Numerical Simulation of Creep Characteristic for Composite Rock Mass with Weak Interlayer

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Abstract. The composite rock mass with weak interlayer is widely exist in engineering, and it’s essential to research the creep behavior which could cause stability problems of rock engineering and production accidents. However, due to it is difficult to take samples, the losses and damages in delivery and machining process, we always cannot get enough natural layered composite rock mass samples, so the indirect test method has been widely used. In this paper, we used ANSYS software (a General Finite Element software produced by American ANSYS, Inc) to carry out the numerical simulation based on the uniaxial compression creep experiments of artificial composite rock mass with weak interlayer, after experimental data fitted. The results show that the laws obtained by numerical simulations and experiments are consistent. Thus confirmed that carry out numerical simulation for the creep characteristics of rock mass with ANSYS software is feasible, and this method can also be extended to other underground engineering of simulate the weak intercalations.

1. Introduction
Layered structure is the most common type of structure in rock engineering. According to the survey, the sedimentary rocks with layered structure accounts for two-thirds of land area in nature, even many metamorphic rocks also have the characteristics of layered structure. Therefore, it was inevitable to encounter a great deal of layered rock mass in underground engineering. In various of rock engineering, the weak interlayer frequently appeared as a special form of layered rock mass. According to many research and practices show that the weak interlayer makes significant impact on the overall stability of rock engineering. And even control it under certain conditions. On the other hand, there are problems that effectiveness of mechanical characteristic, also namely the rheological characteristic of rock mass in longer service life of rock engineering should not be neglected, especially it has brought a series of special problems to design and construction in underground engineering with weak interlayer, due to the significant rheological characteristic of interlayer, which even would cause safety accidents. Therefore, it is necessary to study the creep characteristic of rock mass with weak interlayer. All kinds of rheological experiments within the scope of layered rock mass were carried out by ji Chen [1], bin Hu etc. [2], Ming-rong Shen etc. [3], Pinglao Zhao etc. [4], Zeqi Zhu etc. [5], Baoping Xi etc. [6], Deyi Jiang etc. [7], and the creep characteristic of layered rock mass were simulated by Liang-xiao Xiong, Lin-de Yang [8], An-ming Wang etc.[9] [10], Bing Han etc. [11], Huoming Zhou etc. [12], and so on, thus obtained some valuable conclusions. In this paper, based on creep experiments for composite rock mass with weak interlayer, numerical simulation was carried out, to compare the simulation results with the experimental phenomena and
data, to explore the feasibility of using ANSYS software simulate the creep characteristics of composite rock mass.

2. The creep experiments for composite rock mass with weak interlayer

In this paper, according to the similarity principle, the soft interlayer and the surrounding rock material are made of sand and cement, and the composite cylindrical rock specimen with 30 degree of inclination is prepared, as shown in figure 1(a). The uniaxial compressive creep experiments was carried out after maintenance period of time. Mechanics experiment that adopts hierarchical load method was carried out by the TAW-200 microcomputer control rock triaxial high temperature triaxial test machine of mechanical research center in Qingdao university of science and technology, the duration of each load was determined according to the variation of the strain rate of the specimen, which was finally loaded into the specimen, as shown in figure 1 (b). Compared with the conventional uniaxial compression experiment, damage form was nearly same interlayer still peeling destruction, but the main rock mass was not involved.

![Figure 1. The weak interlayer of rock specimen.](image)

![Figure 2. The uniaxial compression creep curves of class rock mass.](image)
Figure 2 was the creep axial curves obtained from experiments. In curves, the measured displacement was transformed into strain. The characteristics of loading process from composite rock mass with weak interlayer are shown as follows:

1. It can produce strain form each level loading, the higher the stress level is, the larger the instantaneous strain absolute value is.
2. Under the low stress level, the creep curves was straight line, it not occur creep or attenuation creep; However, under the high stress level, the creep curves showed a state of rising, reached steady-state creep, even accelerated creep stage.
3. The interval of the adjacent two levels of stress curves was different, there are no laws that it can increase or decrease of consistence.

Compared the above characteristics with the predecessors' study for rock mass without interlayer the laws are consistence, which means the existing creep models can be used directly when it was built and used for rock mass with interlayer.

3. Based on ANSYS software, the creep characteristic was simulated for composite rock mass with weak interlayer.

3.1. The choice of creep model

There are 13 kinds of creep models which provided by ANSYS software, some of them are suitable for the creep stage of simulating attenuation, such as, TBOPT = 1, 2, 3, 4, 5, 6, 7, 13; Some of them are suitable for the steady creep stage of simulation, such as TBOPT = 8, 9, 10; At the same time, there only two models are suitable to simulate for attenuation stage and steady stage, one is the time hardening model of TBOPT = 11, another is rational polynomial model of TBOPT = 12, the former contains seven parameters and the latter contains 12 parameters. The time hardening model is simple and easy to use relative to rational polynomial model, and if it can accord with the experimental data well, it is the ideal creep model. The form as following:

$$\varepsilon_{cr} = \frac{C_1 \sigma C_2 t C_3 + 1}{(C_3 + 1)} e^{-C_4 / T} + C_5 \sigma C_6 t e^{-C_7 / T}$$

(1-1)

When the temperature impact was not considered, the seven parameters can be degraded to five.

Exporting the creep experimental data, with the aid of matlab software, making the time hardening model be fitted through the least squares, at least the correlated coefficient reached 0.98, and impact was good, therefore, it was shown that experimental data follow the time hardening model.

As figure 2 (b), the fitting comparison illustration between the time hardening model and the measured results of the specimen is given. In illustrations, there are experimental data points with the suffix of letter "e", the fitting curves with the suffix of letter "f". Obviously, for the same series of experimental data, the time hardening model can be fitted perfectly, therefore, it illustrates that the feasibility and reliability of simulate calculation carried out for creep in ANSYS software directly, and it maybe provide more accurate and quantitative reference for the stability of engineering.

3.2. The numerical simulation based on ANSYS software

Geometric model that it was cylinder of $\Phi$ 50 mm x 100 mm and interlayer with 30 $^\circ$, and the bottom of all constraints, the surface load of two Mpa was borne on top. The models were built respectively for interlayer and the main rocks, and input two kinds of material parameters.
Figure 3. The creep experiment curves under step loading

Figure 3 is the curves for loading experiment courses. It can be seen that there is a corresponding instantaneous strain produced at all levels of load loading moment, and deformation would appear step change. In the process of constant load, the instantaneous strain is no longer change, but the creep variables would growth with time, and the steady creep rate would greater with the stress level higher, the creep variable also greater, finally, it also would cause the macroscopic deformation increasing with time. It was consistent with the process of real experiments.

Figure 4. Displacement distribution of sample

Figure 4 provided that the whole strain nephogram of specimens under the pressure 2 Mpa after 25 hours. Total strain was made up by two parts of creep and the elastic strain of instant. The numerical
of main rock mass significantly less than part of interlayer, there was changing in the both sides of rock interface, and total strain value was nearly equal when it would be a certain distance away from the interface. It was consistent with the interlayer parts damaged firstly and the main rock mass could nearly be destroyed in the experiment.

As Figure 5, it was the equivalent stress distribution of the final calculation, the maximum stress concentration on the upper top and downward bottom of interlayer, while the smallest stress concentration on between the upper bottom and the downward top of the interlayer, the final damage of specimens maybe along the interface slip, or it could also through the two position of the stress largest and produce the fracture surface of through interlayer.

![Figure 5. The creep calculation results of sample](image)

However, due to the limit of the software function, in this paper, it can only on the basis of stress analyzing, strain distribution and value within the object to make damage and numerical predictions, and it can't observe the process of the material burst and gradually drop. In view of the diversity and discreteness of materials, we should combine the mechanical characteristics of material to make the actual judgment more proper after obtaining the simulation results, and thus extending the areas of application.

4. Conclusion

In this paper, a typical specimen with inclined interlayer as the representative, through experiments and numerical simulation, mutual verification, the following conclusions:

(1) It is feasible that using the software of ANSYS to simulate the creep characteristic for the composite rock mass with weak interlayer. The experimental phenomena and data were fitted well, so it is a good study method.

(2) This simulated method can be applied to the engineering research of long-term stability, such as simulation of cavity with weak interlayer and slope etc.

In this paper, although only lists a sample of the relevant chart, but it does not mean that only doing one experiment, in fact, it is based on a large number of experimental conclusions and also applicable to other test pieces. For specific engineering structures and projects, the details and the state of the combination of the structural surface need for further study.

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