Experimental Study on Mechanical Properties of Single Fractured Rock-like under Uniaxial Compression

Taoli Xiao1,2, Wanqiang Zhang1*, Yongfeng Tian1, Zonghua Wang1, Xiangfeng He1
1School of Urban Construction, Yangtze University, Jingzhou 434023, China
2Rock and Soil Mechanics Engineering Research Center, Yangtze University, Jingzhou 434023, China

*Corresponding author(Wanqiang Zhang, E-mail: 944394298@qq.com)

Abstract

For gaining deep insight into the characteristics and mechanical of the deep rock mass with single fissure, laboratory tests are carried out on man-made rock specimens by WAW-1000B testing machine. In this paper, the fissure length and the fissure angle are the main influence factors. The research results show that peak strength of the specimen with single fissure have some extent of deterioration compared with intact specimen. With the increase of the fissure length, the peak strength-fissure angle curve gradually becomes steeper; the peak strength of the specimen decreases with the increase of the fissure length; the weakening of the mechanical properties of the specimen is gradually reduced with the increase of the fissure angle. These research results indicate the mechanical properties of rock mass with single fissure which can provide a reference for the research on deep fractured rock mass.

Key words: Rock-like material, Fissure angle, Fissure length, Uniaxial compression, Peak strength

1. INTRODUCTION

With the long geological process, rock has become an increasingly complex medium. Engineering practice and scientific research indicate that there are many fissure structures in the rock mass. The percolation property and mechanical properties of rock mass are greatly influenced by these fissures. In early stage, based on the Griffith strength theory, Hoek, Brace, Walsh and other scholars verified that the existence of micro-fissures and the structural planes will greatly decrease the strength of rock especially the brittle one. Recently, many have carried out a quantity of researches on the mechanical behavior and deformation characteristics of fractured rock under different loading conditions.

Li Shucheng et al. carried out an experimental research on post-peak deformation and failure behavior of fractured rock specimen containing different fissure angles, and ‘a muti-peak phenomenon’ has been introduced for the influence of fissure angle on post-peak stress-strain curve. Zheng Wenxiang et al. discussed the effects of fissure angle on failure strength of rock-like material containing pre-existing multiple fissures under uniaxial compression, and the results show that the failure strength was significantly dependent on fissure angle in the case of the same distribution density of fissure constant. The failure strength is the lowest when fissure angle is 25°, which is inconsistent with the results concluded by Wang Weihua et al. who hold that there was a ‘V-shaped’ law between peak compressive strength and fissure angle, the peak strength reached lowest value when the fissure angle was 45°.

At the same time, Zheng pointed out that the strength of rock-like material has certain degrees of deterioration because of the existence of the penetrating fissure. Regarding to the effect of fissure angle on mechanical characteristics of rock, Chen Xin et al. concluded that there is a ‘V-shaped’ law between equivalent strength and fissure angle when joint spacing kept constant. The equivalent strength reached its minimum when the fissure angle is 45°, which is consistent with the conclusions of Wang weihua. And Chen also pointed out that second peak strain as well as the ratio of residual strength and strength varied with fissure angle in an inverse ‘V-shaped’ law.

Huang Yanhua et al. analyzed the influence of inclined fissure angle on rock material specimen containing two unparalleled fissures. When fissure angle decreases from 0° to 75°, the peak strength decreases first, and then increases.

Yang Shengqi et al. performed an uniaxial compression on brittle marble containing pre-existing fissure and investigated the influence of fissure geometric distribution on the mechanical characteristic, research showed that peak strength decreased with the increase of fissure length, fissure quantity and fissure angle. The law of ‘V-shape’ had not been found when the fissure angle was the only variable. Numerical analysis such as FLAC3D has become another effective method to verify and improve deviations generated by experimental researches.

Pu Chengzhi et al. carried out a study through FLAC3D numerical simulation to look into the effect of fissure angle on failure strength of rock-like material containing multiple fissures under uniaxial compression. Results showed that the fissure angle dominated strength of specimen when the distribution density of fissure
kept constant, and the strength reached its minimum at the angle of 25°. It is worthy of note that this conclusion is inconsistent with the ‘V-shaped’ law concluded by other scholars.

Jin Jin et al. have performed numerical simulation by PFC to study the influence of single fissure angle on failure process and energy mechanism of rock-like material. The results indicated that failure strength reached lowest value at the angle of 15° in strength-angle curve when fissure length is 20mm, which is similar to the conclusion Pu made.

Combing the experimental research and FLAC3D numerical simulation, the influence of the pattern of coalescence mode and fissure angle on rock-like material has been investigated by Yi Yongliang et al.

Yang Shengqi et al. studied the change law on mechanical characteristics of brittle sandstone containing three unparalleled fissures by the experimental test and PFC2D numerical simulation. The results showed that the peak strength increases firstly and then decreases with the increase of the fissure angle. In addition, by adopting particle flow code (PFC 2D), Yang used discrete element modeling to study the change of the peak strength of red brittle sandstone specimens containing two unparalleled fissures under uniaxial compression. The results showed that the peak strength of red brittle sandstone specimens containing two unparalleled fissures increases from 0° to 90°, and decreases from 90° to 180°.

Zhao Yanlin et al. performed numerical simulation and uniaxial compression test to study the effect of occurrence characteristics of intermittent rock on strength and failure of Rock Bridge by ANSYS. Research showed that characterization of equivalent strength of specimen increases as the fissure angle varied from 25° to 90° when fissure density kept constant, which is similar to the research achievement made by Zheng and Pu.

Based on the achievements acquired by predecessors, this paper will continue to investigate the influence of fissure angle and length on mechanical behavior of fractured rock-like material under uniaxial compression. The relationship between peak strength and fissure angle will be analyzed when fissure length kept constant. And the way peak strength varied with fissure angle or fissure will be figured out in detail. The experiment results will provide reference for engineering practice.

2. TESTING PROGRAM

2.1 specimen material and manufacture

The final shaped rock-like specimen was prepared by the following steps: firstly, mixing the mixture of 425# cement: silica powder: iron powder: quartz sand: water reducer: water =1:0.13:0.25:0.8:0.01:0.4 (weight ratio) fully for 120s in low-speed mixer (once a second), which then was put into the steel mold and stocked for 70 times until no bubbles came out. Then, pulling out the thin steel strip (0.4mm) 3h after the pouring and demolding after 24h. And then curing the specimen for 28d.

![Figure 1. Representative model specimen of intact rock mass and fractured rock mass](image)

The representative model specimen of intact rock and fractured rock are shown in Fig.1.

In the above model specimen:
1) Intact rock specimen: the model size: φ50 mm×100 mm.
2) Fractured rock specimen of 6mm: the model size: φ50 mm×100 mm, the fracture size: 6 cm×0.4 mm, and the fissure angle α=0°,15°,30°,45°,60°,75°,90°.
3) Fractured rock specimen of 12mm: the model size: φ50 mm×100 mm, the fracture size: 12 cm×0.4 mm, and the fissure angle α=0°,15°,30°,45°,60°,75°,90°.
4) Fractured rock specimen of 18mm: the model size: φ50 mm×100 mm, the fracture size: 18 cm×0.4 mm, and the fissure angle α=0°,15°,30°,45°,60°,75°,90°.
5) Fractured rock specimen of 24mm: the model size: φ50 mm×100 mm, the fracture size: 24 cm×0.4 mm, and the fissure angle α=0°,15°,30°,45°,60°,75°,90°.

2.2 The experimental equipment and scheme

The uniaxial compression experiment was carried out by the WAW-1000B Microcomputer controlled electrohydraulic servo universal testing machine, as is shown in Fig.2. The data is collected automatically by the system.
3. ANALYSIS OF EXPERIMENTAL RESULTS

3.1 The influence of geometrical parameter on peak strength

3.1.1 The influence of fissure angle on peak strength

Figure 3. Relationship between peak strength and fissure angle

When the fissure length is fixed at 6 mm, 12 mm, 18 mm, 24 mm, the influence of different fissure angles on single fracture specimens’ peak strength is shown in Fig. 3.

1) When fissure length is 6 mm, the peak strength of the specimen is in the range of 35 ~ 40 MPa. The change rate is smaller. Peak strength decreases as the fissure angle varied from 0° to 45°, then increases within 45° ~ 90°.

2) When the fissure length is 12 mm, the change rate of specimen’s peak strength is bigger than that of 6 mm, and the peak strength-fissure angle curve has obvious variation, peak strength of the specimen decreases as the fissure angle varied from 0° to 30°, then increases within 30° ~ 90°.

3) When the fissure length is 18 mm, the change rate of peak strength is more bigger than that of 6 mm, peak strength of the specimen decreases in low amplitude as the fissure angle varied from 0° to 15°, then gradually increases within 15° ~ 90°.

4) When the fissure length is 24 mm, the change rate of peak strength is similar to that of 18 mm, but peak strength of specimen increases as the fissure angle varied from 0° to 90°.

It also can be seen from Fig. 8 that with the increase of fissure length, peak strength of the specimen shows a decreasing trend. And the peak strength-fissure angle curve gradually changes from gentle to steep. It indicates that with the increase of fissure length, the influence of fissure angle on the peak strength of the specimen is gradually increasing.

1) When the fissure length is 6 mm, the minimum value of the peak strength corresponds to angle 45°.
2) When the fissure length is 12 mm, the minimum value of the peak strength corresponds to angle 30°.
3) When the fissure length is 18 mm, the minimum value of the peak strength corresponds to angle 15°.
4) When the fissure length is 24 mm, the minimum value of the peak strength corresponds to angle 0°.
The above phenomenon shows that the peak strength-fissure angle curve is gradually changing from the "V" to the monotone increasing with the increase of fissure length under uniaxial compression. It means that the fissure angle corresponding to the minimum value of peak strength of the specimen is gradually decreasing.

3.1.2 The influence of fissure length on the peak strength

When the fissure angle is fixed, the influence of different fissure length on single fracture specimens’ peak strength is shown in Fig.4.

![Figure 4. Relationship between peak strength and fissure length](image)

It can be depicted from Fig.4 that in comparison with the complete specimen, the peak strength of the specimen with single fissure has different degrees of deterioration. With the increase of fissure length, peak strength of the specimen with single fissure gradually decreases. This is consistent with the numerical simulation by Wang Hui et al.[13]. With the increase of fissure inclination, the trend of peak strength-fissure length curve gradually become gentle, and the decrease range of peak strength is getting smaller. The weakening effect of fissure on peak strength of the specimen gradually decreases with the increase of fissure angle[14].

3.2 Stress-strain curve

The stress-strain curve of the complete specimen under uniaxial compression conditions is shown in Fig.5. The compression phase of the complete specimen persists shorter, and the elastic phase keeps longer. The stress has a small range variation after reaching the peak, and quickly falls to zero. With the sound of clear and melodious crack, the specimen completely lost the carrying capacity[15].

For example, when the fissure length is 6 mm, the stress-strain curve of the representative specimen is shown in Fig.6. The compaction phase is still short, which is similar to the complete specimen. However, the duration of the elasticity of different curves varies. After reaching the peak, the stress of some specimens(0°, 15°, 30°, 90°) fall quickly as the prefabricated fissure propagated and penetrated during loading[16]. In the failure stage, some specimens (0°, 15°, 30°, 45°) appeared in two or relatively obvious stress drops. Combing with the compression process video of specimen, the production, extension and transfixion of the new cracks can be indicated by each stress drop. It is different from complete specimen that there are residual phases in the stress-strain curves of specimen with single fissure. This is because the destruction stage only destroys the integrity of the specimen, and its internal fissures are not fully developed, the specimen has a certain carrying capacity[17].
4. CONCLUSIONS

This paper carried out uniaxial compression test by making single open penetrating rock-like material specimens with specific angle and size. Through research and analysis of test results, the conclusions are the follows:

1) the existence of fissure leads to the deterioration of the strength of specimen.
2) With the increase of fissure length, the peak strength-fissure angle curve is gradually changing from the "V" to the monotone increasing.
3) When the fissure angle is constant, the peak strength of specimen decreases with the increase of fissure length. The extension and transfixion of a single fissure specimen crack have a good correspondence with the stress-strain curve.

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REFERENCES


