A white-LED low-mounted luminaire using the all-positive-contrast-concept like car headlights

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Introduction

The semiconductor industry is providing more and more illumination technology by offering white LED light. In particular, high-flux emitters, deliver a higher level of illumination performance. For road lighting applications there are further benefits, such as the very long operating life (up to 60,000 hours) and the virtually maintenance-free operation.

The quality of the fixed road lighting installation is mainly influenced by the luminance pattern on the road surface. In addition, the ability to see the contrasts of critical objects is essential for safe night driving. Conventional bi-directional luminaries create an alternating contrast pattern (between the object and the road) that causes a reversal from positive to negative, which can make the object invisible. All-positive contrast lighting (as with car headlights) does not exhibit this reversal, making it suitable for use on one-way roads such as motorways and express roads.

A development effort was undertaken to address the following four criteria: (1) Safety: The luminaire system must provide a high visibility level at the distance required to bring a vehicle to a stop safely and at which car headlights cannot make the object visible to a sufficient degree. Furthermore, it must offer stringent control of the light intensity distribution in order to avoid disability glare. (2) The luminaire must offer a lower cost of ownership compared to conventional road lighting. (3) The source must have a minimized lamp flux and energy load used to create the high visibility in order to offer a superior reduction of light pollution. (4) Comfort: The luminaire must provide visual and optical guidance to render the course of the road, the edges of the road and other features.

A low-mounted luminaire was developed to meet these requirements and hence to offer an alternative road safety system, especially for dual carriageways.

Design

The design of the optics was based on an LED array. Optical elements have to be added to a LED-based luminaire in order to enable e.g. a sharp cut-off such as required from car headlights. To fulfill this glare control requirement, a collimator for each LED was designed to achieve a symmetrical beam pattern.

The white Luxeon emitter was chosen for the LED unit because each one will generate 20 lumens. Another desirable benefit was its spectral distribution, which gives a good colour rendering index of 70.

Evaluation

The illumination produced on the measuring screen below (as used in automotive lighting in according with ECE regulation no. 112) is used to evaluate the glare effect. Figure 1 shows the location of the relevant point B50L on the measuring screen (limited at 0.4 lx) and the beam pattern calculated using the optical design of one LED pole. The illuminance level at B50L is 0.41 lx.

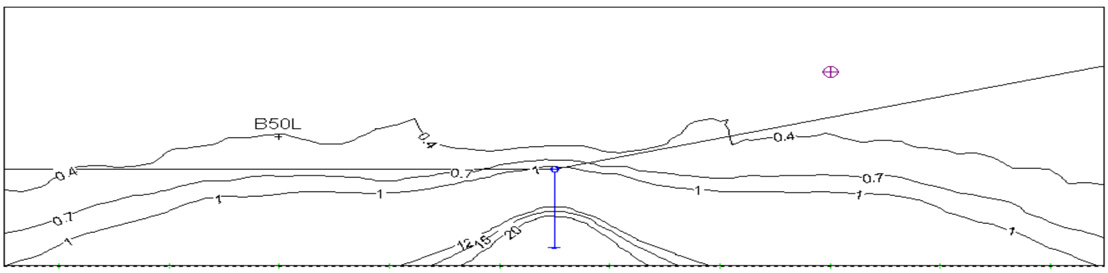

Figure 1 Screen for right-hand lane at a distance of 25 m and iso-lux contour distribution

The glare effect caused by a fixed low-mounted installation is estimated by using the threshold increment (TI) method according to prEN13201-3. It was carried out for the installation indicated in Figure 2. The average initial luminance of the CII road surface is 0.4 cd/m^2 and the initial equivalent veiling luminance is 0.17cd/m^2 (left-hand lane) and 0.11 cd/m^2 (right-hand lane) at a height of 1.5 m above the level of the road. With the data we obtain TI values ranging from 15 to 24. If the lighting level of the car headlights had also been included, the TI values would have been lower than 15 for the two lanes.

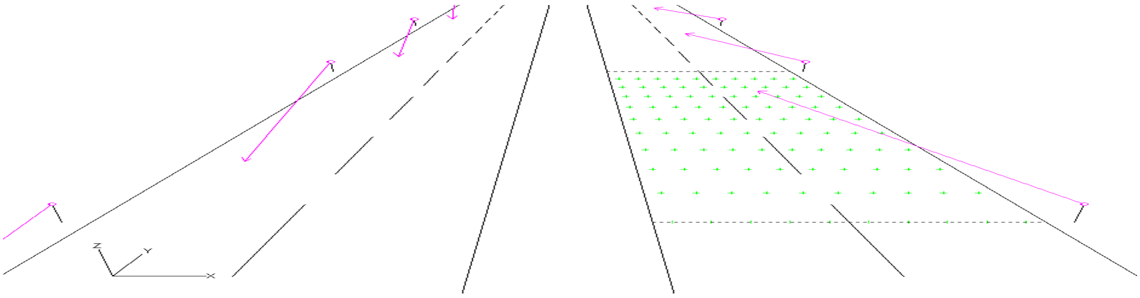

Figure 2 Opposite lighting arrangement mounted at a height of 0.8 on a dual carriageway, both sides 2 lanes each, 3.5 m wide, with pole spacing of 25 m

The visibility of objects is calculated by means of the visibility model described in CIE115 (and Adrian, 1989). A maintenance factor of 0.69 was found to be necessary for the low mounting height of 0.8 m causing a faster decrease of the luminaire dirt depreciation factor. The reflection table had to be extended by adding greater angles of light incidence (from the upward vertical). The reflected illuminance between the road surface and the object itself was not taken into account. As can be seen from Figure 3, the all-positive contrast lighting enables an excellent average minimum maintained visibility level of higher than 10.

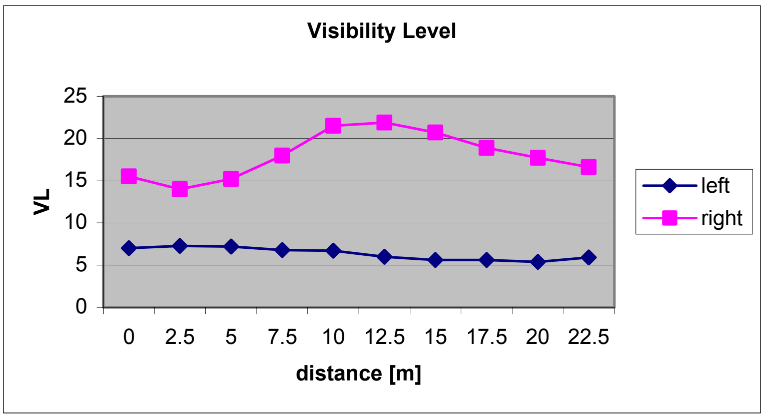

Figure 3 Computed small-target visibility levels (based on a flat square target with a side of 0.18 m and 20 per cent diffuse reflectance) for both lanes in the opposite arrangement

Compared to the lighting level requirements stated in prEN13201-2, the right-hand lane with an average luminance of above 0.3 cd/m^2 can provide sufficient visibility of the kerb side of the road against the surroundings as to offer visual guidance. Moreover, the possible retro reflective painting of the poles can improve guidance, too, especially in wet conditions when the road luminance becomes less uniform.

A conventional opposite road lighting arrangement for high-speed roads with separate carriageways normally delivers at least 805,590 downward lumens per kilometer. The pro beam lighting poles only deliver 31,900 lm per kilometer, which can reduce the reflected upward flux of the dual carriageway by a factor of 25.

Conclusion

The evaluation shows that the designed white LED luminaire can provide safe, fixed road lighting that can generate high visibility levels. Its pro beam lighting can exceed the visibility distances at which headlights reveal critical objects. In addition, it proves that light pollution can be minimized in the extreme while providing additional visual guidance to increase the degree of comfort for drivers, which can affect road safety as well.

References

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[2] *ECE* Regulation no. 112, 2001

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[5] *CIE* 66, Road Surfaces and Lighting, 1984

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