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Visibility Estimation of Textile Warning Materials in the Pedestrian–Vehicle Arrangement

Abstract
This article presents the results of an investigation aimed at improving the visibility of road and street users. Within the scope of this investigation, the following research works have been carried out: the currently available options for applying fluorescent woven fabrics on warning clothing are considered; the casualty scale of pedestrian road-users is estimated; the light intensity in the pedestrian-vehicle arrangement is measured in actual road conditions, and the visibility of modern fluorescent textile fabrics used in warning clothing is assessed.

Key words: *textile warning materials, visibility estimation, warning clothing, fluorescent fabrics, pedestrian-vehicle arrangement, pedestrian road users.*

Introduction

Scientific research carried out in the last decade has enabled technologies to be developed to manufacture functional and interactive textile materials. Among others, these materials are applied in the warning-clothing manufacturing branch, for professional clothing produced with the aim of guaranteeing working safety. For example, firemen must be readily visible in dangerous conditions. Policemen and roadwork workers, who work in the roadway and its traffic lanes, use vests with fluorescent materials, which also ensure that they are visible during bad atmospheric conditions.

Pedestrian road users represent a great proportion of the objects moving on Polish roads. Their safety depends firstly on their visibility in the pedestrian-vehicle arrangement. Many drivers, including experienced ones, have problems while driving in conditions of limited visibility, for example at night, driving over mist-covered roads, and at twilight. In the above-mentioned conditions, the drivers' optical system requires more light to be reflected from objects located in front of the vehicle. This is especially critical for elder drivers. Scientific investigation into eyesight proved that a forty-year old person requires twice as much light to drive a vehicle than a twenty-year old person. These are the reasons why good visibility of the pedestrian road users is of utmost importance for their safety.

Police statistics inform us that fatal accidents to pedestrian road users are most often caused by the following circumstances:

- a lack or insufficient visibility of pedestrians in the conditions of limited visibility,
- drunken pedestrians on the road,
- faulty lighting-system in the car, including erroneously positioned headlights, dirty headlight glasses and dirty car windscreens,
- drunken drivers, and
- speed and mode of driving not adjusted to prevalent atmospheric conditions.

The use of warning clothing can increase the visibility of pedestrians under conditions of limited visibility. The outerwear generally used by pedestrian road users is most often manufactured from fabrics of dark colours. This is especially the case during autumn and winter, which are characterised by low light luminance coefficients. Warning clothing is mostly obtained by fitting standard clothing with systems of fluorescent stripes, suspension elements, and stickers. Unfortunately, such systems are practically not used, as they are not correlated with fashion trends. That is why progress is presently noticeable in the area of manufacturing technologies of new-generation fibres and textile fabrics, new processes for finishing products, and intelligent systems connected with both of them. The aim of these activities is to develop a new generation of warning clothes for general use, as well as to ensure its usability, comfort and attractive appearance.

Topical possibilities of applying modern technologies for designing and manufacturing warning clothing

Lighting woven fabrics as intelligent warning systems – Fibre Optic technology

At present, intensive scientific investigation has been conductedwith the aim of developing woven screens and fluorescent woven fabrics. The most advanced is a technology which uses polymer fibres as optical waveguides (the 'Fibre Optic' technology'). Lumitex Co., USA [1] and the scientific team of Professor Ali Harlin from Tampere, Finland. These are the most outstanding research centres who have mastered the above-mentioned technology [2, 3].

On the basis of this technology, Luminex Co. developed fluorescent woven fabrics, which among others have been applied in illuminated keyboards, illuminated cover straps, and illuminated matrices which enabled sign projection. All these products are characterised by the following features:

- elasticity similar to that of conventional woven fabrics,
- remote control system of lighting effects,
- long life-span,
- high durability and fastness,
- thickness similar to conventional woven fabrics,
- lack of noxious radiation, and
- lack of heat emission on the structure's surface.

The idea of functioning fluorescent woven fabrics, based on the 'Fibre Optic' technology patented by Lumitech Co., is presented in Figure 1. According to this technology, light is emitted through optical waveguide-fibres. Conventional fibres form the warp, whereas weft consists of optical waveguide-fibres which are introduced into the woven fabric during weaving. Compared to traditional waveguide-fibres (for example those used in telecommunication), the optical waveguide-fibres used for weaving fluorescent fabrics have characteristic in-

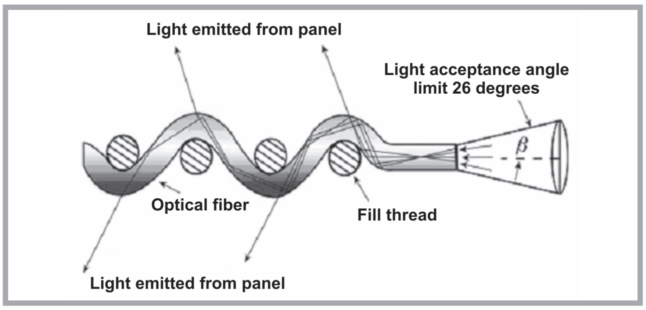

Figure 1. *Scheme of the idea of functioning of Lumitech fluorescent woven fabrics [1].*

cisions (orifices) along its length. These incisions enable the transmission of light which is also transversal to the longitudinal axis of the waveguide. Light-emitting diodes (LED) are most often the light source associated with the ends of optical waveguide-fibres.

Lumitech developed a multilayer panel with the aim of obtaining a uniform intensity of the light emitted from the fluorescent woven fabric's surface. The actual fluorescent woven fabrics manufactured according to the 'Fibre Optic' technology form the middle layers. The overlapping of many layers cause a higher uniformity of the intensity of light which is generated by such a package. A reflective layer manufactured from the laminate and the upper layer of pure vinyl forms the outer layers. The addition of these layers causes a defined direction of the light stream to be obtained, as well as an increase in resistance against mechanical loads.

Fluorescent woven fabrics may be applied in warning clothing for pedestrian road users, and can use light effects to signal the presence of users on the road, thus warning the drivers of the approaching vehicle.

While designing warning clothing, the following investigation problems and research tasks must be carried out:

- evaluating and optimising the visibility of the fluorescent woven fabric structure during different atmospheric conditions,
- solving the problem of light source supply within the system of the clothing used, and
- evaluating mechanical washing, ironing, and other resistances.

Passive textile reflective materials

At present, the newest generation of textile reflective materials used for protective clothing includes reflective material based on glass micro-balls and acrylic micro-prisms. Such materials are manufactured by 3M Polska Ltd [4, 5], among others. They are offered as tapes to be sewn on, and as foils for thermo-welding and gluing, and are intended for use in warning clothing of intensive visibility. Such materials should be placed on the outer side of correctly fastened clothing. Fluorescent paints have also been often applied in warning clothing.

Textile reflective materials on the basis of the glass micro-lens technology

The product of this technology is a kind of woven fabric covered by a layer of glass micro-lenses (Figure 2). Such reflective materials do not differ in appearance from conventional materials in daylight, whereas while illuminated by car headlights at night, they are 2,000 times more visible than a normal white woven fabric. A driver can see pedestrians dressed in clothing with reflective elements at a distance of even up to 300m.

The directions of the falling and reflected light beams are controlled by a precise geometrical system, which causes the light of the oncoming vehicle to be reflected from millions of glass micro-balls, and return to the source of emission.

Textile reflective materials on the basis of micro-prism technology

Micro-prismatic foils (Figure 3) are a reflective material of the newest generation based on micro-prism technology, a material characterised by a high area density of high-precision reflective prismatic micro-particles, up to 7,400 per square millimetre. The light falls subsequently on each of the three prism's surfaces, and comes back to its source which has generated the light stream.

Reflective dyes

The German enterprise Permalight AG has developed and patented a kind of pigment which, without changing the textile features of the material, creates the material's reflective properties based on the photoluminescence phenomenon [6]. This pigment has the ability to store daytime and artificial light, which can next be successively emitted in the form of yellow-green light. Very good annealed pulverised zinc sulphide, with the addition of some substances which serve as activators, is the main component of this pigment. The Permalight pigment can be applied to coat textiles.

Analysis of pedestrian road user casualties

Analysis of police statistics

According to statistics from the Polish Police Headquarters [7] the daily risk of collision for both the pedestrian and the driver is mainly connected with motion on weakly illuminated roads of poorly developed infrastructure. This is a problem not only in towns but also in village regions especially, where the road infrastructure, such as illuminated and isolated sections off footpaths, is insufficient. The scale of pedestrian road user casualties in Poland [7] is presented in Figure 4.

About 50,000-60,000 accidents are reported every year in Poland, which result in 5,000 fatalities and 70,000 injuries. Correctly-designed warning clothing,

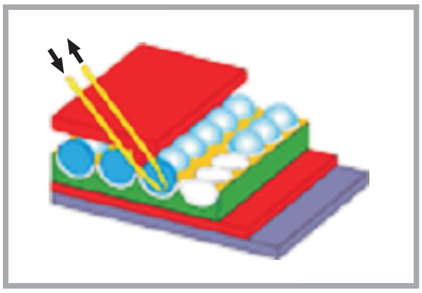

Figure 2. *A reflective material covered by a layer of glass micro-balls [5].*

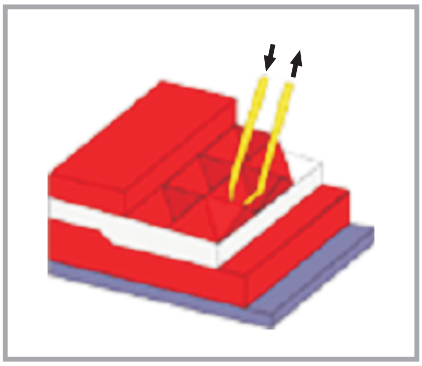

Figure 3. *A reflective material covered by a layer of micro-prisms [5].*

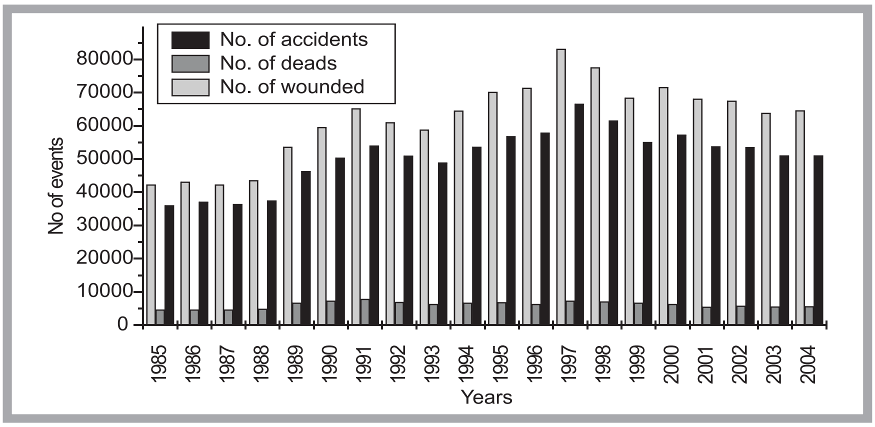

***Figure 4.** The scale of casualty of pedestrian road users in Poland between 1985 and 2004; **Source:** Polish Police Headquarters [7].*

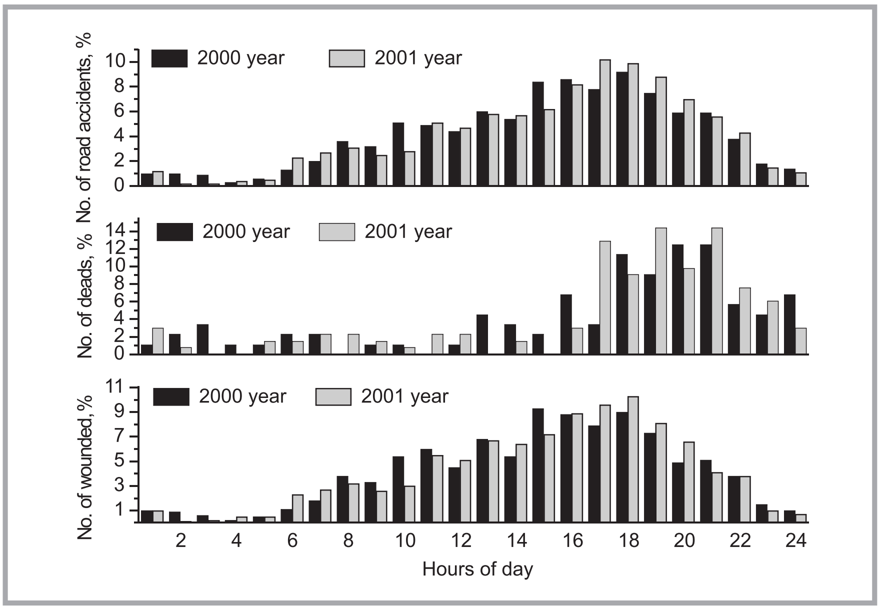

***Figure 5.** Daily distribution of the number of accidents, dead and injured persons over one year on the roads of the province of Łódź (Łódź voivodship); **Source:** Łódź Police Headquarters.*

which considers fashion trends, and most importantly is regularly worn would definitely reduce the participation of pedestrian road users in accidents.

Designing clothing which would consider current fashion trends requires the knowledge of the local climate, the time of day and the age of the users. These were the reasons why, in the scope of this investigation, pedestrian road user casualties were analysed in the light of the above-mentioned factors. The analysis was carried out on the basis of detailed statistics of accidents to pedestrians on roads in the province of Łódź, as made available by the Łódź-Police-Headquarters. The data covers the years 2000 and 2001 [8]. Taken into consideration the potential pedestrian users of warning clothing, dead and injured drivers as well as drunken pedestrians were excluded from the statistical data.

Daily distribution of the statistical data of road accidents

Figure 5 presents the daily distribution of the number of accidents, dead and injured persons over one year, for the years 2000 and 2001.

The distributions demonstrate that in 2000 and 2001, the greatest number of accidents took place in the early evening hours, when the visibility began to be limited, caused by the transition from dusk to night. The greatest percentage of deaths is found between 17:00 and 21:00. This demonstrates the great importance of warning systems which highlight the pedestrians under the conditions of dusk and night. At the same time, we can observe a relative low percentage of deaths within typical school-time, i.e. from 08:00 to 16:00. The number of persons injured in road accidents begins to increase from 07:00, i.e. when more and more pedestrians appear on the roads and streets on their way to school and work. The greatest percentage of injuries was found between 15:00 and 19:00.

Monthly distribution of the statistical data of road accidents

Figure 6 presents the number of accidents with the pedestrians' participation, dead and injured persons in each month of the years 2000 and 2001 in the province of Łódź.

An increase in the number of accidents, dead and injured persons was noted especially over the autumn and winter months. This is connected firstly with the heavy atmospheric conditions prevailing over this time period, as well as the early fall of dusk. However, it should be stated that a relatively high percentage of accidents with the participation of pedestrians also occurs over typical spring and summer months, when the atmospheric conditions are more advantageous than over the autumn-winter period.

Road accident statistics considering age brackets

Figure 7 presents the distribution of the number of persons involved in road accidents, and the number of dead and injured as a function of their age, over the years 2000 and 2001 in the province of Łódź.

Most often persons within the age range of 7 to 14 years and over 40 years of age were involved in accidents. The first group includes children up to secondary school age, and the second age group was divided into two groups: older people (from 40 to 59 years) and the elderly (over 60 years). From this it results that a need exists to design warning clothing aimed at children from 7 to 14 years and for persons over forty. Attention must be directed on the entirely different fashion expectations of people belonging to these three groups.

Summing up the police statistics, we can state that accidents with the greatest number of deaths and injuries occur in the afternoon hours. The months of the autumn and the winter period are the months during which an increase in

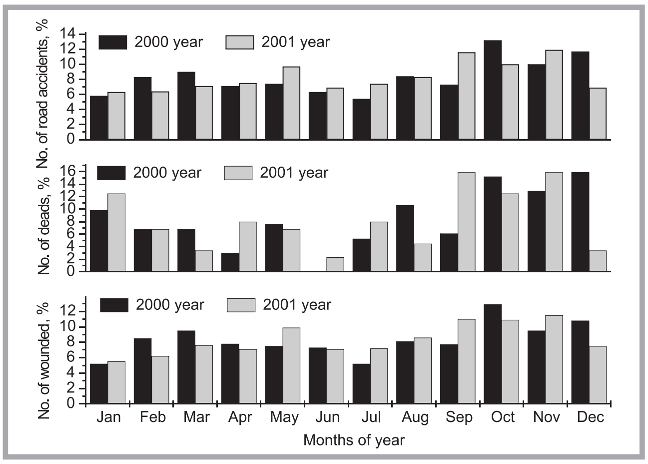

Figure 6. *The number of accidents on roads in the province of Łódź in which pedestriansare involved; the dead and injured persons in each month of 2000 and 2001;* ***Source:*** *Łódź Police Headquarters.*

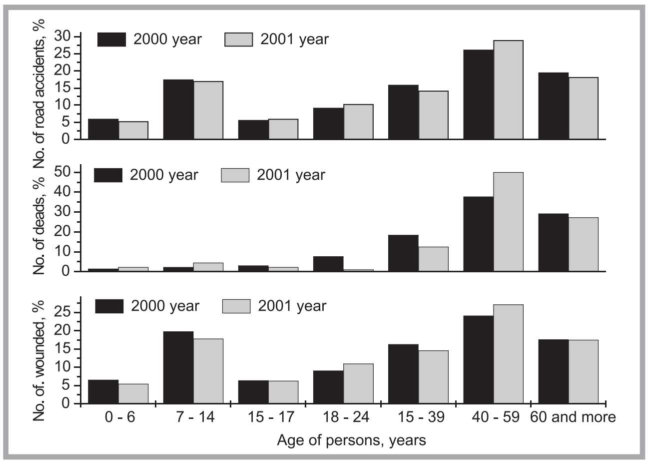

Figure 7. *Distribution of the number of persons which were involved in road accidents on roads of the province of Łódź; the number of dead and injured persons as a function of their age, over 2000 and 2001;* ***Source:*** *Łódź Police Headquarters.*

accidents and the number of deaths and injuries was noted. However, the percentage of accidents involving pedestrians in typical spring and summer months is also high. The greatest numbers of deaths and injuries are observed among children, older persons, and the elderly.

Medical reasons for the increase in casualties

The decrease in the pedestrian road users' visibility to drivers is the result not only of weather conditions but also of the disturbances of the eyes. In recent times, an immense increase has been observed of the proportion of the population suffering from sight defects, especially those who are short-sighted. As this tendency is observed firstly in developed countries, it can be stated with certainty that the following behaviours negatively influence the sight: the steady gaze at TV and computer monitors, too little physical movement, causing eye hypoxia; people working the whole day in artificial illumination (e.g. in supermarkets, offices, etc.); industrial air contamination; and a range of other stresses connected with the development of modern civilisation.

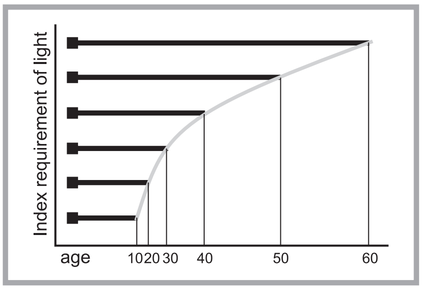

Figure 8. *Requirement of light in relation to human age.*

Scientific investigation proves that older drivers have significantly greater problems with perceiving objects under conditions of difficult visibility than drivers aged between 20 and 30. This causes a decrease in safety on roads, especially considering that, as has been calculated, the most numerous groups of population are those between the ages of 45 and 60. As can be seen from the graph in Figure 8, from the ages of ten to twenty, the amount of light required for good visibility increases steeply, and at the age of sixty it is about three times greater than at the age of thirty.

Method of assessing light intensity for the pedestrian-vehicle system under real road conditions

The design, optimisation, and estimation of a system of increased visibility of pedestrians on the road requires a knowledge of the actual light intensity distribution, i.e. the distribution of the light which falls on the pedestrian as a function of his distance from the vehicle.

The pedestrian who moves on the road's edge is illuminated by a light stream emitted from the car's headlights. The pedestrian's warning system consists of reflective materials with a surface of the total area A. Considering the driver's point of view, the visibility of the pedestrian is closely connected with the light intensity E, which falls on the surface A, and is a function of the distance s and the value A of the surface (Figure 9).

As the distance between the vehicle and the pedestrian decreases, the intensity of light falling on his surface increases to the maximum value, when the vehicle pulls level with him, and then suddenlys fall to zero value (Figure 10).

On the basis of the above-mentioned assumptions, a measuring system was developed which could measure the intensity of the light which falls on the surface of the pedestrian road user in relation to the distance between him and the vehicle. A functional block scheme is presented in Figure 11.

The illumination meter L_2 is matched with the pedestrian, and measures the intensity of light E which falls on his surface from the headlights of the car moving at a constant velocity of v. The light intensity measurements resulting as a function of time E(t) are transmitted to a recorder equipped with an analog-digital transducer and then stored in memory.

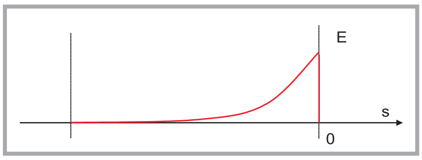

Figure 10. *Dependency of the intensity of light which falls on the pedestrian, in relation to the distance between vehicle and pedestrian.*

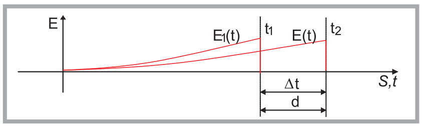

Figure 12. *Light intensity recorded by the optical gauche of the sender and the measuring illumination meter.*

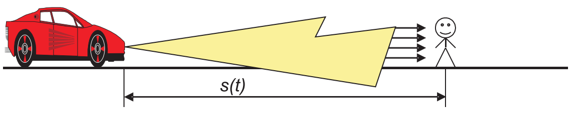

Figure 9.

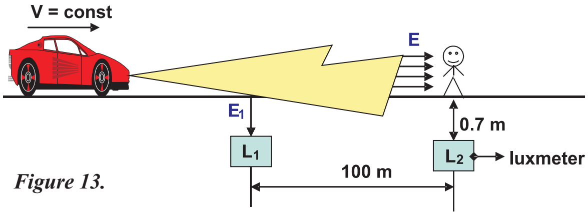

Figure 13.

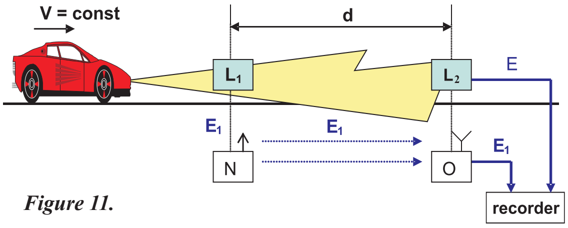

Figure 11.

Figure 9. *Scheme of the pedestrian – vehicle system; E – light intensity, A – area of the passive warning system, s – distance between the car and the pedestrian.*

Figure 11. *Functional block scheme of a measuring system for assessing the intensity the light which falls on the pedestrian from the vehicle's headlights; N – radio sender equipped with an auxiliary illumination meter L_1, O – radio receiver, L_2 – illumination meter, d – distance between sender and receiver, E – light intensity, E_1 – light intensity of the auxiliary measuring system, v –vehicle velocity.*

Figure 13. *Scheme of the measuring system for assessment light intensity with distance indication; L_1 - auxiliary illumination meter, L_2 – measuring illumination meter, E – light intensity, E_1 – light intensity of the auxiliary measuring system, v – car velocity.*

With the intention of estimating the intensity of light falling on the pedestrian as a function of the road distance E(s), an auxiliary measuring system was designed which included the illumination meter L_1, the radio sender, and the radio receiver. The goal of this system was to measure the time Δt, i.e. the crossing time of the vehicle between the illumination meter L_1, and the illumination meter L_2 matched with the pedestrian and placed at the distance d from L_1 (Figure 12).

The distance which permits pedestrians to be seen is within the range of 400 to 500 m. However, to determine the precise time Δt , the illumination meter L_1 was placed at a distance of 100 m from the pedestrian. This distance did not permit the signals to eb transmitted by cable, and so a telemetric link was applied. The decay of the light intensity over the time t_1 (Figure 12), which indicates when the vehicle palls level with the auxiliary illumination meter L_1, causes the decay of the standard signal, which modulates the carrier frequency of the sender.

A standard signal in the form of a rectangular wave with a frequency of 1,000 Hz was used for this solution. Thus, the same reaction will occur at the radio receiver output, which is matched with the analogue input of the A/C transducer connected to the recorder. Recording this signal at the same time as the intensity of light E which falls on the pedestrian enables the time Δt to be measured. Assuming a constant velocity of the vehicle, the time-dependence of light intensity E(t) can be scaled as a function of the road distance s from the equation

$$E(s) = E\left(t \cdot \frac{d}{\Delta t}\right)$$

Assessing light intensity in the pedestrian-vehicle arrangement under real conditions

Test assessments

The method developed was used during the next stages of this investigation to assess the light intensity in the pedestrian-vehicle arrangement under real conditions. The distances of the apparatus arrangement are presented in Figure 13.

To test the real distribution of light intensity as a function of the road distance E = f(s) between the vehicle and the pedestrian, the following conditions were assumed:

- the illumination meter L_2, which measures the light intensity on the surface of the pedestrian road user,

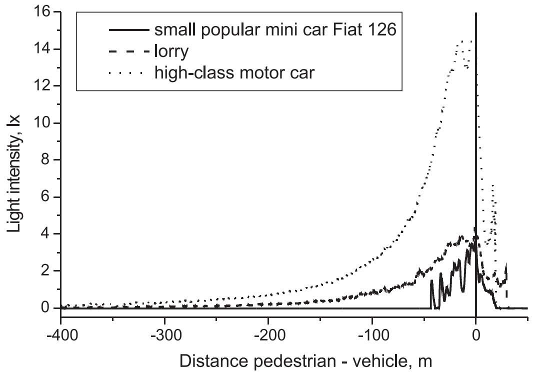

Figure 14. *Light intensity measured as a function of the road distance pedestrian-vehicle.*

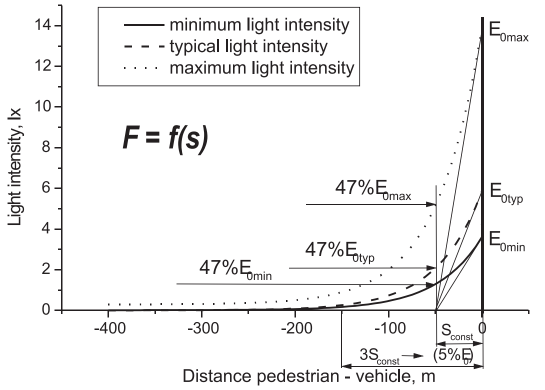

Figure 15. *Approximation functions E = f(s) of light intensity vs. distance pedestrian-vehicle.*

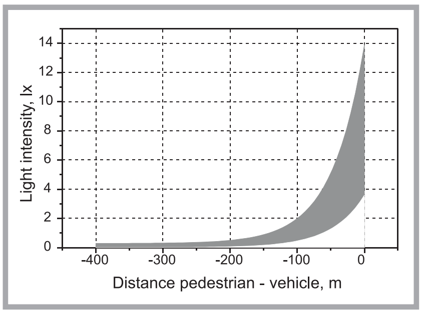

Figure 16. *Area of the light intensity distribution under real conditions as a function of the road distance.*

is placed at a distance of 0.7m on the roadway, as the hard shoulder generally is 1m wide, and the pedestrian always walks either in the middle of the hard shoulder or at its right edge;

- the auxiliary illumination meter L_1, which serves for standardising light intensity in the function of road distance, is placed at a distance of 100 m from the possible position of the pedestrian;
- 100% atmospheric visibility, without any limitations caused by atmospheric conditions; and
- vehicles moving with road lights, and with constant velocity, characteristic of travel outside built-up areas.

Test results

As an example, Figure 14 presents typical characteristic dependencies of light intensity as a function of road distance, recorded with the use of the method described above. The dependencies were recorded for the Fiat 126P (a small popular mini car), a lorry, and a high-class motor car.

A very great differentiation of the light intensity can be observed depending on the type of vehicle. Maximum light intensities within the range of 3.6 lx to 13.6 lx were noted on the line when the vehicle pulls level with the pedestrian. The measurements demonstrated that the effectiveness of warning clothing would also depend on the technical condition of the vehicle's illumination systems.

Experimental model

An approximation of the results obtained was carried out with the aim of obtaining a functional light intensity distribution in the pedestrian-vehicle arrangement. A constant vehicle velocity and the following model form were assumed:

$$E(s) = E_0 \exp\left(\frac{s}{S_{const}}\right)$$

where:

E_0 – maximum light intensity of the light falling on the pedestrian at $s = 0$, in lx;
s – road distance, in m; and
S_{const} – road distance constant, in m.

The road distance constant is a constant which characterises the car's illumination system. Figure 15 presents the approximation function runs for the maximum recorded light intensity distribution $E_{max} = f(s)$, the typical $E_{typ} = f(s)$, which considers all test results obtained in the approximation process, and the minimum $E_{min} = f(s)$.

The following forms of the approximation functions were established:

- maximum light intensity:

$$E_{\max}(s) = 13{,}62 \exp\left(\frac{s}{48{,}26}\right),$$

- typical light intensity:

$$E_{typ}(s) = 5{,}86 \exp\left(\frac{s}{48{,}26}\right),$$

- minimum light intensity:

$$E_{\min}(s) = 3{,}59 \exp\left(\frac{s}{48{,}26}\right).$$

The road distance constant equals about 50 m. At the distance of the road distance constant between the vehicle and the pedestrian, the intensity of the light which falls on the pedestrian is equal to 47% of the maximum intensity. At a distance of three road distance constants, i.e. 150 m, the intensity of the light which falls on the pedestrian falls to 5% of the maximum intensity.

The dependencies of the light intensities $E_{max}(s)$ and $E_{min}(s)$ form an area of possible light intensities as a function of the road distance which occur under real road conditions (Figure 16). Various light intensities on the pedestrian road users' surface may be assumed in relation to the efficiency of the car's illumination system. From this it results that the visibility of the pedestrians on the road depends not only on the quality of the warning system, but also on the quality of the illumination. The analysis carried out above indicates that a need exists to consider the light intensity distribution in the process of designing warning clothing.

Subjective visibility estimation of passive warning systems for different degrees of horizontal dusk/night visibility

A five-degree scale of estimation was elaborated for passive warning systems (Table 1). The particular estimations characterise the visibility of warning materials from the point of view of the vehicle's driver.

Table 1. *Visibility scale of passive warning systems.*

Visibility estimation degree	Visibility characterisation of passive warning systems
5	the whole reflecting element can be clearly identified
4	the whole reflecting element can be identified but is blurred
3	the reflecting element is visible, but without the shape of the reflecting area being precisely determined
2	point visibility; the shape of the reflecting element cannot be determined
1	reflecting element not visible

Table 2. *Characteristic of the samples used in tests.*

Sample number	Characteristic of the textile reflective materials
1	micro-prismatic tape, 2.5 cm wide
2	micro-prismatic tape, 5.0 cm wide
3	glass micro-balls foil, 1.2 cm wide
4	glass micro-balls foil, 1.8 cm wide
5	glass micro-balls foil, 5.0 cm wide
6	black tape 2.5 cm wide with glued glass micro-balls foil, 1.0 cm wide
7	black tape 4.0 cm wide with glued glass micro-balls foil, 2.5 cm wide
8	orange fluorescent tape, 5.0 cm wide with glued glass micro-balls foil, 2.0 cm wide
9	green fluorescent tape, 2.6 cm wide with glued glass micro-balls foil, 1.0 cm wide
10	green fluorescent tape, 10.0 cm wide with glued glass micro-balls foil, 2.5 cm wide
11	green fluorescent tape, 5.3 cm wide

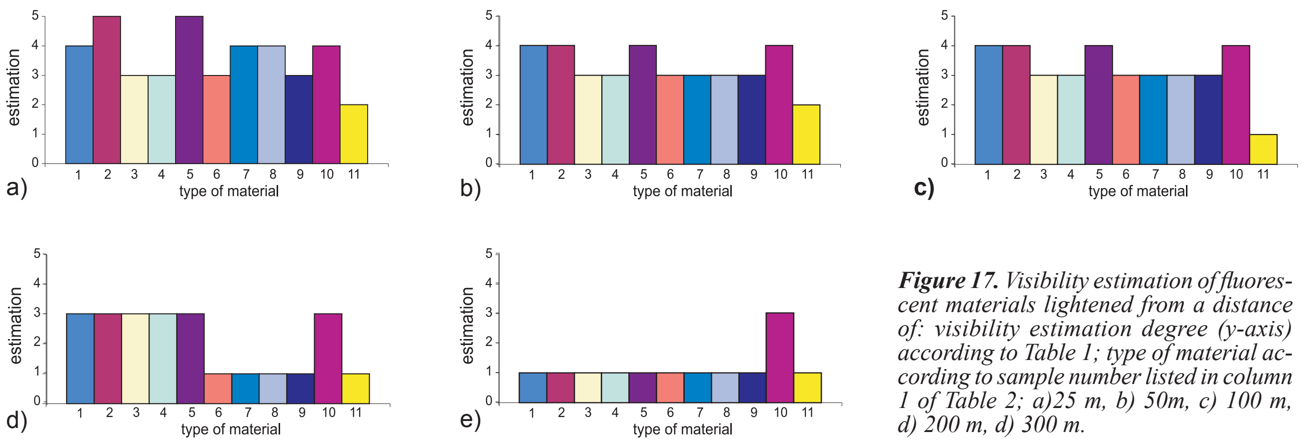

Figure 17. Visibility estimation of fluorescent materials lightened from a distance of: visibility estimation degree (y-axis) according to Table 1; type of material according to sample number listed in column 1 of Table 2; a)25 m, b) 50m, c) 100 m, d) 200 m, d) 300 m.

The visibility estimation of passive warning systems was carried out for 11 various samples of new generation fluorescent foils and tapes used for warning clothing, and made available by 3M Polska. Each sample was marked with a number given in Table 2. The tests were carried out for typical values of light intensity ($E_{typ}(s)$). Each sample was subjectively estimated by assigning a 'visibility estimation degree' according to Table 2; this was carried out by a group of six experts aged from 24 to 40, all of whom were regular car drivers. The tests were carried out under conditions of ideal horizontal visibility.

With the aim of comparing the visibility of the samples tested, the estimation results are listed in graphs for various distances from the light source. In Figures 17, the visibility estimation results of the fluorescent samples tested are shown for illumination distances of 25 m, 50 m, 100 m, 200 m, and 300 m.

At a road distance of 50m, all fluorescent materials of the new generation are visible. Sample No. 11, a conventional fluorescent material, has poor visibility, and from 100m is completely invisible. A very good solution for warning clothing is to join a fluorescent material of 10 cm width with a glued tape of glass micro-balls. This arrangement is readily visible over the whole tested range up to 300m. Unfortunately, fluorescent materials have limited application considering recent fashion trends. If designers could consider the neutrality of warning materials in relation to clothing, and at the same time secure an appropriate protection level, they should apply micro-prismatic tapes, or foils of glass micro-balls, which enable visibility up to 200m in front of the vehicle.

Conclusions

- Illuminated woven fabrics may be applied in warning clothing for the pedestrian road users, and their effects can signal the presence of the pedestrian on the road in front of the vehicle. Among other matters, the following research problems and tasks must be tackled while designing warning clothing: estimating and optimising the visibility of the structure of fabrics under conditions of varying visibility, solving the problem of the light source supply in the system of the clothing used, and estimating of mechanical resistance on washing and ironing.

- By analysing the report of the Łódź Police Headquarters on pedestrian road user casualties, it can be stated that a need exists to design warning clothing with increased visibility for the autumn-winter season, especially for age groups between 7 and 14 years and over 40 years.

- Scientific investigations prove that older drivers have significantly greater problems with perceiving objects under conditions of decreased visibility than do drivers aged between 20 and 30. This causes a decrease in the safety on roads. It was calculated that the most numerous age group is the group of people between 45 and 60 years. Beginning at the age of 20, the amount of light needed for good visibility under the conditions of dusk and night increases significantly every ten years.

- From the light intensity research tests in the pedestrian-vehicle arrangement which were carried out, it results that the intensity distribution as a function of road distance strongly depends on the technical conditions of the vehicle's illumination system. Under the same atmospheric and road conditions, maximum light intensities in the range from 3 lx to 14 lx were stated, depending on the type and state of the car.

- The estimation of the visibility of textile reflective (fluorescent) materials allows us to state that fluorescent materials manufactured on the basis of glass micro-balls have the best visibility. With the increase in the width of the tape, the visibility also increases. The worst visibility was observed for a conventional fluorescent material which was weakly visible, and only at a distance of 50m.

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