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SELECTED ISSUES CONNECTED WITH LIGHTING OF PEDESTRIAN CROSSINGS

Abstract:

In Poland, throughout many years invariably numerous accidents occur with the participation of pedestrians. One of the reasons of such a state of affairs is incorrect lighting of conflict areas dedicated to pedestrian traffic. The article deals with the problem of lighting of pedestrian crossings. The present paper enumerates formal requirements concerning pedestrian crossing lighting from the point of view of the norms applicable in Poland to date. Analysis of the criteria assumed for the assessment of lighting shall be conducted. Investment into road infrastructure research can contribute to the safety improvement of unprotected participants of road traffic.

Keywords: lighting, pedestrian crossing, luminance, assessment, pedestrian safety

INTRODUCTION

Statistical analysis of accidents conducted by The National Police Headquarters [10] indicates a retained and very disadvantageous ratio of fatal road accidents. On Polish roads on average 5.5 thousand people die annually. Researches show that the highest number of accidents occur in built-up areas (about 70%) and the most frequent kind of accident is running over a pedestrian (about 30%). According to the data from annual reports, pedestrians constitute the second, as for the number, group of road accident casualties (that is 1852 fatalities in 2008). About 37% of all road accident casualties in Poland constitute the "unprotected" participants of road traffic. Special attention should be paid to this group because in contrast with road traffic participants travelling in cars, these people are not protected by the car body, they cannot count on the protection of air bags or safety belts. In 2009, 12834 accidents with the participation of pedestrians were reported (29% of the total), in which 1477 persons died (32.3% of the total), and 12328 were injured (22% of the total). The majority of casualties were pedestrians whose behavior is often posing a great threat. In 2009 pedestrians caused 11.3% of incidents. In places accessible to pedestrian traffic (table 1) 8211 accidents were reported, which constitutes 64% of all accidents with the participation of pedestrians. 530 persons died (36.1% of the total number of killed pedestrians), 8320 persons were injured (69.2% of the total number of injured pedestrians).

As the conducted analyses show, the area of pedestrian crossing, which is supposed to be a safe place for the unprotected participants of road traffic (pedestrians and cyclists) is, in fact, a dangerous place in which about 10% of road accidents occur. A detailed analysis of the causes of road accidents with the participation of pedestrians indicates that very often accidents are caused by careless entrance of pedestrians on the road in front of the coming vehicle from behind of the vehicle or obstacle (geometrical visibility restriction).

Table 1. Road accidents and their consequences in places dedicated to pedestrian traffic in 2009 [10]

Selected places of pedestrian traffic	Accidents	Fatalities	Injuries
Pedestrian crossing	3775	230	3809
Junctions	3711	246	3741
Pavement, pedestrian way	420	21	450
Hard shoulder	159	22	165
Public transport stop	146	11	155
Total number	8211	530	8320

The most numerous group of pedestrians – who cause accidents are children of 7 to 14 years of age, and the most numerous group of fatalities constitute persons between 50 and 59 years old. It is worth taking into account the fact that the highest number of accidents with the participation of pedestrians occur in autumn and winter months. As it follows from statistical data [10], in 2009, similarly to the previous years, the highest number of accidents with the participation of pedestrians and the most tragic consequences were also reported in the months between October and December. Number of accidents is presented in table 2.

Table 2. Number of fatal accidents with the participation of pedestrians in a monthly layout in Poland in 2009 [10]

Months	Accidents		Fatalities		Injuries	
	Total	%	Total	%	Total	%
January	1092	8.5	131	8.9	1064	8.6
February	892	7.0	89	6.0	859	7.0
March	1035	8.1	126	8.5	971	7.9
April	899	7.0	98	6.6	893	7.2
May	855	6.7	68	4.6	851	6.9
June	889	6.9	78	5.3	884	7.2
July	792	6.2	89	6.0	797	6.5
August	872	6.8	106	7.2	851	6.9
September	1050	8.2	119	8.1	1008	8.2
October	1475	11.5	190	12.9	1368	11.1
November	1556	12.1	210	14.2	1450	11.8
December	1427	11.1	173	11.7	1332	10.8
Total	12834	100.0	1477	100.0	12328	100.0

The origin of this phenomenon should be sought in bad atmospheric conditions, early twilight, poor visibility of pedestrians and extended braking distance. In these months, 40% of all accidents caused by pedestrians occurred between 4 and 7 p.m.

As it follows from statistical data of the National Police Headquarters [10] the number of accidents on pedestrian crossings has been decreasing since 2001 (fig.1). Nonetheless, a high number of knocking down incidents on pedestrian crossings that is still retained should be disquieting. Pedestrian crossing should guarantee the unprotected participants of the road traffic a safe crossing of the road.

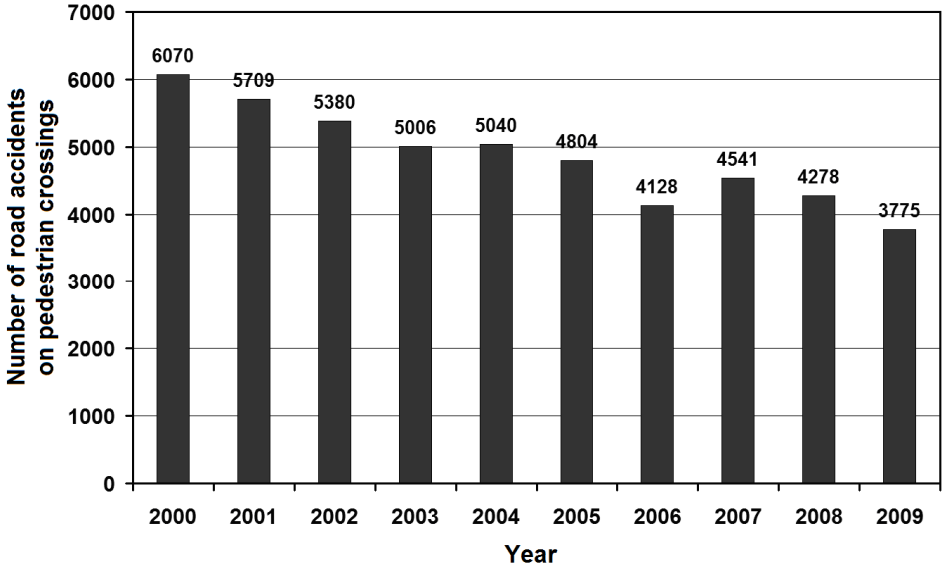

Fig.1. Number of road accidents on pedestrian crossings in the years 2000-2009 [10]

Percentage share of road accidents in these places in relation to the number of accidents with the participation of pedestrians systematically increased from 28.9% in 2000, to 30.4% in 2005. In 2006 it decreased to 27.4%, in 2007 and 2008 equaled 28.5%, and in 2009 an increase to the value of 29.4% was registered.

The main general groups of accident causes with the participation of pedestrians are the following: driver carelessness, pedestrian carelessness and lack of proper visibility of pedestrian participants of road traffic. There is no direct way of influencing careful and rational attitude of drivers and pedestrians. Prevention activities can be carried out in schools and drivers can be trained on driving courses. However, careless behavior factor is independent of the time devoted to prevention activities.

Statistical research conducted by European Commission on Transport [2] proves disadvantageous situation of pedestrians in Poland in comparison with other European Union countries. The number of fatalities with the participation of pedestrians over the years 2008-2009 (fig.2) presented in 2010 unambiguously points to this problem.

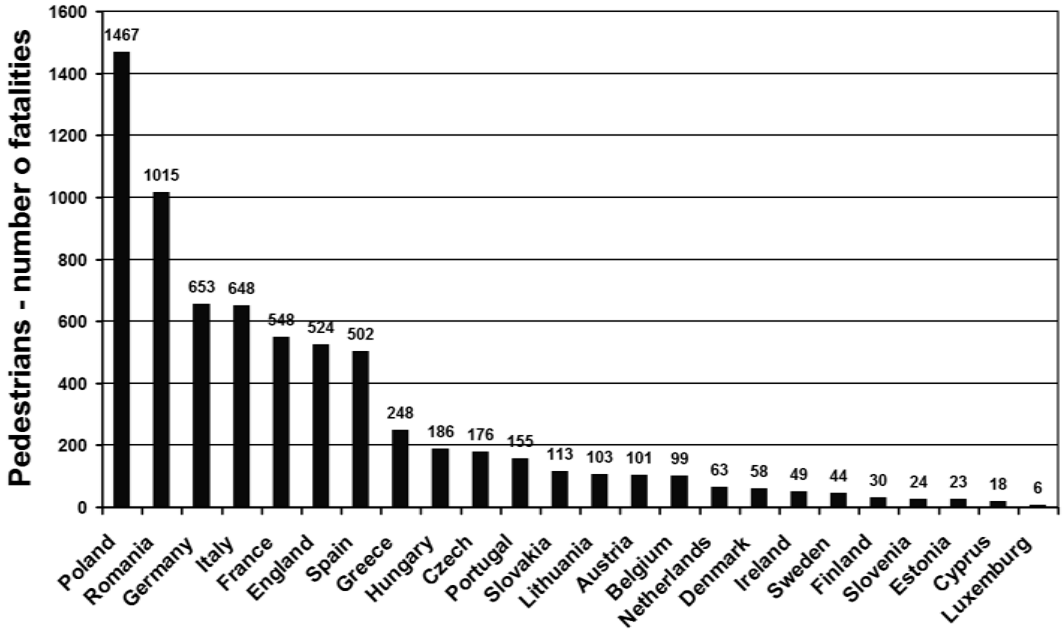

Fig 2. Graphic chart of fatalities with the participation of pedestrians [2]

Pedestrian crossing is an area of increased risk of sustaining injuries or losing life as a result of collision of a pedestrian with fast moving vehicles. As the research conducted in Great Britain [5] in 2003 indicates, 22% of all fatal accidents took place on pedestrian crossings. Among others, it is a cause for special treatment of these fragments of the road. A pedestrian has priority over other vehicles, and crossing the road at a designated place decreases the risk of accident occurrence. As it was established, about 30% of pedestrians fail to observe the rules of crossing the road at designated places [5]. Despite increased efforts put in road infrastructure [4], still almost a quarter of all accidents occur on pedestrian crossings or around them. It follows from the presented research results that a decisive factor in the possibility of noticing a pedestrian are directional reflection coefficients of materials used for clothing worn by pedestrians.

1. FACTORS INFLUENCING PEDESTRIAN SAFETY

A series of criteria can be defined (Table 3) directly or indirectly influencing occurrence of accidents with the participation of pedestrians in the area of pedestrian crossings.

Table 3. Factors influencing occurrence of accidents with the participation of pedestrians

Object	Feature	Parameter
Road	Road classification	Road type or class. Surface condition and type. Carriageway width . Road geometry. Main participant of road traffic. Traffic volume : - in daytime, - at night. Road function depending on the season of the year, e.g. transit or holiday route. Number of access points (exit from property).
Pedestrian crossing	Geometrical visibility of a pedestrian from a driver seat	Restriction of visibility on pedestrian crossing from the point of view of a driver: - permanent: trees, plants, posts, advertisements and other obstacles, - temporary: vehicles parked directly before pedestrian crossing, bus stop. Lack of no-parking area before pedestrian crossing.
	Clarity of pedestrian crossing	Lack or poor condition of vertical and horizontal signage. Existence of elements obstructing informative signs of pedestrian crossing. Lack or poor condition of informative infrastructure on pedestrian crossing, including traffic lights, sound elements for the disabled.
	Accessibility of pedestrian crossing	Lack of designated pavement. Lack or improper location or leveling of pavement in relation to roadway. Lack of hard shoulder. Lack of pedestrian waiting area. Lack of restrictions ordering pedestrian traffic – barriers, chains.
	Location of pedestrian crossing	Improper location of pedestrian crossing e.g. on the curve or hill.
	Road features directly before and after pedestrian crossing	Improper traffic organization. Improper width of carriageways. Lack of safety island or median strip. Lack of cycle lane. Hard shoulder of improper width. Poor technical condition of hard shoulder. Too narrow hard shoulder. Obstacles on hard shoulder e.g. buildings in close neighborhood. Surface of low friction coefficient. Lack of drainage in the neighborhood of pedestrian crossing.

Object	Feature	Parameter
	Lighting of pedestrian crossing or in its neighborhood.	Lack or poor condition of lighting of pedestrian crossing. Improper volumes of luminous flux density and luminance. Advertisements and devices causing glare or improper visual guidance of a driver.
Pedestrian	Geometrical visibility of a vehicle by a pedestrian	Restriction of visibility on pedestrian crossing from the point of view of a pedestrian: - permanent: trees, plants, posts, advertisements and other obstacles, road geometry, - temporary: vehicles parked directly before pedestrian crossing, bus stop.
	Main participant of pedestrian traffic	Using dark clothing. Improper perception of a traffic situation e.g. by children or the elderly. Lack of observing traffic regulations. Psychophysical state of a pedestrian.
Weather	Atmospheric conditions	Periods of rain, snow and fog occurrence.

All of the abovementioned factors can influence the final assessment of pedestrian crossing from the point of view of traffic safety criteria.

However, it should be emphasized that a decisive factor influencing pedestrian safety is the visibility volume of the figure of a pedestrian perceived by a driver of a vehicle approaching a conflict area – pedestrian crossing.

This factor is directly dependent on properly selected and designed lighting of pedestrian crossing. Ensuring proper observation conditions of the neighborhood of pedestrian crossing by drivers allows for noticing a pedestrian at a distance that will make it possible to react properly in a dangerous situation.

2. ASSESSMENT CRITERIA OF PEDESTRIAN CROSSING LIGHTING

Activities can be undertaken aiming at objective improvement of visibility, particularly at places that pedestrians should feel safe, that is on pedestrian crossings. Photometric researches on road infrastructure can contribute to the improvement of the state of safety. Establishing unified valuation criteria of the state of pedestrian crossings and designating key technical parameters can contribute to undertaking preventive measures. Recommendations exist [1,9] which can constitute the basis for creating assessment criteria of pedestrian crossing lighting. This subject was discussed, among others, in researches conducted in the USA [3,4] and in Europe [8,9].

Photometric parameters which should be taken into account when assessing the quality of pedestrian crossing lighting can be the following:

- Vertical luminous flux density in the axis of pedestrian crossing measured from the direction of vehicle's motion.
- Equal distribution of vertical luminous flux density along the axis of pedestrian crossing.
- Horizontal luminous flux density on pedestrian crossing and within waiting area.
- Luminance of the figure a pedestrian and background measured from the direction of a vehicle's motion.
- Contrast of the figure of a pedestrian and background.
- Visibility of a pedestrian on the crossing.
- Glare of a driver parameters on the road stretch before pedestrian crossing.
- Visual guidance of a driver on the road stretch before and after pedestrian crossing.

Because of the possibility of change in lighting conditions perceived by a vehicle driver when approaching pedestrian crossing, in the assessment we should take into account lighting features of the road on which pedestrian crossing is located. In particular, researches should be conducted on the road fragments directly adjacent to the assessed conflict zone (for instance 100m before and after pedestrian crossing).

3. FORMAL REQUIREMENTS FOR PEDESTRIAN CROSSING LIGHTING IN POLAND

In order to revise the current requirements concerning pedestrian crossing lighting, in the first place we should quote the regulations that were previously binding and which were withdrawn the moment European regulations were adopted.

Recommendations of the previously binding norm PN-76/E-02032 ” Lighting of Public Roads” [7] introduced in 1976 referred to assessment of lighting parameters on pedestrian crossings and were expressed by the value of average luminous flux density in the plane perpendicular to vehicle’s motion.

Below, there is a quotation from the norm PN-76/ E-02032 ” Lighting of Public Roads” Point 3.3. – Lighting of designated pedestrian crossings [7].

“On particularly dangerous pedestrian crossing lacking in traffic lights, pedestrians should be visible in the form of light figures against dark background of the road. To achieve this aim, average luminous flux density on vertical plane going through the axis of the crossing from the side of approaching vehicles at the height of 1m over the crossing expressed in lx, should be at least 50 times bigger than average luminance of the road at 50m before and after the crossing expressed in cd/m^2. This luminous flux density should not, however, in any case be smaller than 40lx, and its minimum value at any point of the crossing and the waiting area should not be smaller than 10lx (the waiting area should be considered as the pavement area constituting extension of the crossing by 1m). This requirement does not refer to pedestrian crossings on the roads whose luminance within 50m before and after the crossing equals at least $2cd/m^2$, and its equal distribution is in accordance with the requirements 3.1.1.

On all other pedestrian crossings, pedestrians should be visible in the form of dark figures against light background of the road. In order to achieve this aim, we should obtain the best possible lighting of the background (the road after the crossing) and the smallest possible lighting of vertical surface of a pedestrian from the side of approaching vehicles.”

Between the years 1997 – 2004, in Europe, the norm EN 13201 “Lighting of Roads” was designed and implemented. Full membership of Poland in European Union resulted in the fact that Polish Standardization Committee being a member of CEN/CENELEC was obliged to introduce European regulations into the set of Polish Norms.

Introduction of new European norm PN-EN 13201 under the act of 12 September 2002 “concerning standardization” results in the change of attitude towards the method of designing road lighting including the areas of pedestrian crossings. Application of the norm is voluntary, and the norm itself remains a standardization document which is not a legal act. The same act, simultaneously stipulates that the norm (among others, PN-EN 13201) can be called in legal regulations after its publication in the Polish language with parallel change of the status into legal regulation. Full text of the norm PN-EN 13201has not been published in the Polish language so far.

Designer of road lighting has therefore the freedom in applying the existing but not compulsory regulations of the norm. It should be emphasized that the norm (despite not being a compulsory act) appears in the design guidelines for newly established road investments.

This fact may prove the existence of demand for precise design guidelines for street lighting including conflict zones and pedestrian crossings.

In Poland, since 2007 the road lighting norm PN-EN 13201:2007 [8] has been binding. The norm comprises the following elements:

- Technical report PKN-CEN/TR 13201-1:2007 Selection of lighting classes.
- PN-EN 13201-2:2007 Lighting requirements.
- PN-EN 13201-3:2007 Lighting calculations.
- PN-EN 13201-4:2007 Methods of measurement of lighting parameters.

It assumes different lighting conditions for conflict zones, including pedestrian crossings. Recommendations concerning luminance volume or luminous flux density are not uniform for each pedestrian crossing, which results from the assumed lighting class on a given road stretch stipulated when taking into account a series of road parameters, including conflict zones.

The present state of formal recommendations concerning lighting of pedestrian crossings has been described below in the quoted fragment of the norm PN-EN 13201:2007. Annex B (informative) Lighting of pedestrian crossings [8].

"Pedestrian crossings can require special attention. In some countries norms 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."

SUMMARY

Realization of recommendations of the current norm within the range of selection of road lighting standard is connected with conduction of field research of as-built lighting. In practice this should mean application of luminance method for assessment of photometric features of a chosen road stretch, including pedestrian crossings. On the basis of luminance measurements, the contrast of human figure against the background can be determined, and

by applying computational methods, visibility from the perspective of a vehicle driver can be defined. Measurement tools are currently available which make it possible to measure precisely both luminous flux density and luminance. Thus, there are no obstacles to conducting research on lighting of road infrastructure. Lack of uniform requirements as for the method of conducting measurements and lighting parameter assessment on pedestrian crossing leads to situations in which lighting measurements are not conducted at all or they are conducted randomly.

The author of the present paper has been conducting research on lighting of pedestrian crossings. The issue presented above does not fully cover the whole spectrum of issues connected with pedestrian safety and lighting of pedestrian crossings. It constitutes a mere introduction into further research.

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WYBRANE ZAGADNIENIA OŚWIETLENIA PRZEJŚĆ DLA PIESZYCH

Streszczenie:

W Polsce na przestrzeni lat, niezmiennie dochodzi do dużej liczby wypadków z udziałem pieszych. Jedną z przyczyn tego stanu jest niewłaściwe oświetlenie stref konfliktowych przeznaczonych dla ruchu pieszego. Artykuł opisuje problematykę oświetlenia przejść dla pieszych. W niniejszym referacie zostały zaprezentowane wymogi formalne dotyczące oświetlenia przejść dla pieszych w ujęciu dotychczas stosowanych w Polsce norm. Przeprowadzona została analiza kryteriów przyjętych do oceny oświetlenia. Inwestycja w badania infrastruktury drogowej może przyczynić się do poprawy stanu bezpieczeństwa niechronionych użytkowników ruchu drogowego.

Słowa kluczowe: oświetlenie, przejście dla pieszych, luminancja, ocena, bezpieczeństwo pieszych.