language so far.

Therefore, the designer of road lighting has freedom in applying the existing, yet not binding regulations of the standard. Despite the fact that the standard [1] is not a compulsory act, it is often the basis for drawing up recommendations and guidelines for design of newly-created road investments. It is also a certain determinant of designing rules for lighting designers. This fact shows the need for precise design guidelines for street lighting including conflict areas and pedestrian crossings.

Therefore, since 2007 in Poland a discretionary road lighting standard PN-EN 13201:2007 [1] has existed.

It assumes different lighting conditions of conflict areas, including pedestrian crossings. Recommendations concerning luminance level or luminous flux density are not uniform for every pedestrian crossing, which results from the assumed lighting class for a given road stretch, determined with regard to a series of parameters, including conflict areas. The current state of formal recommendations concerning pedestrian crossing lighting has been described below in a quoted fragment of the standard PN-EN 13201:2007. Annex B (informative). Pedestrian crossing lighting [1].

"Pedestrian crossings can require special attention. In some countries standards exist giving additional indications accounting for national practices. If adequately high level of roadway luminance can be created, then it is possible to arrange lighting frames of normal road lighting in such a way that pedestrians should be visible in good negative contrast, that is as dark figures against light background. In other cases lighting can be solved by means of additional lighting frames. Their aim is lighting of pedestrians being on the crossing or next to it and drawing attention of motor vehicle drivers to the presence of pedestrian crossing. The type of additional lighting frames, their arrangement and direction towards the surface of pedestrian crossing should be such that a positive contrast should be obtained and excessive glare of drivers should not be caused. One of the solutions is fitting the frames at a small distance from pedestrian crossing facing the direction of motor vehicle motion and directing the light to pedestrians being in front of vehicle drivers. In the case of roads without divided directions of driving, the frames are fitted before the crossing in each direction of the traffic stream on that side of the road on which the traffic takes place. For this purpose, lighting frames are used of asymmetrical direction of light causing smaller glare of drivers. Local lighting can be arranged in such a way so as to adequately illuminate pedestrians on the side turned to the traffic direction at all locations of the surface of the crossing. It is recommended that luminous flux density measured in a vertical plane was

much higher than the horizontal luminous flux density of road lighting on the roadway. It is also recommended that the zones at the ends of pedestrian crossings where pedestrians await crossing the road were properly illuminated. Lighting limited to a narrow strip around the surface of pedestrian crossing causes a very strong effect accompanying the increase of attention."

Thus, on the basis of currently used standard [1] the recommended values concerning the levels of luminous flux density and other parameters including luminance and contrast in the area of pedestrian crossings cannot be unambiguously determined. Explicit need for changing this state of affairs exists.

Assessment of human figure contrast on pedestrian crossing

The author of the present paper proposes application of luminance criterion for assessment of the properties of a selected lighting solution for pedestrian crossing.

Conducting measurements according to the instructions included in the standard [1], particularly in the conditions of constant exploitation is difficult to realize, and in the conditions of increased urban traffic it is practically impossible to realize without closing of a given traffic route. For the researches and registration of luminance distribution on a pedestrian figure and in his surroundings, classic luminance meters can be used or technologically advanced matrix meters [10]. Thanks to the development of measurement tools making it possible to take photos of pedestrian crossings calibrated in luminance levels [10], it is possible to calculate the contrast of human figure being at the pedestrian crossing with his surroundings – background. Such an approach allows for taking into consideration real lighting conditions characteristic for the area of pedestrian crossing.

In order to create uniform comparative conditions connected with measurements, reflectance and its character, it was decided that the measurement target would be used which reflects geometrical and reflection properties of a human figure. On the basis of anthropometric data [11] for a 50 percentile figure of an adult man in a sideways position, the measurements of test target have been drawn up in the form of a rectangle of the following measurements 0,25x1 m, which reflects side surface of a human being on pedestrian crossing. The view and positions of situating the target are presented in figure 1.

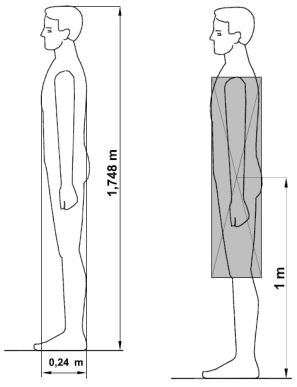

Fig. 1. Anthropometric measurements of a human being and the target for luminance measurement on pedestrian crossing

The centre of the target is situated 1 m above the surface of the road. Adopting such positioning results from the fact of existence of guidelines for this height of measurement [1,3,4], and at the same time the measurements of other figures such as women, children and the disabled on wheelchairs are taken into consideration.

What follows from the conducted researches [12] is that over 90% of clothing worn by pedestrians has reflectance ρ lower than 20%. Figure 2 presents graphic relative cumulative frequency of the variability of occurrence of reflectance of clothing worn by pedestrians.

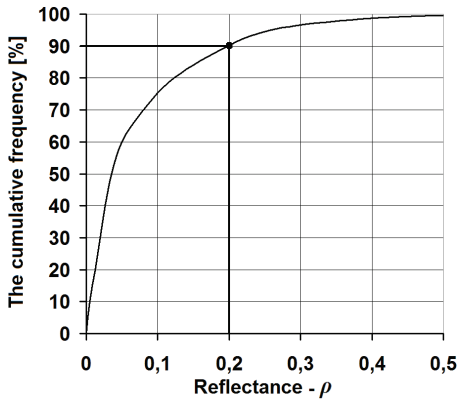

Fig. 2. The cumulative frequency of the reflectances of clothing worn by pedestrians [12]

In order to conduct comparative researches of human figure luminance on pedestrian crossing, it is proposed to use a test target covered with material of reflectance value of $\rho = 0,2$ and reflection characteristics possibly close to equally distributed. At the same time it is assumed that observation conditions of the target – a figure wearing dark clothes - by the driver are disadvantageous. Figure 3 presents basic geometrical parameters and the view of a real target prepared for future field research.

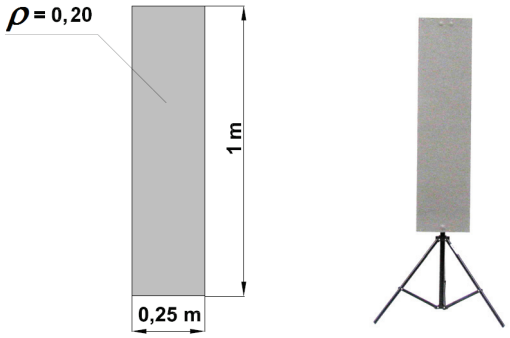

Fig. 3. Target for research of contrast on pedestrian crossing

Figure 4 presents positioning of test target on pedestrian crossing and observation directions.

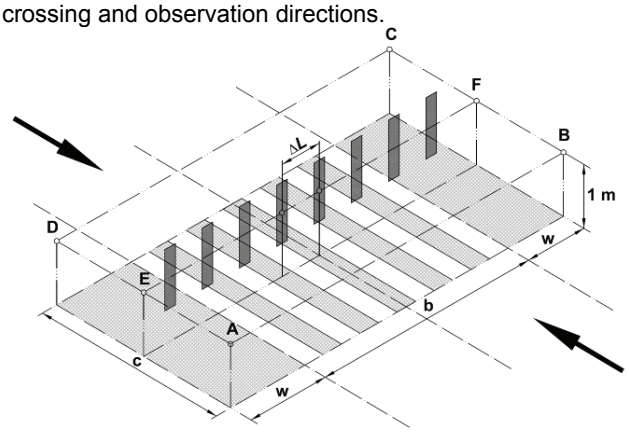

Fig. 4. Test target positioning on pedestrian crossing

Geometry of positioning of the observer and the target is presented in figure 5. Observer A is situated at the distance of 57,28m from the crosswise axis of pedestrian crossing (figure 4, stretch E-F), in accordance with guidelines [1, 3, 13] and maintains the observation angle of the road surface equaling 1º. Observer's eyes are situated at the height of 1,5 m above the road surface. Observation angle goes through the centre of measurement target P.

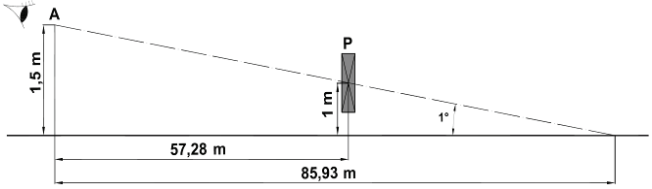

Fig. 5. Measurement geometry of test target luminance

The measurement should be conducted for each direction of traffic, measuring the luminance of targets situated on the whole width of pedestrian crossing, on the stretch E - F (figure 4) with the interval between subsequent readings ΔL ≤ 1,5 m. Performing luminance measurements on the opposite traffic lane in relation to the assumed direction of motion is necessary. Information about the obtained contrast of a pedestrian figure against the background is relevant for the whole roadway and is a reflection of real traffic situation. A pedestrian can be at any place on the roadway in the area of pedestrian crossing. The driver of a vehicle approaching the crossing must be ensured proper observation conditions within the whole area of pedestrian crossing including the waiting or safety area.

Luminance calculations for particular locations of targets should be conducted on the basis of a series of minimum ten measurements, and then average luminance should be calculated for the surface of the target (L_T) and for the background of on the left-hand and right-hand side of the figure of the pedestrian (L_{B1} and L_{B2}).

Contrast for each target on pedestrian crossing should be calculated on the basis of the following equation:

(1) $$C = \frac{L_T - L_B}{L_B}$$

where:
C – contrast,
L_T – target luminance [cd/m^2]
L_B – background luminance [cd/m^2], having in mind that:
$L_B = (L_{B1}+L_{B2})/2$

Measurement surfaces are presented in figure 6.

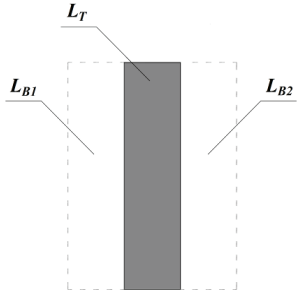

Fig. 6. Measurement surfaces
L_T –Target luminance; L_{B1},L_{B2} – Background luminance

Field research

The article presents sample results of contrast measurement for a selected lighting situation.

For lighting of pedestrian crossing two lighting frames temporarily installed have been used: Thorn IVS 96256916 AREA1 A/A 150W 230V HIT G12 CL2 MTP MA60 [14] in a transversal position. The goal of these frames is lighting of a human figure being on pedestrian crossing from the side of an approaching vehicle. The frames have been situated in the geometry compatible with catalogue recommendations of the producer. The street on which the measurements have been conducted is a two-way single carriageway with one lane for each direction. Figures below show luminance pictures of target illuminated by the frames Thorn IVS on pedestrian crossing for both observation directions. Figure 7 presents the values for direction 1, whereas figure 8 presents results obtained for direction 2 measured by means of matrix meter [10].

Fig. 7. Luminance measurement for targets of the first observation direction (logarithmic scale $\log_2$, unit cd/m^2)

Fig. 8. Luminance measurement for targets of the second observation direction (logarithmic scale $\log_2$, unit cd/m^2)

Table 1 presents collective results of target and background luminance measurement and the value of contrast calculated on the basis of equation 1. Figures 9 and 10 present in a graphic form the values of contrast obtained for both observation directions of the target – human figure.

Table 1. Collective results of luminance and contrast for both observation directions of a human figure on pedestrian crossing equipped with lighting frames Thorn IVS [14]

Object [nr]	Direction 1			Direction 2		
	Target Luminance [cd/m^2]	Background Luminance [cd/m^2]	Contrast	Target Luminance [cd/m^2]	Background Luminance [cd/m^2]	Contrast
1	0,75	1,66	-0,55	0,79	1,71	-0,54
2	1,05	0,32	2,28	0,77	0,33	1,33
3	1,24	0,47	1,64	0,98	0,36	1,72
4	1,86	2,00	-0,07	1,36	0,88	0,55
5	2,33	2,71	-0,14	2,46	0,81	2,04
6	3,60	1,02	2,53	4,77	1,22	2,91
7	4,70	0,80	4,88	6,17	1,13	4,46
8	5,29	1,09	3,85	7,79	1,03	6,56
Average	2,60	1,26	1,80	3,14	0,93	2,38

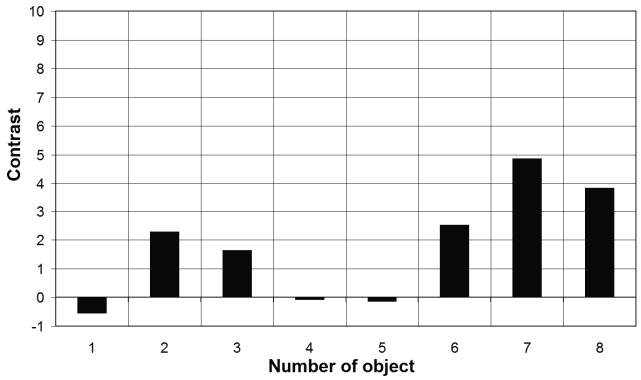

Fig. 9 Contrast luminance of target against background obtained with the use of lighting frame Thorn IVS from the first observation direction

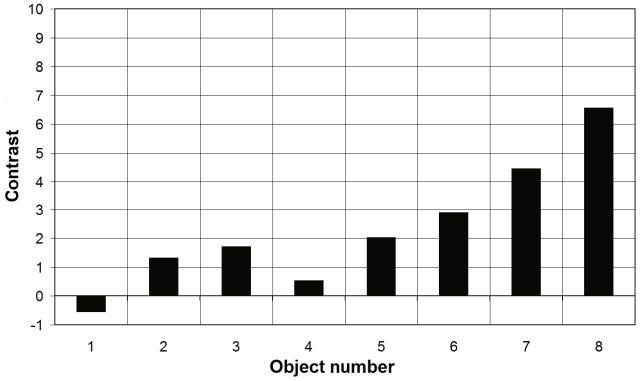

Fig. 10 Contrast luminance of target against background obtained with the use of lighting frame Thorn IVS from the second observation direction

Conclusions

The aim of verification of lighting state is objective improvement of visibility, in particular in places where pedestrians should feel safe, that is on pedestrian crossings.

The paper undertakes the attempt to present the way of luminance measurement and contrast determination on pedestrian crossings. The proposed manner of assessment of luminance parameters allows for explicit verification of the applied lighting concept. It should be mentioned that the obtained value of contrast significantly depends on surroundings luminance (target background) which should be taken into account in real traffic situations.

As it follows from the presented research results, what is worth paying attention to is lighting of pedestrian crossings by means of additional, dedicated lighting frames. In the case of lighting frames Thorn IVS [14] for both observation directions, a very high level of positive contrast is created. Only for objects number 1, the condition of positive contrast has not been fulfilled. This fact was caused by temporary installation of lighting frames. However, in this case we can talk about the possibility of noticing a pedestrian at the negative contrast. For objects 4 and 5 (figure 9) contrast also had negative values. In this case it is caused by appearance of object (vehicle) of higher luminance in the surroundings of pedestrian figures. The lighting solution presented in the paper ensures the drivers the possibility of certain recognition of pedestrian figure being either on the roadway or on the waiting area.

Sample field research presented here confirmed the fact that applying additional lighting on pedestrian crossings is advantageous from the point of view of drivers, ensuring them appropriate levels of contrast indispensable for recognition of a pedestrian figure dressed in clothing of low reflectance.

The proposal of measurement method presented in the paper makes it possible to determine contrast of pedestrian figure on pedestrian crossing and in the waiting area. Luminance measurement accounts for driver's (observer's) existence and measurement geometry connected with him.

The issue presented in the paper does not cover the whole spectrum of problems connected with lighting installed on pedestrian crossing. It is a mere introduction into further research.

The present author plans to conduct field research on a high number of selected pedestrian crossings in the near future. The aim of research is to determine the range of variability of contrast value for different lighting solutions applied on pedestrian crossings.

Research work being conducted aims at establishing requirements or recommendations concerning illumination of particularly dangerous pedestrian crossings in Poland. Adopting uniform valuation criteria for lighting state of pedestrian crossings together with fulfilling key technical parameters can contribute to verification of the applied technical solution in the future.

Photometric research of road infrastructure may contribute to the improvement of poor state of safety of unprotected participants of traffic in Poland.

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