Journal of the Korean Institute of Illuminating and Electrical Installation Engineers Vol. 24, No.3, pp. 1~7 March 2010 24-3-1

An Assessment of the Disability Glare by the Road Lighting System Installed on Guardrails

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Abstract

To find an appropriate illuminance range for the disability glare caused by the road lighting system installed on guardrails, the influence of the disability glare was evaluated in comparison with the road lighting system of a streetlight. To test the disability glare, an indoor laboratory was constructed and a variation of luminance contrast threshold was evaluated. As a result, when the retinal illuminance was increased and glare sources existed within the narrow visual field, the luminance contrast threshold was increased. Although the road lighting luminaire was installed as low as the height of the guardrail on the road, when out of sight, the influence of the disability glare was small in comparison with the conventional road lighting system such as a streetlight.

Key Words : Disability Glare, Road Lighting System, Luminance Contrast Threshold

1. Introduction

If the luminaires with high luminance exist within a visual field at night, the scattering light in the eyes of drivers and a veiling luminance are increased [1]. Thus, disability glare and discomfort glare take place. Because of this, there are a decline of perceptive ability and an increase of visual discomfort. Also, the minimum threshold that is able to recognize a difference between background luminance and object luminance is increased [2].

The new road lighting luminaire, which will be installed in low mounting heights of the guardrail, is being developed at present. In this paper, to find out appropriate luminance for restricting the disability glare caused by the new road lighting system installed on guardrails, an experiment evaluating the influence of the disability glare was performed in comparison with the conventional road lighting system. A variation of luminance contrast threshold was evaluated according to the glare sources of different mounting heights and distances from the subjects.

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Date of submit : 2009. 9. 15
First assessment : 2009. 9. 17
Completion of assessment : 2010. 3. 8

2. Composition of Experiment

2.1 Structure of Laboratory

For the disability glare test, an indoor laboratory was constructed. Figure 1 indicates the structure of the laboratory. Figure 2 shows the pictures of the completed indoor laboratory and front screen, control room and inside of the experimental car.

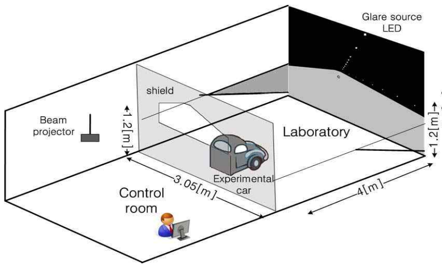


Fig. 1. The Structure of the Laboratory

Fig. 2. The Laboratory and Control Room

The installation spacing and mounting height of the conventional road lighting (pole type lighting) was assumed to respectively 40[m] and 12[m]. And the road lighting system installed on the guardrail was respectively 0.5[m] and 0.9[m]. Each position of the luminaires was projected to the front wall corresponding with the area of roads. As a simulated glare source, LEDs of 5W were installed at the relevant position. Each of the LEDs was turned on and off by operating the light switch.

2.2 Luminance of Simulated Glare Source

In CIE Publication 115, the threshold increment (TI) is recommended from 10 to 15 as the maximum permissible value to limit disability glare. In case of conventional road lighting, the TI value and veiling luminance can be calculated by using equation (1).

$$L_v = K\frac{E_e}{\theta^2},\ TI = \frac{k \cdot E_e}{L_{av}^{0.8} \cdot \theta^2}(\%) \tag{1}$$

Where Lv: veiling luminance of the observer [cd/m²], Ee: the retinal illuminance of the observer [lx], Lav: adaptive luminance [cd/m²], Θ: the angle between the observer and the luminaire [°] [3].

However, the road lighting, which is installed in a low position rather than the eye level of the driver, does not apply, because the angle between an observer and the luminaire is limited from 1.5[°] to 60[°]. And it is difficult to vary the veiling luminance from a simulated glare source. Consequently, when the TI is the maximum value of 10, the vertical illuminance on the retinal by conventional road lighting was calculated, and it was assumed to be within the variable range of retinal illuminance. The retinal illuminance of 6 levels, which was controlled by an LED operating voltage, was provided to subjects. And the luminance at that time was the veiling luminance.

2.3 The Randolt Ring for Perception of Form

In the psychophysical test which measures contrast sensitivity and disability glare, the Pelli-Robson Chart (PRC), which evaluates contrast sensitivity with the standard Randolt ring of a different contrast and appearance, is used [4]. Although for the PRC, luminance and glare conditions were significantly different from the other tests, we used it as a reference point because it had been proven to be a test with good reliability. It is an optotype-based test; the letter "C" of the PRC equals the Randolt ring.

In this experiment, the images of the Randolt ring, which have a different luminance contrast from 0.1 to 0.9, were provided. The Randolt ring had six openings in each direction. This is shown in Figure 3. When a subject was adapted to constant background luminance (1.5[cd/㎡], 0.75[cd/㎡]), the Randolt ring randomly appeared in the front.

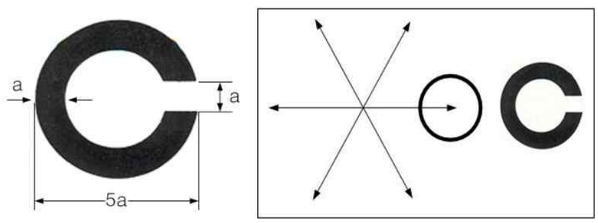


Fig. 3. The Randolt Ring for Perception of Form

2.4 Establishment of the Measuring System

Figure 4 shows the block diagram of the measuring system and the image for the experiment.

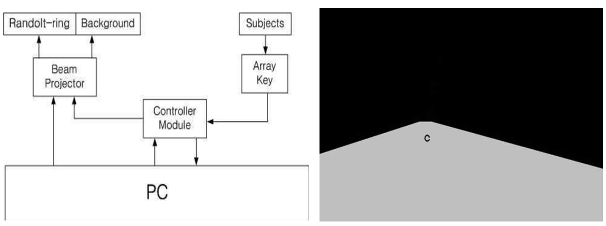


Fig. 4. Block Diagram of Measurement System and the Image of the Randolt Ring

The background luminance and Randolt ring appearance in compliance with two road lighting systems were produced with an image. They were shown as projected images from a beam projector on a large wall placed in front of the car. The program to record a perceptive accuracy and reaction time of subjects was made, and the controller to transmit a signal to a PC was made.

3. Experimental Method

3.1 The Subjects

Three male undergraduate students took part in the preliminary experiment, all in their 20's. In the main experiment, ten male undergraduate students were chosen for measuring perception. After analyzing the test results, if certain aspects had not appeared, it was scheduled to repeat the experiment with more subjects. They are the people who have a driver's license and use glasses or contact lenses to improve their corrected visual acuity more than 1.0.

3.2 The Procedure of Experiment

First, two subjects are visually adapted to a darkroom for 20 minutes, and one of them sits in the driver's seat. After the LEDs are lit up, an image of a road surface with different luminance and a Randolt ring with random openings is presented to the subject. As the subject perceives the opening direction of the Randolt ring, he pushes the button on a keypad corresponding with the direction of the opening. A signal is transmitted to a PC, and the program evaluates perception accuracy. If there is a wrong perception, the image of a Randolt ring with a higher contrast is presented. If there is correct perception, the test is stopped. Until the subject can accurately recognize it, the test condition is provided differently and the test is repeated. A luminance contrast threshold is produced from the luminance contrast of the moment when it is accurately perceived. Because a maximum value of TI was regarded, when a luminance contrast threshold which is identical with the situation of the conventional road lighting comes out, this retinal illuminance will be able to be considered as the maximum permissible value to limit the disability glare.

3.3 Conditions of the Test

The test conditions for the experiment are presented in Table 1. The parameters that are applied in the experiment are background luminance, visual field angle, and illuminance. There were a total of 204 kinds of conditions. Each subject performed 16 tests with a condition of no glare. A visual field angle is an angle between the subject and the luminaire; an angle of the luminaire located away from the subject is small.

4. An Analysis of the Results

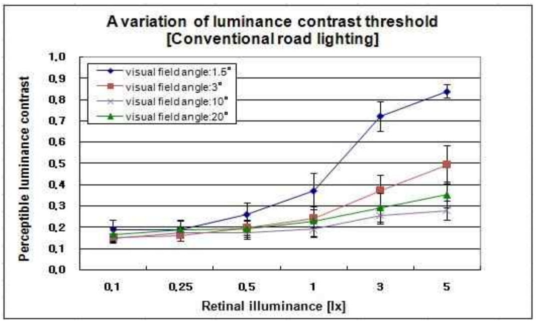
4.1 Results of the Experiment

The value of luminance contrast threshold was presented by using an arithmetic mean value from ten subjects. A luminance contrast threshold is the minimum luminance contrast that the subjects were able to recognize [5]. When a luminance contrast threshold is low, it means that the observer can easily recognize it. If all the results were shown on a graph, it would take up a great number of pages. So, the results which indicate remarkable aspects were presented with graphs.

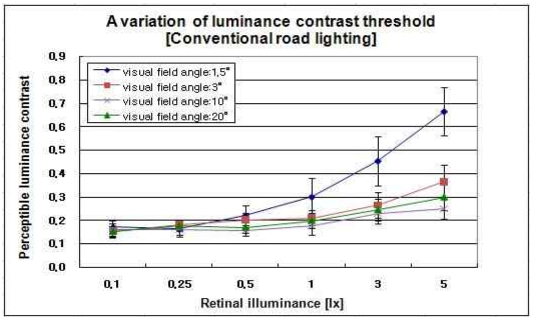
Figure 5 explains a variation of luminance contrast threshold according to the change of retinal illuminance. In general, the effect of glare will increase when the source luminance increases, the background luminance decreases, and the angle between the line of sight and direction of the light source decreases [6]. We know that as the retinal illuminance increases, perceptible luminance contrast

Table 1. The test conditions for the experiment

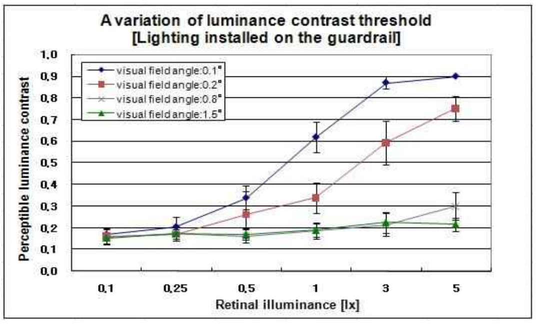
			Conventional road lighting		Road lighting installed on the guardrail	
Background luminance (Lb)	Luminance contrast (C)	Direction of opening	Visual field angle ([°])	Retinal illuminance (Ee)	Visual field angle ([°])	Retinal illuminance (Ee)
1.5	0.1-0.9 (an interval of 0.02)	6 directions	20	5	1.5	5
			10	3	1.3	3
			5	1	1	1
			4	0.5	0.8	0.5
0.75			3	0.25	0.6	0.25
			2.5	0.1	0.4	0.1
			2.2		0.2	
			2		0.1	
			1.5			



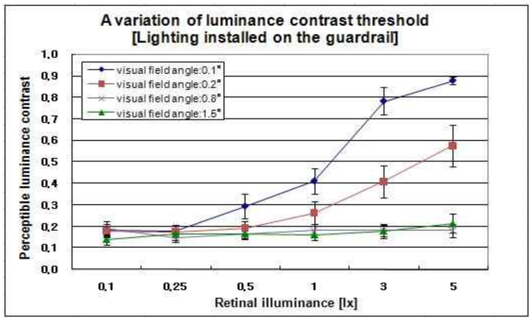
(a) Background luminance: 0.75[cd/㎡]



(b) Background luminance: 1.5[cd/㎡]



(c) Background luminance: 0.75[cd/㎡]



(d) Background luminance: 1.5[cd/㎡]

Fig. 5. Measured result of the main experiment - The effect of retinal illuminance

increases. Also, if same retinal illuminance was presented from identical glare sources, perceptible luminance contrast decreased when background luminance was high.

A variation of luminance contrast threshold according to the change of a visual field angle from simulated glare sources is explained in Figure 6. As a result of conventional road lighting, when the retinal illuminance was high, a variation of luminance contrast threshold was linearly varied with the decrease of visual field angle. However, when the road lighting was installed on the guardrail, a variation of luminance contrast threshold was not severe compared with conventional road lighting. A variation of luminance contrast threshold when the glare source of a different lighting system is located at the same location and only the mounting height is different is indicated in Figure 7.

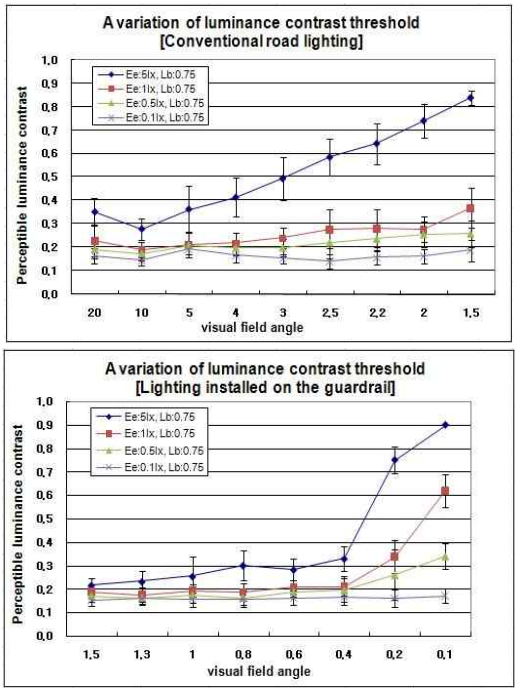
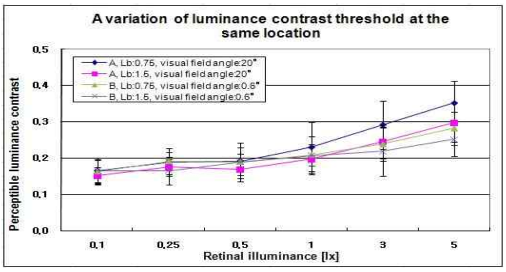
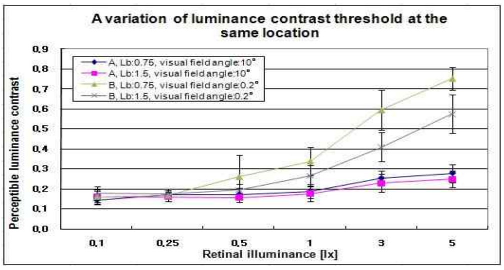


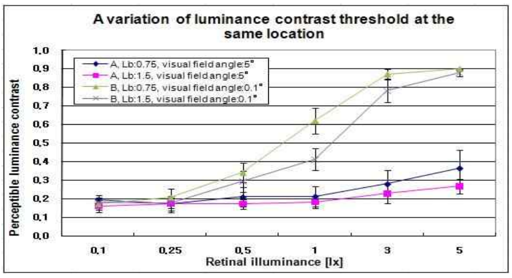
Fig. 6. Measured result of the main experiment - The effect of visual field angle



(a) Location of 29[m]



(b) Location of 69[m]



(c) Location of 109[m]

Fig. 7. The effect of retinal illuminance at the same location

The first luminaire was located 29[m] in front of the subject. This location corresponds with a 20[°] cut-angle indicated from the threshold increment. The visual angles of the simulated glare source, which are located at the same location, are 20[°], 10[°], and 5[°] in the case of a streetlight. And the visual angle corresponding with the road lighting luminaires installed on the guardrail are 0.6[°], 0.2[°], and 0.1[°]. The distances between the luminaire and the subject are exactly 29[m], 69[m], and 109[m].

A variation of luminance contrast threshold with a retinal illuminance at the same location was more severe in the case of the road lighting system. It is thought that the subject was affected by the glare, because the glare source was close to the visual field of the subject. But an influence of conventional road lighting at a close distance was more severe, because the road lighting installed on the guardrail was farther out of sight at the close distance in comparison with a streetlight. Table 2 indicates the retinal illuminance to restrain disability glare by the road lighting installed on the guardrail.

5. Conclusion

If the veiling luminance is equal to the range

Table 2. The retinal illuminance to restrain disability glare by the new road lighting system

Background luminance ([cd/m²])	Distance between the luminaire to the subject	Retinal illuminance	Luminance contrast threshold		Limited value
			Conventional road lighting system	Road lighting system installed on the guardrail	
0.75	Up to 69[m] from the observer	5[lx]	0.35	0.28	-
	From 69[m] to 109[m]	0.25[lx]	0.17	0.17	Below 0.25[lx]
	Above 109[m]	0.1[lx]	0.17	0.19	Below 0.1[lx]
1.5	Up to 69[m] from the observer	5[lx]	0.3	0.25	-
	From 69[m] to 109[m]	0.25[lx]	0.16	0.18	Maximum 0.25[lx]
	Above 109[m]	0.1[lx]	0.16	0.18	Maximum 0.1[lx]

within the visual field of a driver, the influence of the disability glare will be more severe when the glare source is low. Based on the results of the experiment, the retinal illuminance to restrain disability glare by the road lighting installed on guardrails was indicated in Table 2.

The results which were obtained by performing the test could be applied as data which establishes the optical performance of the road lighting system which is installed on guardrails alongside roads.

This work was supported by KOTI (The Korea Transport Institute), and the authors would like to thank them.

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Biography

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