Calibration Method and Measurement Uncertainty Evaluation of Static Deflection Indication Error for Bridge Deflection Measuring Instruments Based on the Height Caliper

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Abstract

Propose a calibration method for static deflection indication error of bridge deflection measuring instrument based on height caliper. Establish a measurement uncertainty evaluation model based on calibration methods and analyze the sources of uncertainty. Based on measurement examples, this paper elaborates on the calibration method and measurement uncertainty evaluation process of the static deflection indication error of the bridge deflection measuring instrument based on height caliper.

Keywords

Metrology; height caliper; bridge deflection measuring instrument; uncertainty in measurement

1. Introduction

Bridge deflection is the vertical displacement of a bridge structure under load, and is an important indicator for measuring bridge deformation and bearing capacity [1]. To accurately evaluate the stability and safety performance of bridge beam structural components, accurate and reliable measurement of bridge deflection is necessary [2]. Common methods for measuring bridge deflection include precision level measurement, connected pipe liquid level measurement, photoelectric measurement, differential GPS method, etc [3]. The photoelectric bridge deflection measuring instrument can measure the static deflection, dynamic deflection, forced vibration frequency, natural frequency, impact coefficient, lateral rotation angle, etc.

of the bridge beam, and is currently widely used [4]. To achieve the traceability of the measurement value of the bridge deflection measuring instrument, reference [3] designed a calibration device based on a grating ruler, which achieves the standard deflection value by controlling the up and down movement of the platform through a motor. The self-developed automatic calibration device for bridge deflection measurement instrument in reference [5] calibrates the vertical and horizontal deflection errors of a new type of non-target video bridge deflection instrument, providing reference for the calibration of bridge deflection instruments. Regarding the traceability of measurement values for bridge deflection measuring instruments, technical specifications [4] specify their measurement characteristics, mainly including longitudinal distance error, static deflection indication error, static deflection measurement variation coefficient, single point maximum dynamic deflection indication error, etc. However, the technical specifications lack analysis on measurement uncertainty. Therefore, this article proposes a calibration method based on a height caliper for the static deflection indication error of bridge deflection measuring instruments, and analyzes its measurement uncertainty to provide reference for related research.

2. Calibration method

According to the technical specification [4], a calibration device as shown in Figure 1 can be constructed to achieve the calibration of the static deflection indication error of the bridge deflection measuring instrument. The distance between the bridge deflection measuring instrument and the height caliper is D. According to the calibration requirements, D should meet 50m ± 10mm, and the target should be stably installed on the height caliper moving platform.

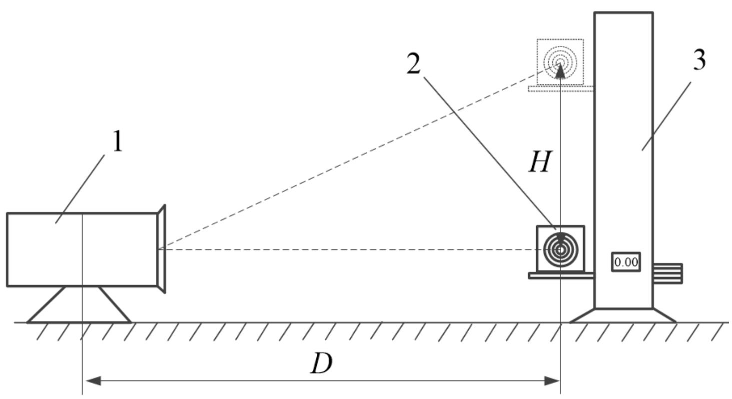

Figure 1. Schematic diagram of calibration method for bridge deflection instrument based on height caliper

1- bridge deflection instrument; 2- taget;3- height caliper

Before calibration, first turn on the deflection gauge and height ruler, move the target from the initial position to the measurement position, and the height ruler outputs the distance of the target movement, which is recorded as the deflection standard value H. Read the distance of the target movement on the deflection gauge and record it as the deflection measurement value h. Then, calculate the static deflection indication error d of the deflection gauge using the following formula

$$d = h - H \quad (1)$$

Where d is the static deflection indication error, h is the static deflection measurement value, H is the static deflection standard value.

3. Evaluation of measurement uncertainty

3.1. Measurement result

Under laboratory environmental conditions, calibrate the static deflection indication error of the deflection measuring instrument according to the above calibration method. The resolution of the calibrated deflection measuring instrument is 0.01mm, and the measurement range is ± (0~500) mm. The calibration process is shown in Figure 2.

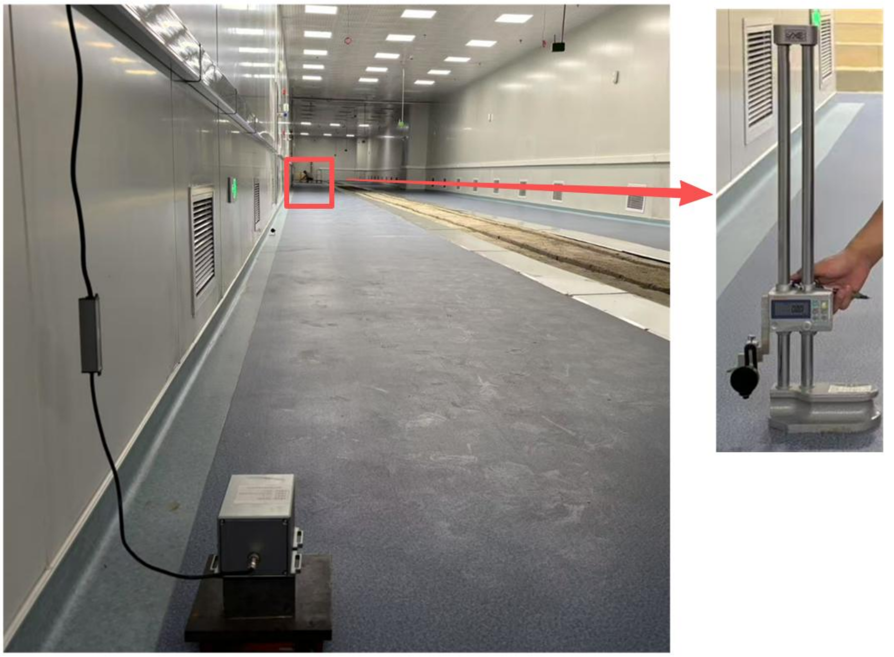

Figure 2. Schematic diagram of calibration process for static deflection indication error of deflection measuring instrument based on height capiler

3.2. Measurement model

The measurement model for the static deflection indication error of the deflection measuring instrument is shown in equation (1).Due to the non correlation between the measured deflection value h and the standard value H, the composite standard uncertainty uc(d) is [6]

$$u_c^2(d) = c_1^2 u^2(h) + c_2^2 u^2(H) \quad (2)$$

Where u(h) is the standard uncertainty introduced by the deflection measurement value, u(H) is the standard uncertainty introduced by the deflection standard value, and the sensitivity coefficients $c_1=1$ and $c_2=1$.

3.3. Sources of standard uncertainty

The sources of standard uncertainty components for the calibration results of the hydrostatic level indication errors are shown in Table 1.

Table 1. Source and explanation of standard uncertainty components in measurement results

ui(x)	Source of ui(x)	Evaluation method
u1(h)	Standard uncertainty components introduced by measurement repeatability	Type A
u2(h)	The standard uncertainty component introduced by the quantization error of instrument resolution	Type B
u1(H)	The standard uncertainty component introduced by height caliper error	Type B
u2(H)	The standard uncertainty component introduced by environmental temperature deviation of 20 ℃	Type B

3.4. Calculation of standard uncertainty

3.4.1. Calculation of $u_1(h)$

Under repeated measurement conditions, the static deflection indication error is measured 10 times and the standard deviation of a single experiment is calculated to be 0.01mm

$$u_1(h) = 0.01\text{mm} \tag{3}$$

3.4.2. Calculation of $u_2(h)$

The resolution of the bridge deflection instrument is 0.01 mm, and the half width of the interval is 0.005 mm, which follows a uniform distribution. Therefore, its standard uncertainty is

$$u_2(h) = 0.005\text{mm}/\sqrt{3} \approx 0.0029\text{mm} \tag{4}$$

The standard uncertainty of the repeatability estimation of the deflection instrument measurement in uncertainty assessment also reflects the influence of quantitative errors in digital display. Therefore, the larger of u1(h) and u2(h) is selected for calculation. The standard uncertainty introduced by the static deflection measurement value of the deflectometer

$$u(h) = u_1(h) = 0.01\text{mm} \tag{5}$$

3.4.3. Calculation of $u_1(H)$

According to the traceability certificate of the height caliper, the expanded uncertainty of its indication error is U=0.025mm, k=2. The uncertainty introduced by the height caliper error is

$$u_1(H) = 0.025\text{mm}/2 \approx 0.013\text{mm} \tag{6}$$

3.4.4. Calculation of u_2(H)

The deviation of environmental temperature from 20℃ mainly affects the displacement value of the height caliper. Assuming the thermal expansion coefficient of the height caliper column material is 11.5x10-6℃-1, and the maximum deviation from the ambient temperature of 20℃ is 10℃, the size change of the height caliper column is

$$\Delta H = 11.5 \times 10^{-6} ℃^{-1} \times 8℃ \times 500\text{mm} \approx 0.01\text{mm} \tag{7}$$

The uncertainty component introduced by the deviation of environmental temperature from 20℃

$$u_2(H) = 0.01\text{mm} \tag{8}$$

The synthesis of the above two items

$$u(H) = \sqrt{u_1^2(H) + u_2^2(H)} \approx 0.017\text{mm} \tag{9}$$

3.5. Combined standard uncertainty

Based on the above analysis, according to equation (2), the combined standard uncertainty uc(d) can be calculated as follows

$$u_c(\delta) = \sqrt{u^2(h) + u^2(H)} \approx 0.020\text{mm} \tag{10}$$

3.6. Expanded uncertainty

Take the inclusion factor k=2. Therefore, the expanded uncertainty of the static deflection indication error of the bridge deflection measuring instrument is

$$U = ku_c(\delta) = 2 \times 0.02\text{mm} = 0.04\text{mm} \tag{11}$$

4. Conclusion

Establish an evaluation model for measurement uncertainty based on the static deflection indication error of a bridge deflection measuring instrument based on a height caliper, and analyze the sources of various uncertainties. Based on measurement examples, this paper elaborates on the evaluation process of the measurement uncertainty of the static deflection indication error of the bridge deflection measuring instrument based on a height caliper, calculates its extended uncertainty, and provides reference for the evaluation of the measurement uncertainty of the static deflection indication error of the bridge deflection measuring instrument.

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