Research on the design and application of a monitoring device for bidirectional deformation cracks

Kai-ren Li, Shangyu Han and Yueming Li

School of Civil Engineering, Nanchang Hangkong University, Nanchang 330063, PR China.

Corresponding author: 1587441573@qq.com

Abstract: The cracks development of geotechnical structures can be generally summarized as transverse deformation and vertical deformation. In order to reduce the difficulty of cracks monitoring and analysis, this paper designs a monitoring device for bidirectional deformation cracks, and analyzes the monitoring principle and scheme of the monitoring device. According to the practical need of bidirectional deformation measurement of geotechnical structures, a set of simple and practical monitoring device is prepared. From the test results, it can be seen that the monitoring device of a monitoring device for bidirectional deformation cracks is convenient to prepare and has high test accuracy, which can meet the monitoring needs of geotechnical structure bidirectional deformation.

1. Introduction
In the process of construction and operation of geotechnical structures, there are often different degrees of damage, and often accompanied by the appearance and development of cracks. In practical engineering, cracks monitoring or detection results are often used as important indexes to evaluate the safety of structures, guide on-site construction and maintenance. A large number of actual monitoring data show that the development of cracks is often multi-directional and irregular, and accurate testing is difficult.

Therefore, in order to improve the accuracy of cracks monitoring, scholars have conducted some researches on cracks monitoring. For example, Lu yi [1] developed three distributed fiber optical sensors suitable for monitoring ground subsidence and cracks, and verified the effectiveness of the technology through on-site monitoring tests. Pei jian-xin [2] monitored the cracks propagation of asphalt specimen in bending test by using the self-made flexible FBG sensor, and analyzed the feasibility of the monitoring method combined with MTS test. Ding zhen [3] believed that the accuracy of slope radar monitoring system was higher than that of GNSS slope monitoring system in the real-time slope monitoring system. Wei lai-long [4] introduced the application of high-precision automatic measuring instrument in the monitoring of retaining wall cracks deformation. Wang zhao-rui [5] introduced the importance of foundation pit deformation monitoring and related monitoring methods. Wu hao-wei et al [6] studied a retaining wall deformation monitoring technology based on fiber Bragg grating sensors.

The analysis shows that although the existing monitoring technology can meet the needs of some engineering tests, there is still room for improvement, which is mainly reflected in: accurate testing of deformation in different directions, rapid data processing, and improvement of environmental adaptability. In addition, existing engineering practice has shown that geotechnical engineering of
cracks often show bidirectional deformation or three-direction deformation. For geotechnical structures with longitudinal constraints, their cracks development often shows transverse deformation and vertical deformation. In view of this, based on the characteristics of bidirectional deformation of cracks in geotechnical structures, a monitoring device for bidirectional deformation cracks is studied in this paper.

2. Design on a monitoring device for bidirectional deformation cracks

2.1 Device design
Based on the deformation characteristics of geotechnical structures, this paper designs a monitoring device for bidirectional deformation cracks to accurately and intuitively show the transverse and vertical deformation of cracks, device section diagram is shown in Fig 1.

2.2 Characteristics analysis
(1) By measuring the oblique deformation between two monitoring points through the ranging sensor, and then measuring the angle between the oblique bar and the horizontal bar, the ranging sensor and the angle between the horizontal and vertical can be calculated, and then we can calculate the transverse and vertical deformation of cracks.

(2) The device is convenient for observation, and can be used for single point observation by frequency readout according to the actual needs of the project. At the same time, data acquisition card can be used for continuous observation to meet the needs of different types of engineering cracks monitoring.

(3) The device combination is simple, not only can carry on the field combination, but also can adjust the ranging sensor and angle measuring sensor's range and precision according to the crack position and opening width.

3. Principle and scheme of monitoring device

3.1 Principle of device monitoring
A monitoring device for bidirectional deformation cracks can accurately decompose the oblique deformation of crack into transverse and vertical deformation, and adjust the range and precision of distance measuring sensor and angle measuring sensor according to the crack position and opening width. The schematic diagram of crack deformation calculation is shown in Fig 2.
After the installation of the device, measure the angle \( \angle 1 \) between the oblique bar and the horizontal bar, and the angle sensor reads angle \( \angle 2 \). Assuming that \( \angle 1 = \alpha \), \( \angle 2 = \beta \), and the elongation of the ranging sensor be \( L \), so that \( \angle 3 = \beta - \alpha \), \( \angle 4 = 90^\circ - \beta + \alpha \), the transverse deformation of the crack is \( x = L \cos(\beta - \alpha) \), The vertical deformation of the crack is \( y = L \sin(90^\circ - \beta + \alpha) \).

3.2 Device monitoring scheme

(1) Preparation before measurement: observing the surrounding environment of the crack, dealing with the measurement site, determine the buried position of the upper vertical bar and the lower vertical bar, and ensure that the upper vertical bar, the lower vertical bar and the horizontal bar are in the same plane and perpendicular to the crack trend.

(2) Bury the vertical bar: drill anchor holes of appropriate depth at selected positions, insert the upper vertical bar and the lower vertical bar vertically into the anchor hole, we should ensure that the horizontal bubble of the vertical bar is centered, and then pour fast-setting cement slurry or binder into the void.

(3) Connect the horizontal bar and the upper vertical bar: after burying the upper vertical bar and the lower vertical bar, fix the horizontal bar and the oblique bar together with the upper vertical bar, and ensure that the horizontal bubble is centered to make the horizontal bar horizontal.

(4) Connect the sensor: connect the two ends of the ranging sensor to the oblique bar and the lower vertical bar respectively, and then fix the two ends of the angle measuring sensor to the oblique bar and the distance measuring sensor respectively.

(5) Adjustment: after the sensor is connected, observe whether the horizontal bubble on the water balance bar moves. Adjust the connection point between the water balance bar and the upper vertical bar to fix it horizontally.

(6) Reading: after the whole device is fixed, the initial reading of the ranging sensor and angle sensor is read through the reading device.

(7) Data processing: according to the set monitoring time, the readings of the angle sensor and the ranging sensor are measured respectively. The angle between the oblique bar and the ranging sensor is calculated based on the reading of the angle sensor, and then the angle between the reading sensor and the horizontal and vertical direction is calculated. Firstly, the oblique deformation of cracks is recorded according to the reading change of the reading sensor, then the transverse deformation and vertical deformation of cracks are calculated according to the angle between the oblique bar and the reading sensor.

4. Analysis of device manufacture and application

4.1 Model making of simple monitoring device

Without changing the principle of the original design device, this paper uses the digital display depth scale to replace the reading sensor. And uses the steel ruler, the horizontal bubble to replace the upper vertical rod, the lower vertical rod and the horizontal bar, and replaces the Angle measuring sensor by
presetting the connection angle between the digital display depth scale and the right angle. After the installation of the device is completed, the changes of the readings of the two digital display depth rulers are recorded, and the bidirectional deformation of cracks is calculated by geometric calculation formula, so that the simple monitoring device can fully reflect the deformation of the observed crack openings in practical function. The simple monitoring and monitoring model after completion is shown in Fig 3 and Fig 4.

![Fig. 3 model of crack opening](image)

![Fig. 4 model of simple monitoring device](image)

(note: 12-upper digital display depth ruler; 13-upper steel rule r; 14-rectangular steel ruler; 15-lower digital display depth ruler; 16-transverse leveling bubbles; 17 - board; 18 to crack; 19- vertical horizontal bubble; x - transverse fracture deformation; y - vertical fracture deformation)

4.2 Simulation test of fracture monitoring

4.2.1 Test steps

(1) Assemble the simple monitoring device as required before the test, and prepare the wood board materials required for the test.

(3) Fix the board vertically and make a bidirectional deformation model of crack opening according to the test requirements; The simple monitoring device is vertically fixed in the board.

(4) Adjustment: after connecting the instrument, make sure the level bubble is centered.

(5) Zero setting: after fixing the whole device, press the button to set the reading to zero.

(6) Data processing: manually simulate fracture deformation, record the data on the digital display depth scale, and calculate and monitor the transverse and vertical deformation of cracks according to the reading of the digital display depth scale and the known geometric relationship of the instrument.

4.2.2 Analysis of monitoring data

In the real-time monitoring process of cracks, cracks deformation can make the simple monitoring device on the digital display depth ruler data changes. We record the above data changes, the lower digital display depth ruler data changes as $\Delta X_1$, the upper digital display depth ruler data changes as $\Delta X_2$, the angle between the two digital display depth ruler as $\angle 5 = \theta$. According to the principle of simple monitoring device model and geometric deformation, cracks can be concluded that the vertical deformation is $y = \Delta X_1 \cdot \sin \theta$, and the crack of lateral deformation is $x = \Delta X_1 \cdot \cos \theta + \Delta X_2$.

Making model of simple monitoring device, the digital display depth gauge Angle are 45° and 60°. The same fracture was monitored, and the opening size of the fracture was changed. Four groups of test data were measured according to the test steps, as shown in Table 1 and Table 2.

| Fracture number | \( \Delta X_1 \) (mm) | \( \Delta X_2 \) (mm) | Lateral deformation of cracks (mm) | Vertical deformation of cracks (mm) |
|-----------------|-----------------------|-----------------------|-------------------------------|-------------------------------|
| 1               | 34.28                 | 11.48                 | 35.72                         | 24.24                         |
By comparing the cracks monitoring data of the two groups of simple monitoring devices, the maximum difference of transverse deformation monitoring for the same crack is 1.23mm, and the maximum difference of vertical deformation monitoring is 1.19mm. The accuracy of simulation test monitoring results is relatively high. Through the model test of cracks monitoring, it can be seen that the device can meet the need of monitoring the bidirectional deformation of cracks, and better reflect the transverse and vertical deformation of cracks. The feasibility and correctness of the device for monitoring the opening of cracks are preliminarily verified.

5. Conclusion

For the geotechnical structures with longitudinal constraints, due to the constraint of longitudinal deformation, their cracks development is often manifested as transverse deformation and vertical deformation. Therefore, it is necessary to accurately evaluate the composition of cracks in different directions. In this paper, a monitoring device for bidirectional deformation cracks and its application were studied, and the following conclusions were obtained:

(1) According to the design principle of the device, the device combination is simple, the monitoring data processing is simple, and the monitoring requirements for the bidirectional deformation of the crack opening can be realized.

(2) From the application effect of cracks monitoring model test, the monitoring accuracy of the designed device is relatively high, and the monitoring equipment cost is low, which preliminarily verifies the feasibility of a monitoring device for bidirectional deformation cracks in engineering application.

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