Measurement of raised pavement marker's photometric performance

He Huayang¹, Leng Zhengwei², Xue Yingqi², Zhou Yishu¹*

¹Research Institute of Highway, Ministry of Transport, Beijing, China
²National Center of Metrization for Equipments of Roads and Bridges, Beijing, China
*Corresponding Author: ys.zhou@rioh.cn

Abstract. Large error exists in the photometric performance test of raised pavement marker. This paper reports a set of retroreflective measurement standard devices built to measure raised pavement markers based on the principle of direct measurement, and the photometric performance of the raised pavement markers was tested. The study also involved calibration of a portable meter using the standard device. According to the experimental comparison, the method proposed in this paper provides a new direction for the development of retroreflection measurement technology. The results measured by the proposed method showed high accuracy. This method can solve the large measurement error problems with indication errors of 2% at most.

1. Introduction

Raised pavement markers on roadways are mainly used to provide guidance to drivers as supplements to regular markings [1]. The basic performance of raised pavement markers is critical to road safety and mainly refers to photometric performance [2]. Photometric performance is usually quantified using the coefficient of luminous intensity [3]. The coefficient of luminous intensity is defined as the ratio of the reflected radiant or luminous flux to the incident flux within the narrow confines of incident and reflected geometrical conditions [4].

This paper proposed a photometric performance measurement method of raised pavement markers and calibration method for the portable retroreflectometer. General procedures for measuring the basic performance of raised pavement markers and retroreflective devices were described. Our own retroreflective device along with our measurements are presented, and we take advantage of these new measurements to extend the study of raised pavement markers and test methods.

2. Materials and Methods

Raised Pavement Marker. Raised pavement markers consist of small retroreflective structures, with many versions existing. A common type of retroreflective structure based solely on light reflection is the so-called cube corner reflector [5]. The cube corner reflector normally consists of three mutually perpendicular planar surfaces. This type of retroreflector can be mass fabricated by, for instance, embossing microprisms into polymers.

The photometric performance of raised pavement markers in the field of traffic safety refers to the coefficient of luminous intensity. The coefficient of luminous intensity is used to specify the performance of retroreflective devices. It considers the retroreflected luminous intensity as a function of the perpendicular illuminance incident on the device. The coefficient of luminous intensity can be
used to describe the performance of roadway delineators. White and yellow raised pavement markers were selected. The coefficients of luminous intensities were in the range of the requirements of GB/T 24725-2009 raised pavement markers. According to the different coefficients of luminous intensity, the raised pavement markers were divided into two levels. They are shown in Figure 1.

Experimental Devices. The experimental devices consist of a standard device and a portable raised pavement marker retroreflectometer.

The standard device involves a light projector source, a photometric scale, an observation angle positioner and a test specimen holder in a suitably darkened laboratory (as shown in Figure 2). The specimen center is 15 m away from the photometric scale entrance aperture. Black curtains and other means are used to eliminate stray light [6].

The raised pavement marker retroreflectometer (as shown in Figure 3) contains an internal light source and photoreceptors. It relies on the method of substitution calibration. The testing principle is the ratio method described in JT/T 690 test method for photometric characteristics of retroreflectors, which belongs to the class of indirect measurement methods.
**Experiments.** First, standard plates were calibrated with the standard system. The standard system simulates the use of the raised pavement marker. When a vehicle is driven at night, the car headlights illuminate the raised pavement markers on the road surface, and the light is reflected by the raised pavement markers and observed by the driver sitting in the vehicle (as shown in Figure 4). Second, a black plate was used to adjust the zero point of the raised pavement marker retroreflectometer. Then, the retroreflectometer was calibrated using the standard plates. Finally, under the geometrical condition specified in the tables below, the reference plate’s coefficient of luminous intensity was measured along the reference direction with the calibrated raised pavement marker retroreflectometer.

![Figure 3 Raised pavement marker retroreflectometer](image)

![Figure 4 Service process of the raised pavement marker](image)

### 3. Results and Discussion

Table 1 presents the measurement results of standard plate A obtained with the standard system. Table 2 and Table 3 present the average value, standard deviation and variance of standard plate A obtained with the standard system.

| Color | Geometric Conditions | Coefficient of Luminous Intensity [mcd/lx] |
|-------|----------------------|------------------------------------------|
|       | Observation Angle | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
| White | 0.2°                | 0° | 834.5 | 835.3 | 835.6 | 835.8 | 836.2 | 836 | 836.3 | 835.9 | 836.3 | 836.4 |
|       |                     | 20° | 530.1 | 530.6 | 530.6 | 530.5 | 530.5 | 530.7 | 530.8 | 531.1 | 530.8 |
|       |                     | -20° | 530.1 | 530.6 | 530.6 | 530.3 | 530.5 | 530.5 | 530.7 | 530.8 | 531.1 | 530.8 |
|       | 0.33°               | 5°  | 754.2 | 754.3 | 754.5 | 754.2 | 754.5 | 754.9 | 754.7 | 755.4 | 755 | 755.1 |
|       |                     | -5°  | 772.4 | 772.5 | 773 | 773.2 | 773.1 | 773.2 | 773.5 | 773.2 | 773.6 | 773.2 |
Table 2 Results of standard plate A (white) obtained with the standard system

| Observation Angle | Angle | Average Value | Standard Deviation | Variance | Minimum Requirement |
|-------------------|-------|---------------|--------------------|----------|---------------------|
| White had an average value of 835.83 mcd/lx at 0°, with a standard deviation of 0.58 and a variance of 0.34.
| Yellow had an average value of 321.97 mcd/lx at 0°, with a standard deviation of 0.51 and a variance of 0.26. |

Table 3 Results of standard plate A (yellow) obtained with the standard system

| Observation Angle | Angle | Average Value | Standard Deviation | Variance | Minimum Requirement |
|-------------------|-------|---------------|--------------------|----------|---------------------|
| Yellow had an average value of 321.97 mcd/lx at 0°, with a standard deviation of 0.51 and a variance of 0.26. |

Table 4 presents the measurement results of standard plate B obtained with the standard system and retroreflectometer.

| Observation Angle | Angle | Coefficient of Luminous Intensity [mcd/lx] |
|-------------------|-------|------------------------------------------|
| Standard System   |       |                                           |
| Retroreflectometer|       |                                           |

Table 4 Results of standard plate B obtained with the standard system and retroreflectometer

| Observation Angle | Angle | Standard System Level 2 | Standard System Level 1 | Retroreflectometer Level 2 | Retroreflectometer Level 1 | Indication Error |
|-------------------|-------|-------------------------|-------------------------|-----------------------------|-----------------------------|-----------------|
| White had a coefficient of luminous intensity of 657.8 mcd/lx at 0°, with a 0.50% indication error. |
| Angle  | Coefficient of Luminous Intensity | Standard Deviation (%) |
|-------|----------------------------------|------------------------|
| -20°  | 444.5 1364.5 449.9 1388         | 1.21% 1.72%            |
| 0.33° | 5° 673.6 744.7 670.7 731         | -0.43% -1.84%          |
|       | -5° 628.1 833.3 630.4 839        | 0.37% 0.68%            |
| 1°    | 10° 226.9 224.8                 | -0.93%                 |
|       | -10° 247 245.5                 | -0.61%                 |
| 2°    | 15° 13.8 13.8                   | 0.00%                  |
|       | -15° 13.7 13.7                 | 0.00%                  |
| Yellow| 0.2° 0° 283.2 747.2 283.5 750  | 0.11% 0.37%            |
|       | 20° 185 641.1 188.1 640         | 1.68% -0.17%           |
|       | -20° 185 641.1 185.6 644        | 0.32% 0.45%            |
| 0.33° | 5° 246.5 445.4 249.8 447        | 1.34% 0.36%            |
|       | -5° 240.5 459.9 239.4 464       | -0.46% 0.89%           |
| 1°    | 10° 74.2 74.6                   | 0.54%                  |
|       | -10° 74.3 74.3                  | 0.00%                  |
| 2°    | 15° 12.4 12.4                   | 0.00%                  |
|       | -15° 12.2 12.2                  | 0.00%                  |

The data from Table 1, Table 2 and Table 3 indicate that the standard deviation of the standard system when measuring the coefficient of luminous intensity is less than 0.6 mcd/lx. Obviously, the standard system has good measurement repeatability.

According to the requirements of JJG (traffic) 059-2004 retroreflectometer, the indication error of the retroreflectometer should be at most ±8%. The experimental results show that with the calibration method, the instrument has an indication error of less than ±2%. The calibration method can meet the requirements of the regulation.

4. Conclusion
This paper introduced a basic performance measurement method for raised pavement markers, for which a standard system was built. According to the experimental comparison, the method proposed in this paper provides a new direction for the development of retroreflection measurement technology. The results measured with the improved method have high accuracy. The method can solve the problem of large measurement error. The indication errors are at most 2%.

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