Calibration Scheme for Portable Retroreflectometers of Road Traffic Signs

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Abstract. Portable retroreflectometers are widely used for engineering measurements and are equipped with a set of work plates that are used to fit fitting curves and switch the working curve in the intrinsic software (self-calibration). The measuring principle employed is the substitution method. Therefore, the accuracy of the work plate values and curve-fitting ability of the internal software are important factors related to the accuracy of the instrument’s measurement results. A calibration scheme for portable retroreflectometers is proposed in this paper. This scheme not only considers calibration in the laboratory, but also on-site measurements. The work plate values can be obtained by a standard retroreflection measurement system, or by a matching portable retroreflectometer. When the work plate values are obtained through the matching instrument, a set of reference plate values must be obtained first. The reference plates, the color and coefficients of retroreflection of which are similar to those of the work plates, were calibrated by the standard retroreflection measurement system using the direct illuminance method. The reference plates were used to adjust the fitting curve in the internal software of the instrument. The work plates were then measured by the matching instrument to obtain a set of work plate values. The reference plates were measured by a self-calibration portable retroreflectometer, and the relative error between the instrument’s results and reference values was calculated.

Keywords: Calibration scheme; Road traffic sign; Portable retroreflectometer; Reference plate.

1. Introduction
Retroreflective materials are used to expand the legibility distance of road traffic signs at night [1]. Various researchers have studied the photometric characteristics of retroreflectors [2-6]. Shekuranec analyzed the importance of road traffic sign retroreflection measurements and provided guidelines for this type of measurement with examples of measurements conducted in Croatia [3]. Su analyzed a retroreflection vocabulary and testing system and computed photometric characteristics at different rotation angles [8]. Some standard retroreflection measurement systems were established to characterize photometric properties of retroreflectors [8,9].

Portable retroreflectometers are widely used for engineering measurements. The measuring principle of a portable retroreflectometer is the substitution method, which relies on work plates. A work plate’s color and coefficients of retroreflection should be similar to those of the measured object. The intrinsic software of a portable retroreflectometer fits a fitting curve between the work plate coefficient of retroreflection and the luminous flux measured by a photoreceptor through a black plate and work plate. The accuracy of the work plate coefficient of retroreflection and fitting curve are the key elements that affect the accuracy of measurement results. The author of Ref. [9] believed that the calibration
organization lacks a suitable scheme for calibrating a portable retroreflectometer, so the measurement results are affected or even distorted when the photometric characteristics of retroreflectors are evaluated. The aim of this study is to propose a suitable calibration scheme for portable retroreflectometers.

2. Reference Plates and Measuring Equipment
A typical reference plate consists of retroreflective sheeting and an aluminum plate. Class III retroreflective sheeting produced by Nikkalite was selected with colors of white, yellow, red, green, and blue (as shown in Fig. 1).

![Image of reference plates](image1)

**Figure 1.** Reference plates.

The measuring equipment included a standard retroreflection measurement system and a portable retroreflectometer. A standard retroreflection measurement system (as shown in Fig. 2) involves a light projector source, photometric scale, observation angle positioner, and test specimen holder in a darkened laboratory.

Portable retroreflectometers mainly contain an internal light source and a photoreceptor, and rely on the substitution method.

![Image of standard retroreflection measurement system](image2)

**Figure 2.** Standard retroreflection measurement system.

3. Calibration Scheme
A portable retroreflectometer is usually equipped with a set of work plates (as shown in Fig. 3), which are used to fit fitting curves and switch the working curve in the intrinsic software. Therefore, the intrinsic software and work plates should be calibrated.

First, the reference plates, the color and coefficients of retroreflection of which are similar to those of the work plates, were calibrated by the standard retroreflection measurement system using the direct illuminance method (these steps can be completed 6–12 months apart). The coefficient of retroreflection was measured three times under each geometric condition, and the average of the measurements was
taken as the standard value of the reference plate. Reference plates were used to adjust the fitting curves in the intrinsic software of the portable retroreflectometer in the calibration laboratory. Then, using the portable retroreflectometer, in accordance with the geometric conditions specified, the work plates were measured along the datum mark. Measurements were conducted three times for each geometric condition, and the average was taken as the coefficient of retroreflection of the work plates. The work plate coefficient of retroreflection can also be directly measured using the standard retroreflection measurement system since less uncertainty is necessary.

When the portable retroreflectometer was used to measure road traffic signs on site, the work plates were used to adjust the fitting curves, and thus, the object—when evaluating the portable retroreflectometer software—should be the combination of the portable retroreflectometer and matching work plates. The calibrated matching work plates were used to perform a self-calibration of the portable retroreflectometer. Based on the geometric conditions specified, the value of the reference plates were measured along the datum mark using the self-calibrated portable retroreflectometer. The relative errors between the reference plate standard coefficient of retroreflection and the measured value were calculated as the indication errors of the portable retroreflectometer.

![Portable retroreflectometer and work plates.](image)

**Figure 3.** Portable retroreflectometer and work plates.

### 4. Results

Experiments must be carried out under different geometric conditions. When measuring the coefficient of retroreflection of a road traffic sign, the observation angles include 0.2°, 0.5°, and 1°, and the entrance angles include −4°, 15°, and 30°.

Table 1 presents the measured values and nominal values of work plates. Fig. 4 presents the relative errors of the portable retroreflectometer measurement results.

**Table 1.** Measured values and nominal values of work plates.

| Geometric Conditions | Coefficient of Retroreflection (cd/lx/m²) | Measured Values | Nominal Values |
|----------------------|------------------------------------------|-----------------|----------------|
| Observation angle    | Entrance angle                           | White           | Yellow         | Red            | Green          | Blue           | White           | Yellow         | Red            | Green          | Blue           |
| 0.2°                 | -4°                                      | 285.8           | 208.0          | 61.0           | 62.5           | 36.3           | 310.2          | 255            | 67.8           | 68             | 39.1           |
5. Discussion and Conclusion
Several work plates were selected for measurement, and their measured and nominal values are shown in Table 1. The measurement results show that no work plate had the same coefficient of retroreflection as the nominal value, indicating that the work plate coefficients of retroreflection used by portable retroreflectometers are decaying.

Portable retroreflectometers are based on the substitution method, which relies on the use of work plates. Therefore, the work plates should be used to calibrate the portable retroreflectometers. The calibrated portable retroreflectometers can then be used to measure road traffic signs. Because of wear and tear during use and inappropriate storage conditions, the photometric characteristics of the work plates tend to change over time, and their coefficient of retroreflection cannot be guaranteed. The results measured with portable retroreflectometers produce large errors when the work plate values are incorrect. The traditional scheme does not focus on the accuracy of the work plate coefficient of retroreflection when they are used to calibrate the portable retroreflectometers. Instead, the scheme relies on the result of the last calibration, but ignores the attenuation of the work plates.

The results measured with the proposed scheme have high accuracy. Meanwhile, the scheme can reduce the measurement error. As shown in Figure 4, the relative errors are less than 2%. Calibration organizations can use this scheme to calibrate portable retroreflectometers.

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