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Study on Monitoring Methods of Stone Cultural Relics - Taking Shaoxing Yangshan Statue as an Example

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Abstract
In recent years, due to the structural factors of the rock mass itself, many rock masses are in an unstable state, and there are many structural fissures in the rock mass.There is a serious seepage phenomenon inside the cave, and the weathering diseases on the surface of the rock mass have appeared to varying degrees. Its cultural, artistic and scientific values need to be continued. Through modern instrument and scientific testing scheme, the horizontal displacement, crack and stress of reinforced anchor cable of dangerous rock mass are monitored in real time. After material reinforcement and repair, continuous monitoring is carried out to check the repair effect and ensure that the repair scheme is effective.
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1. Yangshan Statue and Inscriptions On Precipices Survey

Yangshan statue and cliff inscriptions (including stone Buddha Temple), located in Qixian Town, Shaoxing County, Zhejiang Province, is composed of yangshan statue, Stone Buddha Peak and chenghuangfeng numerous cliff inscriptions, stone Buddha temple. Cliff inscription, located in the main hall of stone Buddha Temple and rear hall of the left side of the stone steps of Chenghuangfeng stone wall, Stone Buddha Peak, stone Buddha niche wall, coexistence of more than 30 square, well preserved, very preservation and research value.

Provincial cultural relics protection units yangshan statues and moya carved stone (stone Buddha temple) protection project of the yangshan statues and cliff inscribed copy of the dangerous rock body to reinforce, anti weathering of inscribed copy protection and restoration project was carried out on the stone Buddha temple, the protection of cultural relics in order to more scientific safety, clear the effectiveness of engineering measures, at the same time of protection project, Carry out the protection project of yangshan statue and Cliff stone carvings (including stone Buddhist temple) of provincial cultural relics protection unit -- dangerous rock reinforcement monitoring project.

2 Monitoring content and frequency

2.1 Monitoring content

Table1 List of monitoring Contents

Monitoring content		The work object
Ontology monitoring of cultural relics	Monitoring of horizontal displacement of dangerous rock mass	No. I, II, III and IV rock masses
	Fracture monitoring of dangerous rock mass	No. I, II, III and IV rock masses
Reinforcement and anchoring member monitoring	Stress monitoring of anchor cable strengthened in dangerous rock mass	No. I, II, III and IV rock masses
Materials for self-preservation of cultural relics		Yangshan Statue and Inscriptions On Precipices

2.2 Period and frequency

The monitoring period is two years (starting from the completion of all monitoring sites, the commissioning of relevant monitoring equipment and the submission of the first monitoring report), once a month in the first year and once every two months in the second year.

In case of drastic changes in monitoring data, natural disasters or other emergencies that may change the stability of the monitored objects during the project monitoring cycle, the monitoring frequency shall be increased, the monitoring frequency shall be increased or the monitoring indicators shall be expanded as required.

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3 Monitoring method and data analysis of horizontal displacement of dangerous rock mass

There are four monitoring objects for yangshan statue and cliff stone carvings level design,which are I, II, III and Iv dangerous rock mass.A total of 13 horizontal displacement observation points are set up. There are six horizontal displacement observation points for No. I rock mass. Two observation points of horizontal displacement are arranged for no.2 rock mass. Three horizontal displacement observation points are arranged for No. III rock mass. Two horizontal displacement observation points are arranged for No. ⅳ rock mass. No. I dangerous rock mass is taken as an example for discussion. The monitoring point layout of No. I dangerous rock mass is shown in Figure 1.

Chart1 NO.1Schematic diagram of monitoring point of horizontal displacement of rock mass

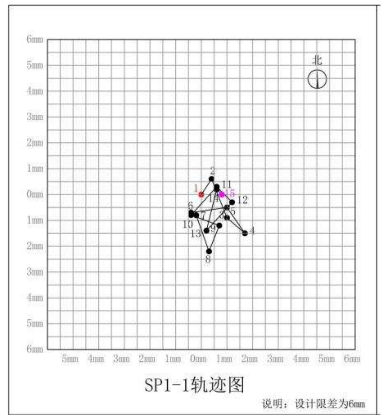

Chart 2 NO.1 Horizontal displacement track diagram of rock mass SP1-1 point

The horizontal displacement monitoring data were collected 15 times from October 26, 2019 to April 23, 2021, and the maximum single change of horizontal displacement of four rock masses was 2.4mm. The accumulative horizontal displacement of I, II and III dangerous rock mass is less than 3.4mm, and the accumulative horizontal displacement of Iv rock is 4.6mm, which requires further observation but is less than the design accuracy limit ±6.0mm. The horizontal displacement track chart shows irregular changes (taking the sp1-1 point of no. I dangerous rock mass as an example, as shown in Figure 2). It can be considered that the horizontal displacement of observation points has no change or no significant change in all observation periods.

4 Fracture monitoring method and data analysis of dangerous rock mass

Fracture monitoring can provide quantitative data basis for judging whether the whole cultural relics of the fracture meter are stable by installing the fracture meter at the crack, collecting data regularly and comparing the multi-period data to calculate the development and change amount and trend of each fracture in different periods. There are 20 fracture gauges for dangerous rock mass in Yangshan statue. There are six fracture gauges for No. I rock mass. No. I dangerous rock mass is taken as an example for discussion. The fracture monitoring point layout of No. I dangerous rock mass is shown in Figure 3.

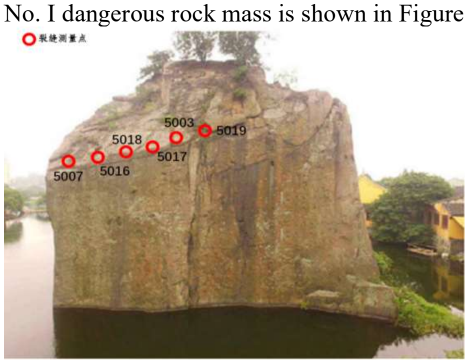

Chart3.NO.1Schematic diagram of rock fracture sensor layout

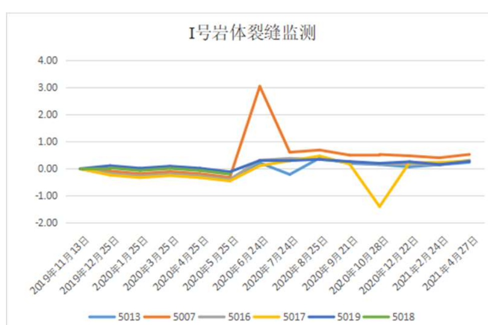

Chart3.NO.1Change diagram of fracture monitoring data of dangerous rock mass

Data were collected from November 13, 2019. The 6 fracture sensors of No. i rock mass varied from 0.24 mm to 0.53mm, the 3 fracture sensors of No. II rock mass varied from 1.15 mm to 0.12mm, and the 5 fracture sensors of No. III rock mass varied from -0.17 mm to 0.4mm. The variation of 6 fracture sensors in No.Iv rock mass is -0.28-0.66mm. During the monitoring period, the monitoring data has a small fluctuation value and a relatively consistent trend, which meets the requirements of the design value. Take the change of crack sensor in No. I dangerous rock mass as an example, as shown in FIG. 4).

5 Anchor cable stress monitoring method and data analysis

The cable stress changes of No. I, NO. II, No. III and No. IV rock masses were monitored by vibrating string anchor cable dynamometer. The main distribution is as follows: No. I rock mass (13 points), No. II rock mass (9 points), No. III rock mass (8 points) and No. IV rock mass (8 points), with a total of 35 points. No. I dangerous rock mass is taken as an example for discussion. The monitoring point layout of No. I dangerous rock mass is shown in FIG. 5.

Chart 5 NO.1 Rock anchoring dynamometer layout point map

The data were collected from November 13, 2019. The stress variation of anchor cable in No. I rock mass is between-9.89--10.5kN, that of anchor cable in No. II rock mass is between -28.52KN--5.89kN, that of anchor cable in No. III rock mass is between -5.91-16.79kN. The stress variation of anchor cable in No. Iv rock mass is between -8.07 and 15.04KN. According to the above data, it can be seen that the sensor data variation of anchor cable in No.I, II, III and Iv rock mass is small, and the values are all small within the range of design control values, meeting the requirements of design values. Take the stress change of anchor cable in No. I dangerous rock mass as an example, as shown in FIG. 6).

6 Monitoring method and data analysis of material protection effect

6.1 Surface reinforcement material monitoring

(1) Color difference monitoring

Through the detection of color difference in the monitoring area, the sensory effect of the area is obtained, so as to evaluate the impact of surface reinforcement materials on the appearance of the cultural relic body. It can be found that the increase of chromaticityΔE is obvious in many regions by monitoring the chromaticity ΔE by the field chromaticity meter and comparing the data of different time. The main reason of analysis is that the point is located outdoors, and the chromaticity change caused by water erosion and microbial growth

（2）Surface hardness monitoring

By detecting the site monitoring area, the surface hardness of the reinforced cultural relic building is obtained, so as to detect the reinforcement effect of the surface reinforcement materials. According to the on-site equipment testing, the average hardness of stone surface at the site monitoring location is between 40HS and 55HS, which is significantly increased compared with the control group, indicating that the reinforcement effect is obvious.

（3）Waterproof effect analysis

According to the analysis of the detection status of the surface moisture content of the stone, the surface moisture content of the stone is small, and there is little difference in the changes of various parts, indicating that the waterproof reinforcement effect is obvious.

6.2 Fracture repair and repair reinforcement material monitoring

（1）Infrared thermal imaging monitoring

The uniform density of fissure repair and reinforcement material was detected by temperature distribution of infrared thermal imaging. Two crack grouting sites were selected for monitoring. The temperature at grouting before spraying water is higher than that at rock surface, indicating that the heat absorption of grouting material is higher than that of rock. Measured five minutes after spraying, the temperature at the grouting place and rock surface basically returned to before spraying, indicating that water does not stay in the material for a long time, the material has good internal water permeability, and the material itself is relatively uniform and compact.

According to the infrared thermal imaging picture (as shown in FIG. 6), it can be seen that the temperature is basically uniform and there is no obvious fault. It shows that the bonding property of grouting reinforcement material is very good, and there is no phenomenon of loosening and disconnecting.

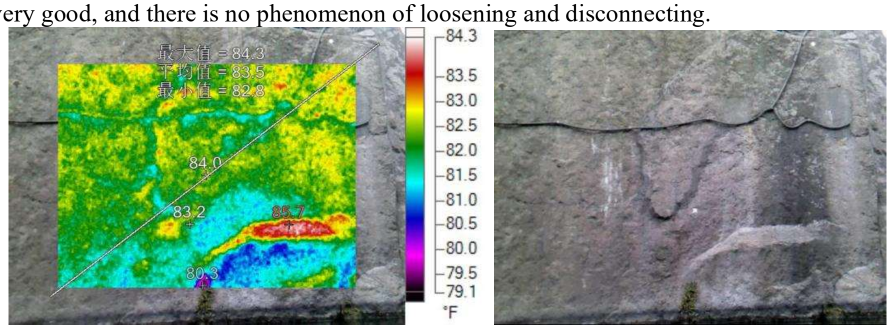

Chart 6 Infrared thermal image of the stone carving at position J1-5

（2）Penetration monitoring

The compressive strength of grouting material was tested by penetration method.

During the monitoring period, the data of penetration strength collected above 10Mpa-11mpa are increased compared with the initial data on November 28, 19, and meet the design requirements, indicating that the grouting effect is good.

7 Conclusion

In addition to the fissures in the body structure,yangshan statues are continuously affected by environmental factors, weathering and water seepage erosion. In view of its existing diseases, traditional detection methods and instruments have been unable to meet the requirements of all-round, multi-level,long-term and real-time monitoring. The introduction of new non-destructive testing instruments not only does not harm the cultural relic itself, but also achieves the purpose of high efficiency accuracy and saving manpower and material resources.After monitoring data is obtained, it is easier to conduct precise analysis of the disease,and timely maintenance and protection under the principle of "minimum intervention", so as to achieve the purpose of preventive protection.

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