Research on Measuring Instrument of Bridge Building Bearing Capacity Based on Computer BIM Technology

Zhongqiang Tu1,∗

1School of Construction Management Jiangsu Vocational Institute of Architectural Technology, Xuzhou, Jiangsu, China, 221116

1Jiangsu Collaborative Innovation Center for Building Energy Saving an Construction Technology, Xuzhou, China, 221116

∗E-mail: choubuzhongjiang@163.com

Abstract. The deflection of a bridge structure is a comprehensive reflection of the operating state of the beam body, and is an important indicator of the bearing capacity of the structure. Especially after heavy loading and speed increase, in order to ensure driving safety, the engineering management department must grasp the change law of the deflection of the beam body in time. There is an urgent need for a measuring instrument that is simple to operate, fast to install, highly practical, and convenient for measuring beam deflection. Based on the comparison of the four commonly used methods for beam deflection measurement in China, a scheme for deflection measurement based on CCD imaging processing technology based on computer BIM technology is proposed, and a bridge deflection measuring instrument is developed for field use. The comparative experiment of on-site bridge deflection measurement proves that the error between the measurement results of the instrument and the measurement results of the bridge deflection special instrument is only 3.0% to 6.9%, which meets the engineering requirements.

Keywords: Deflection, Amplitude, CCD Imaging Processing

Bridge deflection is a comprehensive reflection of the operating status of bridge structures, the most important technical parameter for judging the vertical stiffness, structural bearing capacity and structural integrity of the bridge, and is an important indicator for bridge verification, dangerous bridge reconstruction and acceptance of new bridges [1-2]. After the sixth major speed increase of China's railways, the train's operating speed has been greatly improved. The speed of many existing bridges has greatly exceeded its original design speed. Whether the bridge structure can meet the requirements and equipment is needed. The management department does a lot of inspection and testing work in order to...
grasp the change of bridge deflection in time [1-4], so as to judge the use status of the bridge. Due to the large amount of testing tasks, it cannot be completed with traditional measurement methods [5-6]. For this reason, a measuring instrument that is simple to operate, fast to install, highly practical, and convenient to measure the deflection of the beam body is urgently needed on the site in order to provide a reliable guarantee for the safe operation of the train.

1. Deficiency of existing measurement methods

At present, there are four common methods for measuring bridge deflection:

1.1. Spring wire method

It is mainly used to measure the deflection of dry bridges and lower bridges. Generally, this method cannot be used to measure overpass bridges that have water under the bridge, are affected by railway or highway traffic, and bridges that cross canyons. Another weakness of this method is its low measurement accuracy and large error.

1.2. Inclinometer method

That is, the capacitance servo type inclinometer is connected with the digital integrator to measure the deflection curve of the bridge. This method is cumbersome to use and has high requirements for the quality of the measurement personnel. In addition, the phase difference between the inclinometers, the transient response time, and the effects of zero drift make the measurement accuracy difficult to grasp and not suitable for field use.

1.3. Laser target method

A monochromatic laser is used to aim the light target. When the train passes, the deflection of the bridge is measured according to the output voltage of the light target. This method is difficult to install and calibrate, and the resolution of the deflection is not high.

1.4. Camera measurement method

That is, the industrial camera and computer image processing technology are used to collect real-time image of the target installed in the beam, and the image data is processed by the computer to obtain the bridge dynamic deflection data and curve, and calculate the vibration technical parameters such as impact coefficient. The disadvantage of this method is that the equipment is large, inconvenient to install and use, and expensive, especially when the calibration is very complicated.

Through the above analysis, it can be seen that the existing four methods of bridge deflection measurement are all inadequate, and some of them have strong limitations. In order to meet the needs of ensuring railway safety after a large speed increase, it is urgent to develop new, convenient and scientific bridge deflection measuring instruments as soon as possible. Based on the investigation and considering the conditions of the site and the quality of the measurement personnel in the management department, the technical staff put forward a scheme of using CCD imaging technology to perform deflection measurement, and carried out the research and development of bridge deflection measurement instruments.
2. New system composition and working principle based on BIM technology

2.1. Composition of measurement system

The system consists of a CCD sight, a portable computer, a coded scale and a fixed base.

The fixed coding scale passes through the optical system to form an optical image on the photosensitive surface element of the CCD. The CCD device converts the light information on the photosensitive element into a charge amount proportional to the light intensity. The CCD is driven with a clock pulse of a certain frequency, and the video signal of the measured object is obtained at the output end of the CCD. The size of each discrete voltage signal in the video signal corresponds to the intensity of the light received by the photosensitive cell, and the timing of the signal output corresponds to the order of the position of the CCD photosensitive cell. After the binarization processing is performed on the video signal output by the CCD through a subsequent processing circuit, the measured object is separated from the background.

By calculating the width of the coded ruler image, and calculating the height reading of the fixed coded ruler according to the numerical calculation method of the ruler image and the coding principle, this data is the static deflection of the bridge.

By continuously acquiring and measuring multiple CCD images, calculating the height readings of the coded ruler under dynamic conditions, the dynamic deflection of the bridge is obtained.

2.2. Principle of CCD photoelectric measurement deflection

When the CCD optical system is aimed at the coding ruler, the optical axis of the system is aligned with a certain position of the ruler. The height of the ruler measured by CCD is \( H \). When the bridge vibrates, the ruler also vibrates up and down.

\[
\Delta H = H_1 - H
\]  

It is the dynamic deflection of the bridge.

Continuously capture and measure multiple CCD images, calculate the continuous deflection readings of the coding scale, and obtain the changes in bridge deflection over time and the interval frequency. The principle of deflection CCD photoelectric measurement is shown in Figure 1.

![Figure 1. Principle of photoelectric measurement of deflection CCD](image)
3. Main technical performance and parameters

3.1. Main technical performance

1) After aligning with the target, no calibration is needed, and the system can automatically perform functions such as detecting illumination and focusing.

2) The high-speed linear array CCD is adopted, and the sampling frequency can reach more than 200 Hz.

3) The coded scale is used. The scale does not require a power source, which is easy to operate and has a large measuring range.

4) According to the dynamic measurement value, the vibration curve can be drawn automatically, and the maximum deflection value and impact coefficient can be calculated.

5) The instrument can not only measure the deflection of the bridge, but also measure the arch and lateral amplitude of the bridge.

3.2. Main technical parameters

1) Measurement accuracy: not more than 0.5 mm.

2) Sampling frequency: 100 ～ 200 Hz.

3) Vibration frequency range: 0 ～ 20 Hz.

4) Amplitude resolution: not more than 0.1 mm.

5) Measuring distance: 2 ～ 70 m.

6) Amplitude measurement range: 0 to 150 mm.

7) Instrument weight: not more than 5 kg.

8) Features of the instrument

The instrument is small in size, light in weight, simple in operation, convenient to carry, and strong in practicality. When measuring the deflection of the beam body, the instrument can be placed on the ground or on the pier platform, and is not affected by train vibration, rivers, underpass roads and railways, etc. Impact.

4. Comparison and analysis of test results

4.1. Comparative analysis of measurement results

In order to verify whether the instrument meets the needs of on-site measurement, on April 13, 2016, the instrument was used in conjunction with the Beijing Railway Bureau Bridge Verification Team to make a comparative measurement of the mid-span deflection of the left beam of the fourth hole of the 12th bridge of the Fengsha Line. Table 1 shows the comparison between the data measured by the
instrument and the bridge inspection team. Figure 2 is a comparison of the measured deflection time-domain curves.

Table 1. Comparison table of mid-span deflection measurement data

| Test number | Locomotive model | Model | Speed/ (km • h⁻¹) | Bridge time | The instrument measures the disturbance value/mm | Bridge inspection team measure disturbance value/mm |
|-------------|------------------|-------|-------------------|-------------|-----------------------------------------------|-----------------------------------------------|
| 1           | 8K               | goods | 57                | 11:11       | 8.96                                          | 8.47                                          |
| 2           | 8K               | goods | 59                | 11:23       | 8.61                                          | 8.09                                          |
| 3           | 8K               | goods | 60                | 11:37       | 8.50                                          | 8.23                                          |
| 4           | DF4              | goods | 64                | 14:08       | 10.10                                         | 9.73                                          |
| 5           | 8K               | goods | 60                | 15:30       | 8.36                                          | 7.82                                          |
| 6           | DF4              | goods | 63                | 16:01       | 9.48                                          | 9.77                                          |

From the measurement results of the two measurement methods shown in Table 1, the error between the measurement results of the instrument and the special instrument for deflection of the bridge inspection team of Beijing Railway Bureau is between 3.0% and 6.9%, and the average deflection of the two test methods is different. 3.9%, which meets the engineering requirements; from the waveform diagrams of the deflections measured by the two (Figure 2), the time domain curves are quite consistent, and the deflections generated by the locomotive and the vehicle have a correct response on the waveforms, indicating that the instrument can meet Measurement requirements.
4.2. Comparison of working efficiency and required cost of two measurement methods

For the measurement of the deflection of a hole beam, using the conventional method of the bridge inspection team, measurement equipment such as displacement sensors, bridges, filters, collectors, calibration blocks, generators, vibration lines, and computers with processing software are required, and before the measurement, tents need to be set up and calibrated. Generally, 5 people need 3 hours to be ready. Because more measuring equipment is needed and the transition is difficult, it is inconvenient to perform multi-hole and multi-location measurements. Water or overpass bridges affected by railway and road traffic and bridges over canyons cannot be measured with this method. When using the "portable bridge deflection measuring instrument" to measure the bridge deflection, only two surveyors are needed. From the installation of the measuring scale and the installation and commissioning of the instrument, it can be completed in only 0.5 h by two people. In addition, the transition is particularly easy. Two people can measure at least 20 holes per day, which not only saves labor, labor and efficiency, but also guarantees personal safety.

5. Conclusion

The deflection measuring instrument uses CCD imaging technology based on BIM technology. By performing indoor performance tests and real bridge comparison tests on the instrument, it is explained that the error between the measurement results of the instrument and the measurement results of the bridge verification team using a dedicated deflection instrument is 3.0%. Between 6.9% and 6.9%, the average deflection of the two test methods is different, which meets the engineering requirements. At the same time, the instrument solves the shortcomings of the four commonly used measurement methods in the past, and can also measure bridges that cross the canyon with water under the bridge or that are affected by railway and highway traffic, and bridges that cross the canyon. In addition, the instrument can greatly improve work efficiency and reduce personnel, materials and a large amount of additional investment in the equipment management department.

Acknowledgments

Jiangsu Province Construction system Science and Technology Project in 2018: integrated Application of bim Technology in Integrated Management Corridor Construction and Operation and maintenance (2018 ZD 132).

Jiangsu Collaborative Innovation Center for Building Energy Saving an Construction Technology Project: Information Management of Building Firefighting Equipment Base on BIM(SJXTQ1604).

References

[1] Rana Acharyya, Arindam Dey, Bimlesh Kumar. Finite element and ANN-based prediction of bearing capacity of square footing resting on the crest of c - φ soil slope[J]. International Journal of Geotechnical Engineering, 2018(1):1-12.

[2] Behnam Atazadeh, Mohsen Kalantari, Abbas Rajabifard. Building Information Modelling for High-rise Land Administration[J]. Transactions in Gis, 2017, 21(1):91-113.

[3] Gregory J. Fisher, William James Qualls. A framework of interfirm open innovation: relationship
and knowledge-based perspectives[J]. Journal of Business & Industrial Marketing, 2018, 33(1):10-21.

[4] Ling Ma, Rafael Sacks, Uri Kattel. 3D Object Classification Using Geometric Features and Pairwise Relationships[J]. Computer - aided Civil & Infrastructure Engineering, 2018, 33(2):15-32.

[5] James Bogenberger, Clifford Whatcott, Nanna Hansen. Combined venetoclax and alvocidib in acute myeloid leukemia[J]. Oncotarget, 2017, 8(63) :110-125.

[6] Chanakya Boddupalli, Ayan Sadhu, Ehsan Rezazadeh Azar. Improved visualization of infrastructure monitoring data using building information modeling[J]. Structure and Infrastructure Engineering, 2019(4):1-17.