Research Progress on Unloading Creep Test of Fractured Rock Mass

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Abstract: The results of the research on fractured rock mass test and constitutive model are mainly described. Domestic scholars have carried out a lot of research on rock failure test and rock creep test including uniaxial and triaxial compression tests, and considered different in the test. The influence of factors such as crack inclination angle, crack length and rock bridge length, but consider the creep test about these factors is relatively less than normal. Many scholars have established a large number of rock nonlinear creep models through various theories, but these models still have shortcomings, and it is impossible to establish a constitutive model describing the whole stage of creep of different fractured rock masses.

Keywords: Fractured rock mass; Destruction test; Creep test; Constitutive model

1. Introduction

The rheological property of rock mass refers to the time-related deformation, flow and failure properties of rock under external load, temperature and other conditions, which are mainly manifested in elastic aftereffect, creep, relaxation, strain rate effect, aging strength and creep damage and fracture [1]. Fractured rock mass is water conservancy, transportation, mining and other underground engineering field widely encountered a class of complex engineering medium, its internal is rich in various kinds of defects, such as micro cracks, voids, joint macro discontinuous surface structure, which weak the integrity of the rock mass structure and mechanical parameters, and has important effect on the mechanical properties of rock mass [2]. Many laboratory tests have been done on the rheological properties of intact rock mass under uniaxial compression, bending, torsion (shear) and conventional triaxial stress, but few have been done on fractured rock mass. What kind of fracture rock samples are used for rheological test and how to establish relevant creep model based on the test results have become an urgent problem to be solved in future research.

2. Indoor Destruction Test

The research on fracture rock mass failure model test can be traced back to the 1960s. A large number of experts and scholars at home and abroad have conducted a large number of model tests on fracture rock mass under different stress paths and obtained valuable research results.

Brace and Bombolakis (1963) [3] have studied the initiation and propagation of cracks in glass samples which under the condition of uniaxial compression, and then explained with the theory of fracture mechanics of Griffith. Wu gang and sun jun (1998) [4] carried out the failure test of fractured rock mass under the state of unloading stress, and found that different fractured rock samples have different deformation and failure characteristics, and their failure strength is in the order of uniaxial compression strength. Yang et al. (2009) [5] conducted uniaxial compression tests on cylindrical marble rock samples with pre-existing fractures, and studied the influence of fracture geometry on the strength and deformation and failure behavior of brittle marble materials. Huang da et al. (2010) [6] generalized six fracture rock mass models of similar materials with different fracture conditions based on the three gorges project underground powerhouse rock mass as the prototype, and carried out failure tests under two different unloading stress paths for these models, and studied the strength, deformation characteristics and failure forms of fracture rock mass. The results of the study show that the fracture expansion has a step and suddenness, and the displacement has a multi-stage jump, and when the fracture breaks through, there will be a large step. At the same time, the number of sudden jumps of the single fracture rock mass model is obviously less than that of the double fractures. Xiao taoli et al. (2012) [7-8] used the high-strength silica mortar material model to prefabricate a single crack with a specific crack length and a specific crack inclination, and conducted conventional triaxial compression test on the material model to study the strength characteristiscs and failure characteristics of the rock sample. The test results show that the crack Angle leads to the initiation of a new crack, and the length of the crack affects the size of the crack expansion. The confining pressure is the main influencing factor of the macroscopic fracture mode. Lu yanni et al. (2013) [9-10] carried out triaxial

compression tests under different confining pressures on prefabricated single-fracture rock samples, and studied the influence of fracture length and fracture inclination angle on the strength and failure characteristics of rock samples. The results show that when the confining pressure and inclination are constant, the peak strength decreases with the increase of the crack length. With the increase of confining pressure, the effect of fracture length and fracture inclination on peak strength becomes less and less obvious. Then the fracture penetration mechanism of single fracture rock samples with different freeze-thaw cycles under triaxial compression was studied. Huang yanhua et al. (2016) [11] configured a set of model specimens containing non-parallel dual-fracture rock materials, and then conducted conventional triaxial compression tests under different confining pressures. The results show that both the crack dip Angle and the confining pressure determine the penetration mode of the fractured rock sample. When the confining pressure increases to a certain extent, the shear failure zone connected to the crack tip causes the failure of the sample.

3. Indoor Rheological Test and Constitutive Model Study

Chen(2004) et al. [12] established a viscoelastoplastic constitutive model that can reflect damage coupling in the creep stage of fractured rock mass based on the theory of damage and fracture mechanics by connecting the plastic-damaged fracture element and Kelvin model in series. Song-lin Yang (2004) [13] Betti reciprocal theorem and the linear viscoelastic fracture mechanics principle of fractured rock mass under uniaxial creep compliance and the volume change of the creep compliance theory of expression, and through the self-consistent theory to consider the crack interaction on the influence of rock mass creep compliance, analyses the crack density parameter and poisson's ratio is changed, the change rule of rock mass creep compliance compared the considering and not considering crack interaction fractured rock mass creep compliance. Guo chenye et al. (2010) [14] used MTS815 rock mechanics test system to conduct post-peak creep test study on fractured sandstone by changing the loading level under confining pressure. It is found that there are three stages of creep in fractured sandstone, but the change of axial displacement is small. There is also a long-term strength, which can be obtained from the stress-strain relationship. Shen linfang et al. (2010) [15] carried out creep tests on single-fractured granite under constant stress, osmotic pressure and chemical solution permeability, and analyzed the creep deformation characteristics of rock mass containing fractured surface under stress, seepage and chemical reaction. The results show that the water has physical softening effect on the rock matrix around the fracture, so that the lateral rheological deformation increases obviously, and the influence on the axial deformation is small or not obvious. Chen fang (2012) [16] carried out an indoor triaxial rheological test on hard and brittle diabase in the dam area of dagang shanshui hydropower station, and studied the law of axial, lateral and volume deformation of fractured rock mass changing with time. The aging evolution model of mechanical parameters of fracture rock mass was introduced into the octahedral strain energy strength model to establish the rheological strength aging model of hard and brittle fracture diabase. Wang yu et al. (2015) [17] conducted rheological tests on the through-fracture rock mass under different unloading paths. The results show that the crack dip Angle, confining pressure state and unloading path all have an effect on the rheological characteristics of the fractured rock mass. Zhong zhu [18] and zheng yinzhu [19] have carried out uniaxial compression creep tests on uniplanar and non-uniplanar fault prefabricated fractured sandstone. The test results show that the instantaneous axial strain, total axial creep and instantaneous circumferential strain increase with the increase of fracture inclination, but the total circumferential creep decreases with the increase of fracture inclination. Yang chao et al. (2016) [20] carried out a triaxial unloading creep test on discontinuous dual fractured sandstone samples under the path of constant axial pressure graded unloading confining pressure. Based on Lemaiter strain equivalence principle and Sidoroff energy equivalence principle, they proposed a creep damage model suitable for this type of sandstone and established the relationship between intact rock and fractured rock mass. Yuan xiaoqing et al. (2016) [21] introduced Lemaitre strain equivalence principle to establish a 3d damage constitutive model of non-penetrating fractured rock mass based on macroscopic and microscopic defect coupling. This model is used to analyze the mechanical properties of rock under low confining pressure. Wang qihu et al. (2016) [22] introduced the plastic element of fractured rock mass and established the constitutive model of the whole process of rock creep.

4. Numerical Simulation of Creep Model

Numerical simulation has been widely used in the study of crack propagation and creep characteristics of fractured rock mass, and many important research results have been obtained. For example, Yang et al. (2015) [23] used finite element model (FEM) to simulate uniaxial compression progressive failure process, scale effect and anisotropy characteristics of fractured rock mass, and deformation modulus of fractured rock mass. It is found that the critical strain corresponding to uniaxial compressive strength exists in the fractured rock mass regardless of its deformation modulus,

direction and size. Wang tongxu et al. (2016) [24] introduced the accumulated creep damage tensor into FLAC 3D to develop a constitutive model that can simulate the creep crack growth. This model can be used to analyze the law of fracture damage evolution process under creep conditions. Du qiang et al. (2016) [25] introduced the loss tensor and developed the strain softening damage constitutive model of fractured rock mass in FLAC 3D.

5. Thinking and Cognition

Based on the analysis and thinking of previous research results, it is believed that in the future, scholars still need to carry out detailed and systematic research in the following aspects in the research field of fracture rock creep characteristics:

At present, the research on fracture rock mass is basically based on rock-like materials, and the material model is made of plexiglass, PMMA, unsaturated resin, ceramics and gypsum, which are basically the same as the basic mechanical parameters of typical rock materials to be studied, and then the fracture preparation of rock-like materials is carried out. The precast fractures are mainly divided into single fractures, double fractures and multiple fractures. However, under natural conditions, the distribution of fractures in the rock mass is irregular, while the prefabricated fractures cannot produce fracture morphology similar to that of the natural rock mass, and the obtained crack propagation law may be inconsistent with the actual law. Therefore, in the following study, the test of fractured rock mass under natural conditions can truly reflect the mechanical characteristics of fractured rock mass. How to make the fractured rock mass under natural conditions is a must in the future test.

In practical engineering, there are more and more problems of fracture rock mass creep caused by excavation, and the existing rock mechanics models and failure criteria mainly considering loading can no longer meet the needs of practical engineering. However, there are few researches on unloading test of fractured rock mass, especially based on creep test under unloading stress path. Deep mining, in order to better adapt to the deep underground cavern excavation and construction of large water conservancy, traffic engineering, the need for unloading creep test creep over time in the process of gradual damage internal causes are analyzed, especially the creep strength parameters in the process of weakening and the creep of rock fracture inner link between aging damage evolution.

For the existing creep models, many scholars have focused on the nonlinear deformation characteristics of the accelerated creep stage. However, the nonlinear characteristics of fractured rock mass are not only in the acceleration stage, but also in the whole creep process. It is under this stress that the accumulation and expansion of fracture damage leads to the nonlinear deformation of rock. In the following study, a constitutive model based on the whole process of creep damage should be established.

Based on the good secondary development environment of FLAC 3D, the constitutive equation of unloading creep process of fractured rock mass can be accurately established, and embedded in the numerical simulation software, which can be accurately applied to practical engineering applications with strong feasibility and reasonable Suggestions for practical engineering.

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