Study on the Temperature to the Uniaxial Creep Property of the New Similar Soft Rock

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Abstract. In this paper, the standard specimen is made of the new similar soft rock, whose cementing agent is paraffin. The standard specimen are experimental research of creep properties under six temperature ranging from 10°C to 60°C, which can obtain that the raising temperature has a huge impact on creep property law of the similar soft rock. The creep curve of soft rock only shows decay and constant creep law within 2h under 10°C and at 2.5MPa. However under 60°C and at low 0.25MPa, the creep law shows acceleration within 2h and the slope of the stress-strain curve is increasing. While the average creep modulus is decreasing and the capacity of resist deformation. COMSOL is used to numerically calculate the creep characteristics of similar roadway. The maximum elastic strain energy density and the maximum equivalent creep rate of roadway increase with the increasing of temperature. The gradient increasing indicate that similar roadway accelerate into the rheological stage under the action of high temperature, When large deformation, instability and failure are more likely to occur. The maximum strain and energy accumulation of roadway occur at the edge and key points of roadway. Strengthening and supporting key areas is the key to the stability of soft rock engineering.

1. Introduction

The stability control of soft rock engineering has always been one of the major problems perplexing China's coal mine production and construction. In the process of soft rock mining and support in the deep engineering, the influence of temperature on the inherent plasticity, swelling, disintegration, rheology, and turbulence of soft rock can’t be ignored [1-3]. For a long time, many scholars worldwide have conducted several studies on the experimental determination of basic physical and mechanical parameters of high-temperature rock mass, deformation mechanism, failure criterion, and damage and failure mechanisms [4-5].

At present, the experimental research on the creep characteristics is mainly focused on hard rock or soft rock with high strength. The creep test cycle is long, the temperature requirements are high, and the experimental safety is difficult to ensure. Using the similarity criterion of model experiment select appropriate similar materials to replace the original soft rock for creep experimental research, that can work out at lower temperature and in shorter time. which greatly saves the experimental cycle. The creep law of different original rocks can be simulated through different similar rock mass materials. The experimental phenomenon can better reflect the instability failure gradually accumulated over the deformation characteristics [6-7].

According to similar criterion, new types of soft rock similar materials with different proportions are prepared by using river sand as aggregate, industrial paraffin wax as binder, iron powder and
gypsum used as auxiliary materials in this paper. The creep experiment of soft rock in created and further numerically verified by COMSOL.

2. Creep experiment

2.1 Preparation of similar specimens and determination of physical parameters

The weaker cementitious polymer cement paraffin is selected as the cementing agent of the similar materials. Paraffin wax has better heat sensitivity and can simulate plastic destructive rock with lower strength and greater deformation. 40 mesh river sand is selected as the aggregate, gypsum and industrial iron powder are used as auxiliary materials to prepare the four test pieces with paraffin: river sand: gypsum: iron powder ratios are 1:6:1:1. The sample is a cylinder with a diameter of 50mm and a height of 100mm.

![Figure 1. TAW-200 multifunctional material mechanics testing machine system. 1-Liquid nitrogen tank, 2-Valve, 3-Display platform, 4-Material mechanics tester, 5-High and low temperature environmental test chamber, 6-Sliding frame, 7-Indentation head, 8-Soft rock specimen](image)

Uniaxial compression experiment and Brazil splitting experiment on similar specimens at room temperature are performed by using a TAW-200 electronic multifunctional material mechanics testing machine. A series of parameters including compressive strength, tensile strength, elastic modulus, and Poisson’s ratio are obtained after calculation(table 1.). The main mechanical parameters of similar materials in the corresponding shale model are obtained by calculation under similar conditions. It can be seen that the similar materials prepared in this paper can better meet the similarity criterion, that is, they have high similarity with the prototype materials.

| Rock name         | Compressive strength (MPa) | Tensile strength (MPa) | Elasticity modulus (GPa) | Poisson's ratio | Cohesion (MPa) | Density g/cm³ |
|-------------------|---------------------------|------------------------|--------------------------|----------------|----------------|--------------|
| Calculated value  | 0.23~4.1                  | 0.05~2.06              | 0.46~1.18                | 0.09~0.35      | 0.1~1.56       | 2            |
| Experimental value| 3.12                      | 0.76                   | 0.48                     | 0.31           | 1.17           | 1.987        |
2.2 Creep experiment
The graded load creep test scheme is adopted. Loading on the same rock sample step by step, keeping each loading constant for a certain time, and obtaining the creep curve of the specimen under different stress levels. This experimental scheme can avoid the influence of discrete factors caused by the specimen in the preparation process and curing process. For graded loading at different temperatures is table 2 and each stage of loading lasts for 2h.

Table 2. Rated loading at different temperatures

| loading method | Temperature(℃) | Load(MPa) |
|---------------|----------------|------------|
| step loading  | 10             | 1, 1.5, 2, 2.5 |
|               | 20             | 1, 1.5, 2, 2.5 |
|               | 30             | 1, 1.5, 2 |
|               | 40             | 0.25, 0.5, 0.75, 1 |
|               | 50             | 0.15, 0.2, 0.25, 0.3, 0.35, 0.5 |
|               | 60             | 0.1, 0.15, 0.2 |

3. Results and Analysis

Within 2h, the axial strain of similar soft rock shows obvious laws of deceleration creep stage and stable creep stage under four stress levels, and the creep stress variable gradually increases with the increase of loading stress level. The creep variable (0.0083) with stress level of 2.5MPa is more than twice that of 1.0MPa (0.004)(Figure 2(a)). Figure. 7 (b) shows the creep curve of similar soft rock at 60 ℃. It can be seen from the curve that under the low stress level of 0.1MPa and 0.15Mpa, the creep of similar soft rock shows the law of deceleration creep and stable creep stage, while the deceleration creep stage is the main stage. Under 0.25MPa, even if the stress is still low, the similar soft rock begins to show the law of accelerated creep stage, and the similar soft rock enters plastic failure. Comparing the creep curves of the two temperatures, it can be seen that the temperature has a great influence on the creep characteristics of similar soft rocks. The creep variable under the 0.1MPa stress level at 60 ℃ is about 2.5 times that under the 2.5MPa stress level at 20 ℃ in 2 hours.

From the creep characteristic data extract the stress value, strain value, time value and temperature value after creep for 1h, and draw the stress-strain isochronous curve at different temperatures, as shown in Figure. 3. It can be seen that the stress-strain curve of similar soft rock is basically linear, and the temperature has little effect on the stress-strain relationship in the temperature range of 20 ℃ and below. With the increasing temperature, the stress-strain curve shifts upward, and the higher the temperature, the greater the shift amplitude. In order to reflect the influence of temperature on the
creep deformation capacity of similar soft rocks, the reciprocal of the slope of the straight-line section of the stress-strain curve is defined as the average creep modulus. Obviously, the average creep modulus decreases continuously with the increase of temperature, especially at 30-40 °C (Figure 4).

![Creep Stress-Strain Curves of soft rocks at different temperatures at 1h](image1)

**Figure 3.** Creep Stress-Strain Curves of soft rocks at different temperatures at 1h

**Figure 4.** The average creep modulus varies with temperature at 1h

4. Numerical simulation

![Numerical Computation Model and Grid](image2)

**Figure 5.** Numerical Computation Model and Grid

![At the same time similar to soft rock Y-direction strain cloud under different temperatures](image3)

**Figure 6.** At the same time similar to soft rock Y-direction strain cloud under different temperatures
Figure 7. At the same time similar to soft rock X-direction strain cloud under different temperatures

Assuming that the cross-section of the roadway model is circular with a radius of 0.05mm, we take the cross-section of the model with a geometric size of 0.2m×0.2m as the research object. As the axial symmetry nature of the geometric model, only one quarter the cross-section is selected as the numerical calculation object. The geometric size and grid division of similar soft rock roadway model are given in Figure 5. It is worth to note that the degrees of freedom are 8567. Using the COMSOL multi-field coupling function and the fitted rock-soil constitutive model and calculation method, the creep process of the similar soft rock roadway model are numerically simulated during the loading.

The numerical calculation of similar soft rock roadway at different temperatures is carried out at 2 hours. Figure 6. and Figure 7. respectively show the strain cloud in Y direction and X direction at the interface of similar soft rock roadway at the same time under different temperatures. The creep variable in Y direction gradually decreases from the top of the roadway to the side, and the creep variable in X direction changes just opposite.

Figure 8. Effect of temperature on strain Maximum creep strain

It can be seen from Figure 8 that the maximum creep strain of 1# point in Y direction and the maximum creep strain of 2# point in X direction gradually increase and the increasing gradient increases with the increase of temperature, which indicate that similar soft rocks accelerate into the rheological stage under the action of high temperature, resulting in large deformation instability and failure. Figure 9 shows the changes of maximum elastic strain energy density and maximum equivalent creep rate with temperature during creep. It can be seen that both increase with the increase of temperature. The energy of similar soft rock is mainly concentrated at the roadway edge, so the roadway edge stability support is the key to the safety of the whole roadway project.
5. Conclusion

(1) The creep curve of soft rock only shows decay and constant creep law within 2h under 10℃ and at 2.5MPa. However under 60℃ and at low 0.25MPa , the creep law shows acceleration within 2 hours. It can be seen that the increase of temperature has a great influence on the creep characteristics of similar soft rocks.

(2) With the increasing temperature, the stress-strain curve shifts upward and the soft rock creep is more sensitive to load. The average creep modulus decreases continuously, then, the deformation resistance of similar soft rock decreases.

(3) Through numerical calculation, the strain in Y direction, X direction, maximum elastic strain energy density and maximum equivalent creep rate increase with the increase of temperature. And the increase gradient increasing indicate that similar soft rock accelerates into the rheological stage under the action of high temperature. When large deformation, instability and failure are more likely to occur. The maximum strain and energy accumulation of roadway occur at the edge and key points of roadway. Strengthening and supporting key areas is the key to the stability of soft rock engineering.

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