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Study on Uniaxial Compressive Strength of Single-fractured Similar Rock with Different Degrees of Penetration

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Study on Uniaxial Compressive Strength of Single- fractured Similar Rock with Different Degrees of Penetration

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Abstract. In order to study the influence of uniaxial compression test conditions on the strength and deformation characteristics of single-fractured similar rock with different penetration degrees, the author conducted the uniaxial compression test on prefabricated single-fractured similar rock using TAW-200 electronic multifunctional material mechanics testing machine. And quantitatively analysed the relationship between strength, elastic modulus and stress-strain of single fracture similar rock under uniaxial compression. The results show that the influence of uniaxial compression test on the peak strength is related to the penetration degree. The peak strength of specimens is the largest when there is no damage and the smallest when there is complete penetration (100%), but the peak strength of specimens not only decreases with the increase of penetration degree, but also relates to the crack dip angle. When the crack dip angle is different, the variation law of peak strength with penetration degree is also inconsistent; The influence of uniaxial compression test on elastic modulus is also related to penetration degree and crack dip angle, but the influence degree is different.

Key words: uniaxial; single fracture; similar rock; elastic modulus; stress-strain.

1. Introduction

The underground rock mass undergoes long-term geological chronology and has very complex characteristics. The rock mass is also called multiphase composite porous media material because of its uneven distribution of voids and fractures and its inclusion of air, groundwater and other fluids. There are many different kinds forms of crack in the rock in the nature. For example, there are differences in fracture angle, fracture penetration degree, fracture opening and closing degree, number of fractures and the form of fracture intersection. The presence of these fracture factors will seriously affect the mechanical properties of rock and caused a lot of rock mass engineering accidents such as slope instability, tunnel collapse, roadway floor heave and roof fall. Therefore, it is of great theoretical and practical significance to study the strength, deformation and other mechanical properties of fractured rock mass for the design, support and long-term stability of rock mass engineering, such as slope protection, mining, tunnel excavation and so on.

The strength, deformation and other mechanical properties of rocks and similar rocks have always been the focus of many domestic and foreign researchers [1-6]. By comparing with the mechanical properties of fractured rock under static load, the effects of fracture angle on the strength and deformation characteristics, crack propagation law and the trend of failure process of similar rock



specimens under SHPB. Wang Weihua [7] and others carried out SHPB loading tests on pre-fabricated fractured rock specimens with different angles. Li Shuchen [8] et al. carried out uniaxial compression test on prefabricated similar rock specimens with penetrating joint type, and systematically studied the relationship between the post-peak stress-strain curve, failure mode, post-peak residual strength, post-peak poisson's ratio and fracture angle of similar rock specimens with penetrating joint type. Wang Guoyan [9] et al. used the RFPA numerical analysis system of rock fracture process to conduct numerical simulation on the failure process of single fracture rocks with different angles under uniaxial compression, and explored the influence of initial fracture angle on the fracture propagation direction and damage fracture mode of regenerated fracture rock mass. Wang Yongyan [10] et al. carried out uniaxial and triaxial compression and creep tests on prefabricated single fracture similar rock specimens, and studied the relationship between strength, creep characteristics and fracture angle of similar rock specimens. Chen Xin [11] et al. carried out uniaxial failure tests on prefabricated fracture gypsum specimens with different joint angles and joint connectivity, and analyzed the influence of continuous changes in joint angles and joint connectivity on uniaxial compression strength, deformation, elastic modulus and stress-strain curve of fractured rock mass.

Most of the above studies have carried out uniaxial compression tests on complete and penetrating fractured rock samples. The strength and deformation characteristics of complete and penetrating fractured rock samples under uniaxial compression test conditions are discussed. However, few studies have been conducted on the influence of penetration degree on rock strength. In practical engineering, there are often complex rock masses with different fracture angles and penetration degrees. In view of this, uniaxial compression tests were carried out on prefabricated similar rock samples with single fractures of different penetrations to obtain various physical and mechanical parameters of similar rock samples and analyze their strength and deformation characteristics, so as to provide theoretical references for the design, construction and maintenance of underground engineering with complex joints and fractures.

2. Preparation and experimental design of single-fractured similar rock specimens

According to the similarity principle and existing research results [12-15], cement, river sand and water are selected as raw materials, and standard cylindrical rock specimens with size of $\phi 50 \times 100$ mm are made according to the ratio of 2:1:0.12, respectively, as shown in Figure 1. Among them, the cement model is 425# ordinary Portland cement, and the grain size of river sand is 40 mesh. Cylindrical crack specimen mould, insert (thickness is 0.8mm), 40 mesh stainless steel screen, small electronic scale and tamping tool are needed in the preparation of similar rock specimens, as shown in Figure 2. The prefabricated fractured specimens were removed 12 hours after preparation and maintained in a dry and ventilated environment for 7 days. The cracks are located in the center of the standard cylindrical similar rock samples, and the inclination angles of the cracks are 0° , 45° and 90° with penetration degrees of 25%, 50%, 75% and 100%. at the same time, the complete standard cylindrical similar rock samples are selected for comparison.



Fig.1 The standard cylindrical rock specimen



Fig.2 The main test tools and cylindrical crack specimen molds

The test equipment adopts TAW-200 electronic multi-functional material mechanics testing machine developed jointly by Changchun Chaoyang Test Machine Factory and Qingdao University of Science and Technology. As shown in Figure 3, the loading mode is force-controlled loading, and the loading rate is 50 N/s.



Fig.3 TAW-200 electronic multi-function material mechanics testing machine

3. Analysis of test results

In order to ensure the consistency of compaction and minimize the discreteness of test data, the author selected the test data with similar density among the groups of specimens. The parameters of direct uniaxial compression test specimens are shown in Table 1.

Table.1 The test data parameters under penetration degree

Angle	Penetration Degree	Density/(g/cm)	Peak Load/ KN	Uniaxial Strength/ MPa	Elasticity Modulus/ GPa
0°	25%	1.94	20.3	10.34	2.29
	50%	1.99	20.1	10.19	1.8
	75%	1.93	17.5	8.92	1.88
	100%	1.9	8.2	4.18	1.5
	full	1.91	30	15.29	2
45°	25%	1.93	25	12.74	2.78
	50%	1.94	16.3	8.31	1.45
	75%	1.91	23.5	11.98	2.5
	100%	1.9	17.4	8.87	2
	full	1.93	24.1	12.28	1.81
90°	25%	1.96	32.8	16.71	3.08
	50%	1.95	19.14	9.75	1.87
	75%	1.92	26.3	13.4	2.29
	100%	1.94	26.5	13.5	2.5
	full	1.92	28.5	14.52	1.9

3.1. Stress-strain curve and peak strength curve of uniaxial compression test

The stress-strain curves of uniaxial compression under different penetration degrees are shown in Figure 4, and the curves of peak strength of uniaxial compression varying with penetration degrees are shown in Figure 5. Longitudinal comparison shows that the variation of uniaxial compressive strength with penetration degree is full > 25%, 50% > 75% > 100%, when the fracture angle is 0° and the peak strength

decreases with the increase of penetration degree. Among them, the peak strength of nondestructive specimens is the largest, and the peak strength of complete penetration specimens is the lowest. When penetration degree is less than 75%, the peak strength is almost not affected by penetration degree. When the penetration degree is greater ($>75\%$), the influence is more obvious, and the peak strength decreases with the increase of penetration degree, as shown in Figure 4 (a). When the crack dip angle is 45° , the change rule of uniaxial compressive strength with penetration degree is full, 25%, 75% $>$ 50%, 100%. When penetration degree is low ($<50\%$), the peak strength decreases with the increase of penetration degree, but when penetration degree is 50% to 100%, the peak strength increases first and then decreases with the increase of penetration degree, and peak appears when penetration degree is about 75%, as shown in Figure 4 (b). When the crack dip angle is 90° , the variation of uniaxial compressive strength with penetration degree is 25% $>$ full, 100%, 75% $>$ 50%. On the contrary, the peak strength of non-destructive specimens is not as high as that of penetration degree is 25%. The reason is that the test results have random errors, but when penetration degree is 25% to 75%, the peak strength decreases first and then increases. When penetration degree is 50%, the peak strength is the smallest, but when penetration degree is 50%, the peak strength is the smallest. When the penetration degree is greater than 75%, the peak strength is hardly affected by the penetration degree, as shown in Figure 4 (c). Lateral comparison shows that the peak strength of specimens with different penetration degrees is also related to crack dip angle, except for the difference of peak strength due to randomness of non-destructive specimens, as shown in Figure 5.

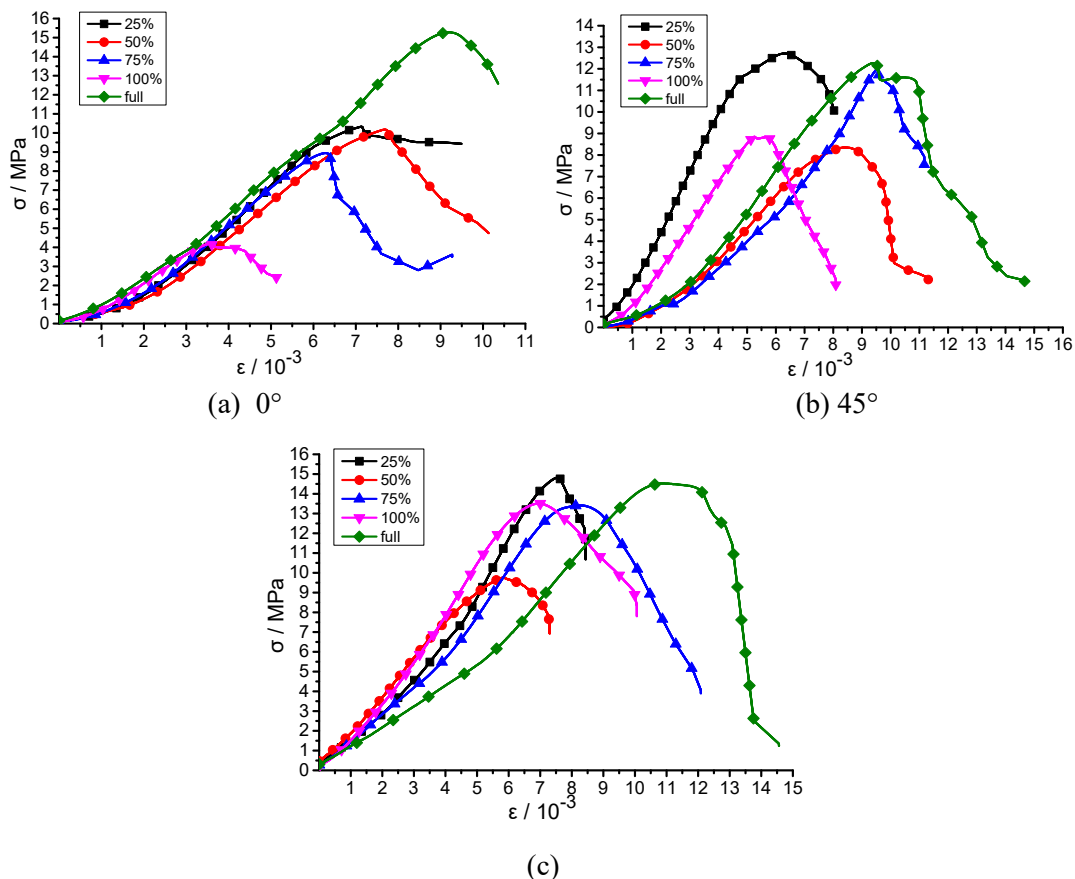


Fig. 4 The uniaxial compression stress-strain curves under different penetration degrees

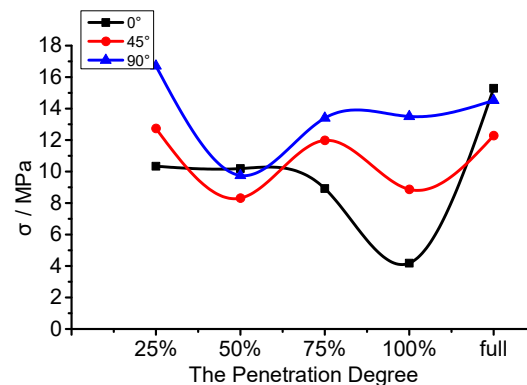


Fig. 5 The uniaxial compression peak strength curves under different penetration degrees

In summary, without considering the random error, the peak strength of specimens is maximum without damage and minimum with complete penetration (100%). Moreover, the peak strength of specimens is also related to the crack dip angle. When the crack dip angle is different, the law of the peak strength changing with the penetration degree is also different.

3.2. Change of Elastic Modulus in Uniaxial Compression Test

The curve of elastic modulus varying with penetration degree is shown in Figure 6. It can be seen from the graph that when the penetration degree is less than 50%, the elastic modulus of the specimens with crack dip angles of 0°, 45° and 90° decreases with the increase of penetration degree. When the penetration degree is between 50% and 100%, the influence of penetration degree on elastic modulus is different. The elastic modulus of specimens with 0° and 45° crack dip angle increases first and then decreases with the increase of penetration degree, while the elastic modulus of specimens with 90° crack dip angle increases with the increase of penetration degree. In conclusion, the elastic modulus of specimens under uniaxial compression test is related to penetration degree and crack dip angle, but the influence degree is different. When the penetration degree is small (< 50%), the crack dip angle has little effect on the elastic modulus, and the elastic modulus decreases with the increase of penetration degree. When the penetration degree is large (> 50%), the effect of the crack inclination on the elastic modulus is obvious, and the change rule of the elastic modulus under the dual action of penetration degree and the crack inclination is complex.

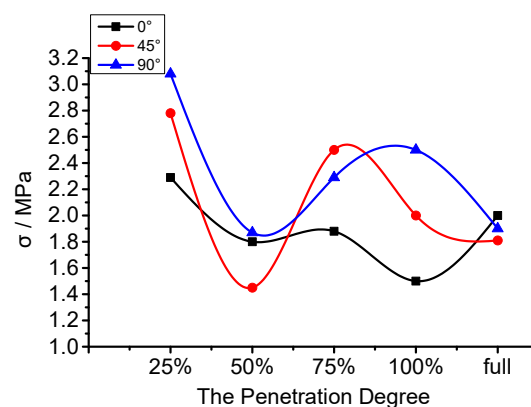


Fig. 6 The uniaxial compression elasticity modulus curves under different penetration degrees

4. Conclusion

Through uniaxial compression tests on prefabricated single-fractured similar rock specimens, the effects of different penetration degrees on stress-strain curves, peak strength and elastic modulus of specimens are studied. The main conclusions are as follows:

(1) The influence of uniaxial compression test on the peak strength of single-fractured similar rock is related to the penetration degree. The peak strength of specimen is the largest when there is no damage and the smallest when there is complete penetration (100%). However, the peak strength of specimen does not decrease monotonously with the increase of penetration degree. It is also related to the crack dip angle. When the crack dip angle is different, the variation of peak strength with penetration degree is also different.

(2) The influence of uniaxial compression test on the elastic modulus of single-fractured similar rock is also related to the penetration degree and the crack dip angle, but the influence degree is different. When the penetration degree is small ($< 50\%$), the crack dip angle has little effect on the elastic modulus. The elastic modulus decreases with the increase of penetration degree. When the penetration degree is large ($> 50\%$), the effect of the crack dip angle on the elastic modulus is obvious.

In this paper, the variation rules of peak strength and elastic modulus of uniaxial compression of single fracture similar rock with four penetration degrees of 25%, 50%, 75%, 100% and crack dip angles of 0° , 45° , and 90° are analyzed and some valuable understandings are put forward, which provide useful references for subsequent experimental studies.

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