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Research on Guarantee Technology of Measurement Accuracy of Pavement Damage Detection Equipment

Lu Liu¹,a, Genqiang Jing¹,b and Hongbo Guo¹,c

¹ Research Institute of Highway Ministry of Transport, People’s Republic of China, 8 Xitucheng Road, Beijing 10088

¹liulu@ncmerb.com, bgq.jing@rioh.com, c.hb.guo@rioh.com

Abstract. Whether the tests result of road damage rate is accurate or not, it is affected by many factors. The article describes the measurement standards developed for pavement damage detection equipment, including pavement damage measurement standard devices and pavement damage standard test blocks. The pavement damage measurement standard device detects pavement cracks through image recognition technology and measures its geometric parameters. The pavement damage standard test block simulates the pavement texture using engineering plastics, and then uses a laser engraving process to process typical pavement cracks to realistically reproduce the actual form of pavement cracks. The article gives a metrological traceability diagram of the amount of pavement damage detection equipment, and carries out repeatability tests and stability tests to verify the measurement standards.

1. Overview
Pavement breakage rate is one of the main technical parameters of pavement condition assessment, and it is also a key indicator to measure the level of pavement maintenance. The measurement of pavement damage is the basic requirement for the scientific analysis and assessment of the technical conditions of the highway. The pavement damage detection system is commonly used in the transportation industry. It has become an essential tool for the investigation and evaluation of the pavement network maintenance status in China. The accuracy of the measurement results is very important. For a long time, due to lack of enough attention on the measurement verification/calibration work of the pavement damage detection equipment, it still lacks the safeguard technical measures to judge the measurement accuracy, which causes the instrument and equipment manufacturers to have no fear that the equipment will be brought to the market without rigorous testing. It is a common phenomenon that the user departments buy the equipment blindly without effective means of evaluating the quality and accuracy of the value. This has created an embarrassing situation in the current field of pavement damage detection where "the quantity is not uniform and the credibility is poor". This article researches the assurance technology of measurement accuracy for the pavement damage detection equipment, an indispensable tool for the collection and processing of pavement damage information. It mainly includes: the development of measurement standard device, the research of the metrological traceability block diagram and the repeatability and stability test design.

2. Development of measurement standard device
The measurement standard device is the medium for metrological traceability of instrument and equipment, and it plays an extremely important role in the traceability of instrument and equipment. In order to trace the magnitude of surface damage detection equipment, a key standard device such as a
pavement damage measurement standard device and a pavement damage standard test piece was developed. Among them, the essence of the pavement damage measurement standard device is an image measuring instrument with a large surface area and the required measurement capability, which is used to accurately measure geometric parameters with irregular shapes. The standard device for pavement damage measurement achieves metrological traceability of the value through the upper level measurement standard. The pavement damage standard test piece is a type of measured object that can maintain the same value in a short period of time, and is used for the comparative measurement of the standard device and the equipment to be inspected.

2.1 Pavement damage measurement standard device
The digital camera imaging principle is used to develop a standard device for pavement damage measurement. The image recognition technology is used to detect pavement cracks and measure their geometric parameters. It can be used to accurate measurement of pavement damage standard specimens. Its essence is an image measuring instrument. However, compared with ordinary image measuring instruments, the main features are:

(1) Using linear array cameras to achieve linear scanning imaging, measuring large format;
(2) The measurement accuracy can meet the metrological traceability requirements of pavement damage detection equipment;
(3) Using active illumination under no interference conditions, the imaging conditions are not affected by the outside world;
(4) Using automatic image recognition technology, crack measurement is performed without artificial intervention.

The standard device for measuring pavement damage consists of a rack, lighting source, digital imaging module, transmission mechanism, computer image processing module, and display module, as shown in Figure 1. The main technical indicators are as follows:

(1) Resolution: not more than 0.2mm;
(2) Measurement range: not less than 500mm × 1000mm;
(3) Maximum allowable error in area measurement: ±1%.

![Figure 1. Pavement damage measurement standard device](image)

Explanation:
1 - transmission mechanism; 4 - digital imaging module;
2 - display module; 5 - rack;
3 - computer image processing module;
2.2 Pavement damage standard test block
The pavement damage standard test block (as shown in Figure 2) simulates the pavement texture with engineering plastics, and then uses a laser engraving process to process typical pavement cracks to realistically reproduce the actual shape of the pavement cracks. The standard test block has a certain degree of flexibility. When it is normally placed on the pavement, it can closely fit the pavement. The standard test block is used as the measurement object in the measurement process of the value transmission. It is first measured and assigned by the standard equipment for road damage measurement. Then it is placed on the test pavement and measured by the road damage detection system. After comparison, the metrological traceability of the standard device for measuring the pavement damage was traced.

The main technical indicators of the standard test block for pavement damage include:
(1) The area is not less than 1m × 1m and the thickness is not more than 3mm;
(2) The linear expansion coefficient is not more than 7×10^{-4} / °C;
(3) The standard test block should be surface-cleaved with clear scratches and no other scratches or stains that could affect recognition.

![Figure 2. Pavement damage standard test block](image)

3. Metrological traceability diagram
The standard device measures the value of the pavement damage standard test piece as a pavement damage reference value (standard value), and the equipment to be inspected compares the measured value of the pavement damage standard test piece with the reference value (standard value) to realize the metrological traceability. The meter included in this measurement standard includes three parts: a pavement damage measurement standard device, a pavement damage standard test block, and an auxiliary measuring instruments. The pavement damage measurement standard device is a measurement instrument that needs to be developed in this project, and is also the main standard device of this measurement standard. The metrological traceability relation of the value is shown in Figure 3.

In the figure, auxiliary measuring instruments refer to the universal measuring instruments used for measurement and traceability of vehicle-mounted pavement damage detection systems, such as steel rulers, steel tape measures, total station instruments for length measurement, and test boards for resolution testing. Auxiliary measuring instruments shall be traced to the national length reference by means of verification or calibration by means of a statutory metrological verification agency.
4. Repeatability test

The reproducibility of the measurement standard refers to the ability to repeat measurement of the same measurement under the same measurement conditions. The measurement standard provides the ability to display similar values and is used to characterize the dispersion of measurement results. Under repetitive conditions, n independent repeat measurements are performed on the regular certified or calibrated object using the measurement standard. If the obtained measurement result is \( x_i \) \((i = 1, n)\), the repeatability \( C_v \) is calculated by the following formula:

\[
C_v = \frac{S}{\bar{x}} \times 100\%
\]

In formula (1):

- \( C_v \) - The repeatability of the total pavement area damage measurement, \( m^2 \);
- \( S \) - The standard deviation of the total pavement area damage measurement, \( m^2 \);
- \( \bar{x} \) - The arithmetic average of the total pavement area measurement results, \( m^2 \).

At the temperature of 22°C, humidity of 43% RH, and illumination intensity of 322.3lx, the pavement crack measurement standard device was used to measure the crack area of two standard specimens with different fracture degrees for 10 times, taking the average of 10 results. Standard deviation, relative standard deviation and other data, as shown in Table 1.
Table 1. Repeatability test record table for standard device for pavement damage measurement

| Specimen number | Specimen A (transverse) | Specimen B (crack) |
|-----------------|-------------------------|--------------------|
| 1               | 0.2564                  | 0.4828             |
| 2               | 0.2565                  | 0.4832             |
| 3               | 0.2564                  | 0.4825             |
| 4               | 0.2568                  | 0.4826             |
| 5               | 0.2563                  | 0.4831             |
| 6               | 0.2561                  | 0.4825             |
| 7               | 0.2561                  | 0.4834             |
| 8               | 0.2565                  | 0.4828             |
| 9               | 0.2565                  | 0.4825             |
| 10              | 0.2560                  | 0.4830             |

Average value $\bar{x}$: 0.2564 0.4828

Standard deviation $s(\bar{x})$: 0.00023 0.00031

The relative standard deviation $C_v$: 0.08% 0.06%

Note: According to the regulations of JJG (Traffic) 077-2015, “The area of a single crack is calculated by multiplying the length of the crack by the width of the affected area by 0.2 m, and the area of the block-shaped cracks and cracks is calculated based on the circumscribed rectangular area of the damaged area along the direction of travel.”. Medium crack area is the result of this rule.

In the above table, the repetitiveness results of the standard device were taken from the larger of the two data sets as the standard device. The repeatability of the measurement standard device was: $C_v = 0.08\%$.

5. Stability test

Stability refers to the ability of a metrological standard device to maintain its metrological characteristics constant over time. It refers to the consistency of the measurement results obtained when a stable subject is measured within a specified time interval using the metrology standard. Therefore, the stability of the measurement standards is related to the length of the time period considered. Measurement standards are usually composed of metering standards and supporting device, So generally speaking, the stability of metering standards should include the stability of metering standards and the stability of supporting device.

According to the requirements of JJF 1033, a new measurement standard should generally undergo more than half a year's stability assessment to prove that the value of its recurrence is stable and reliable before it can apply for measurement standard assessment. For this purpose, it is necessary to make a set of n repeated measurements of the verification standard at regular intervals (greater than one month), and take the arithmetic average as the measurement result of the group. A total of m groups ($m \geq 4$) were observed. Take the difference between the maximum and minimum values in the
m measurement results as the stability of the new measurement standard over this time period. Starting from May 2015, a set of (10) tests are performed on standard specimens of two different fracture levels on a monthly basis using a pavement damage measurement standard device. Under the condition that the reproducibility requirements are met, average values are taken as the month. The results of the stability test \( (y_i) \) were observed for a total of 6 months. The results of the measurements are shown in Table 2. Because of the wide distribution of the area of standard specimens for pavement damage, in order to eliminate the effect of the area difference on the measurement stability of the standard device, the relative range was used to measure the stability of the standard device, is:

\[
RR = \frac{y_{\text{max}} - y_{\text{min}}}{\bar{y}}
\]  

Table 2. Stability test record table of standard device for pavement damage

| Standard test piece | Specimen A (transverse) | Specimen B (crack) |
|---------------------|------------------------|--------------------|
| 2015.05             | 0.2562                 | 0.4835             |
| 2015.06             | 0.2569                 | 0.4823             |
| 2015.07             | 0.2557                 | 0.4831             |
| 2015.08             | 0.2565                 | 0.4829             |
| 2015.09             | 0.2563                 | 0.4828             |
| 2015.10             | 0.2562                 | 0.4830             |
| Average value \( \bar{y} \) | 0.2563                 | 0.4829             |
| Range \( |y_{\text{max}} - y_{\text{min}}| \) | 0.0012                | 0.0012                |
| \( \frac{|y_{\text{max}} - y_{\text{min}}|}{\bar{y}} \) | 0.47%                  | 0.25%                |

Note: According to JJG (Traffic) 077-2015, "A single crack damage area is calculated by multiplying the crack length by the affected width by 0.2m, and the block cracks and crack damage areas are calculated according to the circumscribed rectangular area of the damaged area along the direction of travel", The crack area in the table is the result of this rule.

In the above table, the stability of the standard device is the result of the assessment of the stability of the standard device. The stability index of the standard device during the evaluation cycle is: \( RR = 0.47\% \).

6. Conclusions
The pavement damage detection system is a commonly used test and detection system in the transportation industry. Its core technology is the use of high-speed, high-resolution digital imaging technology. Under the normal driving conditions of the vehicle, the vehicle-mounted system can quickly obtain high-resolution images of the pavement, and process measure and count information on the area, type, and degree of damage to the pavement through post-processing software. Due to the complexity of its technical principles and implementation methods, the problem of measurement traceability has not been effectively solved for a long time, which has affected the reliability of
measurement data to a great extent, and the measurement accuracy of pavement damage detection equipment lacks guarantee technology. The project studied the standard device and metrological traceability method for vehicle-based pavement damage video detection system, and carried out repeatability and stability tests to verify the feasibility of the technical solution. The main conclusions are:

(1) The use of large-format image measurement systems is an effective technique to solve the problem of measuring irregular geometric quantities accurately.

(2) It is universally applicable to use pavement damage standard specimens as media for calibration of vehicle-mounted pavement damage video detection systems;

(3) The technical solution of this project can provide technical guarantee for the measurement accuracy of the pavement damage detection equipment.

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