Relative method of measurement photometry data 
of road markings and road sign

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Abstract
Relative method of measuring retroreflective properties of road sign, road marking and
other retroreflecting materials is discussed. Description of two measuring units for testing
materials in laboratory conditions is given. Construction of units and possible errors of
measuring are described.

Keywords: Optical measurements, road markings, road sign, retroreflection

1. Introduction
Retroreflection properties of road surfaces and road markings $R_L$ at night illumination
(Russian standard GOST R 51256, ASTM E1710, DIN EN 1436) is equal to the ratio
luminance $L$ of a site of road marking to Illuminance on this site, created by a source of
radiation “$A$” type. Corners of illumination $1.34^\circ$ ($\varepsilon$ on Fig. 1) and observation $2.29^\circ$ ($\varepsilon+\alpha$ on
Fig. 1) corresponded a real situation on a road. Divergence of beams of a source of
illumination is made 20 minutes. Measurements will usually carry out by standard beforehand
calibrating devices. If measurements samples of road marking on laboratory equipment on a
technique specified standards are made, for increase of accuracy of measurement expeditiously
to lead calibration illuminance meter and luminance meter on this equip
ment too by reference
lamp of luminous intensity or reference illuminance meter.

2. Measuring method description
An illuminance meter is calibrated usually by a method of replacement and on it there is
the illuminance $E$ from source “$A$” type, as is used for determination of the coefficient of
retroreflective luminance (CRL) of road markings and road surfaces. Luminance meter is
calibrated with help of a photometer test plate with high reflectance and angle distribution of
radiation, close to Lambertian. More often is used milk glass MC20 with visual reflectance
$\rho=0.95 - 0.97$. The plate is put under a corner, close to normal to an illuminated surface and
on it there is the illuminance $E$. Luminance $L$ of a plate is equal $L = E\rho/\pi$, where $\rho$-reflectance
of a plate in a direction of observation. Knowing luminance, it is possible to count CRL of
this plate, as the illuminance $E$ on it is measured. It is equal $C_{\text{RL}} = 1000 \frac{E\rho}{E\pi} = 1000\rho/\pi$.
Here the multiplier 1000 is entered that the luminance would enter account in mkd, as it is
accepted for CRL instead of in kd, as in case of luminance meter calibration. By substituting
in the received formula $\rho=0.95$ we shall receive meaning $C_{\text{RL}} = 310 \text{ mkd/lx m}^2$. This
meaning is in the same limit of measurement, as more often measured samples of road
markings.

From here follows, that the measurement of CRL of a sample of road marking can be
made by comparison with measurement of a photometer test plate, i.e. is measured luminance
of a sample of road marking (readout n1), then on the same place a reflecting plate about
perpendicularly to a direction of illumination is put, as it luminance on the whole direction is
identical, and is measured it luminance (readout n2). Then CRL is equal $C_{\text{RL}} = 1000 \frac{\rho}{\pi}$
(n1/n2) or 318ρ (n1/n2). It is necessary to notice, that the readout n1 and n2 are as a rule on the same scale luminance meter, it reduces a common error of measurement. The final formula is entered by the ratio of readouts, therefore the absolute calibration luminance meter is not necessary, is not necessary also to have illuminance meter, as illuminance in the formula is reduced. The measuring value in this case is transferred by photometer test plate. Its reflectance can be measured by the usual way. For working devices the error of measurement reflectance is in limits 0,35-2 %. And to calibrate it is necessary only this plate, luminance meter is used as photometer of comparison and to it only good linearity of a scale of the device is required. Similarly the measurement can be made and on a highway in dark time of days. In this case the plate is put near road marking, the surface of marking is covered by headlights of the automobile and luminance meter readout from the plate and from a site of marking are removed consistently (Fig. 1). Such technique simplifies measurements and raises their accuracy. Similarly it is possible to measure CRL Qd at daytime illumination too. A plate is better to stay at 45° angle to direction of observation. All dimentions (Fig. 2) is shown in meters and it can be decreased in the same proportion for laboratory measuring unit.

![Fig. 1. Method of retroreflection luminance measurement: 1 – High sensitivity luminance meter; 2 – standard illumination source “A” – type; 3 - illuminating spot on the road; 4 – Illuminance meter 1 – 20 lx (diffuse photometer test plate in described relative method).](image)

If to measure retroreflective properties at a corner of fall, close to normal to a measuring surface, as it is done in case of measurement of retroreflection properties road sign, retroreflective materials and various labels of safety from retroreflecting materials (RPRM) the light flow, getting on luminance meter, will be about on three thousand times more, than in a considered above case of measurement of a sample of road marking. It will be well coordinated with the requirements Russian GOST 10807-78 (CEN, DIN and ASTM specifications also), where the dimension RPRM is resulted in kd/lx m², instead of in mkd/lx m², as in the previous case. Therefore for measurement RPRM this way approaches only then, when luminance meter has an opportunity to change the sensitivity on three thousand times about. When such opportunity is not present or the sensitivity luminance meter is insufficient for measurement of RPRM from a milk plate, expediently to find a sample with large luminance factor, which have reflecting mirror surfaces. Hence, for a good mirror RPRM can reach 37868 for divergence illuminating beam 20 minute and it is impossible to use as standard sample for calibration of the device without additional absorption [1]. RPRM of standard sample should be comparable to the top limit of a scale of measurement of existing really materials (up to 2000). It is possible in this case before a mirror to put additional optical filter or to use additional attenuator. It is necessary to take into account its selectivity in
visible area of a spectrum. Best transmittance of filter or attenuator measures on this equipment also.

We shall consider an opportunity of use for calibration sample a glass prism or wedge, in which the reflection occurs from one surface. Factor refraction of glass K8 on wavelength \( \lambda = 546 \text{nm} \) is equal \( n = 1.51829 \). Knowing it, it is possible to calculate reflectance from a forward side under the simplified formula of Fresnel for a case of normal fall of light: \( \rho = \frac{n_2 - n_1}{n_2 + n_1} \), where \( n_1 \) and \( n_2 \) – factors refraction of two environments, on border of which there is the reflection, in this case \( n_1 = 1 \), since first environment is air. Then we receives reflectance is equal 4.24%. Recognizing that \( \rho = \frac{E_2}{E_1} \), it is possible to calculate RPRM for a prism: \( k = 1605 \). This meaning quite satisfies to the necessary requirements for etalon sample. To work with a reflecting sample is much more difficult, as it is necessary to catch reflected beam. It is probably to make only on laboratory measuring unit. Such sample can be expediently to use only as calibration or testing one.

Luminance \( L \) can be measured by another way in this unit with confidence formula \( E = L \omega \). Illuminance \( E \) determined as flux through diaphragm before illuminance meter. Angle \( \omega \) determined as cosines ratio half diameter diaphragm to distance from diaphragm to measuring sample. From it other way of measurement of RPRM turns out. In this case for both measurement (\( E \) and \( L \)) it is enough to have only illuminance meter, and absolute calibration it is not required, it is necessary only to be had a linear dynamic range in limits of three orders. The measuring procedure will be simplified if we used precisely measured filter with visual transmittance about 0.001. In this case we do not change sensitivity of illuminance meter. Illuminance \( E_1 \) on the sample is measured with filter (readout \( n_1 \)) and then is measured \( E_2 \) without filter (readout \( n_2 \)). If the transmittance of filter is \( \tau \) we have the next formula for calculating RPRM \( k = 1605n_2\tau/n_1 \). An illuminating meter will be very simple in this case and not calibrated. We must precisely stand illuminating and viewing angles in this method so calculation of coefficient \( K \) was made for fixed angle. Therefore the spot size on sample is obtained by using calibrated diaphragm on it. If it is necessary to have another angle the new coefficient in formula calculated as it is made in [1]. A distance between illuminating source and sample must be fixed precisely also.

Diameter diaphragm referred to distance from a sample up to light source corresponds to a flat corner in 20 minutes. Are in such a way maintained demanded by standard angular requirements parity. The measuring unit turns out is very simple and does not require expensive luminance meter. Its lack is requirement to work in darkness. The error of measurement is determined by errors of removal of two readouts on illuminance meter and error of exhibiting of required corners. Last it is necessary to take into account, as a source of radiation in unit is not dot. Therefore it is desirable to test still measuring units by etalon sample.

The procedure of measuring became simplest if the same size diaphragm used before illuminating meter and near measuring sample. We shall notice, that in the above mentioned formula the meaning \( E_2 \) should be measured also in direct affinity from a sample, what rather difficulty to make, as illuminance meter blocks a falling beam. The Illuminance \( E_2 \) is more convenient for measuring in a place of a presence of a source, as it is stipulated by standards. Taking into account, that measuring sample is on distance \( R \) from a source, and the illuminance is measured on distance \( R \) from a sample, i.e. on 2\( R \) distance from a source, the illumination on distance 2\( R \) will fall in 4 times in comparison with illumination near a sample. Therefore in formula for \( k \) it is necessary to increase received value in 4 times, i.e. finally the formula of account for this purpose of a case accepts a kind \( k = 6420E_2/E_1 \), though the scale measuring meanings remains former i.e. up to 2000 and real meaning of RPRM of a prism or wedge as equally calculated earlier 1605.
Described ways of measurement RPRM and CRL allow to get from absolute measurements to relative, that much reduces an error of measurements. An error of absolute calibration of the worker luminance meter and illuminance meter according to the requirements Russian GOST 8.023-2003 makes about 10 % for each device, and the error of calibration of a plate from milk glass, as was specified above, does not exceed 2 %. In offered a way in a general in error of measurement does not enter an error of absolute calibration of devices, which much surpasses all other making errors of luminance meter and illuminance meter. In view of stated it is possible to make a conclusion, that in laboratory conditions for measurement RPRM expediently to use unit with only illuminance meter, for measurement of retroreflection lumiance CRL of road marking – unit with one luminance meter. In conditions of measurement on a road the most suitable way of measurement is by using one luminance meter and diffuse disseminating Lambertian sample.

3. Measuring unit

Requirements to Laboratory measuring unit using above described relative method is familiar as in a case of standard method of measuring retroreflected lumiance CRL. Dimention of relative method measuring unit is the same as in a case of using recomended method of measurements. It depends on lenght of room, where the unit is mounted. It is desirable to have a small lenght of unit for lessing lenght measuring sample, but there are few reasons not to decrease the lenght of unit. This require to choose illuminance source and luminace meter with small apertures (depends on angle \( \alpha = 0.95^\circ \) on Fig. 1), that decreases a distance to measuring sample or illuminating spot on the sample. If this demand is fulfilled, another demand must be take into account. An area of spot on the sample must be not less then 50 cm\(^2\). In any kind the distance must be not less approximatel 2-3m (Table 1). In relative method of measurement instead of illuminance meter (Fig. 1) used Photometer test plate and calibration of luminance meter is not needed.

Table 1. Possible main dimensions measuring units and samples with retroreflective properties.

<table>
<thead>
<tr>
<th>Distance, m</th>
<th>Height above road level, mm</th>
<th>Length of measuring spot l, m</th>
<th>Area of measuring spot, ( \text{cm}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1340</td>
<td>4,5</td>
<td>6750</td>
</tr>
<tr>
<td>3,8</td>
<td>152,5</td>
<td>0,58</td>
<td>128</td>
</tr>
<tr>
<td>1,82</td>
<td>72,3</td>
<td>0,27</td>
<td>28</td>
</tr>
</tbody>
</table>

The measuring unit has the next parts:
1. Small beam divergence illumination source with color temperature 2856 °C (“A” – type).
2. High sensitivity Luminance meter with observation angle 10 – 20 minutes and small aperture.
3. High reflectance factor Photometer test plate (\( \rho = 0.9 – 0.95 \)).

In a case of measuring RPRM unit is mounted on Photometry bench. Angle of illumination determined by diameter of diaphragm near sample and distance to it. According to standard demands it must be 20 minutes. Another demand is to have 20 minutes angle between illumination and observation directions, it is not permits to have big size of illuminance source and illuminance meter.
For example, if we used diaphragm 20 mm diameter (Fig. 2) the distance must be 3450 mm for 20 minutes angle, as standard is required. In this case the same illuminance meter can be used for measuring illuminance on the sample and luminance of the sample. Of course it must work in a dark room. The measuring unit is found very simple in this case. It consists of only illuminance source “A” – type, illuminance meter and two diaphragms. Illuminance meter is used here as comparison photometer and not require absolute calibration. A common error of it consist only errors of two readouts. Measuring value is proportional regular reflectance. If regular reflectance is equal 1, meaning RPRM is 37868. If take into account decreasing $E_2$ in 4 times as was said above for prism calculation formula will be $RPRM = \frac{151472}{n_2/n_1}$ where readouts $n_2$ and $n_1$ corresponds illuminances $E_2$ and $E_1$. If additional filter is used it transmittance $\tau$ put before $n_2$.

4. Conclusion
Relative method of measuring retroreflecting properties of different materials allows simplifying measurements and decreases errors of measurements. Instead of measuring absolute meaning of luminance and illuminance it is proposed to measure luminance factor of samples in a case of measuring road marking and regular reflectance in a case of measuring road sign and retroreflective properties of different labels of security. Results of these standard measurements can be calculated into retroreflecting coefficients in according to standards on these kinds of measurements.

References