The 1st and 2nd ‘Short-Term Prediction of Rock Failure Competition’ was held in Taiyuan, China

The prediction and forecasting of major natural and engineering disasters in rock systems such as earthquakes, landslides, rock bursts and gas protrusions is a major problem that is far from being solved by humans. Professor Yangsheng Zhao of Taiyuan University of Technology, who is also the Chairman of the Supervisory Board of the Chinese Society of Rock Mechanics and Engineering and the academician of Chinese Academy of Science, proposed a simplified scientific problem of “short-term prediction of rock failure” based on a detailed and in-depth study of the mechanism of the occurrence of the above major disasters, and advocated a competition to promote the rapid solution of this problem. The innovative development of theories, methods, technologies and monitoring instruments to overcome this problem will surely be continuously promoted and even directly used for the prediction of major natural disasters in rock systems, which is undoubtedly of great significance and value to human disaster prevention and mitigation.

The 1st (October 2021) and 2nd (August 2022) “Short-term Prediction of Rock Failure Competition” organized by Chinese Society of Rock Mechanics and Engineering, Organizing Committee of Chen Zongji Lecture in Journal of Rock Mechanics and Engineering, Taiyuan University of Technology, Shanxi Province Rock Mechanics and Engineering Society, and Key Laboratory of In-Situ Property-improving Mining of Ministry of Education, Taiyuan, China. The competition was successfully held at Taiyuan University of Technology, Taiyuan, China. There were 14 teams in the first competition and 12 teams in the second competition from Chinese universities and research institutes. such as: Northeastern University, Dalian University of Technology, China University of Mining and Technology, Wuhan University, Central South University, Institute of Geology of China Earthquake Administration, Liaoning Technical University, Taiyuan University of Technology, etc.

The content of the short-term prediction of rock failure competition includes: (1) the time of rock failure, (2) the energy released by rock failure, and (3) the location and type of rock failure. The competition is characterized by: (1) the uniqueness of the answers; (2) the practicality and science of the competition; (3) the challenge of the competition process; and (4) the comparison of the advantages and disadvantages of different theories, methods and instruments. So far, no competition has been conducted in the world to forecast the failure of rocks by using different testing theories, methods and instruments during the same rock loading test at the same time. The 1st and 2nd competitions showed that high-level research teams from China competed

on the same stage, comparing the advantages and disadvantages of different rock instability failure theories, methods, techniques and monitoring instruments developed by each of them, and learning from each other. It is very meaningful to promote the development of rock failure prediction and even the prediction of major natural disasters in rock systems.

Short-term Prediction of Rock Failure Competition

1) Test conditions and basic requirements

The test machine used in the competition is the XPS-1000 servo-controlled rock mechanics multifunctional test machine of the Key Laboratory of the Ministry of Education of Taiyuan University of Technology for in-situ modification of mining. The performance of the testing machine: axial pressure 10 MN, axial displacement, load can be servo-controlled loading, and computer real-time recording and storage. Can implement constant displacement rate, constant load rate loading, can also be implemented according to a certain slope and pulse form of loading. Competition using constant displacement rate loading. Each competition to complete the forecast of granite, sandstone 2 kinds of specimens failure. The size of the rock specimen for the competition is a rectangular specimen of 200 mm×200 mm×400 mm. Direct contact sensors can be installed on all 4 sides of the specimen.

Test equipment installation requirements: each team is limited to a maximum of five contact sensors (e.g. strain gauges, or acoustic emission probes, etc.) on the surface of the test piece, with a maximum linearity of less than 20 mm between the individual sensors and the test piece; no drilling of holes in the test piece, or injection of fluid into the test piece, nor the installation of sensors actively emitting electromagnetic or vibration signals on the surface of the test piece. The number and size of sensors, or non-contact test probes, etc. installed outside the test piece is not limited. All contact or non-contact testing instruments used shall not interfere with the testing of other teams.

During the competition, several teams will form a competition team and adopt their own theories, methods and instruments to test and forecast the loading failure process of the same specimen at the same time. Before the competition, the specimen is fixed on the testing machine, and then each team installs their own sensors, and after the competition organizing committee supervises and inspects them, they install protection and shielding equipment around the testing machine and start the competition process, and each team is required to submit the forecast results before the specimen failure.

2) Scoring indicators and rules

The Sub-Committee of Earthquake Prediction, which is subordinate to the International Association of

Seismology and Geophysics of the Earth (IASPEI), gives the three elements of earthquake prediction as follows: location, magnitude, and time of earthquake occurrence. Correspondingly, the main scoring indicators of the rock failure short-term and imminent prediction competition are as follows: The prediction time, including the time when the prediction results are submitted and the time when the specimen failed; The location (coordinates) and shape of the main fracture; The energy released by the specimen failure.

3) Prediction theories and methods adopted by each team in the 1st and 2nd competitions

The teams participating in the competition have adopted almost all currently available nonlinear theories and methods, Including the catastrophe theory of rock fracture, elastic-plastic theory, dilatation theory of rock fracture, speckle theory, convolution neural network of machine learning, etc. The monitoring methods include traditional strain gauges, acoustic emission, emerging or self-developed deformation measurement sensors, thermal infrared imaging, optical fiber strain sensors, DIC full-field surface strain measurement, etc.

The theories and methods mentioned above can be summarized into three categories.

① Based on acoustic emission, strain measurement, numerical simulation or machine learning algorithm.

② Based on non-contact deformation measurement and acoustic emission test.

③ Based on displacement, thermal infrared imaging, and acoustic emission testing

4) Stress-strain curves and failure types of rock specimens in the previous two competitions

The upper and lower end faces of the granite and sandstone specimens used in the competition have not been polished, the loading method cannot be equivalent to the uniaxial compression test. The loading mode of the rock specimens used in competitions is a constant displacement rate. The testing machine automatically records all data of axial load, time, and axial deformation in real-time (Figure 1).

The recorded stress-deformation-time curve of granite specimens shows that two specimens exhibit weak nonlinear characteristics and brittle fracture characteristics before peak strength, while the other two specimens exhibit extreme nonlinear characteristics before peak strength, and even show two peak stress and delayed softening failure characteristics. The duration of all four granite specimens from the beginning of loading to failure varies from 3500 to 6000 s, with a difference of more than 40%. Before the peak strength, there are significant nonlinear softening characteristics and multi-peak stress point fluctuation characteristics. The four sandstone specimens all have the characteristics of small-scale failure after peak strength, and then lasting for a period of time before complete instability and failure. These time-dependent failure characteristics of rock greatly increase the difficulty of predicting the failure time of rock, which is also never involved in the traditional rock mechanics theory. Overall, granite is mainly an X-shaped fracture, while sandstone is mainly

X-shaped and vertical split fracture (Fig.2).

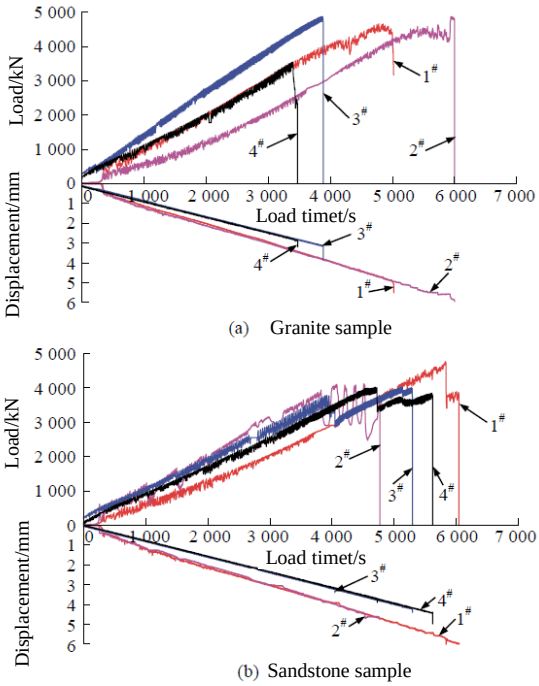

Fig.1 Axial load, displacement and time curve of samples

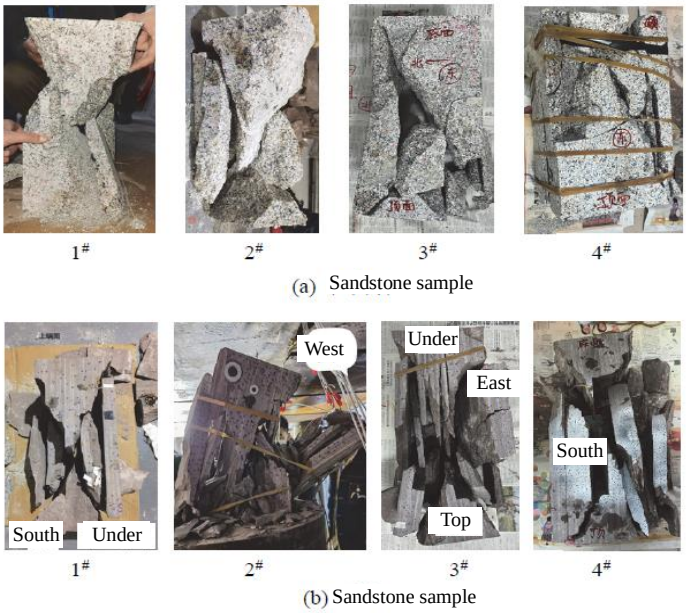

Fig.2 Fracture forms of samples

According to the results of the two competitions, the short-term prediction of rock failure is still at the primary level.

In each competition, the top three teams are selected according to their total scores and awarded certificates. After the competition, the team members said that this competition has an international horizon and leads the development direction of the discipline. Through the competition, they verified the accuracy of their theory, algorithm, and monitoring technology, and found their shortcomings. The results of the competition practice pointed out the direction for future research, The team members thanked the Society for providing them with a good opportunity to learn and communicate and said that they should carefully summarize the competition and strive to have better performance in the next competition.

The competition process was broadcast live online. This competition is held once a year at Taiyuan University of Technology, Taiyuan City, China. The third competition is planned to be held in August 2023. Universities, research institutes, and enterprises in the field of rock mechanics and engineering from around the world are warmly welcome to organize teams to join in the competition.

During the competition, the Chairman of the Chinese Society of Rock Mechanics and Engineering, CAS Member, Professor He Manchao. Vice Chairman of the Society, CAE Member, Professor Kang Hongpu, and other professors observed and guided the competition.